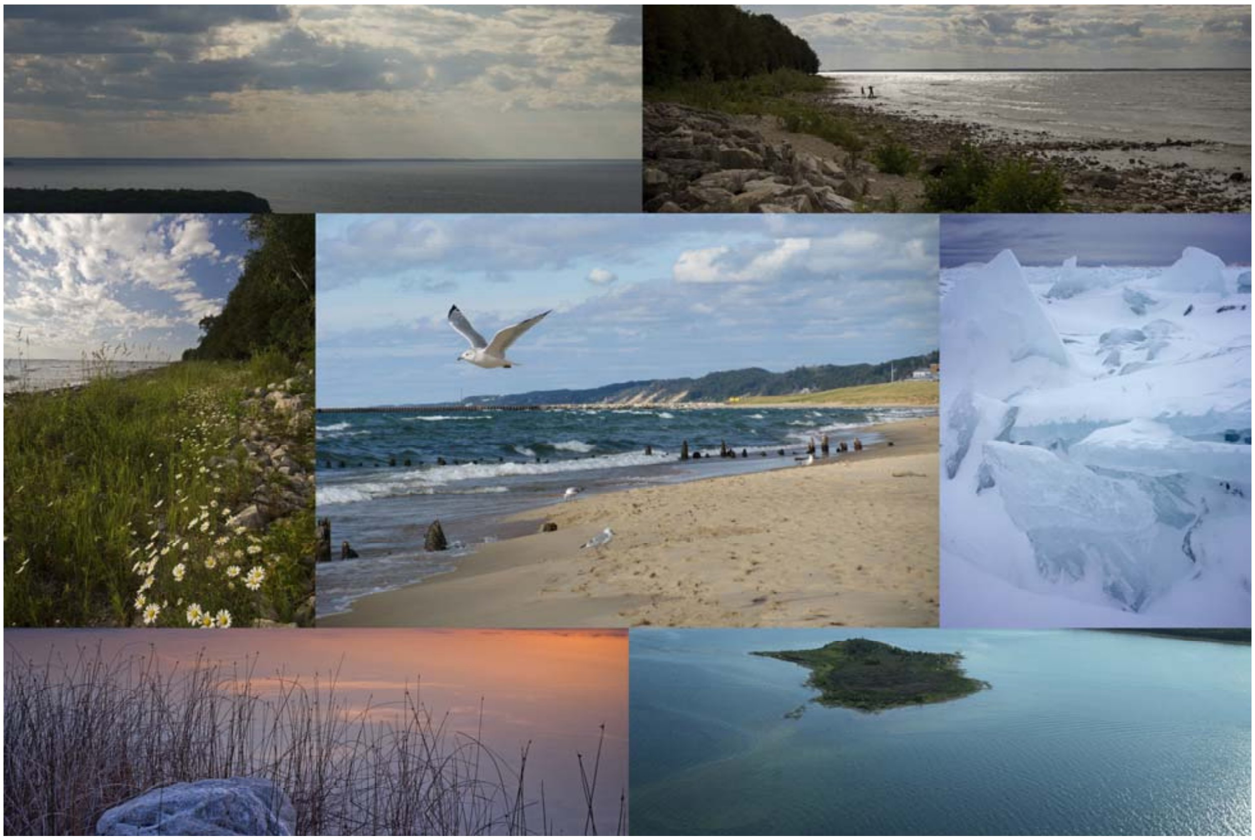
MICHIGAMI: GREAT WATER

Strategies to Conserve the Biodiversity of Lake Michigan



Technical Report

The Nature Conservancy

Michigan Natural Features Inventory

Prepared by the Lake Michigan Biodiversity Conservation Strategy Core Team

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From upper left – going around clockwise: Green Bay (Mark Godfrey, TNC); Green Bay (Mark Godfrey, TNC), Ice Shoves, Lake Michigan (TNC); Rocky Island (Chris Cantway); Wilderness State Park (Ron Leonetti); Green Bay shore (Mark Godfrey, TNC). Center: Saugatuck Dunes (Melissa Soule).

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Disclaimer

This report reflects the best efforts of the preparers to accurately represent the expertise and views expressed by project participants. The Conservation Action Planning process is iterative in nature and the Lake Michigan 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 Michigan Biodiversity Conservation Strategy (LMBCS) was initiated to provide a more in-depth assessment of the lake’s biodiversity status and threats, as well as develop a comprehensive set of strategies to maintain and increase the viability of Lake Michigan’s biodiversity and abate the threats to biodiversity. The Strategy was developed by The Nature Conservancy and Michigan Natural Features Inventory, and is the product of a two-year planning process involving roughly 170 individuals from 79 agencies and organizations from around the lake. The project builds on and supports similar biodiversity conservation strategies that have been completed for Lakes Ontario and Huron. The Strategy aims to facilitate coordination of actions among diverse and widespread partners, providing a common vision for conservation of Lake Michigan, 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 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 Michigan.

EXECUTIVE SUMMARY

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

-Vision statement adopted by The Steering Committee

Lake Michigan, the second largest Great Lake (by volume) and fifth largest lake in the world, is an ecologically rich and globally significant ecosystem. Stretching over 300 miles north to south, its coastline harbors boreal forests and coastal fens in the north and dry sand prairies and oak savannas in the south. In fact, Indiana Dunes National Lakeshore is among the most biologically rich of all U.S. National Parks, on a per-area basis, due to the co-occurrence of southern and northern species. The dunes along the eastern shore of the lake are the largest system of freshwater dunes in the world, and the shorelines provide food and shelter for millions of migrating birds every year. In the water, the variety of nearshore habitats provide spawning or nursery grounds for many fish species, supporting important fisheries; migratory fish connect the lake to its tributaries; and in the offshore, a window of opportunity exists to restore the historic communities once found here and nowhere else in the world.

Lake Michigan and its associated biodiversity, however, are at great risk. Invasive species, climate change, water pollution, rapid and poorly planned residential and industrial growth, altered hydrology, and incompatible agriculture, forestry, and fishery practices are taking a toll on this national treasure and critical resource. With more than 10 million people living near, depending on and benefiting from a healthy Lake Michigan, there is an increased sense of urgency to address these threats.

The Lake Michigan Biodiversity Conservation Strategy (LMBCS) is a multi-agency initiative designed to identify specific strategies and actions to protect and conserve the native biodiversity of Lake Michigan. It is the product of a two-year planning process involving roughly 170 individuals from 79 agencies and organizations from around the lake. The goals of this planning process include:

- Assemble available biodiversity information for Lake Michigan.
- Define a multi-agency vision of biodiversity conservation for Lake Michigan.
- 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.
- Promote coordination of biodiversity conservation in the basin.

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. This effort was managed by staff of The Nature Conservancy and Michigan Natural Features Inventory, working closely with the Great Lakes National Program Office of the USEPA—funders of the project through the Great Lakes Restoration Initiative. At each step of the way, a

Steering Committee of over 40 representatives from Federal, State, County, and local agencies and organizations advised the plan authors. Involvement of these key individuals, several of whom are part of the Lakewide Management Plan (LaMP) or associated stakeholder groups (the LaMP Forum and Watershed Academy), as well as the Great Lakes Fishery Commission, tribal organizations, and other experts and stakeholders throughout the watershed is critical to the long-term success of this effort.

The first step in the planning process was to establish the scope for the plan. The biodiversity encompassed by Lake Michigan Biodiversity Conservation Strategy includes those conservation targets within the lake itself and in the immediate coastal area (roughly 2 km inland from the shoreline). The assessment and strategy design, however, considered the influence of the whole Lake Michigan watershed on this focal biodiversity.

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 Michigan has considerable regional variation in climate, ecology, economics, and dominant land use, with the most striking variation found along the north-south gradient. To address the differences within the lake and along the coastal zone, we divided the lake into five generally recognized basins for reporting units: Northern Basin, Central Basin, Green Bay, Mid-Lake Plateau, and Southern Basin. To facilitate viability and threats assessments we further divided these reporting units into offshore and coastal-nearshore units (assessment units). In the main body of the report and appendices, we present our findings for both levels of stratification.

Describing Lake Michigan biodiversity and assessing its health

The project Core Team, Steering Committee, and other partners identified seven focal targets to describe the biodiversity of Lake Michigan and its immediate coastal area:

1. **Open Water Benthic and Pelagic Ecosystem** (i.e., offshore; waters deeper than 30 m)
2. **Nearshore Zone** (waters shallower than 30 m)
3. **Native Migratory Fish** (Lake Michigan fish with populations that require tributaries for a portion of their life cycle, including lake sturgeon (*Acipenser fulvescens*), walleye (*Perca flavescens)*, and suckers (*Catostomus commersonii*).
4. **Coastal Wetlands** (wetlands with historic and current hydrologic connectivity to, and directly influenced by Lake Michigan)
5. **Islands** (including both naturally formed and artificial islands)
6. **Coastal Terrestrial Systems** (upland and wetland systems within ~2 km of the shoreline)
7. **Aerial Migrants** (all types of migrating birds, insects, and bats dependent on Lake Michigan)

Engaging numerous experts and employing recognized Key Ecological Attributes (KEAs) and indicators of viability, the Core Team assessed the current viability status of each of the seven targets both by assessment unit, reporting unit and lakewide. These assessments provide a snapshot of the status of biodiversity in Lake Michigan and their desired status. Overall, the viability for the biodiversity in Lake Michigan is *Fair*, which indicates that human intervention is required to restore its biodiversity to a self-sustaining condition and prevent irrecoverable declines (Table a). The viability is also presented in

Table a by the five reporting units and by targets. With the exception of Islands and coastal wetlands, most targets ware rated as *Fair*. While this summary gives us an overall picture of Lake Michigan, 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	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin	Lakewide
Nearshore Zone	Fair	Fair	Fair	Fair	Fair	Fair
Aerial Migrants	Fair	Fair	Fair	Fair	Fair	Fair
Coastal Terrestrial Systems	Fair	Fair	Fair	Fair	Fair	Fair
Coastal Wetlands	Good	Good	Good	Fair	Fair	Good
Islands	Good	Good	Good	Good	Good	Good
Native Migratory Fish	Fair	Fair	Fair	Fair	Poor	Fair
Offshore Benthic and Pelagic Ecosystem	Fair	Fair	Fair	Fair	Fair	Fair
Overall Biodiversity Health	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	Fair

Table b. Goals for 2030 to assure long-term viability.

Target	Goal
Open Water Benthic and Pelagic Ecosystem	By 2030, to assure that the offshore benthic and pelagic zone of Lake Michigan 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, with substantial representation by multiple coregonid species (e.g., cisco or lake herring (*Coregonus artedi*), bloater (*Coregonus hoyi*), kiyi (*Coregnus kiyi*)); • Lake trout (*Salvelinus namaycush*) will maintain self-sustaining populations in each major area of the offshore; • Self-sustaining populations of native predators (such as lake whitefish (*Coregonus clupeaformis*) and lake trout) maintain relatively stable populations consistent with Fish Community Objectives.

Target	Goal
Nearshore Zone	By 2030, as evidence that the nearshore is improving as habitat for native fish and invertebrates: • Greater than 75% of native nearshore fishes are represented within each area of the lake; • Late summer cladaphora standing crop is below 30 gDW/m^2 on hard substrates; • The 5-year average chlorophyll-a concentrations are between 0.5-3.0 µg/L; • The average shoreline hardening index is less than 20%; • Average annual sediment loadings are less than 0.075 tons/ac.
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 Michigan 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 Michigan 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.
Islands	By 2030, to ensure that islands remain as intact and sustainable ecological systems: • A minimum of 60% of Lake Michigan islands are owned and managed for conservation; • A minimum of 80% of the total area of Lake Michigan 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.

<table>
<tr><th>Target</th><th>Goal</th></tr>
<tr><td>Coastal Terrestrial Systems</td><td>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;
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.</td></tr>
<tr><td>Aerial Migrants</td><td>By 2030, so that Lake Michigan 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.</td></tr>
</table>

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. Using a weighted-averaging approach that considered the respondent's expertise level, we calculated overall threat-to-target ranks, related threats across all targets and overall threat ratings for each target.

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

- **Northern Basin**: Aquatic Invasive Species; Terrestrial Invasive Species; Dams & Other Barriers; Climate Change; Contaminated Sediments
- **Central Basin**: Aquatic Invasive Species; Terrestrial Invasive Species; Housing & Urban Development; Climate Change
- **Green Bay**: Aquatic Invasive Species; Terrestrial Invasive Species; Housing & Urban Development
- **Mid-Lake Plateau**: Aquatic Invasive Species; Climate Change

- **Southern Basin**: Shoreline Alterations, Pollution (Urban & Household); Pollution (Agriculture & Forestry); Aquatic Invasive Species; Terrestrial Invasive Species; Housing & Urban Development; Climate Change; Pollution (Industrial)

To address the most critical threats to biodiversity and restore badly degraded conservation targets, the Core Team hosted a strategy development workshop in Chicago 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 & Urban Development and Shoreline Alterations;
4. Urban Non-Point and Point Source Pollutants;
5. Restoration of Offshore Fisheries;
6. 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 Michigan. Based on these models, workshop participants identified specific strategies to abate these threats, then identified highest priority strategies and developed a detailed set of outcomes at least one. The final set of ten featured biodiversity conservation strategies for Lake Michigan is presented in Table C in the third column.

Climate change was a key consideration in several of strategies. In particular, the likely increases in the intensity of storm events is an important consideration in planning for NPS management (4a), and improving connectivity (6a) helps fish and other aquatic species respond to increasing temperatures.

Priority areas

To complement the lake-wide strategies and better direct conservation action to the local scale, we conducted an analysis of ecological significance analysis to rank smaller coastal units and islands in Lake Michigan. 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 (Ewert et al. 2012 and Henson et al. 2010 respectively). Priority areas are not relevant to the Open Water Benthic and Pelagic Ecosystems zone, and while relevant to Migratory Fish and the Nearshore Zone, we lack sufficient data to do this type of analysis.

Table c. Summary of featured strategies in the Lake Michigan 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 – increases in peak storm intensities and run-off	a. Development of a communications network within the agricultural community: i. Use existing agricultural communications networks in new ways to expand/improve implementation of conservation practices to naturalize hydrology and reduce NPS ii. Identify key influencers and create incentives for their delivering the message iii. Prioritize where to focus if possible based on conservation needs b. Market mechanisms: nutrient trading: iv. Enable market mechanisms for changing behavior to increase BMP adoption v. Develop linkages between agricultural landowners/operators and out of compliance point sources vi. Requires viable market, supportive regulatory framework, aggregator, ability to quantify beneficial impacts
2. Preventing and reducing the impact of invasive species	• Vectors: seeds, horticulture and live organism trade, cargo and shipping containers, recreation, waterways and canals • Insufficient capacity • Insufficient knowledge and awareness • Insufficient coordination • Lack of political will	a. Agreements among Great Lakes States for invasive species in Lake Michigan i. One governor takes lead (MI). ii. Discussions leading to an agreement to proceed. iii. Gap analysis of need to take to governors. iv. Bring in risk assessment studies. b. Early detection and rapid response network for invasive species in Lake Michigan v. Raise funds for all aspects of strategy. vi. Train people to provide data. vii. Data collection. viii. Develop shared and unified GIS and information management system. ix. Develop strategic Great Lakes surveillance system. x. Develop rapid response capability.

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 • Socio-economic: 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, and professional experience	a. Use coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes i. Spatial ecological information is easily accessible and priority places and opportunities are identified across the Basin ii. Communities collaborate to develop ecologically based coastal strategies iii. Coastal targets are effectively integrated into a variety of local plans, ordinances, and planning activities – leads to ecological management of public lands, incentives for conservation actions, adoption of protective zoning ordinances, and acquisition of desired lands iv. Future development fully addresses coastal biodiversity and supporting processes v. Low impact development projects and practices are increased and future development is directed to the most appropriate places vi. Ultimately these actions lead to a decrease in shoreline hardening and impervious surfaces particularly in areas where they will have the biggest impact
4. Reducing the Impacts of Urban Non-Point and Point Source Pollutants	• Economy/population pressure • Climate change – increases in peak storm intensities & run-off • Imperviousness • Lack of knowledge/understanding – biodiversity, how to control NPS • Lack of enforcement • Emerging contaminants • Legacy pollutants	b. Expand implementation of green infrastructure and strengthen NPS management i. Develop and promote standards and incentives to increase green infrastructure practices through local codes and ordinances and sharing model codes and ordinances ii. Address regulatory barriers to adoption of green infrastructure iii. Increase in green infrastructure creates increased sewer capacity (reducing CSOs) and increased urban habitat iv. Reducing effective impervious area to increase infiltration, reduce runoff and to moderate impacts of climate change

Strategy	Key factors in situation analysis	Strategies selected for focus in workshop
5. Restoration of Offshore Fisheries	• Historic and current impacts of commercial fishing • Sport-fishing • Treaty constraints • Lack of resources and interest in comprehensive restoration • Federal agency native species mandates • State agency funding/constituencies • Aquatic invasive species (especially alewife (*Alosa pseudoharengu)*, sea lamprey (*Petromyzon marinus*)) • Stocking	a. Restore cisco (*Coregonus artedi*) in Lake Michigan i. Restore cisco to a self-sustaining population that can be sufficient forage for lake trout and Pacific salmon (Oncorhynchus spp) ii. Would require a comprehensive restoration plan called for by the Lake Michigan Committee (GLFC), participation by key stakeholders iii. Funding secured for a pilot stocking effort – for a long enough term to achieve success or confirm infeasible (10 years) iv. Expand stocking if needed to reach self-sustaining levels desired lakewide b. Broaden constituency for sea lamprey control v. Partnership among NGO's , state agencies, and GLFC established vi. Public awareness for sea lamprey control need increased vii. State Department maintains sea lamprey control funding
6. Improving Habitat Connectivity by Reducing the Impact of Dams and Other Barriers	• Pressures to keep • Cost • Invasive species control • Human use values • Inadequate BMPs • Legal lake level structures • Sediment control • Pressures to remove • Fisheries/ecosystem restoration • Property values • T/E species conservation • Costs/liabilities • Road safety/permanence	a. Increase connectivity to Lake Michigan through development and use of a comprehensive lowest barrier decision tool i. Tool would answer questions related to costs and benefits, considering value to species, habitat, as well as risks and societal benefits ii. Priorities for critical watersheds and barriers would be set using the tool iii. Watershed plans would be updated to incorporate recommendations iv. The priority barriers would guide spending v. Enough connectivity would be restored to achieve 25% of all habitat types being connected to Lake Michigan and having one viable run of lake sturgeon in each applicable region of Lake Michigan, by 2020 b. Increase connectivity at road-stream crossings at a large scale vi. Seek to leverage existing funds by requiring that grant funds include cost-sharing from road agencies vii. Identify priorities and agreement to focus on these priorities for stream crossing improvements based on connectivity restored, species benefitting, ecosystem

Strategy	Key factors in situation analysis	Strategies selected for focus in workshop
		benefits, cost, feasibility and potential risks (aquatic invasive species) viii. Complete an economic analysis and document ecological justifications such that road managers, resource management agencies, and state lawmakers are convinced of need for either increased funding and/or higher regulatory standard for road-stream crossing. ix. Establish demonstration projects in key watersheds and share results with road managers, resource management agencies, and state lawmakers. x. Increased application of road-stream crossing best practices results in priority watersheds (see strategy 6a) being 80% connected by 2040 and a 20% improvement in connectivity in priority watershed by 2020.

The Door Peninsula east coastal watershed unit (CWU) in Wisconsin received the highest score for coastal terrestrial biodiversity. Three units located in the Upper Peninsula of Michigan, the Calumet River CWU located in Indiana and Illinois, and the Lake Charlevoix CWU encompassing the northwest tip of the Lower Peninsula of Michigan also scored *High*. The top eight highest scoring units for Coastal Terrestrial Systems condition are all located in Michigan with seven of those units located in the Upper Peninsula of Michigan.

Only three units scored *High* in both terrestrial biodiversity and condition. All three are located in the Upper Peninsula of Michigan. The only unit with a high biodiversity value and very low condition score is the Calumet River CWU located in the Chicago-Gary metropolitan region.

Regarding coastal wetland biodiversity, the only unit to score in the *Very High* category was the Cut River CWU. All of the units that scored *High* for Coastal Wetland condition are located in Michigan. The Garden Peninsula CWU received the highest wetland condition score in the Lake Michigan Basin. It is important to note that although coastal wetlands on islands were not analyzed, Waugachance Point, located in the northwestern most point of the Lower Peninsula of Michigan, is a significant set of islands for wetland biodiversity. Waugachance Point harbors federally listed coastal wetland species as well as three different types of wetland communities. Garden and Hog Islands, both part of the Beaver Island Archipelago, also harbor significant wetland biodiversity values.

The Cut River CWU located in the Upper Peninsula of Michigan is the only unit to score high for both coastal wetland biodiversity value and condition. This unit contains some very significant wetlands, such as the large wetland complex at Pt. Aux Chenes, and a large percentage of its contributing watersheds are under public ownership. Both the Lower Peshtigo and Lake Charlevoix CWUs are the only two units with somewhat high biodiversity scores but relatively low condition scores.

Priority areas for aerial migrants are 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 highlight that the Lake Michigan Basin provides good spring stopover habitat across the lake for waterfowl, with a high concentration of good habitat found along the southeast shoreline and the Michigan portion of Green Bay. There also appears to be good stopover habitat for shorebirds along the southeast shore of the lake.

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 Michigan are Beaver, Garden, and Hog Islands located in the Northern Basin just east of Petoskey, Michigan, and Washington Island located just north of the Door Peninsula in Wisconsin.

Ecosystem services

While the LMBCS 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 ten most important ecosystem services provided by Lake Michigan 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 four states representing public agencies at all levels of government, as well as private organizations and others, completed the survey. Not surprisingly, supplying fresh water, purifying water, and the water cycle were all among the top ten most important services. Other top ten benefits included recreation, primary productivity, wildlife and fish habitat, aesthetics, climate regulation, “sense of place”, and nutrient cycling.

Among the recommended strategies, respondents estimated that reducing impacts from urban non-point and point source pollution would have the greatest positive effect on these ecosystem services, followed by coastal conservation and reducing agricultural non-point pollution. Services identified as most likely to be improved included wildlife and fish habitat, recreation, and primary productivity. Respondents found no strategies that would negatively affect ecosystem services, nor ecosystem services that would be degraded by the recommended strategies.

Implementation recommendations

The LMBCS presents key components of a common vision for the conservation of Lake Michigan 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 LMBCS. These recommendations include:

1. The Lake Michigan LaMP adopts the LMBCS 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. LMBCS 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. Michigami: Great Water

During the time of uncertain cartography and treacherous exploration, Lake Michigan went by many names: “Grand Lac”, “Lake of the Stinking Water", “Lake of the Puants”, “Lac des Illinois”, “Lac St. Joseph”, and “Lac Dauphin”, based on the impressions of inhabitants and the circumstances (GLIN 2012). Finally the name Michigan was settled on, a word believed to come from “Michigami” an Ojibwa word for “great water” (Freelang 2011).

As a national treasure and critical resource for 10 million people, Lake Michigan truly deserves the name “great water.” Lake Michigan is one of five Laurentian Great Lakes, which together consist of 21% of the world’s freshwater and 84% of the freshwater for North America. Lake Michigan is 483 km long and averages 120 km in width, and covers 5,775,673 ha. Bordered by the four states of Michigan, Wisconsin, Illinois, and Indiana, it is the only Great Lake that is entirely within the United States. It is the second largest Great Lake by volume (GLIN 2012), and the fifth largest lake in the world.

The abundance of natural resources attracted Native Americans to the lake and its coastal areas starting with the last glacial retreat 10,000 years ago and Europeans since the 1700’s (U.S. EPA 2011). For the past 10,000 years, the lake has served as a critical source of game, fish, wild plants, water, transportation, economic development, and cultural and spiritual satisfaction to the people in the region. Historically, Lake Michigan was a significant aquatic highway into continental North America for European fur trappers, just as it is an important shipping artery for ocean going vessels today. Lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), lake sturgeon (*Acipenser fulvescens*), cisco or lake herring (*Coregonus artedi*), burbot (*Lota lota*), and yellow perch (*Perca flavescens*) were important in the establishment of the Lake’s fishing industry in the 1800’s. At the turn of the 20th Century, the commercial catch averaged more than 40 million pounds comprising lake trout, cisco, lake whitefish, deepwater ciscos (*Coregonus* spp.), yellow perch, suckers (Catostomidae) and walleye (*Sander virtreus)* to a lesser extent (Wells and McLain 1973). Until the mid-1900’s, Lake Michigan contained one of the largest lake trout fisheries in the world. Commercial fishers continued to harvest around 25 million pounds of fish, although this represented major shifts in species composition with the loss of lake trout, decrease in lake whitefish, severe declines and extirpations of the ciscoes, and rapid proliferation of introduced alewife (*Alosa pseudoharengus*) populations.

One of the most distinctive aspects of Lake Michigan is it has a longer north-to-south extent than any of the other Great Lakes. This north-to-south orientation encompasses a diverse climate, which allows for the Southern Basin of Lake Michigan to experience a longer growing season and greater annual productivity, more similar to Lake Erie and Ontario, while the northern portions of the basin experience colder conditions for a longer period of time, similar to Lake Huron. Not only does this north to south orientation provide for an interesting mix of plant and animal species, it may also provide more opportunities for some lake and coastal species to move in response to climate change than is possible for other Great Lakes.

The geology of the northern portion of the basin is characterized by silurian dolomite formed some 400 million years ago. This resistant limestone formation is characterized by an escarpment that stretches from Niagara Falls in New York through the Door Peninsula in Wisconsin. Several rare plants and animals, such as the globally imperiled dwarf lake iris (*Iris lacustris*) and recently documented rare land snails, have adapted to this unique geologic formation. Associated with this escarpment, limestone bedrock forms a number of islands and shoals in the lake creating diverse pattern of bathymetry in the northern portion of the lake. These shoals provide important fish spawning habitat particularly for one of the most important predators in the lake, the lake trout (*Salvelinus namaycush*).

In other areas, particularly the southern portion of the lake, the geomorphology of the coastal zone is characterized by glacial landforms created 3,000 to 15,000 years ago as the last glacial advance retreated. These areas are characterized by large dune formations, glacial till, end moraines, lakeplains, and drumlin fields. Separating the shallower Southern Basin from the Northern Basin of the lake is a wide, relatively shallow offshore formation called the Mid Lake Plateau. The plateau is of resistant limestone origin, and is believed to have played an important role in lake trout production by serving as a spawning reef.

The Great Lakes historically maintained offshore fish communities found nowhere else globally. These included several fish species and subspecies that were endemic to the Great Lakes and a diversity of morphotypes (populations that had developed distinct physical differences from other populations of the same species due to reproductive isolation (e.g. populations spawning on different reefs or in different tributaries)—a process that can eventually lead to speciation), some of which were unique to Lake Michigan. This included eight coregonid species (Smith 1964) and at least two morphotypes of lake trout (Eshenroder and Burnham-Curtis 1999). While these offshore communities have been greatly altered and much of the diversity is lost, many of the key species and morphotypes remain, offering potential for restoration of native offshore Lake Michigan fish communities.

Onshore, this variation in climate and geomorphology creates a diversity of natural communities and habitats for coastal species. The eastern shore of Lake Michigan, benefiting from the predominant westerly winds, waves and storms, boasts 111,289 ha of dunes; the largest collection of freshwater dunes in the world. The largest stretch of dunes starts at the Indiana National Lakeshore in northern Indiana and continues northward to Sleeping Bear Dunes National Lakeshore in northern Michigan.

A variety of coastal wetlands can be found along Lake Michigan. Many of these Great Lakes wetlands are found at or near the mouth of large river systems where a sand barrier has created an area of protection from waves and storms. Lake Michigan harbors more (by number and area) of these unique “barred drowned river mouth” Great Lakes marshes than any of the other Laurentian Great Lakes; this system includes 30% more of these wetlands than the lake with next highest values, Lake Ontario (Environment Canada et al. 2004). Other globally significant wetland types found along the Lake Michigan shoreline include coastal fen, northern fen, interdunal wetland, and other types of Great Lakes marsh. Globally significant coastal systems found along the Lake Michigan coastal zone include open dunes, dry sand prairie, Great Lakes barrens, dry sand savanna, alvar, wooded dune and swale limestone bedrock lakeshore, lakeplain prairie and southern mesic forest.

These natural communities provide habitat to a large number of rare species, many of which are only found in the Great Lakes region. Examples of globally significant plants found in the Lake Michigan coastal zone include: Pitcher's thistle (*Cirsium pitcheri*), Houghton's goldenrod (*Solidago houghtonii*), Dwarf lake iris (*Iris lacustris*), prairie white-fringed orchid (*Platanthera leucophaea),* ram's head lady's slipper (*Cypripedium arietinum*), spatulate moonwort (*Botrychium spathulatum*), ginseng (*Panax ginseng*), prairie moonwort (*Botrychium campestre*), and Lakeside daisy (*Hymenoxys herbacea*). Examples of globally significant animals found in the Lake Michigan coastal zone include: Piping plover (*Charadrius melodus*), Hine's Emerald dragonfly (*Somatochlora hineana*), and Lake Huron locust (*Trimerotropis huroniana*).

1.2. Strategy scope

The health and long-term sustainability of biodiversity in Lake Michigan depends on how we manage resources within the lake, and on actions that take place in neighboring systems that are hydrologically connected to the lake. Thus, the spatial scope for this strategy comprises both the geographic extent of the biodiversity conservation targets (biodiversity scope) and the area within which stresses to biodiversity originate and actions to abate those stresses must occur (geographic scope).

1.2.1. Biodiversity scope

The scope of the biodiversity encompassed by Lake Michigan Biodiversity Conservation Strategy includes only those conservation targets within the lake itself and in the immediate coastal area (roughly 2 km inland from the shoreline). While this project does not focus on biodiversity in the watershed outside of the lake and coastal area, it does consider factors in the watershed that influence biodiversity conservation targets. Strategies are identified to address those watershed factors (thus the larger geographic or planning scope).

1.2.2. Geographic scope

The geographic scope of the project covers the watershed and open waters of Lake Michigan (Figure 1.)

1.3. Vision statement

> *"We envision a healthy Lake Michigan that sustains the full array of natural ecosystems and the services[1] they provide. A resilient Lake Michigan is sustained by collaborative, ecosystem-based management, now and into the future."*

[1] *"Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth"* (MEA 2003, p. 49)

Furthermore, a healthy Lake Michigan ecosystem is characterized by:

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

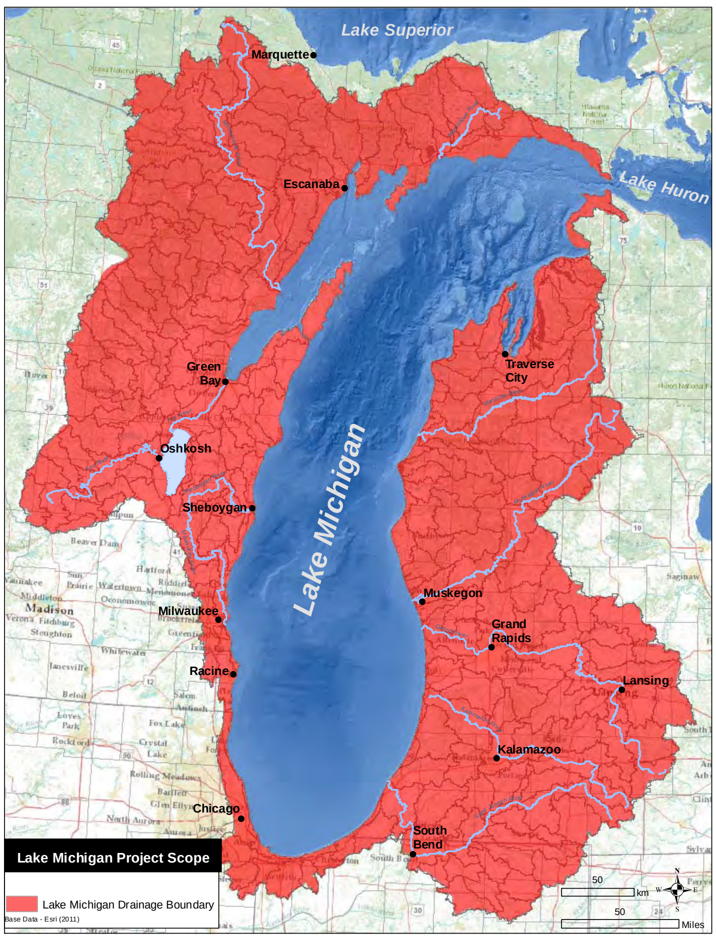

Figure 1: Geographic scope of the Lake Michigan Biodiversity Conservation Strategy

1.4. Working group organization and public participation

1.4.1. Project coordination

To ensure cooperation and coordination across geopolitical boundaries and agencies involved in the LMBCS, this project was guided by a Steering Committee and managed by a Core Team. The Core Team developed and facilitated the process, and produced the final report; this group consisted of individuals from The Nature Conservancy, Michigan Natural Features Inventory and the U.S. Environmental Protection Agency. A Steering Committee consulted on the process, partner involvement, and content. It included representatives from numerous agencies and organizations associated with the LaMP and LaMP Public Forum, as well as other stakeholders, experts, and partners (see full list in Appendix A).

1.4.2. Stakeholder and partner engagement

The Core Team provided a variety of opportunities for organizations and individuals to contribute to the Lake Michigan report including: regular conference calls, webinars, e-mail communications, quarterly project updates, project websites, a strategy development workshop and attendance at LaMP Public Forum meetings. The Lake Michigan report is the product of a large group of individuals from many agencies and organizations who are concerned about and responsible for safeguarding the health and sustainability of Lake Michigan for biodiversity and people (see Appendix B for a detailed list of contributors).

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

The Nature Conservancy's Conservation Action Planning (CAP) process was used to develop the LMBCS. 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).

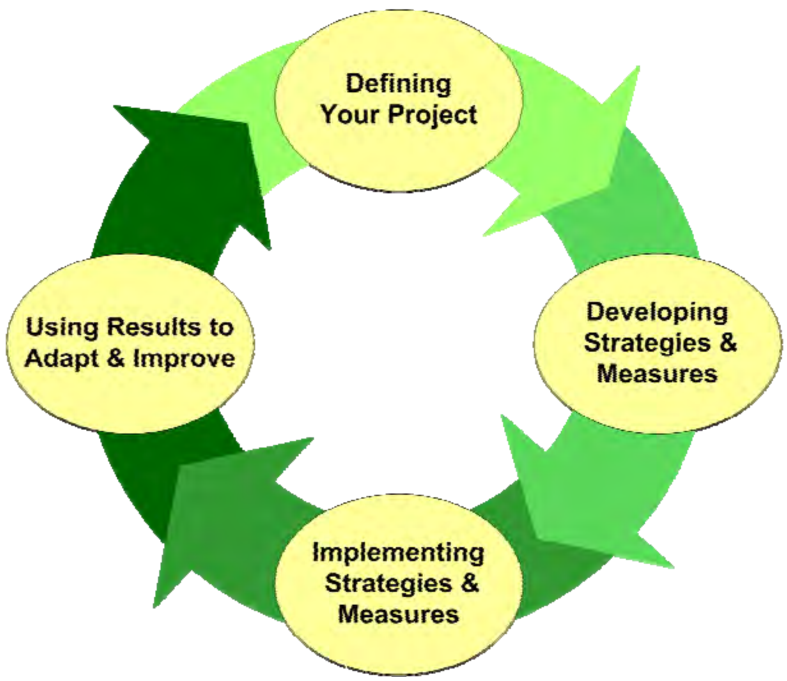

Figure 2: The Conservation Action Planning Process

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

[2] 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 Michigan LaMP and other lakewide 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, integration and “climate-smart” thinking was our goal. We drew from our experiences re-evaluating CAPs for Lake Huron and Lake Ontario (as documented in Poiani et al. 2010) as we engaged in the CAP process for Lake Michigan.

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 of the following chapters and their corresponding appendixes.

2.1. Defining the project

The first step of the process is defining the project (Figure 2; TNC 2007). Through this step project participants are identified including the Core Team, advisors or Steering Committee members, and **stakeholders**. In this step 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. It 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 (**nested targets**).

2.2. Developing strategies and measures

Developing strategies and measures consists of five main steps: assessing viability of biodiversity conservation targets, identifying critical threats, completing a situation analysis, developing conservation strategies, and 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 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 targets will look like. For many 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 KEA is an aspect of a target's biology or ecology that, if missing or altered, would lead to the loss 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 1). 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 1.

Box 1. 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 2 for the rules used in this project).

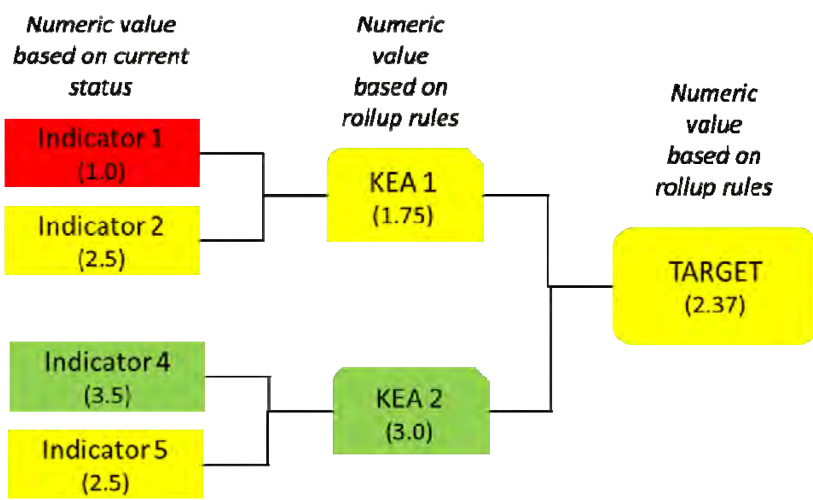

Figure 3: Example of the aggregation process used in the viability assessment (see Box 2 for aggregation rules).

Box 2. 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 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 3). 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 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, 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.

Box 3: 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).**

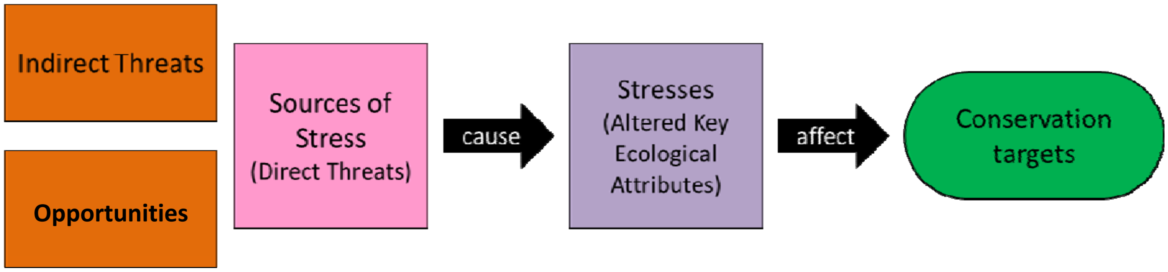

Figure 4: Elements of a conceptual model or situation analysis

2.2.4. Developing conservation strategies

A conservation strategy is a broad course of action intended to achieve a specific objective (i.e. outcome) that abates a critical threat, enhances the viability of a 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 or if an opportunity is taken, then a thematic target might be improved. 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 to implement based on their specific **benefits**, **feasibility** and **costs**.

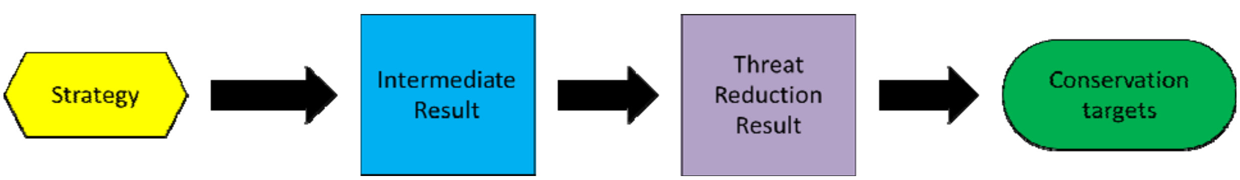

Figure 5: Elements of a results chain

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 (process) and status of the biodiversity features (outcomes) 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 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 and tracking a set of successful strategies. Lake Michigan has considerable regional variation in climate, ecology, economics, and dominant land use. Similar to Lake Huron, the most striking variation for Lake Michigan can be found along the north-south gradient.

To address these differences both within the lake and along the coastal zone, we divided the lake into 5 reporting units, which roughly corresponding to the major basins in the lake and are described in more detail below. We further divided each basin into assessment units based on geomorphology, landcover and element occurrences (see Appendix D for details on the methodology used to define these spatial units).

The stratification approach suggests five reporting units and seventeen assessment units, nested hierarchically as depicted in Figure 6 (see Appendix G for a description of each Reporting Unit).

Reporting units: Lake Michigan does not have universally recognized basins. Studies of the bathymetry of the lake have led to the identification of major features in the lake (e.g., NOAA study at http://www.ngdc.noaa.gov/mgg/greatlakes/lakemich_cdrom/html/geomorph.htm) including basins, ridges, and groups of islands. The proposed stratification of the lake into four basins and Green Bay has some commonalities with the NOAA study. Boundaries between reporting units are generally defined by lake circulation patterns, as determined by Beletsky et al. (1999), and are consistent with the Great Lakes Aquatic Gap Analysis Aquatic Lake Units. However, the specific boundary locations were also highly informed by bathymetry, existing boundaries between coastal reaches, element occurrence distribution patterns, and large tributary influences. The Northern Basin unit is not so much a basin as a bathymetrically diverse area of reefs and islands known as the Islands Area, with a deep channel running through the Mackinac Strait. Green Bay stands as a reporting unit due to its separation from the Central Basin by the Door Peninsula, Garden Peninsula and the chain of islands lying between them; it includes the Whitefish Channel and Fan. The Central Basin includes the Two Rivers Ridge and Door-Leelenau Ridge and Chippewa Basin. The Mid-Lake Plateau is a recognizably shallower, though still offshore, submerged moraine feature, and the Southern Basin corresponds pretty well to the South Chippewa basins, as well as dominant circulation patterns.

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. Assessment units are represented by numbers (see Figure 6).

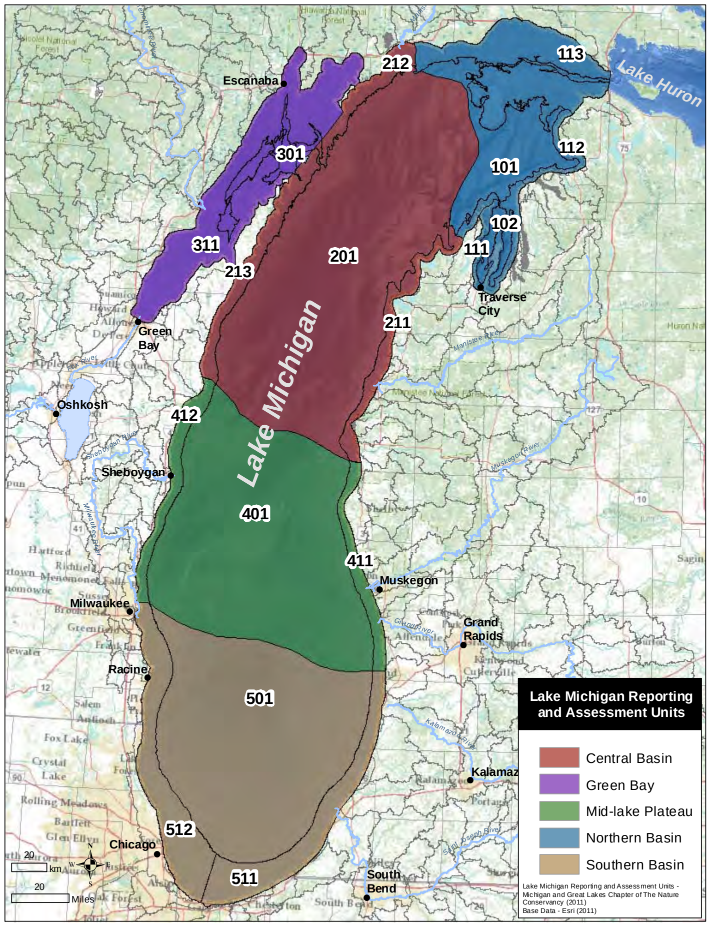

Figure 6: Lake Michigan stratification units.

4. BIODIVERSITY CONSERVATION TARGETS AND VIABILITY ASSESSMENT

In this chapter, we first describe each of the biodiversity conservation targets for the LMBCS, 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 Michigan's biodiversity when all targets are considered together.

Appendix E details the viability analysis for each target including 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 biodiversity conservation targets used by other Conservation Strategies (Lake Ontario Biodiversity Strategy Working Group 2009, Franks-Taylor et al. 2010) and complemented with the input from the project Core Team, Steering Committee, and other partners (see Box 4 for a brief definition of each conservation target).

Box 4: Summary of Biodiversity Conservation Targets

1. **Open Water Benthic and Pelagic Ecosystem (i.e., Offshore Zone):** waters deeper than 15 m
2. **Nearshore Zone:** waters shallower than 15 m, including the coastal margin
3. **Native Migratory Fish:** including lake sturgeon, walleye, suckers, native lamprey, sauger, mooneye, river darter, and channel darter
4. **Coastal Wetlands:** wetlands with historic and current hydrologic connectivity to, and directly influenced by Lake Michigan
5. **Islands:** including both naturally formed and artificial islands
6. **Coastal Terrestrial Systems:** upland and wetland systems within ~2 km of the shoreline
7. **Aerial Migrants:** all types of migrating birds, insects, and bats dependent on Lake Michigan

In order to assess viability, the Core Team collected initial Key Ecological Attributes (KEAs) and indicators for Lake Michigan from previous Strategies (Lake Ontario Biodiversity Strategy Working Group 2009, Franks Taylor et al. 2010), as well as from, the State of the Lakes Ecosystem Conference (SOLEC) reports (SOLEC 2005, 2007, 2009), and according to a literature review[3]. In order to account for the unique attributes of Lake Michigan, KEAs and indicators developed for other lakes were adjusted based on

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

information gained through 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 apply to multiple conservation targets (i.e., “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 CAP rating categories (i.e., *Poor*, *Fair*, *Good*, or *Very Good*, see definitions in Box 1) 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 feature 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.

Box 5. 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 Michigan 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 Ecosystem or Offshore Zone of Lake Michigan includes open waters beyond the 30 meter bathymetric contour from the mainland or islands, including reefs and shoals that occur within the Offshore Zone (Figure 7). Nested within this target are phyto-and zooplankton, benthic invertebrates, forage fish (benthic and pelagic), top predator fish, and shoals and reefs. 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.

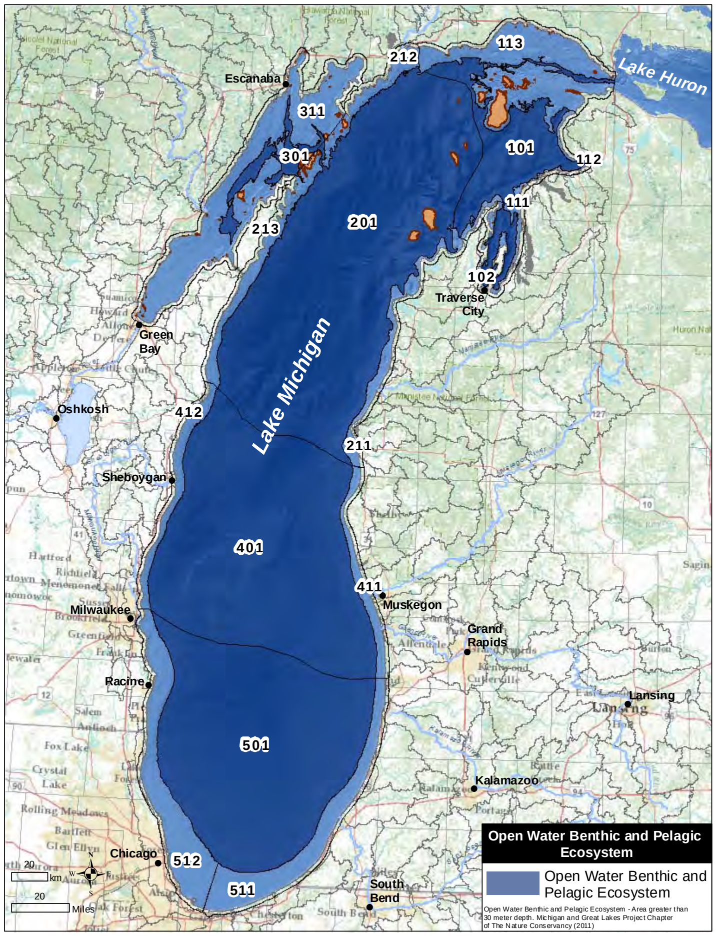

Figure 7: The Open Water Benthic and Pelagic Ecosystem or Offshore Zone of Lake Michigan. Note that Islands (highlighted in orange) are not considered part of the Offshore Zone.

Historically, Lake Michigan supported a large population and fishery for lake trout (*Salvelinus namaycush*), the top fish predator, and widespread cisco populations (also called lake herring) (*Coregonus artedi*), the main prey for the lake trout, as well as seven other ciscoes, including the still commercially important lake whitefish (*Coregonus clupeaformis*). In 1927, total fish production for Lake Michigan was estimated to be 25,000,000 lbs. with half of that being coregonids (Koelz 1927). The combined impact of overfishing, sea lamprey (*Petromyzon marinus*) predation, alewife invasion, and habitat degradation led to the collapse of the lake trout fishery and the loss of the forms of lake trout that had adapted to deep water offshore habitat (Bronte et al. 2008), as well as the decline of commercial whitefishing from thousands of fishers to only a few (Egan 2011).

Lake trout was the top predator in the lake, able to take advantage of many habitat types and types of prey, which provided a stabilizing influence on the fish community (Bronte et al. 2008). Although no longer of commercial value, lake trout still represent an important cultural resource with the potential to support commercial, sport and tribal fisheries in the future. Currently, lake trout play an important seasonal role in the sportfishing industry, and for many are valued as an indicator of the overall health of Lake Michigan. Cisco have been displaced by two invasive species, alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) (Bronte et al. 2008).

The Offshore Zone features many reefs, which are most abundant in the northeastern and central regions (Rutherford et al. 2004). These reef habitats historically supported a fish community comprising deepwater species including lake trout, lake whitefish and other coregonids (Rutherford et al. 2004). While the deepwater reef habitat is still available for spawning, the stocks of fish that would use them have been greatly reduced. Instead, today's lake trout stocks (from hatcheries) spawn in shallow reef habitat, which has been degraded by sedimentation, dreissenid mussel colonization (zebra and quagga mussels), and increased densities of invasive egg-predator fish such as round gobies (*Neogobius melanostomus*), rusty crayfish (*Orconectes rusticus)*, and common carp (*Cyprinus carpio*) (Rutherford et al. 2004, Jonas et al. 2005). Given these conditions, natural recruitment has not been significant (Bronte et al. 2008).

The main documents informing the management of the Offshore Zone of Lake Michigan include the Great Lakes Fishery Commission's (GLFC) A Guide for the Rehabilitation of Lake Trout in Lake Michigan (Bronte et al. 2008), GLFC's Lake Michigan Environmental Objectives – draft 2 (Rutherford et al. 2004), and the Joint Strategic Plan for Management of Great Lakes Fisheries (GLFC 2007).

Nested targets include: benthic invertebrates (e.g., *Diporeia*), forage fishes (benthic and pelagic), piscivorous fish (benthic, pelagic), shoals and reefs, phytoplankton, zooplankton.

Goal: By 2030, to assure that the Open Water Benthic and Pelagic Ecosystems of Lake Michigan 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, with substantial representation by multiple coregonid species (e.g., cisco or lake herring, bloater (*Coregonus hoyi*), kiyi (*Coregnus kiyi*));
- Lake trout will maintain self-sustaining populations in each major area of the Offshore Zone;
- Self-sustaining populations of native predators (such as lake whitefish and lake trout) maintain relatively stable populations consistent with Fish Community Objectives.

4.2.1. Viability of the Open Water Benthic and Pelagic Ecosystem

The viability of the Offshore Zone is difficult to evaluate because this system is in flux. In the past 25 years, dramatic changes have occurred in the lower food web of Lake Michigan, including proliferation of zebra and quagga mussels, which are two invasive dreissenid mussels (*Dreissena polymorpha* and *Dreisenna rostriformis bugensis*), and an invasive predatory zooplankton called bythotrephes (Vanderploeg et al. 2012). While the impact of these invasions is not fully understood (Vanderploeg et al. 2012), researchers have documented the loss of the spring phytoplankton bloom, declines in phytoplankton productivity, an almost complete disappearance of a once abundant invertebrate (*Diporeia* spp.) and declines in others (*Mysis* spp.) (Fahnenstiel et al. 2010). In addition, Lake Michigan has the lowest estimated lake-wide prey fish biomass since sampling started in 1973 (Madenjian et al. 2012), including alewife, a once problematic invasive species now valued for its role in sustaining salmon for sport fishing. Nutrient levels in Lake Michigan now resemble those in Lake Superior (Mida et al. 2010). Zooplankton composition has shifted as well to dominance by large predatory calanoids, a type of copepod, due perhaps to a complex interplay of low total phosphorous, expansion of dreissenid mussels and bythotrephes, and decreases in forage fishes (Vanderploeg et al. 2012). This oligotrophication of Lake Michigan raises questions about the level of production the lake can sustain (Mida et al. 2010). It is unknown if these conditions will persist or if the system can indeed shift back to a more mesotrophic status. Whether or not this is desired is a value judgment beyond the scope of this assessment. Thus, we have assessed viability for the Offshore Zone against a desired future condition of stability in the upper trophic levels (indicated by lake trout and lake whitefish) and having greater representation of native species in the prey base (both plankton and fish).

To add complexity to an already complex system, the dynamics of open water species and systems (i.e., nutrient and sediment transport, food webs) within Lake Michigan 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 already leading to earlier initiation and longer duration of stratification (Austin and Colman 2007). 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/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.

For this assessment, the overall viability of the Offshore Zone is rated *Fair* (Figure 8, see Appendix E for details). Contributing to this ranking is the state of macroinvertebrates including the disappearance of *Diporeia* as well as the peak densities of dreissenid mussels, low prey biomass, as well as the lack of evidence for any lake trout natural reproduction. While lake whitefish continue to persist and in some parts of the lake are increasing in biomass, overall all most management units show a decline in biomass, size at weight, and in recruitment.

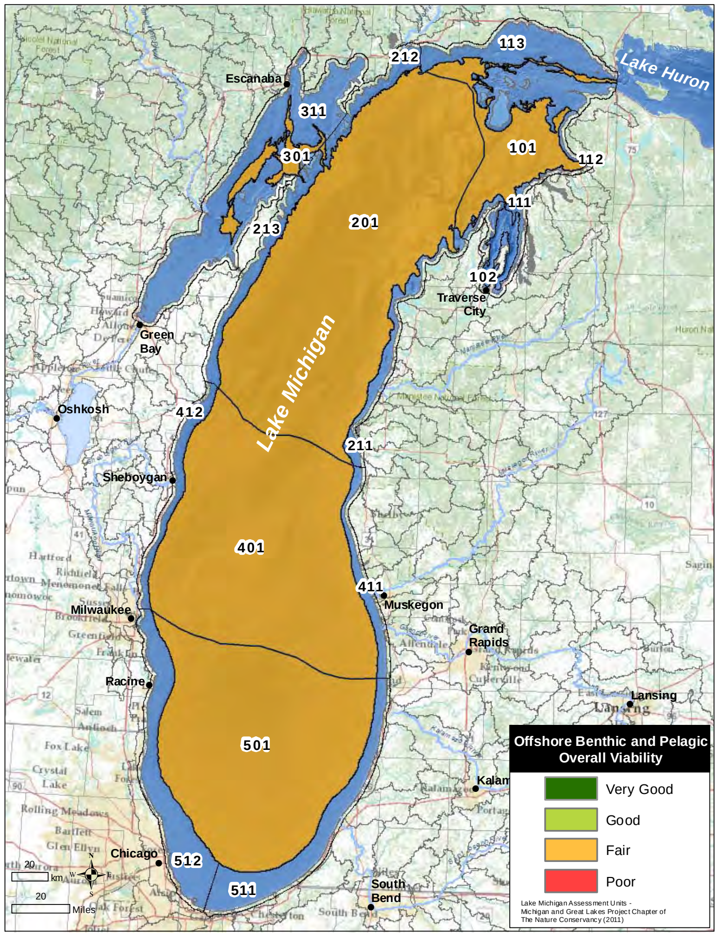

Figure 8: Viability of the Open Water Benthic and Pelagic Ecosystem at the assessment unit level.

4.3. Nearshore Zone

The Nearshore Zone target includes submerged lands and the water column of Lake Michigan starting at 0 meters (the shoreline) and extending to 30 meters in depth, including Nearshore Zone islands, reefs, shoals, freshwater estuaries, but excluding coastal wetlands and areas upstream from river mouths (Figure 9). The 30 meter depth is generally where the thermocline intersects with the lake bed in late summer or early fall (Edsall and Charlton 1997, Rutherford et al. 2004). Because Lake Michigan water levels are dynamic—varying seasonally, annually, and in multi-decadal cycles (Argyilan and Forman 2003, Wilcox et al. 2007)—so too is the Nearshore Zone dynamic, with the Coastal Terrestrial System and the Offshore Zone will become Nearshore Zone in some years, and vice versa. The Nearshore Zone includes a variety of substrate types (e.g. silt, sand, gravel, cobble, bedrock), as well as submerged and emergent aquatic vegetation. Coastal Wetlands are a critical habitat within the Nearshore Zone, but are detailed as a separate conservation target in this plan because of their specific importance to Lake Michigan biodiversity. To the extent that Coastal Wetlands influence nearshore species assemblage structure or processes outside of marsh habitats, they were also considered here. The Nearshore Zone is the most productive portion of Lake Michigan and supports a higher richness and diversity of fish and invertebrates than Open Water Benthic and Pelagic Ecosystem habitats. A wide variety of nearshore habitats are used for spawning or nursery grounds for many different fish species, including many species that provide important fisheries. For example, sand or cobble shorelines provide spawning habitat for species such as yellow perch and smallmouth bass (*Micropterus dolomieu*) (Robillard and Marsden 2001, Kaemingk et al. 2011). Nearshore reef habitats provide spawning habitat for nearshore species such as walleye and yellow perch (Robillard and Marsden 2001, Rutherford et al. 2004), as well as offshore species such as lake trout, lake whitefish and cisco (Barton et al. 2011, Rutherford et al. 2004). The structure and function of the Nearshore Zone is highly influential to several of the other targets in this plan, including the Offshore Zone, Coastal Wetlands, Native Migratory Fish, and Coastal Terrestrial System.

Figure 9: Distribution of the Nearshore Zone in Lake Michigan.
Note that Islands (highlighted in orange) are not considered part of the Nearshore Zone.

Nested targets include: native submerged aquatic vegetation, shore birds, waterfowl, reptiles and amphibians, benthic macroinvertebrates (e.g., *Hexagenia* spp.), mussels, nearshore reefs and dependent species (e.g., lake trout), and fishes (e.g., spottail shiner(*Notropis hudsonius*)).

Goal: By 2030, as evidence that the nearshore is improving as habitat for native fish and invertebrates:

- Greater than 75% of native nearshore fishes are represented within each area of the lake;
- Late summer *Cladophora* standing crop is below 30 gDW/m^2 on hard substrates;
- The 5-year average chlorophyll-a concentrations are between 0.5-3.0 µg/L;
- The average shoreline hardening index is less than 20%;
- Average annual sediment loadings are less than 0.075 tons/ac.

4.3.1. Viability of the Nearshore Zone

The Nearshore zone viability of Lake Michigan is considered *Fair*, overall. However, there is significant variability across the lake (Figure 10). The Nearshore along the northern shoreline of Lake Michigan is in *Good* condition due largely due to low shoreline and watershed development and fairly intact indicator species and community measures. However, most of the Lake Michigan Nearshore is considered *Fair*, and the southwestern portion of the lake is in *Poor* condition. Specific nearshore indicators that are considered *Poor* lakewide include densities of quagga and zebra mussels (*Dreissena* spp.) densities of *Diporeia*, and *Cladophora* standing crop. *Diporeia* are large amphipods that have been historically abundant across the lake bottom and are important food resources to numerous Lake Michigan fish species. *Cladophora* is a type of algae that grows along the lake bottom and can become a nuisance when phosphorus concentrations are high and growth becomes very dense. Indicators that are considered *Good* lakewide include shoreline hardening, the proportion of the watershed and coastal areas that are in natural land cover, and smallmouth bass populations in the northern part of the lake.

One difficulty in the development of indicators and goals for the Nearshore Zone is the tenuous state of the offshore food web, which is driven by the massive proliferation of invasive quagga mussels. While lower phosphorus loading would help to address problem *Cladophora* growth in the Nearshore, it could compound the oligtrophication that is occurring in the offshore food web, further impacting offshore fishes (Bootsma et al. 2012). As described in more detail in the climate change review (in Appendix H), many climate-related stressors have the potential to directly, or indirectly influence the viability of the Nearshore Zone. As a system that integrates terrestrial and aquatic systems, the Nearshore Zone 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. These changes can influence energy flow and nutrient loading within the system, and can potentially contribute to anoxic conditions in some locations. While changes in habitat availability are the only climate change threat individually ranked in our assessment, these other indirect impacts were considered during strategy development.

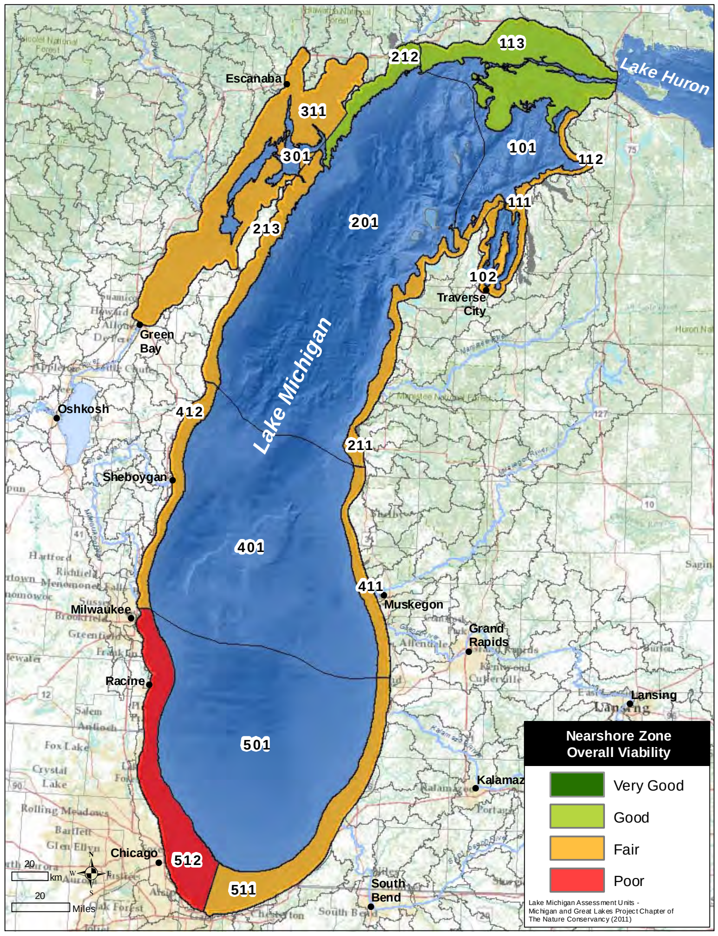

Figure 10: Viability of the Nearshore Zone at the assessment unit level

4.4. Native Migratory Fish

The Native Migratory Fish target includes native Lake Michigan fish 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). Many different Great Lakes fish species migrate into tributaries, including at least 30 species in Lake Michigan (Trautman 1981, Becker 1983, Herbert et. al. 2012). These include Lake Michigan fishes that spawn almost exclusively in rivers, such as lake sturgeon or shorthead redhorse (*Moxostoma macrolepidotum)*, as well as species that spawn in both lake and riverine habitats, such as walleye, yellow perch (*Perca flavescens*) or white suckers (*Catostomus commersonii)*. Historically, virtually all tributaries would have been utilized by Lake Michigan migratory fish species. While these fish spend a portion of their life in nearshore, coastal wetland, or offshore systems (each of 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 Michigan (Madenjian et al. 2002, Madenjian et al. 2010), 2) an important part of their life takes place in tributaries (which are not specific conservation targets in this plan), 3) they provide important functional ties between the Great Lakes and their tributaries (Flecker et al. 2010, Childress 2010) and 4) they aid in the migration of other native organisms between the Great Lakes and their tributaries (Sietman et al. 2001, Woolnough 2006, Crail et al. 2011).

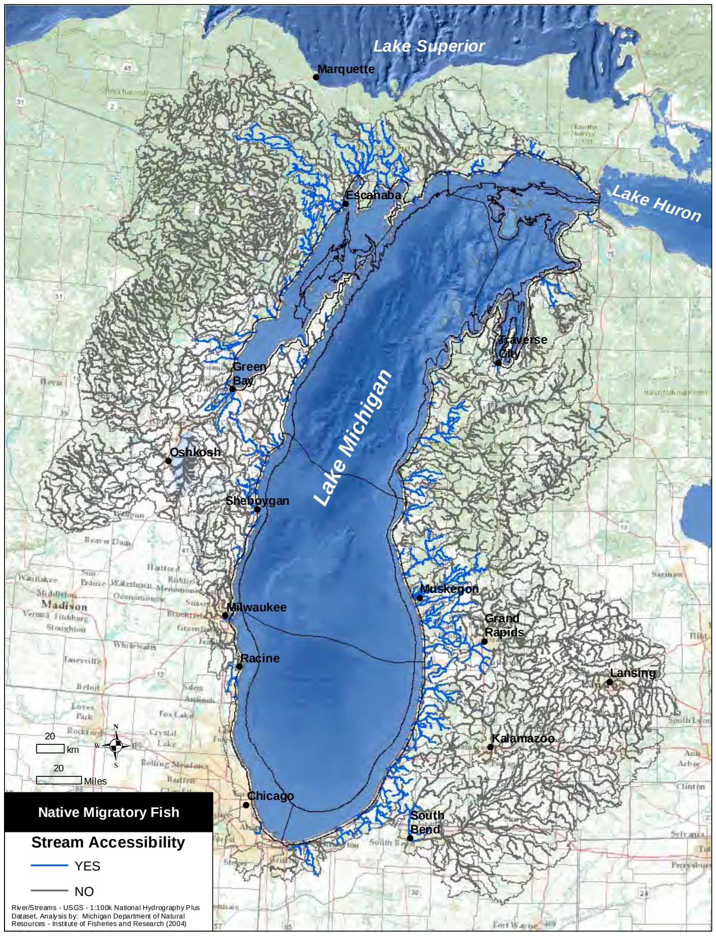

Figure 11: Stream accessibility for Migratory Fish in Lake Michigan.

Native migratory fish populations are highly imperiled in Lake Michigan due to loss of access to riverine habitat, habitat degradation, and other factors like historic overfishing. For example, 83% of tributary stream habitat is unavailable to Migratory Fish due to fragmentation caused by dams, and some of the remaining 17% is inaccessible due to problem road-stream crossings (Figure 11). Lake sturgeon were historically very important commercially in Lake Michigan, but they are now considered rare in Lake Michigan and regionally. Several other migratory fishes are now rare in Lake Michigan and most have experienced significant (>50%) population reductions. This loss results in changes in nearshore community structure and alters the functional relationships between Lake Michigan and its tributaries.

Nested targets include: lake sturgeon, walleye, suckers, northern pike (*Esox Lucius)*, lake whitefish

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 Michigan 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 Michigan 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 Michigan has a viability of *Fair*, overall (see Figure 12 and Appendix E for details). However, several assessment units are in *Poor* condition and only the northeast assessment unit is in *Good* condition. As a result, we can conclude that major intervention would be required across multiple assessment units to move the Native Migratory Fish target in Lake Michigan to a *Good* status. Indicators for Migratory Fish are based on connectivity of different stream types (sizes) and status of several migratory fish populations. Assessment units that were rated as poor were dominated by poor scores across both connectivity and migratory fish population indicators. Several assessment units that scored *Fair* (Green Bay and the assessment units along the Michigan shoreline of the Northern and Central basins and Mid-Lake Plateau) had poor connectivity, but had higher scores (*Fair* or *Good*) for most migratory fish population indicators. Conversely, the Wisconsin shoreline of the Mid-Lake Plateau had *Fair* connectivity, but *Poor* fish populations. The northeast assessment unit in the Northern Basin that scored *Good* overall had *Good* to *Very Good* connectivity across stream types and mixed (*Good*, *Fair*, and *Poor*) migratory fish populations.

Specific native migratory fish indicators that are considered *Poor* lakewide include the proportion of creek, headwater stream, and tributary wetland habitat connected to the lake, as well as the status of lake whitefish tributary spawning populations. No migratory fish indicators are considered *Good* or *Very Good* at a lake-wide scale. Since the connectivity indicators were directly related to dams and all of the migratory fish populations are being significantly impacted by dams (based on the expert interviews we conducted for this assessment), it is difficult to imagine significant improvement in Lake Michigan Migratory Fish without substantial improvement of fish passage around key dams. Given the importance of temperature-related factors to fish biology (see Appendix H), climate change is also an important consideration when assessing the future viability of Migratory Fish. While Lake Michigan is relatively well buffered from temperature increases, especially below the thermocline, streams and nearshore waters could potentially exceed species temperature preferences, reducing the quality of these habitats and potentially limiting migration.

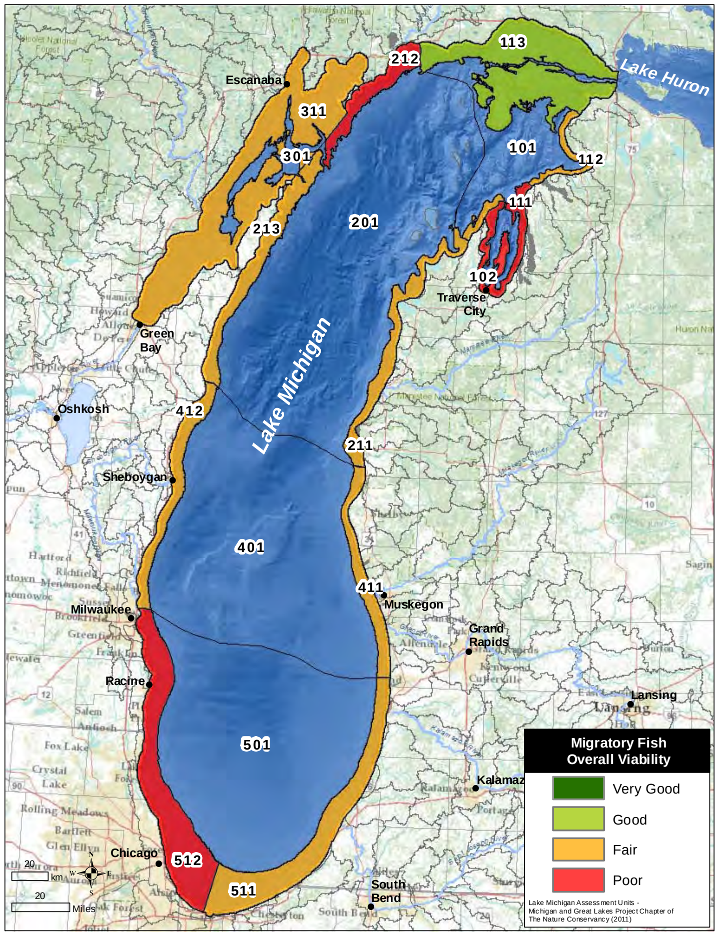

Figure 12: Viability of Native Migratory Fish at the assessment unit level

4.5. Coastal Wetlands

Great Lakes Coastal Wetlands provide numerous functions including habitat, nutrient and sediment processing and retention, buffering of wave energy, and others, and as such are extremely important ecosystems in all of the Great Lakes. They are dynamic, in that vegetation zones move upslope or downslope 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 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 LMBCS, 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 Michigan (Albert et al. 2003) (Figure 13).

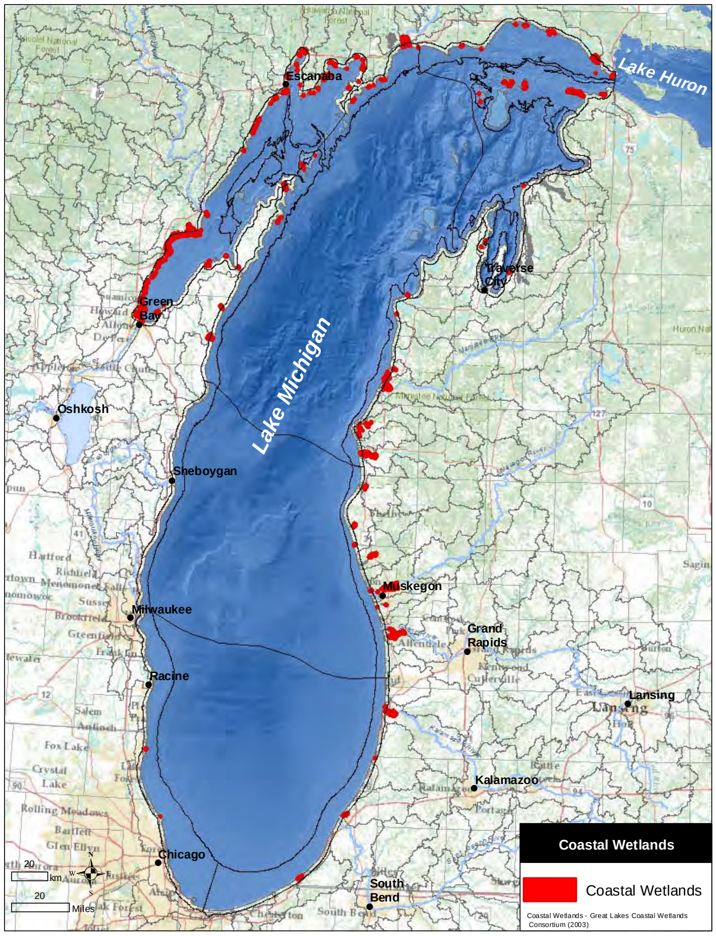

Figure 13: Distribution of the Coastal Wetlands in Lake Michigan

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

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

Overall, the current status of Coastal Wetlands in Lake Michigan is *Good*, which suggests that though some indicator, especially in the Southern Basin, are in *Poor* status, most are in *Good* or even *Very Good* status and there is hope that conservation actions can restore the viability of these important ecological systems. Coastal Wetland status is consistently rated as *Good* in assessment units around the lake (Figure 14), with the exceptions of assessment units 412, on the central Wisconsin coast, and 511 on the southwest Michigan/northwest Indiana coast. Wetland extent in unit 412 has been dramatically reduced, according to experts, and land cover in watersheds contributing to both units 412 and 511 has been heavily converted to agriculture. *Poor* values for each of these indicators lowered the overall viability score for wetlands in these two units.

Current status ranks of specific indicators for Coastal Wetlands are predominantly *Good*, with roughly equal numbers of *Very Good* and *Fair* ranks. There is some variability within and across assessment units (see Appendix E for details). Wetland-dependent bird species are rated *Good* or *Very Good* in all assessment units for which data are available, and percent natural land cover within 500m of mapped wetlands each scored *Good* or *Very Good* across all units. In contrast, the March – June water level increase was rated *Fair* across all units, and EO ranks for nested species targets varied from *Fair* to *Very Good*. We had limited data for the wetland macrophyte index, which was rated *Fair* in both assessment units for which data were available. The ongoing wetland surveys should facilitate a more complete assessment of this and other indicators, and overall Coastal Wetland viability.

Achieving goals for Coastal Wetland 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 also be at risk from increased run-off, which is predicted to result from increases in peak storm intensities. This risk increases the importance of restoration of Coastal Wetlands as they can help protect coastal communities from storm surges, which are also likely to increase in intensity as storm intensities increase.

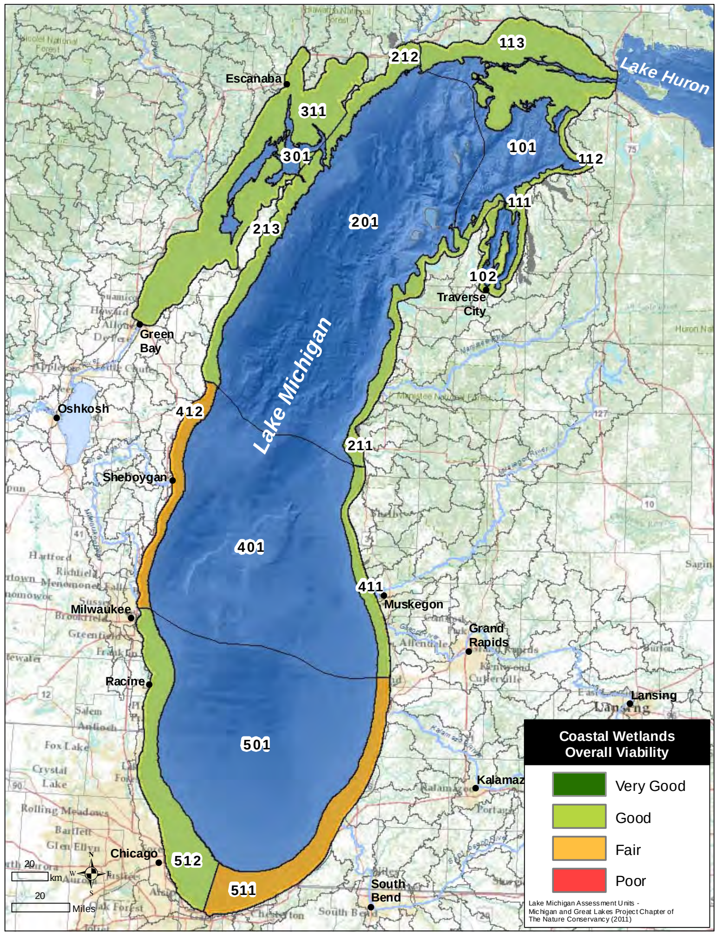

Figure 14: Viability of Coastal Wetlands at the assessment unit level.

4.6. Islands

The target Islands comprises all land masses within Lake Michigan that are surrounded by water, including both naturally formed and artificial islands that are ‘naturalized’ or support nested targets. Over 32,000 islands, the largest system of islands in fresh-water in the world, enrich the biodiversity, culture, and economics of the Great Lakes region (Henson et al. 2010). These islands support outstanding examples of plant communities and endemic plant species 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.

These islands may provide reference sites for community dynamics valuable for both ecological and economic reasons. Ecologically, interactions between species on islands may continue to drive the ecosystem dynamics that provide guidance for management in other places. Economically, the consequences of maintaining and protecting intact landscapes may have many benefits. For example, 1) certain tree species, such as ash, may increase in value as they disappear from the mainland, 2) lower densities of deer may ensure the full spectrum of plant regeneration and result in more stable predictable sources of timber income and also 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 residents alike, and 3) 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 Michigan has approximately 725 islands, mostly in northern part of the lake (Figure 15), with a total area of 34,818 ha (Henson et al. 2010). Many of these islands are part of the Niagaran escarpment and are underlain by limestone and dolomite. At least six globally rare species are known from these islands, including dwarf lake iris (*Iris lacustris*), Pitcher's thistle (*Cirsium pitcherii*), and Piping Plover (*Charadrius melodus*). Large dune systems characterize some of the larger islands such as Beaver, High, South and North Fox and South and North Manitou islands. At least some of the islands support plant communities which have not been altered by the emerald ash borer (*Agrilus planipennis*) or overabundant white-tailed deer (*Odocoileus virginianus*) and thus provide critical refugia for relatively intact landscapes, and imbedded species such as Canada yew (*Taxus canadensis*), which have become very local or vanished from the mainland (see Hatt et al. 1948). Lake Michigan islands are home to many colonies of nesting waterbirds, including American White Pelicans (*Pelecanus erythrorhynchus*), Double-crested Cormorants (*Phalacrocorax auritus*), Common Tern (*Sterna hirundo*), Caspian Tern (*Sterna caspia*), Herring Gull (*Larus argentatus*) and Ring-billed Gull (*Larus delawarensis*), and herons. Nearshore areas and nearby shoals are important spawning and nursery areas for many fishes and support important recreational fisheries for smallmouth bass (*Micropterus dolomieu*) and other species.

Of the Lake Michigan islands, Beaver, Garden, Hog and Washington islands are considered to have the greatest priority for conservation based primarily on biodiversity value, which includes the presence of species, plant communities, and ecological systems of conservation priority, physical diversity and threats; threats include shoreline development and associated infrastructure, introduction and spread of invasive species, introduction of native species found on the mainland but not islands, and climate change. Beaver 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 (Henson et al. 2010). Although approximately 45% of the islands are considered to be in some form of protection, or conservation designation (such as Important Bird Areas, see Figure 19), many islands of high conservation interest remain unprotected and should be the focus of future work.

Figure 15: Distribution of Islands in Lake Michigan.

Nested targets include: colonial nesting waterbirds, imperiled[4] species (e.g., Pitcher's thistle), all natural communities that occur on islands (e.g., island forests, alvars, cobble lakeshores), stopover habitat for migrating landbirds.

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

- A minimum of 60% of Lake Michigan islands are owned and/or managed for conservation;
- A minimum of 80% of Lake Michigan 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;

[4] All G1 – G3 species and any additional species listed as threatened or endangered by a state or province, or declining species such as birds recognized by Partners in Flight.

- 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.

4.6.1. Viability of Islands

Lake Michigan islands are concentrated in the northern half of the lake, with southern islands being typically small and, in some cases, artificial. The viability assessment reflects that pattern, and many data gaps remain (see Appendix E for details), which affects ratings. Of the indicators that have been rated to date, current status varies, with some indicators being rated mostly *Very Good* or *Good* (e.g., artificial shoreline hardening index, house density, and EO ranks of nested community targets), and others exhibiting a range from *Poor* to *Good* (e.g., EO ranks of nested species targets and road density), while others show a dichotomous pattern of *Poor* or *Very Good* (e.g., percent natural land cover). This latter result may reflect the contrast between large, natural islands in the northern part of the lake as compared to the small, largely bare or artificial southern islands, but may also suggest that islands that are naturally rocky are being classed as having little natural cover; this potential error will need follow-up work.

The overall viability of Lake Michigan Islands is *Good*, with most Assessment units having *Good* or *Very Good* ratings except for Assessment Unit 102 in the Northern Basin that has a *Poor* rating (Figure 16). Though all reporting units are rated as *Good*, there is some variability. Only the Southern Basin and Mid-Lake Plateau received a *Poor* rating for any indicator, that being "Percent natural land cover on entire island." This rating largely reflects the relatively high proportion of artificial islands in southern and central Lake Michigan compared to northern Lake Michigan; artificial islands include breakwaters and other concrete or rock structures with little or no vegetation. Beyond the viability ratings, islands are particularly under protected in Green Bay and near Escanaba. Finally, there is a need to inventory islands for invasive species that have the potential to alter ecosystem dynamics.

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).

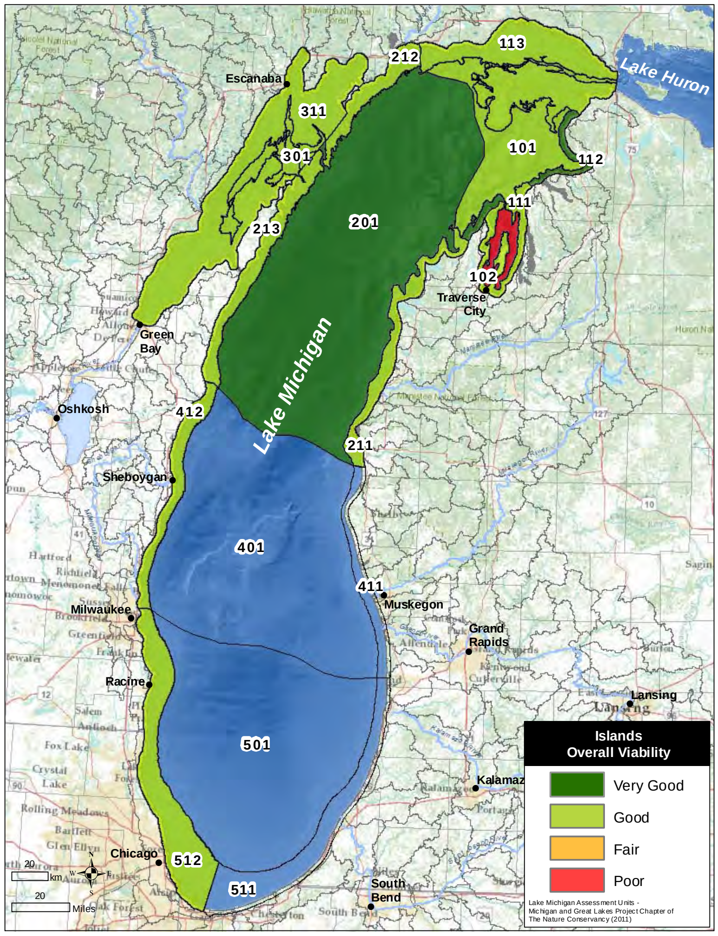

Figure 16: Viability of Islands at the assessment unit level

4.7. 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 17). 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 Michigan. 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).

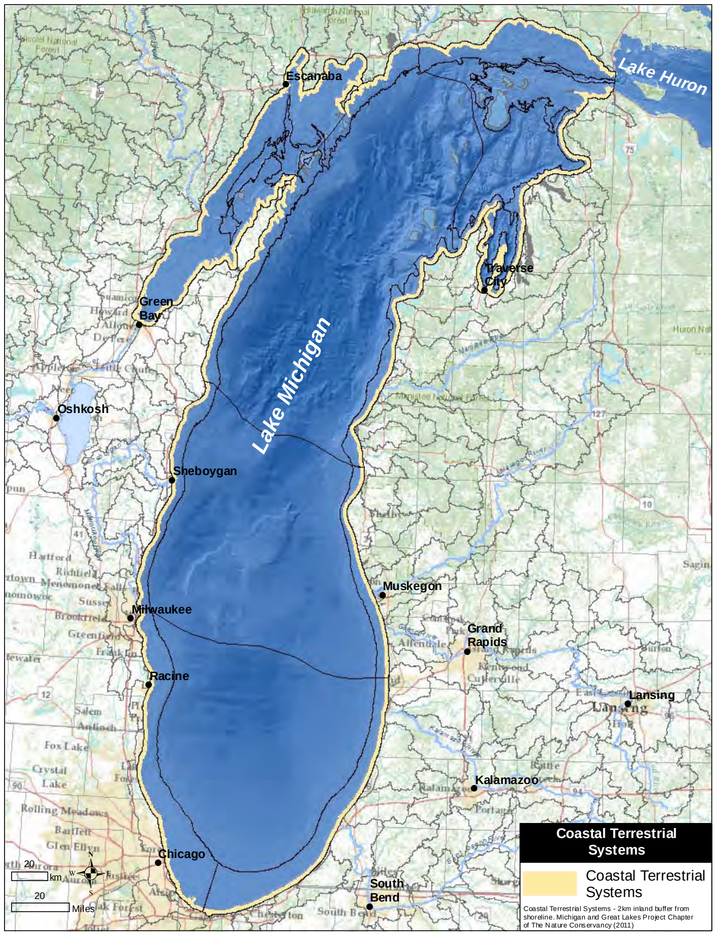

Figure 17: The Coastal Terrestrial System in Lake Michigan

This dynamic environment provides critical habitat for migratory birds (SOLEC 2009), and supports numerous endemic and globally rare species and coastal communities. Lake Michigan's coastal terrestrial environment is primarily characterized by open dunes, coastal forests, broad sandy beaches, bluffs, and exposed limestone bedrock. Additionally, interdunal wetlands, and isolated forested and non-forested wetlands within the 2 km buffer are also found throughout the Coastal Terrestrial System. 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 Michigan contains both the highest number of nested targets and number of occurrences. Along the 1,660 miles of shoreline, 3,834 element occurrences representing approximately 698 different unique natural features are known to occur here (based on 2010 data from the four state heritage programs). Coastal Terrestrial System nested targets are restricted to plants, animals and natural communities tracked by each of the four heritage programs located in the Lake Michigan 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. A partial list of priority nested targets are listed below by category (plant, animal, and natural community).

The Coastal Terrestrial System is threatened in Lake Michigan due to continued habitat loss from development, fragmentation, separation from the lake by hardened shoreline structures, and the spread of invasive species.

Nested targets:

Plants: Pitcher's thistle (*Cirsium pitcheri*), Houghton's goldenrod (*Solidago houghtonii*), Dwarf lake iris (*Iris lacustris*), Lake Huron tansy (*Tanacetum huronense)*, Ram's head lady's slipper (*Cypripedium arietinum)*, Michigan monkey flower (*Mimulus glabratus michiganensis*, Climbing fumitory (*Adlumia fungosa*), Ginseng (*Panax quinquefolius)*, Fasicled broom-rape (*Orobanche fasciculata*), Prairie dunewort (*Botrychium campestre*), Eastern prairie fringed orchid (*Platanthera leucophaea)*; and showy orchis (*Galaeris spectabilis*)

Animals: Lake Huron locust (*Trimerotropis huroniana)*, Piping plover (*Charadrius melodus)*, Hines emerald dragonfly (*Somatochlora hineana*), Caspian tern (*Sterna caspia*), Common tern (*Sterna hirundo)*, Land snails (various species), Karner blue butterfly (*Lyceaides melissa samuelis*), and eastern massasauga rattlesnake (*Sistrurus catenatus catenatus)*

Natural Communities: Open dunes, Interdunal wetland, Wooded dune and swale complex, Coastal forests (boreal forest, northern mesic forest, southern mesic forest, northern dry mesic forest, southern dry mesic forest, rich conifer swamp, hardwood swamp), Limestone bedrock shoreline, Sand and gravel beach, Cobble beach, Prairie, Savanna, Alvar, Great Lakes barrens, Clay seepage bluff, Cliff (moist and dry), Northern wet meadow, and Emergent marsh.

Goal: The desired future condition for the Coastal Terrestrial System was based on input from coastal experts most familiar with the Lake Michigan 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 priority nested targets are adequately represented across the lake (adequate representation will be determined later);
- 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 unaffected by shoreline alterations

4.7.1. 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. For more details on specific indicators of viability, see Appendix E.

The overall viability of the Lake Michigan Coastal Terrestrial System was assessed as *Fair*. With approximately 1,660 miles of shoreline, it is not surprising that the viability of Lake Michigan's Coastal Terrestrial System is highly variable (Figure 18). The variability primarily occurs along a north to south gradient, with the northern reporting units having higher viability than the southern units. Overall, road density and housing density received the worst ratings.

In general, the Coastal Terrestrial System on the mainland is more degraded than similar systems on the Islands due to high accessibility for people. Much of the Coastal Terrestrial System around Lake Michigan has some sort of human influence ranging from small isolated cottages and associated infrastructure such as roads in the northern portion of the basin, to large metropolitan cities such as Chicago, Milwaukee, and Gary in the southern portion of the basin.

The viability of the Coastal Terrestrial System in the Southern Basin reporting unit (which encompasses portions of Wisconsin, Illinois, Indiana, and Michigan coastal area) is considered to be in *Fair* condition (Appendix G). This area has the highest level of urbanization in the region with very high road and housing density. The cities of Milwaukee, Chicago, and Gary are all found in this unit. Most of the shoreline has some sort of shoreline hardening due to the high amount of urban infrastructure, and there is also a very high number of piers and groins. However, of the remaining natural community element occurrences in the area, 78% are considered to be high quality. Natural communities found in this unit include open dunes, prairie (dry sand, dry-mesic and wet-mesic), interdunal wetland, southern mesic forest, and southern dry-mesic forest. Priority rare plant species found in this area include Pitcher's thistle, ginseng, showy orchis, and eastern prairie fringed orchid. Priority animal species include piping plover, Karner blue butterfly and eastern massasauga rattlesnake.

Viability of the Coastal Terrestrial System in the Mid-Lake Plateau (which encompasses both Wisconsin and Michigan shoreline) is considered to be in *Fair* condition. Road density and housing density are considered in *Poor* condition, artificial shoreline, percent natural landcover within 2-10 km of the shoreline and species element occurrences are in *Fair* condition on both sides of the lake, while all other indicators are rated higher on the Michigan side of the unit. Natural communities from highest to lowest priority included shoreline communities such as Great Lakes dune, Great Lakes ridge and swale, interdunal wetland, northern sedge meadow, emergent marsh and Great Lakes beach, as well as several coastal forest communities including northern wet-mesic forest (cedar swamp), northern mesic forest, northern dry-mesic forest, southern mesic forest, and southern dry-mesic forest. Priority plant species include Pitcher's thistle, Clustered Broomrape (*Orobanche fasciculata*) and ginseng.

Viability of the Coastal Terrestrial System in the Central Basin (which encompasses both Wisconsin and Michigan shoreline) is considered to be in *Fair* condition. All indicators in this unit range from *Fair* to *Very Good* with the exception of road density which is in *Poor* condition. Natural communities found here include Great Lakes alkaline rockshore, Great Lakes dune, Great Lakes dune and swale, Great Lakes beach, as well as a number of coastal forests. Priority plant species found here include Pitcher's thistle, dwarf lake iris (*Iris lacustris*), Lake Huron tansy (*Tanacetum huronense*), ram's-head lady's-slipper (*Cypripedium arietinum*), dunewort (*Botrychium compestre*), and climbing fumitory (*Adlumia fungosa*). Significant animal species found in this unit include Piping Plover, Lake Huron locust, Hine's emerald dragonfly (*Somatochlora* hineana), and several rare land snails.

Viability of the Coastal Terrestrial System in the Green Bay reporting unit is considered to be in *Fair* condition. The majority of indicators were given a *Good* rating, with only road density and housing density rated as *Poor*. Natural communities indicative of this unit include a number of shoreline communities such as alvar, limestone bedrock shoreline, limestone bedrock cliff, Great Lakes barrens, open dunes, wooded dune and swale complex, beach, interdunal wetland, as well as other wetland and forested communities including boreal rich fen, moist cliff, dry cliff, emergent marsh, hardwood swamp, southern hardwood swamp, and coastal forests. Priority plant species are Pitcher's thistle, dwarf lake iris, ram's-head lady's-slipper and climbing fumitory. Priority animal species found in this unit are piping plover, Hine's emerald dragonfly, Lake Huron locust and several rare land snails.

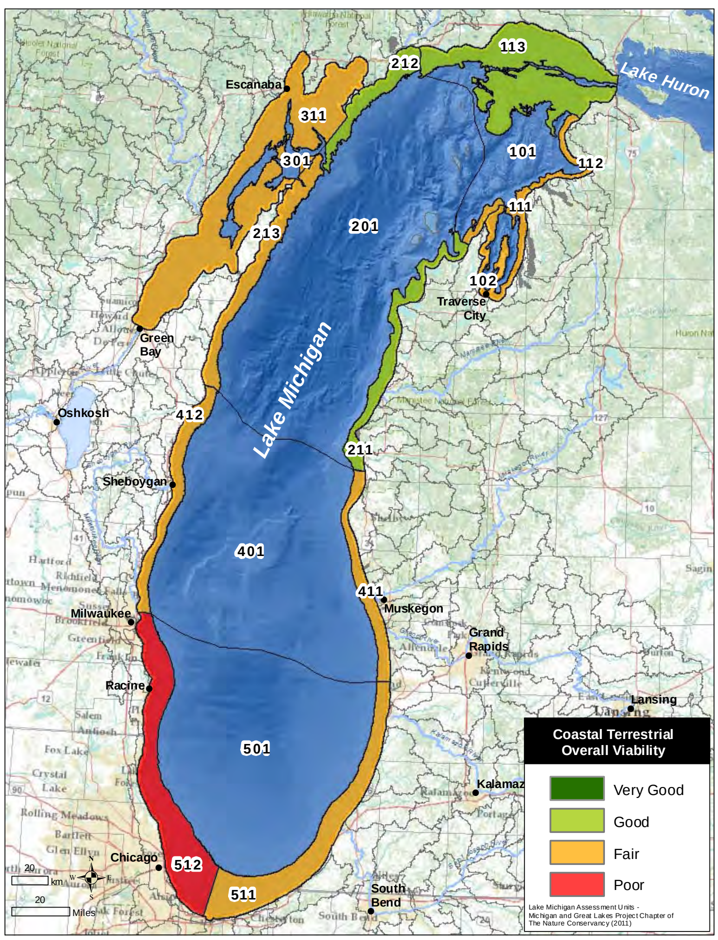

Figure 18: Viability of Coastal Terrestrial Systems at the assessment unit level.

Viability of the Coastal Terrestrial System in the Northern Basin is considered to be in *Fair* condition. The majority of indicators received a *Good* rating, while road density was the only indicator given a *Poor* rating. Most indicators had a range of conditions with the lowest ratings associated with assessment unit 111, and the highest ratings associated with assessment unit 113. There is a diverse assemblage of natural communities found across this unit similar to the Green Bay unit. Natural communities include wooded dune and swale complex, open dunes, Great Lakes barrens, conifer swamp, limestone bedrock beach, limestone cobble beach, sand and gravel beach, and coastal forests.

Priority plant species found here are Pitcher's thistle, dwarf lake iris, ram's-head lay's-slipper, Pompelly's brome grass, and Lake Huron tansy. Priority animal species in this unit are Lake Huron locust, piping plover, common tern, caspian tern, and numerous rare land snails.

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.

4.8. Aerial Migrants

Aerial Migrants are defined as birds (landbirds, waterfowl, shorebirds, and other waterbirds such as loons) that use open waters of Lake Michigan and adjacent shorelines during spring and fall migration; bats and insects 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 Michigan. This diverse set of bird species occupies a wide range of habitats where they refuel and rest at stopover sites (Figure 19). The Great Lakes serve as major migratory corridors for some waterfowl and waterbirds while the adjacent shoreline provides critical habitat to other migrants such as landbirds, including many species of raptors (Figure 20). Highest concentrations of landbird migrants tend to be within 2 km of the shoreline, especially during spring migration, while 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 habitat (e.g., flooded agricultural fields, wetlands) close to the lake.

Lake Michigan, and its shoreline, provide state important stopover sites for waterfowl, shorebirds, landbirds (songbirds and raptors) and waterbirds (loons, grebes, Pelecaniformes, herons, rails, cranes, gulls and terns) at many locations scattered along the Wisconsin, Illinois, Indiana, and Michigan shorelines and one globally important stopover site, Cowles Bog, Indiana (National Audubon Society 2012). Landbird concentration sites have been best described along the western and southern areas of Lake Michigan, but also are known to occur along the eastern and northern shores of the lake. High numbers of Long-tailed Ducks (*Clangula hyemalis*) and Greater Scaup *(Aythya marila*) occur during migration on Lake Michigan. Shorebirds also stopover along Lake Michigan shores but in smaller numbers than landbirds and waterfowl. Identifying, protecting, and managing important stopover sites in the Great Lakes region may contribute disproportionately to maintaining populations of at least some migrant species, including Long-tailed Duck.

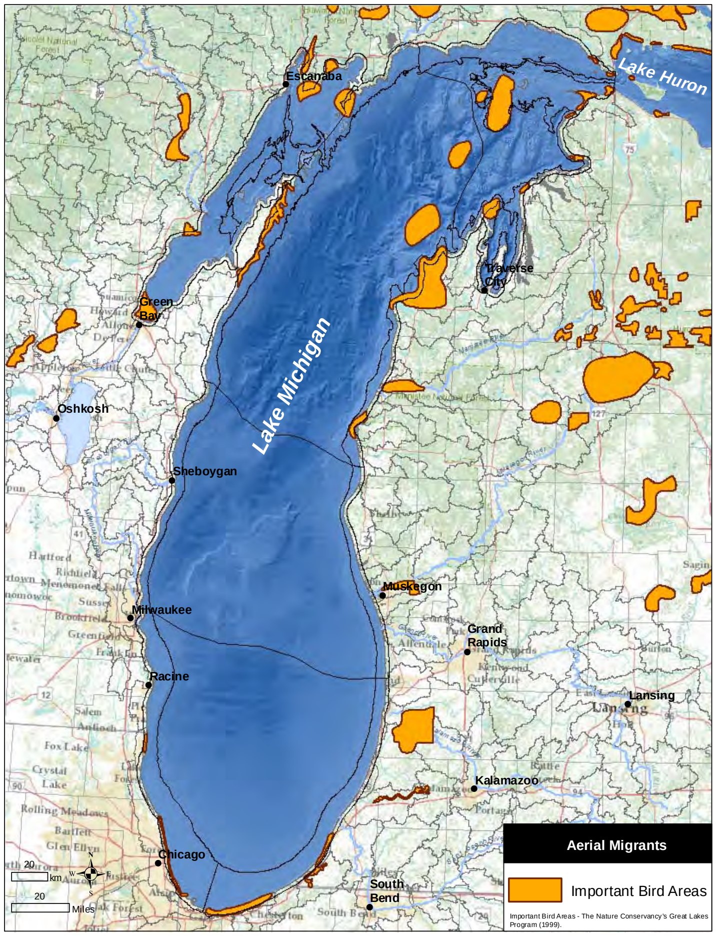

Figure 19: Important Bird Areas in Lake Michigan

Both the waters of Lake Michigan and adjacent shoreline, especially in southern and central portions of Lake Michigan, have been altered by anthropogenic activities. Habitat loss, and consequences of habitat loss such as habitat fragmentation and increased presence of invasive species, pose the greatest current threat to Aerial Migrants. Other threats may also contribute to loss or degradation of stopover habitat including pollutants (especially in Green Bay), buildings and other structures on or near the shoreline, and infrastructure for energy production. These threats primarily affect Aerial Migrants through loss of food resources and secondarily by direct mortality from disease (e.g., botulism) or striking structures.

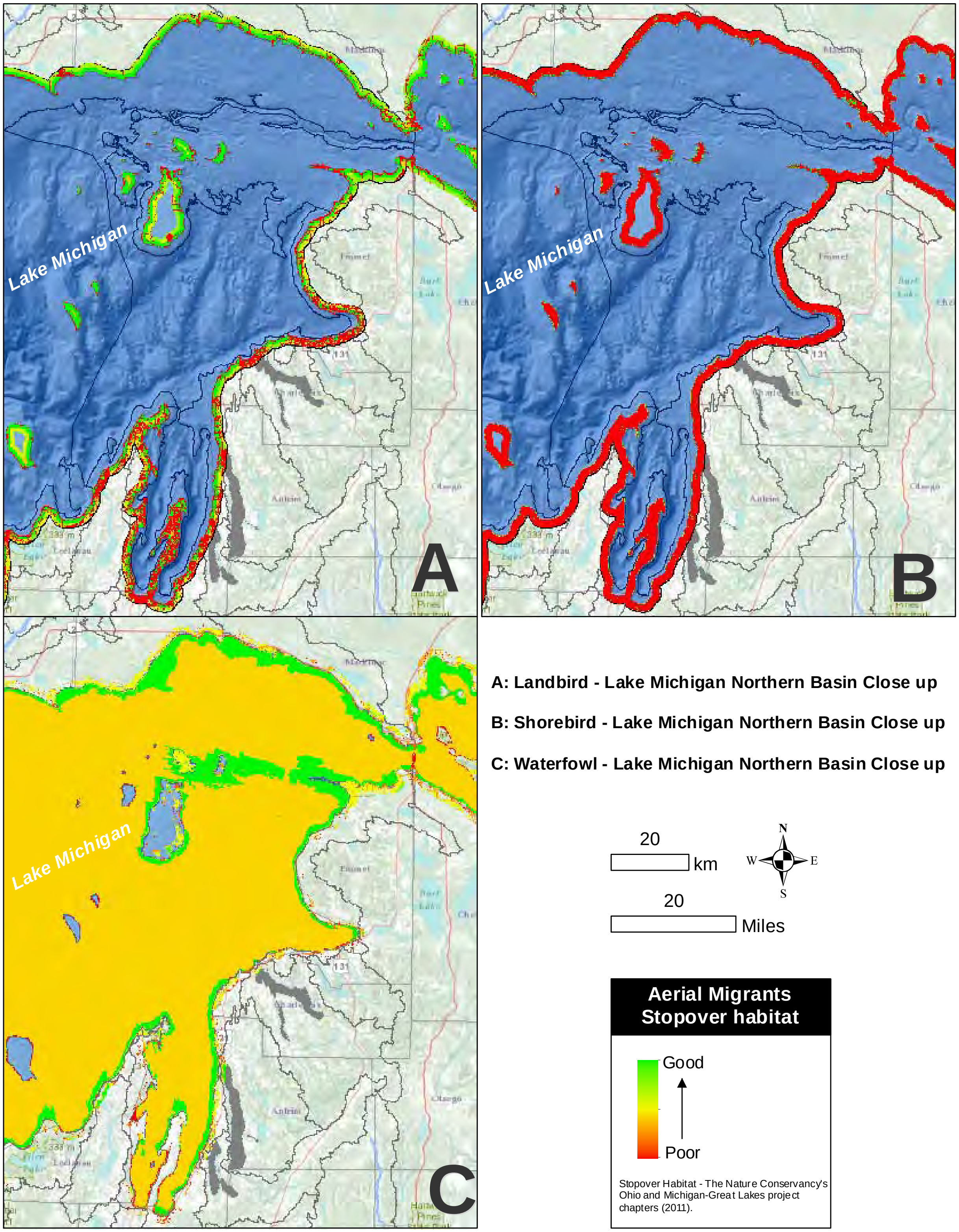

Figure 20: Example of habitat stopover sites in Lake Michigan for three bird groups (Data from Ewert et al. 2012).

Nested targets include: all types of migrating birds.

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

By 2030, so that Lake Michigan 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.

4.8.1. Viability of Aerial Migrants

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 for landbirds when 1) landscapes are relatively intact and 2) stopover sites are relatively close to water, either the Great Lakes or inland non-Great Lakes waters; for shorebirds when 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; and for waterfowl when 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 ≤ nine meters. The criteria for establishing viability 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).

The overall viability for aerial migrants is *Fair* with only one assessment unit having a *Good* rating (Figure 21). However, the viability assessment for migrating birds along Lake Michigan suggests that current habitat availability is *Very Good* for landbirds and *Fair* to *Poor* for shorebirds and waterfowl; these ratings are probably consistent with presettlement stopover habitat distribution. Forests and other suitable habitat for land birds is generally well distributed around Lake Michigan except in the Chicago and Milwaukee metropolitan areas and even there substantial areas remain in national, state, and regional parks and forest preserves. Because the shoreline of Lake Michigan, especially along the eastern shores, is often sand dominated, there are few permanent wetlands, except at drowned river mouths. As a result there is relatively little habitat that supports large numbers of migrating waterfowl and shorebirds, hence the low rating for these bird groups. However, there are opportunities to ensure that remaining stopover habitat for shorebirds and waterfowl is protected, restored or created. These actions would probably enhance ratings somewhat but new criteria need to be adopted to evaluate the potential improvement possible. This requires assessing the presettlement distribution of potential habitat by assessment unit and then working to define new goals within each assessment unit that include both this past reference point, and consideration of what might be possible as the climate continues to change.

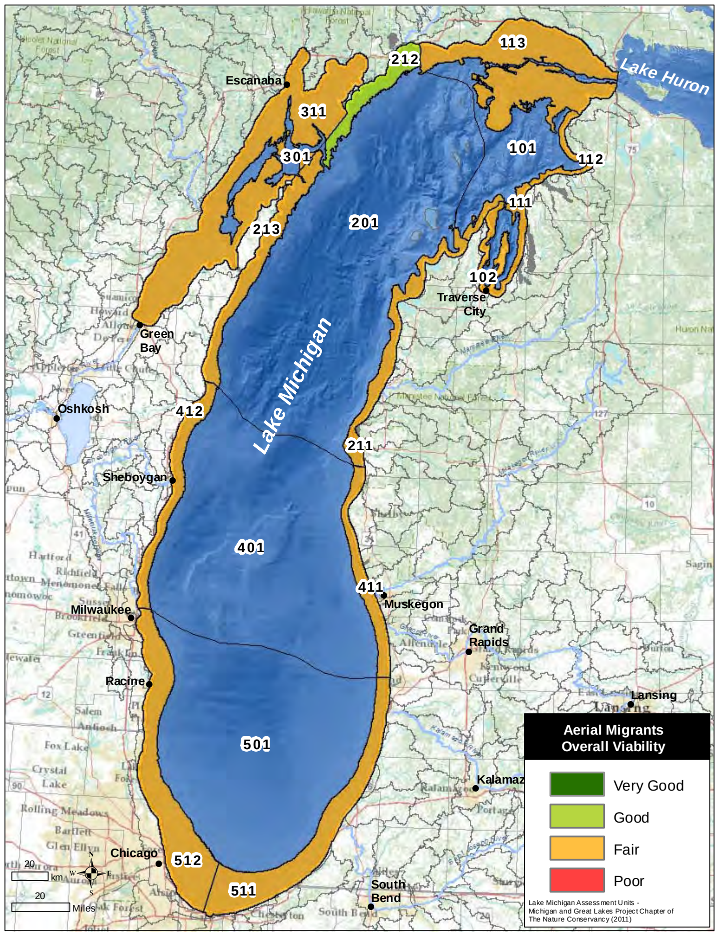

Figure 21: Viability of Aerial Migrants at the assessment unit level

While our goals for Aerial Migrants focus on measuring habitat availability, changes in climate may also influence how well systems in the Lake Michigan 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 insect emergence, or plants and the insects that eat 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.

4.9. Lakewide viability assessment

Lakewide, the viability of Lake Michigan is considered *Fair* (Table 1). This rating indicates that lakewide viability falls outside the acceptable range of variation and thus requires human intervention. (For more information on indicator ratings see Box 1). The lakewide status of five of the conservation targets is considered *Fair*, while two targets—Coastal Wetlands and Islands—are considered *Good*. Restorative efforts need to occur broadly across the targets rated as *Fair*, while maintaining the current *Good* status for Coastal Wetlands and Islands.

Table 1: Lakewide viability assessment summary

Target	Landscape Context	Condition	Size	Overall
Nearshore Zone	Good	Fair	Fair	Fair
Aerial Migrants	Fair	*Not applicable*	*Not applicable*	Fair
Coastal Terrestrial Systems	Fair	Fair	*Not applicable*	Fair
Coastal Wetlands	Good	Good	Fair	Good
Islands	Fair	Good	*Not applicable*	Good
Native Migratory Fish	Poor	*Not applicable*	Fair	Fair
Offshore Zone	Good	Fair	*Not applicable*	Fair
Overall Biodiversity Health	Fair	Fair	Fair	Fair

It is important to highlight that while the lake receives an overall *Fair* status and the overall status of most conservation targets is *Fair* (Table 1) nearly one third of the indicators across conservation targets are considered *Poor* (Figure 22, see also Appendix E for more details on indicator ratings), indicating that substantial restorative work will be necessary to move Lake Michigan from *Fair* into an overall status of G*ood*.

Also while five of the targets received an overall *Fair* rating (Table 1), the specific status of indicators within those targets is highly variable (Figure 23). For example, while the Nearshore Zone and Coastal Terrestrial targets have a higher proportion of indicators rated as G*ood* than either *Fair* or *Poor*, the Offshore Zone target has proportionally fewer indicators rated G*ood* and the second most indicators rated as *Poor.* Aerial Migrants indicators have the second highest proportion of indicators rated *Very Good*, but the highest rated as *Poor*. Further, all indicators for Migratory Fish are rated as *Fair* or *Poor* lakewide. As a result, more extensive restorative intervention would be required to move the Offshore Zone, Migratory Fish or Aerial Migrants from *Fair* to *Good*.

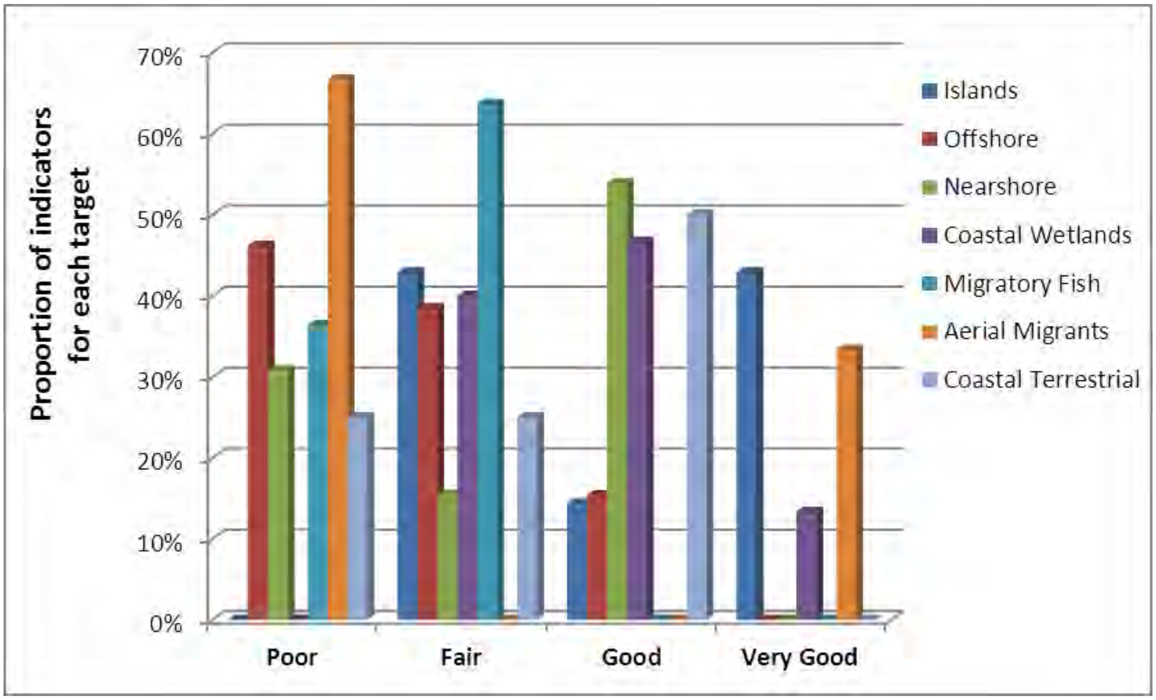

Figure 22: Proportion of indicators for each conservation target that fall within each of the four rating categories (*Poor*, *Fair*, *Good*, or *Very Good*) across Lake Michigan. This demonstrates the general status of Lake Michigan across all conservation targets.

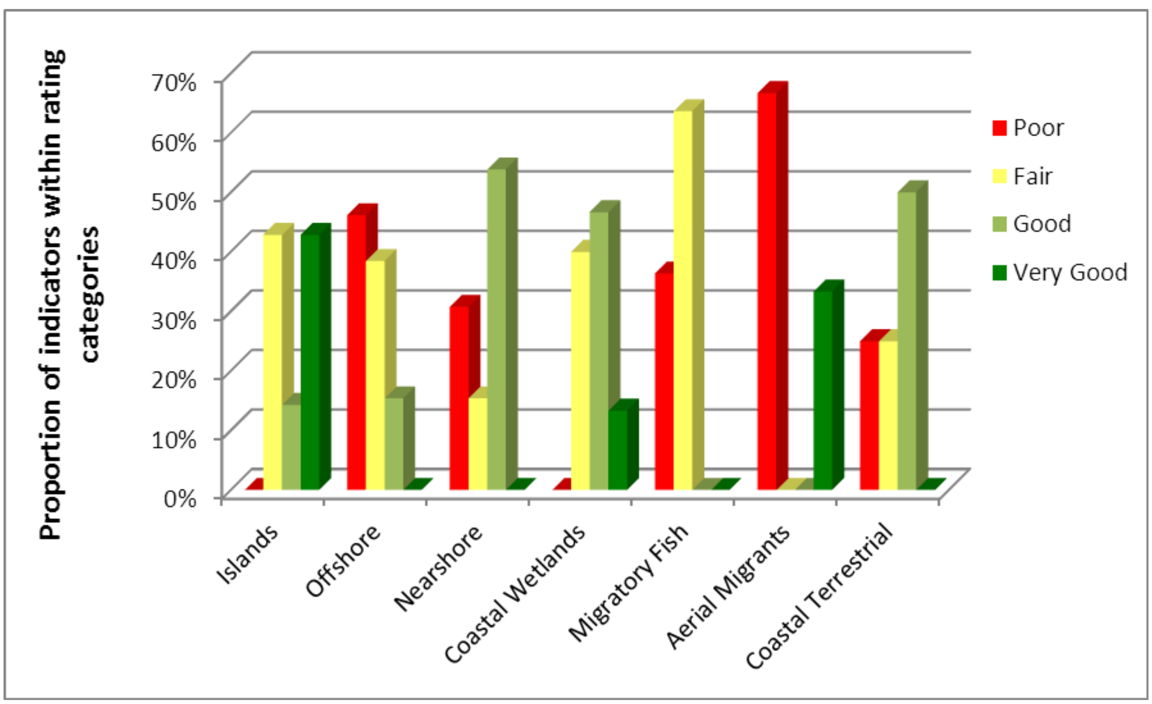

Figure 23: Proportion of indicators for each rating category (*Poor*, *Fair*, *Good*, or *Very Good*) for each conservation target across Lake Michigan. This demonstrates how the status of indicators varies among targets.

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 2).

5. THREATS TO 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 Michigan biodiversity conservation targets. Threat ranks for each reporting unit are included in Appendix G.

5.1. Threat assessment methods

Threats to biodiversity were assessed at the reporting unit level and then aggregated lakewide. To assess threats the Core Team began by compiling a list of threats from previous Biodiversity Conservation Strategies, including the Lake Huron and Lake Ontario BCS reports (Lake Ontario Biodiversity Strategy Group 2009, Franks Taylor et al. 2010), as well as from relevant regional and local plans, other initiatives and reports including the Lake Michigan LaMP and the Great Lakes Environmental Assessment and Mapping project (GLEAM). The Steering Committee provided additional suggestions to complete the initial list. For consistency purposes we followed a published taxonomy of threats and conservation actions (Salafsky et al. 2008). The team then developed online surveys, one for each of the four reporting units[5]. For each survey, we invited roughly 275 experts (including agency staff, academics, private consultants, organization scientists and others, see Appendix B) to rate the **Scope**, **Severity**, and **Irreversibility** of each threat to each target for each reporting unit (see Box 3)[6], and also to document their level of confidence with each rating (using the categories of *Very High*, *High*, *Medium*, and *Low*). We provided additional rows for experts 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 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

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[5] Using *SurveyMonkey* a provider of web-based surveys.
[6] 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.

5.2. Critical threats to Lake Michigan biodiversity

Of the 18 threats that were included in the survey (Box 6), 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 *Very High* ranks in two basins—Green Bay and the Northern Basin. The threat of terrestrial invasive species was ranked *High* in four of the five basins, and two other threats (housing/urban development and climate change: habitat shifting/alteration) were ranked *High* in three of the four basins (see appendix G for details on climate change impacts). The other *High*-ranked threats include pollutants and contaminants from point and non-point sources, dams and barriers, and shoreline alterations. Note that in addition to contributing to the threat titled "Habitat shifting and alteration", climate change acts as a threat multiplier in some cases (e.g., for the "Pollution: Agriculture and Forestry sources" threat, increases in storm intensities tend to increase the magnitude of the threat). 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 represented a definite challenge. While it is likely that not all participants considered climate change interactions with these other stressors in their threat ranking, the need to address, and think ahead about climate change was emphasized in the strategy development steps.

Box 6: 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

These results are not surprising and many of the critical threats are reflected in several of the subgoals of the Lake Michigan LaMP (U.S. EPA 2008): LaMP subgoal 8 addresses both aquatic and terrestrial invasive species; subgoal 6 addresses sustainable land use; subgoal 7 addresses existing contaminants and pathways for pollutants (and subgoals 1-3 indirectly address these threats via human use of water and fish); subgoal 4 incorporates dams as one of multiple threats to habitats and natural communities; and climate change is mentioned as a challenge to meeting many of the LaMP subgoals. The Great Lakes

Fishery Commission Strategic Vision for 2011 – 2020 (GLFC 2011) also describes many of these threats in a historical perspective, focusing especially on sea lamprey and other aquatic invasive species report.

It is important to note that the threat rankings presented here are based entirely on expert surveys, and that the distribution of experts across threats was uneven. Whereas the results for the majority of threats are reliable, there may be exceptions for threats or geographic regions for which the number of experts was low, and those experts chose to emphasize (and over-rank) threats with which they happen to be most familiar.

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

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Invasive aquatics	Very High	High	Very High	High	High
Invasive terrestrial	High	High	High	Medium	High
Housing/urban development	Medium	High	High	Medium	High
Climate: habitat shifting/ alteration	High	High	Medium	High	High
Contaminated sediments	High	Medium	Medium	Medium	Medium
Dams/other barriers	High	Medium	Medium	Medium	Medium
Pollution: agriculture/forestry	Medium	Medium	Medium	Medium	High
Pollution: industrial	Medium	Medium	Medium	Medium	High
Pollution: Urban/household	Medium	Medium	Medium	Medium	High
Shoreline alterations	Medium	Medium	Medium	Medium	High

*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 7)

Box 7: Aggregated Critical Threats

1. **Invasive species**
2. **Agricultural non-point pollution**
3. **Urban non-point source pollution**
4. **Housing and urban development, coupled with shoreline alterations**
5. **Dams and barriers**
6. **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 is pollution from agricultural non-point sources a critical threat?

Agricultural non-point source (NPS) pollution is considered a *High* overall threat in the Southern Basin and a *Medium* threat across the other four Reporting Units (Table 3). It poses threats to every target except Islands at some locations, with the Nearshore Zone, Coastal Terrestrial, Coastal Wetlands and Native Migratory Fish being at least moderately threatened by agricultural non-point source pollution across every region (Table 4). It is considered a *High* threat to the Nearshore Zone in Green Bay and a *High* threat to Coastal Terrestrial Systems and Coastal Wetlands in the Southern Basin. 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).

Table 3: Overall threat ranks for agricultural non-point pollution in reporting units of Lake Michigan

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Pollution: agriculture /forestry	Medium	Medium	Medium	Medium	High

Table 4: Ratings of threat to each target for agricultural non-point pollution in reporting units of Lake Michigan

Reporting unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Northern Basin		Medium		Medium	Medium	Medium	Medium
Central Basin		Medium	Medium	Low	Medium	Medium	Medium
Green Bay		Medium			High	Medium	Medium
Med-Lake Plateau		Medium		Low	Medium	Medium	Medium
Southern Basin		Medium		Medium	Medium	High	High

Agricultural non-point source pollutants impact Lake Michigan through changes in watershed hydrology and increased contributions of sediment, nutrients, and other pollutants (e.g., pesticides). Altered hydrology from agricultural land use (particularly without conservation practices) results in greater water runoff and reduced infiltration. As a result, streams and associated habitats, such as river-mouth coastal wetlands, experience greater fluctuations in water levels (i.e., increased flooding and increased drought). Increased runoff indirectly contributes to increases in NPS pollutants, such as sediment and nutrients, which would already be highly elevated due to increases in soil exposure and nutrient applications on agricultural lands. These elevated loadings of sediment, nutrients, and other pollutants then impact habitats within coastal rivers, and Lake Michigan Coastal Terrestrial, Nearshore Zone, Coastal Wetland, and Offshore Zone.

Native Migratory Fish are affected by agricultural NPS through habitat degradation in rivers, as well as to the lake habitats they utilize downstream. Stream habitats are degraded by excess sediment and nutrients, which can degrade spawning substrates--especially coarse substrates (e.g., cobble, gravel, sand) —by covering them with sediment or algal growth—and can reduce water quality through increased turbidity (water cloudiness) and lower dissolved oxygen (Corbett and Powles 1986, Anderson et al. 2006, Diana et al. 2006, Gillenwater et al. 2006). These NPS contributions also degrade coastal systems (i.e., Nearshore Zone, Coastal Wetlands, Coastal Terrestrial). Coastal Wetlands and Nearshore Zone areas with high agricultural NPS contributions generally have turbid water that suppresses aquatic vegetation growth and are dominated by tolerant fish and invertebrates (Uzarski et al. 2005, Shear 2006, Trebitz et al. 2007, Rutherford et al. 2004). Offshore systems are somewhat buffered from these impacts, but agricultural NPS can cause offshore water quality problems in localized areas or under extreme circumstances. At the same time, offshore fish assemblages can be impacted since some offshore species/populations (e.g. lake whitefish, lake trout, cisco) spawn or nursery in nearshore habitats that are susceptible to agricultural NPS (Rutherford et al. 2004). Application of agricultural conservation practices can help to reduce each of these non-point contributions.

5.2.2. Why are invasive species a critical threat?

Invasive species, both aquatic and terrestrial, are at least a *Medium* threat in every Reporting Unit of Lake Michigan (Table 5). Aquatic invasives are ranked a *Very High* to *High* threat and terrestrial invasive species are mostly ranked *High*. All targets, Islands, Native Migratory Fish, Aerial Migrants, Offshore Zone, Nearshore Zone, Coastal Terrestrial and Coastal Wetlands, are threatened by invasive species (Table 6). Invasive species are a pervasive threat to all aquatic and terrestrial targets in all portions of Lake Michigan, including lakes and streams on Lake Michigan islands.

Table 5: Overall threat ranks for invasive species in reporting units of Lake Michigan

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Aquatic invasive species	Very High	High	Very High	High	High
Terrestrial invasive species	High	High	High	Medium	High

Aquatic and terrestrial invasive species are critical threats for similar reasons. They become dominant in communities and ecosystems as they outcompete native flora and fauna in the absence of predators, parasites and pathogens which results in reduction of native species and alteration of community composition and function, nutrient dynamics, and anthropogenic use of the Great Lakes and nearshore coastal communities. 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.

Aquatic invasive species are particularly difficult to control because they disperse so readily, rapidly invading new habitats. Given this mobility, once established there are relatively few management options available to control the 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.

Table 6: Ratings of threat to each target for invasive species in reporting units of Lake Michigan

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Aquatic Invasive Species							
Northern Basin		High	High	High	High	High	High
Central Basin		High	Medium	High	High	Medium	High
Green Bay		High	High	High	High	High	High
Mid-Lake Plateau		High	Medium	High	High	Medium	Medium
Southern Basin		High	Medium	High	High	High	High
Terrestrial Invasive Species							
Northern Basin	High	Medium	Medium	Low	Medium	High	High
Central Basin	Medium	Low		Low	Medium	High	High
Green Bay	High	Medium	Medium	Low	Medium	High	High
Mid-Lake Plateau	Medium	Medium	Medium		Low	Medium	Medium
Southern Basin	High	High	High	Low	Medium	High	High

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

The initial threat assessment for Lake Michigan indicated that urban, household and industrial sources of pollution are *Medium* threats to biodiversity in most reporting units, ranking *High* only in Southern Lake Michigan (Table 7). Likewise, the threat of contaminated sediments ranked *High* only in one reporting unit, but, in contrast, it was ranked *High* in the Northern Basin[7]. In November of 2011, the

[7] The *High* rank for contaminated sediments in the northern basin was noted by several reviewers as being too high. We recognize the potential for these kinds of errors in an expert-based assessment, and stress that this

project Steering Committee suggested that the cumulative impact of these threats to biodiversity rises to a level that should be considered important lakewide, and recommended that they be considered together for development of threat abatement strategies—a recommendation that was implemented in the strategy development workshop in December, 2011.

Expert participants in the strategy development workshop quickly questioned the results of the threat assessment, noting that the impact of contaminated sediments and industrial point sources on biodiversity have diminished in recent decades. In addition, the group noted that strategies for industrial pollution and contaminated sediments (e.g., those associated with Super Fund sites and AOCs) have been ongoing for decades and that these threats have plateaued or are even diminishing; hence, developing new strategies for those threats shouldn't be a priority for the Lake Michigan Biodiversity Conservation Strategy. In contrast, urban non-point source pollution is increasingly seen as a threat, contributing sediments and pollutants—including nutrients and contaminants—to the lake and degrading not only tributaries but the Nearshore Zone and Coastal Wetlands systems as well. Increases in storm intensities associated with climate change (see Appendix H) are also expected to increase threats related to pollution carried by stormwater, and overflows of combined sewage and stormwater handling facilities. Consequently, in an adaptive move, the group developed strategies to address urban sources of pollution, both point and non-point.

The effects of these pollutants on the Nearshore Zone and associated targets of Coastal Wetlands and Native Migratory Fish are partly understood and include causing deformities and reducing reproductive success through various mechanisms.

Table 7: Overall threat ranks for contaminated sediments and pollution in reporting units of Lake Michigan.

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Contaminated sediments	High	Medium	Medium	Medium	Medium
Pollution: airborne sources	Medium	Medium	Medium	Medium	Medium
Pollution: industrial	Medium	Medium	Medium	Medium	High
Pollution: Urban/household	Medium	Medium	Medium	Medium	High

ranking is preliminary and, even with errors, provides guidance for identifying priority strategies at a lake wide scale.

Table 8: Ratings of threat to each target for contaminated sediments and pollution in reporting units of Lake Michigan.

Reporting unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Contaminated sediments							
Northern Basin	Medium		High		High	Medium	Medium
Central Basin	Low		Low		Medium	Low	Medium
Green Bay	Low		Medium		Medium	Medium	Medium
Mid-Lake Plateau	Low		Low		Medium	Medium	Medium
Southern Basin	Medium		Low		Medium	Medium	Medium
Pollution: Airborne sources							
Northern Basin		Medium		Medium	Medium	Medium	Medium
Central Basin		Medium		Medium	Medium	Medium	Medium
Green Bay		Medium		Medium	Medium	Medium	Medium
Mid-Lake Plateau		Medium		Low	Low	Medium	Medium
Southern Basin		Medium		Medium	Medium	Medium	Medium
Pollution: Industrial sources							
Northern Basin				Medium	Medium	Medium	
Central Basin				Medium	Medium	Medium	Medium
Green Bay				Medium	Medium	Medium	Medium
Mid-Lake Plateau				Medium	Medium	Medium	Medium
Southern Basin				Medium	High	High	High
Pollution: Urban and household sources							
Northern Basin	Medium	Medium	Medium		Medium	Medium	Medium
Central Basin	Low	Medium			Low	Medium	Medium
Green Bay	Medium	Medium	Low		Medium	Medium	Medium
Mid-Lake Plateau	Low	Medium	Low		Medium	Medium	Medium
Southern Basin	Medium	Medium	Medium		High	High	High

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

The threat of housing and urban development ranged from medium to *Very High* to the following four targets: Aerial Migrants, Islands, Coastal Terrestrial Systems, and Coastal Wetlands (Table 9). Coastal Terrestrial and Coastal Wetlands were the two targets that received the highest rated threats from housing and urban development. The threat of shoreline alteration ranged from *Medium* to *High* to the following four targets: Islands, Coastal Terrestrial, Coastal Wetlands, and Nearshore. The highest threat rating (*High*) from both the shoreline alterations and housing and urban development threats occurred in the Southern Basin for the Nearshore Zone, Aerial Migrants, Coastal Terrestrial, and Coastal Wetland targets (Table 10). Other basins that received at least two *High* ratings from the housing and urban development threat included both the Central and Mid-Lake Plateau Basins.

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.

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

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Housing/urban development	Medium	High	High	Medium	High
Shoreline Alterations	Medium	Medium	Medium	Medium	High

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 fish and wildlife 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).

Physical processes such as littoral flow and sediment transport create and maintain the structure and function of Coastal Wetlands, Coastal Terrestrial, Nearshore Zone and Island habitat and drive many species assemblages (Scheuerell and Schindler 2004), including fish populations and richness (Brazner 1997). Lake bed modifications 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 over time. Vehicular traffic continues to impact and alter shorelines environments by compacting sand at beach settings and disturbing habitat and wildlife. Cottage development along the shoreline is also associated with dune removal or alteration.

Table 10: Ratings of threat to each target for housing and urban development and shoreline alterations in reporting units of Lake Michigan (NS= Not Specified)

Reporting unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Housing & Urban Development							
Northern Basin	Medium		Medium		NS	High	Medium
Central Basin	Medium		High		NS	Medium	Very High
Green Bay	Medium		Medium		NS	High	High
Mid-Lake Plateau	Medium		Medium		NS	High	Medium
Southern Basin	Medium		High		NS	High	High
Shoreline Alterations							
Northern Basin	Medium		NS		Medium	Medium	Medium
Central Basin	Medium		NS		Medium	Medium	Medium
Green Bay	Medium		NS		Medium	Medium	Medium
Mid-Lake Plateau	Medium		NS		Medium	Medium	Medium
Southern Basin	Medium		NS		High	High	High

5.2.5. Why are dams and barriers a critical threat?

Dams and barriers were thought to be a *High* threat to the Nearshore Zone in the Southern Basin, and to Coastal Wetlands in the Northern Basin. When summarized across geography, the Northern Basin was ranked a highly threatened by dams and other barriers, with the rest of the lake receiving a *Medium* rank (Table 11). Four Lake Michigan conservation targets, Migratory Fish, Nearshore Zone, Coastal Wetland Systems and Coastal Terrestrial Systems, are threatened by dams and barriers. The degree of threat to these targets varied across geography and target, the most highly threatened target being Native Migratory Fish, which was ranked *High* in all parts of the lake except the Central Basin (Table 12).

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

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Dams/other barriers	High	Medium	Medium	Medium	Medium

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

Reporting unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Northern Basin		High			Medium	Medium	High
Central Basin		Medium			Medium	Medium	Medium
Green Bay		High			Low	Low	Medium
Med-Lake Plateau		High			Medium	Medium	Medium
Southern Basin		High			High	Medium	Medium

Historically, a continuum of habitat from Nearshore Zone and Coastal Wetlands up into the tributaries has sustained fish populations and communities in Lake Michigan (Rutherford et al. 2004). Currently, only 17% of Lake Michigan tributary habitats are currently accessible to Lake Michigan fishes due to blockage from dams (Rutherford et al. 2004), and an unquantified portion of those are inaccessible due to other barriers such as poorly installed road-stream crossings. These barriers have led to the loss or decline in many migratory fish populations throughout the Lake Michigan basin. Most Great Lakes fish utilize (sometimes require) coastal wetland habitats for at least a part of their life cycle (Jude and Pappas 1992). Yet despite their importance, wetlands have been severely altered. For example, coastal areas in southern and western Green Bay have lost 60-75% of their wetlands, or wetland systems have been isolated from the bay by diking (Rutherford et al. 2004). 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).

Tributaries play a key role in shaping nearshore habitats, and provide 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 (Rutherford et al. 2004). Loss of coarse nearshore sediments is a major problem in many areas in Lake Michigan (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). In addition, native (and non-native) migratory fish transfer materials and provide processes (e.g., benthic disturbance) that influence the structure and function of both tributary streams and the Great Lakes, which we are only beginning to understand (Flecker et al. 2010, Childress 2010), and loss of these processes can result in a variety of modifications. As a result of all of these modifications, dams and other artificial barriers impact a variety of ecosystem services resulting in socio-economic impacts to people (Richter et al. 2010).

5.2.6. Why is climate change considered a threat?

Global climate change is already contributing to six major types of changes in the Lake Michigan watershed: 1) increased air and summer surface water temperatures; 2) increased duration of the stratified period; 3) changes in the direction and strength of wind and water currents; 4) flashier precipitation (increases in the intensity of storms, and drier periods in between); 5) decreased ice cover; and 6) changes in lake levels (see Appendix H for more details). As increases in global temperature accelerate, we can expect the pace of many if not all of these current trends to increase as well. All of these factors act as important drivers of ecological processes in lake systems, and many can limit the suitability of Lake Michigan habitats for key targets, or increase the threat associated with current stressors (i.e., invasive species, algal blooms). Further, these factors often interact with one another, complicating our ability to anticipate climate change trends and impacts. Variability in climate change projections, especially possible changes in precipitation, which contributes to uncertainty in future lake levels, 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 Michigan

	Northern Basin	Central Basin	Green Bay	Mid-Lake Plateau	Southern Basin
Climate: habitat shifting/ alteration	High	High	Medium	High	High

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

Reporting unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Northern Basin	Medium	Medium	Medium	Medium	High	Medium	High
Central Basin	Medium	Medium	Medium	Medium	Medium	High	Very High
Green Bay	Medium	Medium	Low	Medium	Medium	Medium	Medium
Mid-Lake Plateau	High	Medium	Medium	Medium	High	High	High
Southern Basin	High	Medium	High	Medium	High	High	High

6. STRATEGIES TO ABATE CRITICAL THREATS AND RESTORE BIODIVERSITY

This chapter describes strategies to abate critical threats in Lake Michigan. 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).

6.1. Identifying strategies and designing high priority strategies

In order to identify and develop strategies, a workshop was held that brought together 85 experts from academic institutions, environmental NGOs, and governmental agencies. The workshop objectives were: 1) to develop strategies to abate key threats and restore biodiversity in Lake Michigan 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 7, except climate change, was the topic of a breakout group discussion. All breakout groups were asked to consider climate change impacts on targets, threats, and strategy effectiveness during the development of their specific strategies. An expert familiar with current climate change trends and projections was included in each of the breakout group sessions, 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[8], 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 priority strategies is based on the addition of the rating of its **feasibility** and **potential impact**[9]. For each of these high priority strategies, the groups then elaborated result chains[10], detailing the intermediate outcomes and assumptions associated with implementing the strategy, and identifying specific objectives and measures that would help to guide 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, to a greater or lesser extent (see Appendix I for more details on the methodology used during the workshop).

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[8] Figure 4 depicts the elements of a conceptual model or (or situation analysis).
[9] The rating process varied from breaking groups, some used qualitative measures and some quantitative measures.
[10] Figure 5 depicts the elements of a result chain.

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 following at least two reviews of the strategy draft reports.

Although the elaboration of strategies followed the same methods (i.e., elaboration of situation analysis and result chains) it is important to highlight that due to the nature and complexity of each assessed threat, and due to the participatory nature of the strategy development process, the final products for each strategy may vary in terms of the detail 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 in or concerned with biodiversity in Lake Michigan. We did not attempt to set priorities among these, but will work closely with the LaMP, the Great Lakes Fishery Commission, and other agencies and organizations to formulate priorities where appropriate. Also, future work should focus on increasing the spatial resolution for application of these strategies, and answering questions identified in the process of developing the strategies.

6.2. Reducing agricultural non-point source pollution

Agricultural non-point source (NPS) 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. These pollutants can result in a wide variety of impacts to Great Lakes waters and the rivers that deliver it, including excessive algal blooms, excessive sedimentation, increased water turbidity, degraded water quality, and reduced dissolved oxygen concentrations. This already dominant and pervasive threat to the Great Lakes is likely to increase as several climate-change related factors (i.e., increases in peak storm intensities that produce more run-off, the potential for agriculture to expand north, longer growing seasons, and the need for additional pesticides to address new or more challenging pest problems).

Since agriculture is the dominant land use in the Lake Michigan Basin (U.S. EPA 2012), resulting non-point sources play an important role in the health of the system. Because of the scope of agriculture nationally and regionally, and because agricultural land use has such influence on aquatic systems, there is a very large network of federal, state, and local agencies and organizations that work on agricultural conservation practices. USDA Farm Bill programs play a major role in financing conservation in agricultural landscapes. In addition, there are some state regulations that help limit agricultural NPS pollution. In the Great Lakes, Coastal Management Programs have developed (or are developing) Coastal Nonpoint Pollution Control Plans which will, in part, address agricultural non-point source issues related to coastal areas. While these efforts provide important contributions, they have yet to provide the level of NPS pollution abatement that we need to assure the health of Lake Michigan. Therefore, we identified a suite of eleven lakewide strategies that would help to address agricultural NPS pollution. We have developed detailed descriptions for two of these strategies, developing a communications network within the agricultural community and increasing incentives for conservation practice adoption through the development of market-based alternative funding mechanism.

6.2.1. Priority strategies

A large number of people participated in the discussion of this threat at the workshop in Chicago in December, 2011. First, they evaluated the key factors that drive Agricultural NPS pollution. In Lake Michigan, Agriculture NPS results primary from incompatible agricultural management practices and incompatible ditching and tiling practices, which are ultimately driven by large-scale socio-economic factors (e.g., commodity prices, Farm Bill funding). Agriculture has always contributed NPS pollution, but agricultural production has intensified, shifting from smaller farms interspersed with natural landcover towards larger fields without fence rows or riparian vegetation, and without seasonal vegetative cover (e.g., pasture or cover crops). This has resulted in decreased water infiltration and increased runoff, which results in greater amounts of sediment and nutrients washing into streams. Best management practices (BMPs) to minimize impacts of these trends are only occasionally adopted, and generally in a patchwork fashion that is not targeted toward ecologically sensitive areas. One reason for this low rate of implementation and lack of targeting of BMPs is that there is often not sufficient technical support staff to adequately facilitate enrollment in BMP funding programs (e.g., Farm Bill in the U.S.) and there is resistance to targeting money into specific, strategic areas due to political pressure for taxpayer funding to be distributed evenly. Global trends, such as moves toward biofuels (e.g., fuels derived from corn, sugarbeets, grasses) influence commodity prices and can complicate efforts to promote conservation practices. However, some biofuels offer potential conservation opportunities – for example if cellulosic technologies and associated markets are developed to promote perennial vegetation cover. Altered hydrologic regimes resulting from excessive ditching and tiling compounds non-point source pollution problems. Finally, high density livestock are a NPS issue because their waste is often applied to adjacent fields at incompatible concentrations or at times that are susceptible to high runoff potential.

From this model, the group identified almost 20 potential strategies (Figure 24). The group evaluated these potential strategies and rated each with regard to impact (in terms of threat reduction) and feasibility. Two strategies were identified as the highest priority (Table 15): Development of a communications network within the agricultural community; and market mechanisms: nutrient trading. A detailed summary of each strategy follows.

Table 15: Priority strategies for agricultural non-point source pollution of Lake Michigan. 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
BMP implementation - Communications strategy to -increase BMP adoption (Region-wide Agriculture watershed sponsorship + communication and public delivery)	Tier 1
BMP implementation - Enable market mechanisms for changing behavior to increase BMP adoption (Nutrient Trading + Payment for Ecosystem Services)	Tier 1
Connect BMPs to climate change; promote benefits of natural systems (wetlands, riparian vegetation) and BMPs in preventing impacts like flooding and promoting infiltration/reducing drought stress	Tier 2
Map the distribution of non-point sources and impacts on specific system types	Tier 2
Cropping Trends – marginal crop restoration; natural conditions; local demos	Tier 2
Landscape approach to wetland restoration promote maintenance and enhancement of wetland functions as a principle for directing the location and goals for wetland remediation	Tier 2
BMP implementation – VRT; precision farming	Tier 2
Overarching – educate about support/environmental sound agriculture as necessary and sustainable land use (vs. development and sprawl as threats)	Tier 2
BMP implementation – Third-party certification regulation	Tier 2
Drainage - Do drainage assessment reductions	Tier 2
Drainage – Prepare for climate change issues; update drainage practices to account for more drought and greater potential for downstream flooding	Tier 2

6.2.2. Strategy 1: Development of a communications network within the agricultural community

Incentives have been available for conservation practices through the Farm Bill for decades. However, more effective adoption of agricultural conservation practices (i.e., the right practices, in the right places, in the right amounts) is essential to reduce agricultural non-point source runoff. Since these practices are voluntary, it is clear than some farmers actively choose to not implement them. However, studies demonstrate that adoption rates increase with active outreach, so clearly some farmers are either unaware of the details of the programs or are unwilling to actively seek out USDA agents to adopt the programs on their own. In addition, federal, state, and county funding cuts are resulting in reduced capacity to promote these programs through conservation districts, extension offices, and other traditional means. It is clear that other avenues to familiarize landowners and farmers with these practices should be explored, and additional or alternative incentives to promote their adoption should also be evaluated.

One model for reaching more farmers is the existing private-sector network that already communicates with farmers on a daily basis. These include the broad network of companies that sell (or lease) equipment, seed, or other supplies to farmers. Banks that provide farmers with loans are another common connection with farmers. These existing networks may be able to provide information and alternative or additional incentives to farmers to increase adoption of conservation practices.

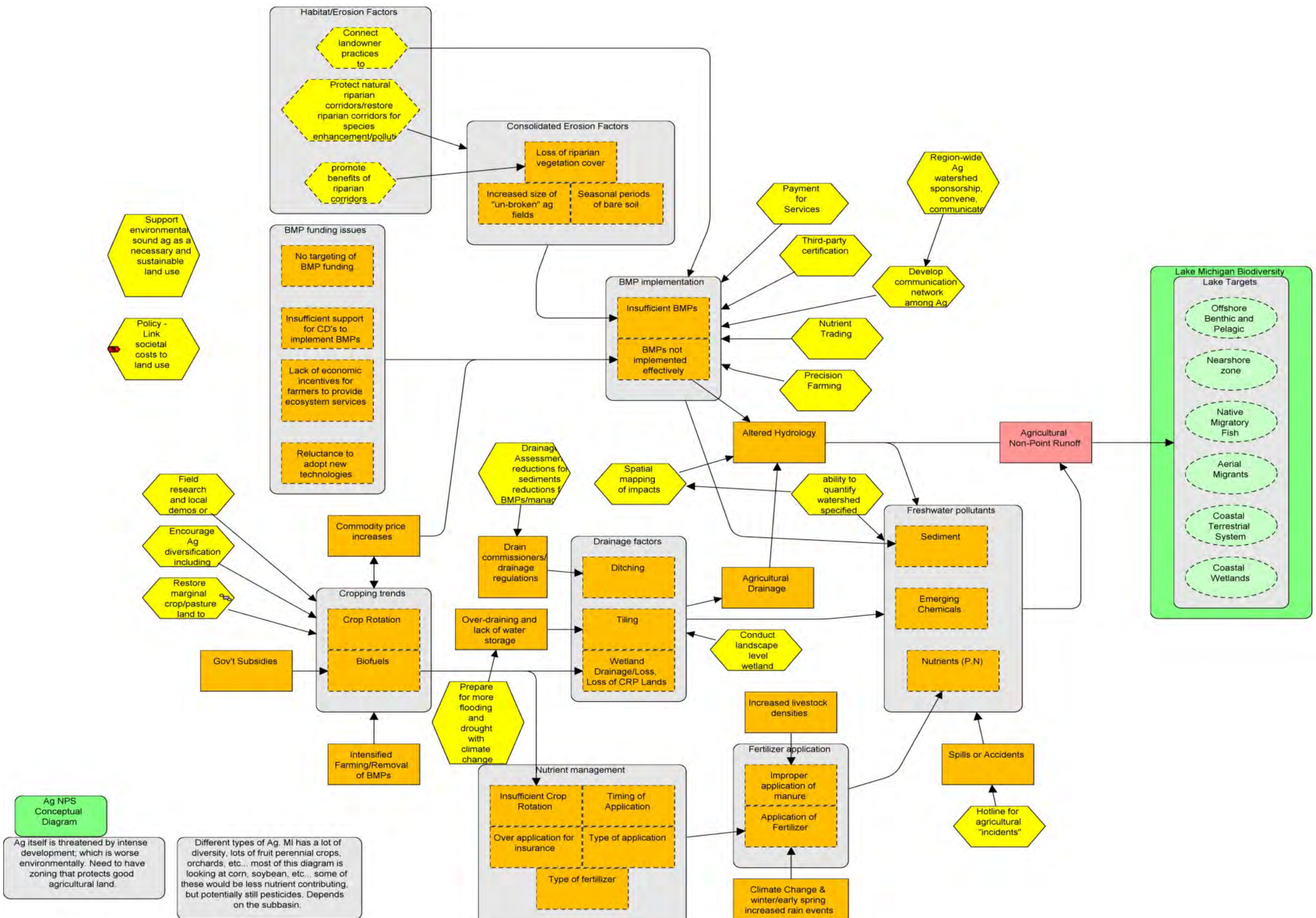

Figure 24: Conceptual model of agricultural non-point sources of pollution in Lake Michigan.

Strategic actions

1. Identify priority areas at ecologically relevant scales that are driven by conservation targets, but may also be influenced by the potential for effective messengers and the likelihood that the message will resonate within the area.
2. Evaluate key influencers to identify one or more influencers that could most effectively influence farmers to increase implementation of conservation practices. The evaluation should include:
    a. An assessment of where producers and landowners get their information and who they trust.
    b. An assessment of which potential messenger has motivations that best align with conservation messages.
    c. An assessment of key "demos" and "early adopters."
    d. An assessment of potential counter-incentives that could be carried by potential key influencers.
3. Work with key influencer(s) and other key partners (e.g., NRCS, extension) to identify target audience, to identify conservation practices that forward conservation goals and resonate with the messenger(s) and audience, and to develop an effective message that will increase conservation practice implementation, but will also result in increased profits, reduced risk, and safer/healthier communities.
4. Create Technical Delivery System that will be most effective (e.g., meetings, certification process, conventions, demonstrations).
5. Influencer begins disseminating information, with coordination and complementary messages by existing networks (e.g., Agricultural Extension, NRCS, Conservation Districts).
6. Evaluate whether farmers/landowners are buying into the message.
7. Evaluate whether resources are sufficient and, if not, what additional resources would be necessary.

Results, objectives and measures

The strategy is to utilize existing agricultural communication networks, but in new ways, to significantly improve implementation of conservation practices by 2025, so that hydrology is more naturalized, future changes in climate and hydrology are anticipated, and non-point source pollutants are reduced.

Result 1: Priority areas to focus communications have been identified at ecologically relevant scales.

Result 2: Key influencers that can most effectively influence farmers to increase implementation of conservation practices identified. Potential conservation influencers may be crop consultants, lenders, equipment, seed, or chemical sales companies, banks, or market companies.

> *Objective 1: By 2013, identify key influencer(s), venues, and at least one message to begin developing.*

Result 3: Effective message created.

Message should be personalized and motivating to both the key influencers delivering the message and the land owner/operators that will ultimately be asked to make changes on the ground. Messages will also vary by conservation practice and geographically. Conservation practices should be evaluated based on their costs and benefits at multiple scales, using both ecological and economic measures.

Result 4: Information is disseminated effectively and is well-coordinated.

Result 5: Required resources are made available, including:

a. Technical assistance for farmers to help implementing practices.
b. Money and equipment.
c. A Regional information hub is created.
    i. The hub needs to be a trusted source for information.
    ii. The hub could be co-sponsored by NRCS and others, which would increase visibility in the community, and provide funding opportunities.
d. Adequate resources for inspection and enforcement of best practices by farmers, potentially through a certification process.

Result 6: Farmers/landowners buy in to the message.

Result 7: Farmers act on new information (Go/No Go: if they don't act, this strategy fails)

a. If not, it may require more support (see number 5)

Result 8: Conservation practices are being implemented effectively in sufficient densities and in the right locations.

Result 9: Progress toward key ecological goals is achieved, such as more natural hydrology and reduced freshwater pollutants (sediment, nutrients, emerging chemicals)

Monitoring should be in place at multiple scales that ensures that conservation practices are providing the projected benefits.

Priority or opportunity areas for implementation

There was some discussion at the December 2011 workshop of possible locations in southwest Michigan and Green Bay where this could be initiated, but no decision was reached regarding areas for implementation.

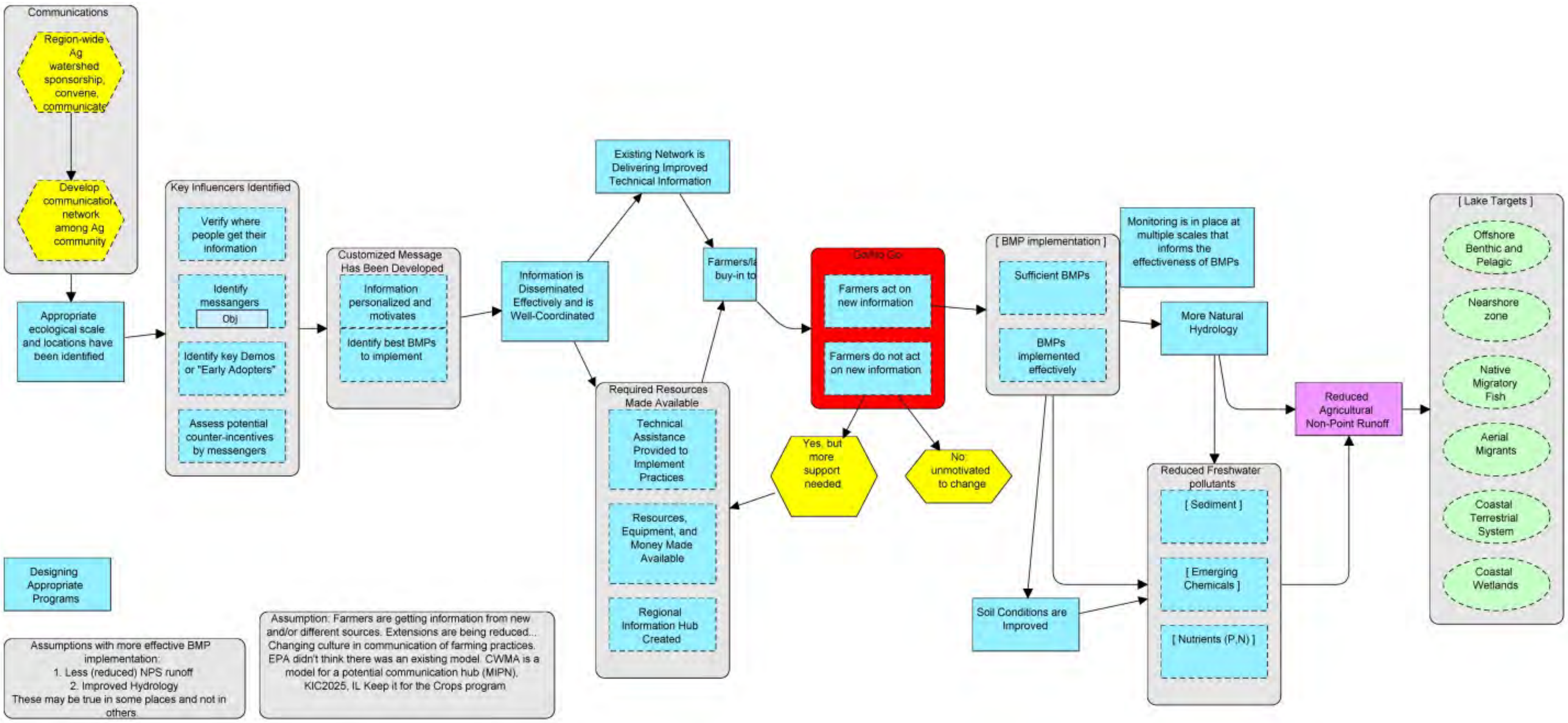

Figure 25: Results chain for the Communications strategy for abating agricultural non-point source pollutants in Lake Michigan.

Related strategies and initiatives

- Lake Michigan LaMP Subgoal 2, Subgoal 7
- Michigan Agriculture Environmental Assurance Program
- Great Lakes Conservation Effects Assessment Project (CEAP) project - could help inform priority locations and in setting goals.
- Institute of Water Research (Michigan State University) High Impact Targeting: http://35.9.116.206/hit2/home.htm
- The Conservation Technology Information Center at Purdue University: http://www.ctic.purdue.edu/Core4/Conservation%20Choices/
- Conservation Agriculture Systems Alliance (CASA): http://www.ctic.purdue.edu/resourcedisplay/253/
- Great Lakes Restoration Initiative Action Plan Nearshore goal 5, http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Section 6217 Coastal Management Plans; for example, the Indiana 6217 plan includes substantial information on agricultural conservation practices and which agencies oversee which program: http://www.in.gov/dnr/lakemich/files/6217_Final.pdf

Likely participating agencies and organizations

Agri-businesses, crop consultants, agriculture extension, NRCS, conservation districts, State Departments of Agriculture, university researchers, conservation organizations, watershed groups, farming groups (such as state chapters of Farm Bureau and Farmer's Union)

6.2.3. Strategy 2: Market mechanisms: nutrient trading

Despite decades of funding available through the Farm Bill to encourage farmers to adopt conservation practices, many agricultural watersheds still struggle with excessive runoff and high nutrient loads. It is clear that we need to develop additional financial incentives to increase the competiveness of, and therefore the adoption of, conservation practices.

One possible mechanism to increase incentives for conservation practice adoption is to develop alternative funding mechanism through markets. One possible way to create a market is to develop linkages between agricultural landowners/operators and organizations that are identified as out of compliance point sources of nutrients.

Strategic actions

1. Complete due diligence (evaluate the costs and benefits of establishing a market, learn from other project's failings or successes).

2. Develop a suite of market criteria and evaluate potential watersheds where a market may be feasible (e.g., are potential market aggregators present?).

3. Develop a market mechanism and process.

4. Create baseline map(s) of potential practices that would reduce nutrient inputs, and projected benefits across the landscape.

5. Identify out-of-compliance point sources (buyers) and in-compliance farmers (sellers).

6. Identify and garner resources to promote and manage the market (e.g., technical assistance for practice implementation, equipment availability, regional information hub).

Results, objectives and measures

Result 1: Criteria for watershed market is met

a. Final criteria are established and agreed upon.

b. Viable market area(s) is (are) identified.

c. Supportive legal NPS regulatory framework created.

d. Market aggregator created/identified (Go/No Go).

e. Market mechanisms and process have been developed.

f. Ecological benefits have been projected.

g. Any additional criteria are met.

Result 2: Identified compliance farmers (Sellers) AND Identified out of compliance point sources (Buyers)

Objective: By 2015, a location has been identified that meets the criteria for a watershed market and willing buyers have been identified.

Result 3: Beneficial impacts have been quantified

Result 4: Required resources made available

a. Technical Assistance Provided to Implement Practices
b. Resources, Equipment, and Money Made Available
c. Regional Information Hub Created (to house and access some of the fundamental principles and practices, which can then be tailored to specific locations

Objective: By 2016, required resources have been secured to initiate at least one project in the Lake Michigan basin to test use of markets to implement agricultural conservation practices.

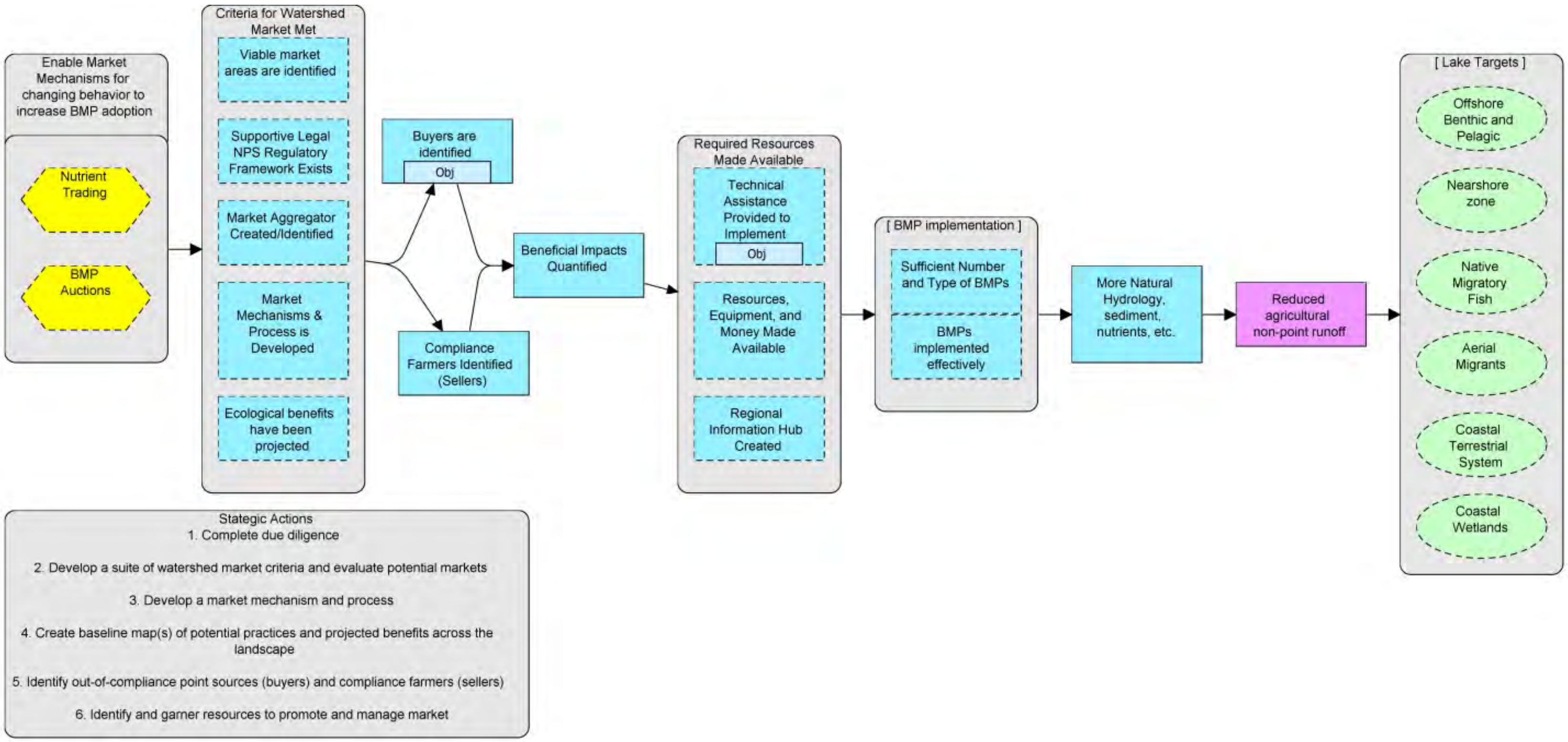

Figure 26: Results chain for the market mechanisms strategy for abating agricultural non-point source pollutants in Lake Michigan

Result 5: BMP implementation

a. Sufficient number and type of BMPs
b. BMPs implemented effectively

Result 6: More Natural Hydrology, reduced sediment and nutrient runoff

Priority or opportunity areas for implementation

Possible areas for implementation include southwest Michigan or areas of Wisconsin within the Lake Michigan basin.

Related strategies and initiatives

- Lake Michigan LaMP Subgoal 2, Subgoal 7
- Michigan Agriculture Environmental Assurance Program
- Great Lakes Conservation Effects Assessment Project (CEAP) project - could help inform priority locations and in setting goals
- Ohio EPA Water Quality Trading Program: http://www.epa.ohio.gov/dsw/WQ_trading/index.aspx
- Ohio River Water Quality Trading Project: http://my.epri.com/portal/server.pt?open=512&objID=423&&PageID=243561&mode=2&in_hi_userid=2&cached=true
- Maryland Nutrient Trading Program: http://www.mdnutrienttrading.com/farmers/
- Great Lakes Restoration Initiative Action Plan Nearshore goal 5, http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- The U.S. Army Corps of Engineers (USACE) - Great Lakes Tributary Modeling Program www.glc.org/tributary

Likely participating agencies and organizations

Agri-businesses, crop consultants, agriculture extension, NRCS, conservation districts, university researchers, State Departments of Agriculture, conservation organizations, watershed groups, state chapters of Farm Bureau and Farmer's Union.

6.3. Preventing and reducing the impact of invasive species

Invasive species include all species that are not native to the Lake Michigan ecosystem and that have or are likely to have a significant negative impact on biodiversity or human well-being. Of the 123 aquatic non-indigenous species collected in the Lake Michigan basin since 1871, 77 occur in the lake itself and all but 11 of these are listed by the Great Lakes Aquatic Non-indigenous Species Information System (GLANSIS) as "established". Not all of these are considered invasive; some are culturally valuable, such as the sockeye (*Oncorhynchus nerka*) and Chinook salmon (*Oncorhynchus tshawytscha*). Others, such as the spiny water flea and Dreissenid mussels, have fundamentally shifted the trophic system of Lake Michigan or have otherwise altered ecosystem attributes such as water clarity and nutrient levels, while some (e.g., sea lamprey) are direct and serious threats to native species by increasing mortality rates. Invasive species, even those not yet arrived in the Great Lakes (such as the bighead (*Hypophthalmichthys nobilis*) and silver (*Hypophthalmichthys molitrix*) carps present in the Chicago Area Waterway System), have become the focus of increasing public attention due to their real and potential impacts to the regional economy, as well as to biodiversity. As stated by the Asian Carp Regional Coordinating Committee (2012, p. 1):

> *"The most acute AIS threat facing the Great Lakes today is movement of carp not native to the United Sates (bighead and silver)—collectively known as Asian carp—through the Chicago Area Waterway System (CAWS), Wabash River, Grand Calumet River, and possibly other pathways that can connect the Great Lakes to the Mississippi River Basin."*

Climate warming has the potential to increase the rate of invasive species establishment, both by promoting movement into the region by species that are common in the southern U.S., and by making the lakes and terrestrial systems more hospitable to invasives that have already made it to the region, but have not been able to establish due to some constraint (i.e., cold water, harsh winter conditions).

We have developed two strategies to address invasive species. These strategies apply to both terrestrial and aquatic invasive species. The first is to secure agreements among Great Lakes states and provinces to articulate and implement common policies, risk assessments, and funding that will minimize the probability of invasive species entering the Great Lakes region through shipping, live trade, recreational/boating and horticultural pathways. The second strategy is to form an early detection and rapid response network in the Lake Michigan basin (and perhaps the Great Lakes region) that effectively detects invasive species before they become established in Lake Michigan. Experts did not recommend strategies for particular species, acknowledging that prevention, detection, response, and control efforts are being developed for priority species such as bighead and silver carps and that the LMBCS should focus on broader recommendations for improving coordination on reducing threats from invasive species.

6.3.1. Priority strategies

Both the terrestrial and aquatic conceptual models emphasize: 1) increasing awareness of the serious threats of invasive species to the integrity of ecological systems, 2) development of mechanisms by the newly informed or energized institutions/agencies to reduce introduction of invasive species, and 3) effective deployment of early detection and rapid response protocols. All strategies suggested in the breakout session in December 2011, workshop focus on these principal themes and the importance of securing consistent funding through collaborative efforts, basinwide and locally. Experts settled on two priority strategies to develop more fully, recognizing the others all are related and, in some cases, key components of the success of the two priority strategies (Tables 16 and 17 and Figures 27 and 28).

Table 16. Priority strategies to address the threat of aquatic invasive species to Lake Michigan biodiversity. 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 for Aquatic Invasive Species	Priority
Agreements among Great Lakes States for invasive species in Lake Michigan	Tier 1
Early detection and rapid response network for invasive species in Lake Michigan	Tier 1
Create Responsible Agency	Tier 2
Inspection/Checkpoints	Tier 2
Invasive permitting to fund prevention/control	Tier 2
Messaging strategy (it's not just Asian carp)	Tier 2
Protective measures for ballast water	Tier 2
Research on Methods	Tier 2
Restoration of wetlands/food web	Tier 2
Risk assessment (underway)	Tier 2
Share success stories with public/professionals/politicians	Tier 2
Stakeholder group to provide cover	Tier 2
Surveillance network including online reporting (esp. citizen involvement)	Tier 2

Table 17. Priority strategies to address the threat of terrestrial invasive species to Lake Michigan biodiversity. 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 for Terrestrial Invasive Species	Priority
Early Detection & Rapid Response Network + Detection Data Collection	Tier 1
Campaign to change political awareness/will	Tier 2
Contractor's BMPs/requirements i.e. biomass removal	Tier 2
Cost of not managing until too late	Tier 2
Decrease consumer demand (education/outreach)	Tier 2
Educating field personnel on BMP's	Tier 2
Increased research funding	Tier 2
Strategic control of source populations in and out of basin	Tier 2
Understand/communicate economic impact	Tier 2

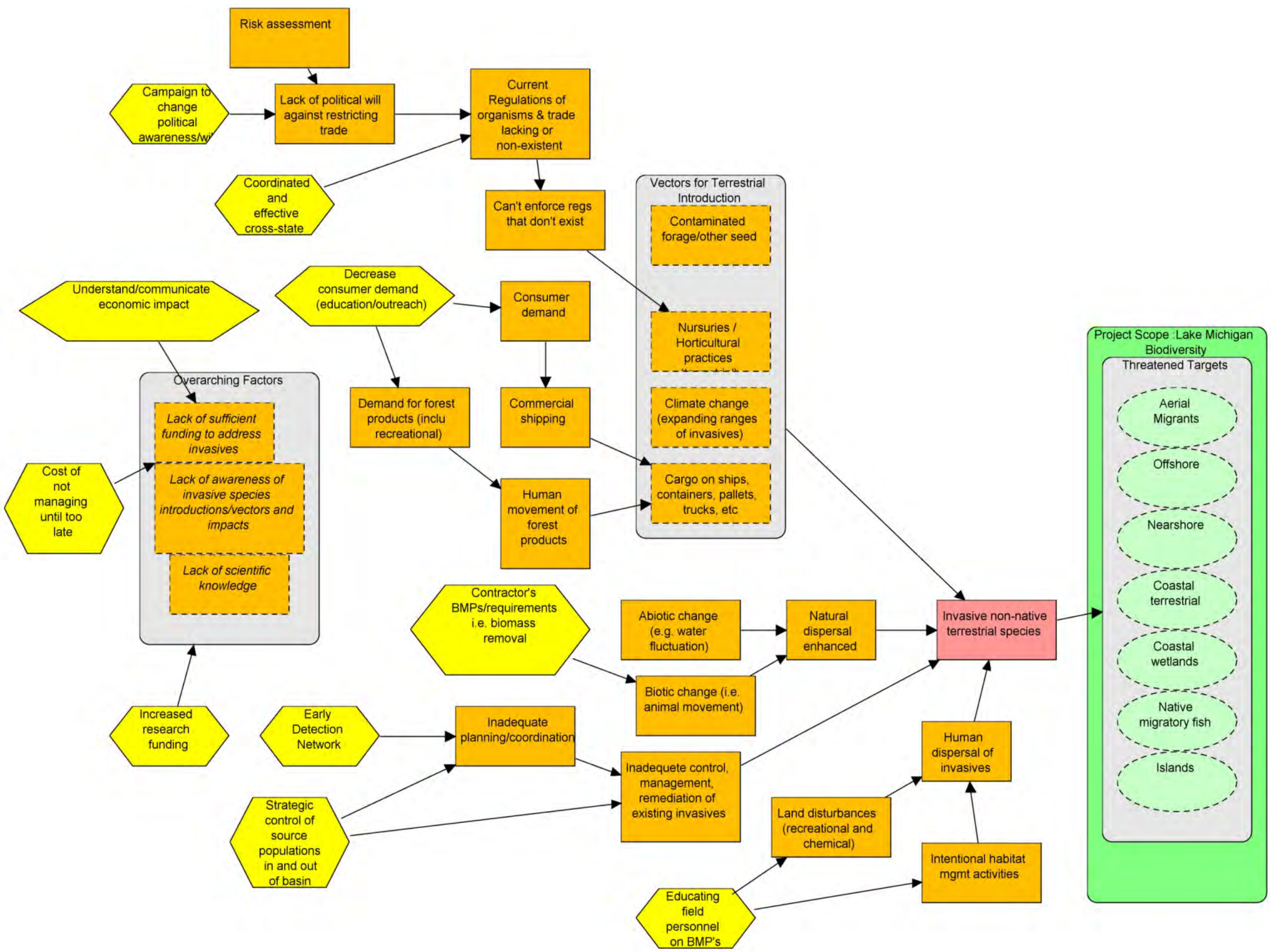

Figure 27: Conceptual model of terrestrial invasive species in Lake Michigan.

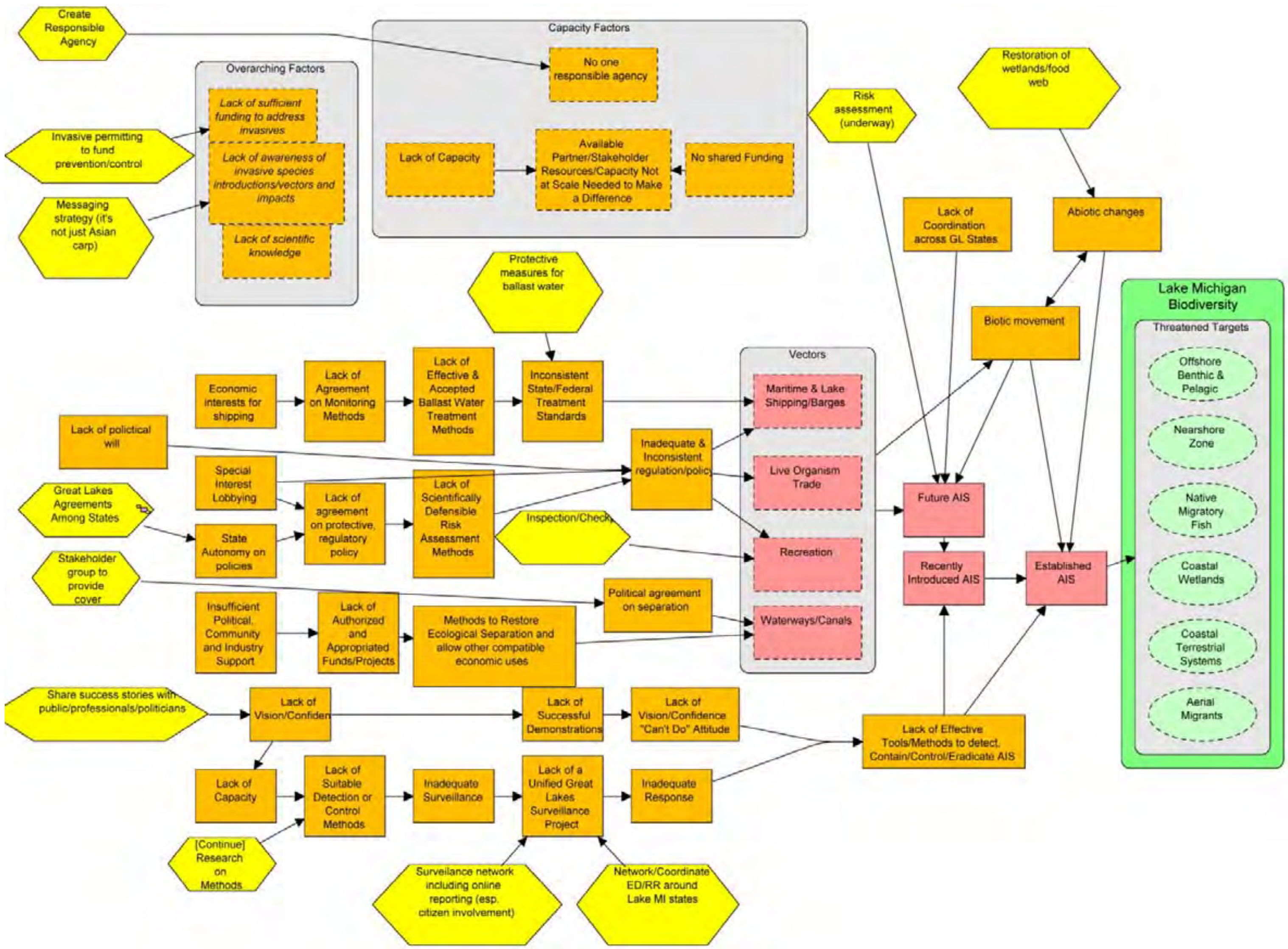

Figure 28. Conceptual model of aquatic invasive species in Lake Michigan.

6.3.2. Strategy 1: Agreements among Great Lakes States for invasive species in Lake Michigan

The focus of this strategy is to secure agreements among Great Lakes states and provinces to articulate and implement common policies, risk assessments, and funding that will minimize the probability of invasives entering the Great Lakes region through shipping, live trade, recreational/boating and horticultural pathways (NOTE: this strategy does not address the pathway of inter-basin connections, such as the Chicago Area Waterways System and many others. The LMBCS Core Team, Steering Committee and partners have agreed that ongoing studies and negotiations (e.g., Great Lakes and Mississippi River Interbasin Study, 2012) should be allowed to play out, so there are no recommended strategies in this report). There are two principal desired outcomes of these strategies: 1) no new established invasive species and 2) existing invasive species populations are contained, reduced or eliminated (at least locally) (Figure 29).

Strategic actions

The principal strategic action is to work with state and provincial officials to adopt a common set of policies and risk assessment protocols, highly focused on potential pathways of introduction, to apply throughout the Lake Michigan/Great Lakes region.

1. One governor takes lead (MI).
2. Discussions leading to an agreement to proceed.
3. Gap analysis of need to take to governors.
    a. Conclusion needs to show need for state action at regional scale, and provide taxonomic examples of policy gaps.
4. Bring in risk assessment studies.

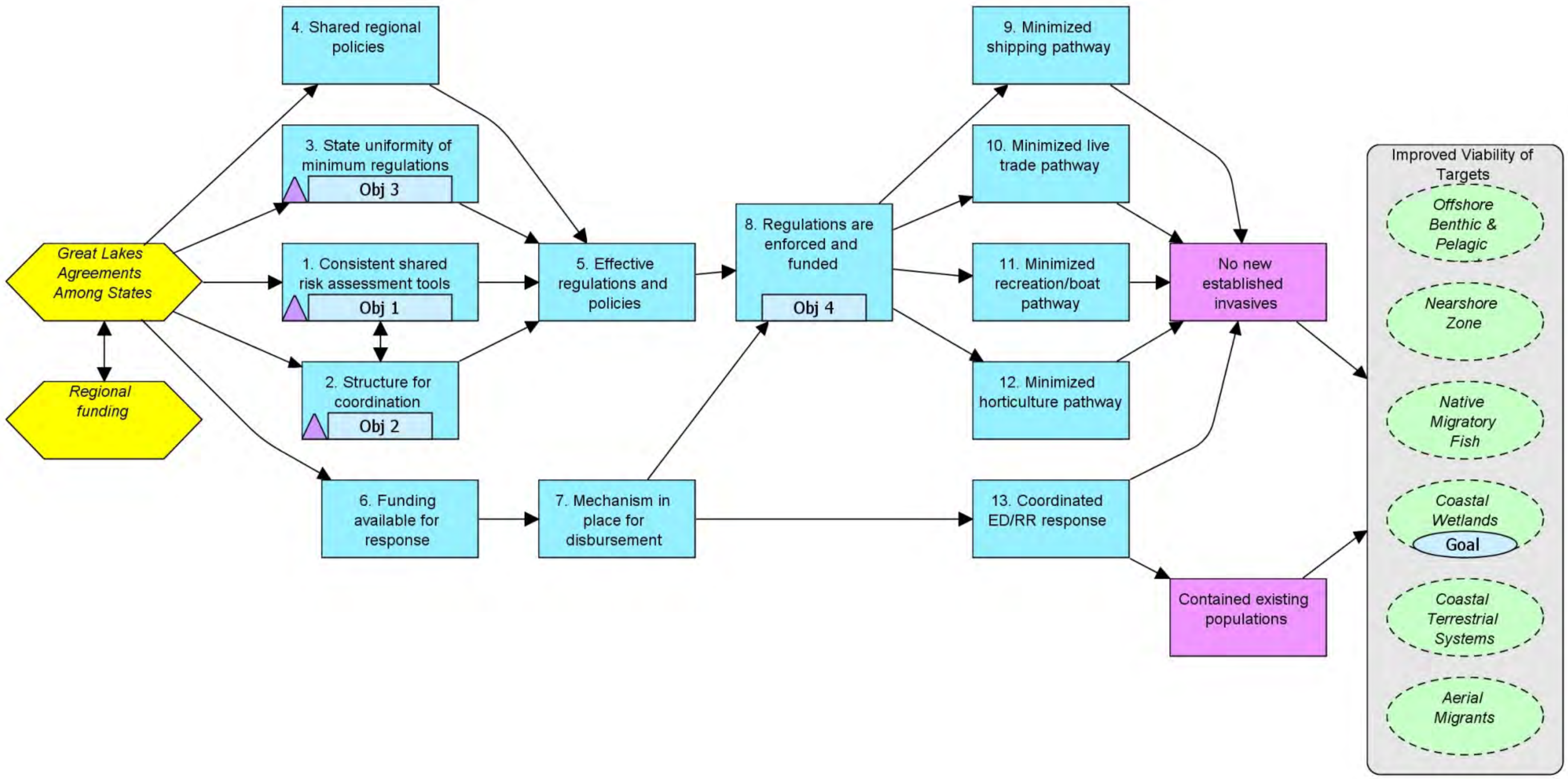

Figure 29: Results chain for the agreements among states strategy.

Results, objectives and measures

Result 1. Consistent, shared risk assessment tools.

Objective 1. By 2013, all ten Great Lakes states and provinces will reach agreement on risk assessment tools for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These tools would need to be based on the latest science.

Potential measures:

- Number or proportion of states and provinces in agreement;
- Alignment of tools with the recommendations of the IJC Work Group on Aquatic Invasive Species Rapid Response (Dupre 2011).

Result 2. Structure for coordination.

Objective 2. By 2013, all ten Great Lakes states and provinces will reach agreement on a structure for coordination for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture).

Potential measures:

- Number or proportion of states and provinces in agreement.

Result 3. State uniformity of minimum regulations.

Objective 3. By 2014, all ten Great Lakes states and provinces will reach agreement on minimum protective regulations related to at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These regulations would need to be science based and linked to the risk assessment tools mentioned in Result 1 above.

Potential measures include:

- Regulations are drafted;
- Number or proportion of states and provinces in agreement;
- Legislative activity milestones (e.g., does it go to study committee, are there hearings?).

Result 4. Shared regional policies.

Result 5. Effective regulations and policies.

Result 6. Funding available for response.

Result 7. Mechanism in place for disbursement.

Result 8. Regulations are enforced and funded.

Objective 4. By 2020, funding for enforcement of regulations:

1) *has increased by (some percentage in comparison with 2012 levels)* ***OR***
2) *is adequate to fully enforce regulations* ***OR***
3) *is sufficient to support X number of personnel for each pathway*

Result 9. Minimized shipping pathway.

Result 10. Minimized live trade pathway.

Result 11. Minimized recreation/boat pathway.

Result 12. Minimized horticultural pathway.

Result 13. Coordinated ED/RR response.

Threat abatement result 1. No new established invasives.

Threat abatement result 2. Contained existing populations.

Priority or opportunity areas for implementation

Because this strategy involves agreements between states, it applies equally lake-wide.

Likely participating agencies and organizations

All state governments and government agencies are likely to participate in this strategy, as well as supporting organizations.

6.3.3. Strategy 2: Early detection and rapid response network for invasive species in Lake Michigan

The focus of this strategy is to form an early detection and rapid response network in the Lake Michigan basin (and perhaps the Great Lakes region) that effectively detects both terrestrial and aquatic invasive species before they become established in Lake Michigan. Many of the pieces of this network are in place, and several agencies and organizations are collaborating to achieve this lakewide network building on existing efforts focused on invasive plants such as the Midwest Invasive Plant Network (http://mipn.org/index.html) and the Midwest Invasive Species Information Network (http://www.misin.msu.edu/). The recently launched Great Lakes Early Detection Network (http://www.gledn.org/cwis438/websites/GLEDN/Home.php?WebSiteID=17) is a product of this coordinated effort and covers the entire Lake Michigan basin. It is currently focused on plants, especially terrestrial plants, and many challenges remain before this network will be fully functional and effective. There are two principal desired outcomes of this strategy: 1) no new established invasive species and 2) existing invasive species populations are contained, reduced or eliminated (at least locally).

Strategic actions

1. Raise funds for all aspects of strategy. Currently, systems are challenged to find funding, and there are disparate efforts to raise funds ongoing. The Great Lakes Early Detection Network

(GLEDN) is continually on soft funding and would like sustainable funding; also applies to Heritage programs; GLANSIS faces the same challenge.

2. Train people to provide data. Training should be directed both at volunteer-level (citizen science) and professional (agency staff, for example). Avian Monitoring for Botulism Lakeshore Events AMBLE, https://www.nwhc.usgs.gov/amble/) and Wildlife Health Event Reporter (WHER, http://www.whmn.org/wher/ websites as examples for volunteer monitoring (developed by USGS with input from other groups).

3. Data collection. This will be an ongoing activity.

4. Develop shared and unified GIS and information management system. This system is nearly in place and functional now. There remains some inconsistency in data storage and maintenance among systems. Unification could occur by all component networks implementing the same data storage and maintenance protocols (which isn't the case now), or by structuring GLEDN so that it can take data from multiple formats and unify them in one system. GLEDN is taking just a few attributes.

5. Develop strategic Great Lakes surveillance system. This system should be coordinated and strategic. Michigan Aquatic Invasive Species Management Plan focuses on pathways, for example. Will require training of multiple audiences, and could serve as a model for a lakewide system.

6. Develop rapid response capability.

Results, objectives and measures

The above actions will lead to several results and could play an important role in reducing the threat of invasive species to Lake Michigan and more broadly. The strategy includes several ongoing actions and is adaptive, with feedback from surveys and data collection informing priorities for future surveys (see results chain Figure 30).

Result 1. People are trained to provide data. As described in the Action 2 above, professionals and volunteers will be trained to provide data to the network.

Result 2. Priority areas and species are defined. Survey priorities, both species and geographic areas, are defined and agreed upon.

Result 3. Data is collected. Methods for data collection will undoubtedly vary from volunteer reports to research publication. This result will be an ongoing part of this strategy.

Result 4. Unified Data Management System. This result is termed a “Go/No-Go” result in that if it is not achieved, the strategy will fail and other options will need to be considered. It has two component results:

4a. Sustainable funding for data management is in place. There is one objective for this result:

Objective 1. By 2013, sustainable funding for all components of data management infrastructure is in place. Currently, network pieces are in place and linked through GLEDN, but need sustainable funding. This objective has two measures:

- Measure 1. Distribution of funding. This measure relates to whether all critical components of network are funded.
- Measure 2. Level of funding from sustainable sources.

4b. Unified and shared GIS distribution data are available. There is one objective for this result:

Objective 2. By 2013, all lakewide data systems are compatibly linked and accessible for both upload and download from one site. This system will enable both online mapping and interactive input and editing of data by qualified users.

- Measure 1. Quality assurance/Quality Control: The system meets data management standards.
- Measure 2. Accessibility: Users in a majority of basin can easily access data and add records; should not require membership or log-in.
- Measure 3. Spatial coverage: The system covers the entire Great Lakes basin and incorporates all existing systems.

Result 5. Agencies and managers are warned of outbreaks. This result requires and alert mechanism as a component of the system.

Result 6. Local surveyors verify new outbreaks and survey for nearby species. Managers and volunteers respond to alerts from the system by surveying and verifying newly reported outbreaks and monitoring for species that have been found nearby.

Result 7. Information passed to appropriate response agency.

Result 8. Response enabling outcomes. This result has two components:

8a. Rapid response is possible. Rapid response requires that there are accepted methods for control or eradication, and that treatment is feasible. Need to understand the location and any ownership or property rights issues, as well as authority for response.

Objective 3. By 2020, for all species listed in the unified database, accepted and effective control protocols exist.

- Measure 1. Percentage of species that have accepted protocols.

8b. Adequate coordination in response. This outcome includes having legal permits in place as well as interagency coordination, and can entail both permits for chemical application as well as legal authority to act in a given location.

Result 9. Sufficient response to invasive detection. Ultimately, the intent of this strategy is that every outbreak is detected and then eradicated or contained, depending on the invasiveness of the species and other factors.

Threat abatement result 1. No new established invasives.

Threat abatement result 2. Contained existing populations.

Priority or opportunity areas for implementation

Identification of priority areas for surveys is part of this strategy and can be informed by ongoing work, such as that on the Eastern Shore of Lake Michigan (http://www.sustainourgreatlakes.org/Projects/ProjectProfiles/FullScaleInvasivePlantControlEasternLakeMI.aspx).

Related strategies and initiatives

- Great Lakes Early Detection Network: http://www.gledn.org/cwis438/websites/GLEDN/Home.php?WebSiteID=17
- Great Lakes Restoration Initiative Action Plan, Focus Area 2: Invasive Species, Goal 1, Objective to establish eight state aquatic nuisance species management plans (http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf).
- ILLINOIS STATE COMPREHENSIVE MANAGEMENT PLAN FOR AQUATIC NUISANCE SPECIES: http://www.iisgcp.org/il-ans/media/ilansplan.pdf
- Indiana Aquatic Nuisance Species (ANS) Management Plan: http://www.in.gov/dnr/fishwild/files/inansmanagementplan.pdf
- Lake Michigan LaMP, Subgoal 8: Are aquatic and terrestrial nuisance species prevented and controlled?
- Lake Michigan LaMP, Subgoal 8: Are aquatic and terrestrial nuisance species prevented and controlled?
- Michigan DNR Invasive Species program: http://mi.gov/dnr/0,4570,7-153-10370_59996---,00.html
- Michigan's Aquatic Invasive Species State Management Plan Update: Prevention and Control in Michigan Waters. March, 2012 draft: http://www.michigan.gov/deq/0,4561,7-135-3313_3677_8314-276823--,00.html
- Midwest Invasive Species Information Network: http://www.misin.msu.edu/
- Recommendations of the Great Lakes Panel on Aquatic Nuisance Species: http://www.glc.org/ans/panel.html
- Wisconsin Invasive Species Program: http://dnr.wi.gov/topic/Invasives/

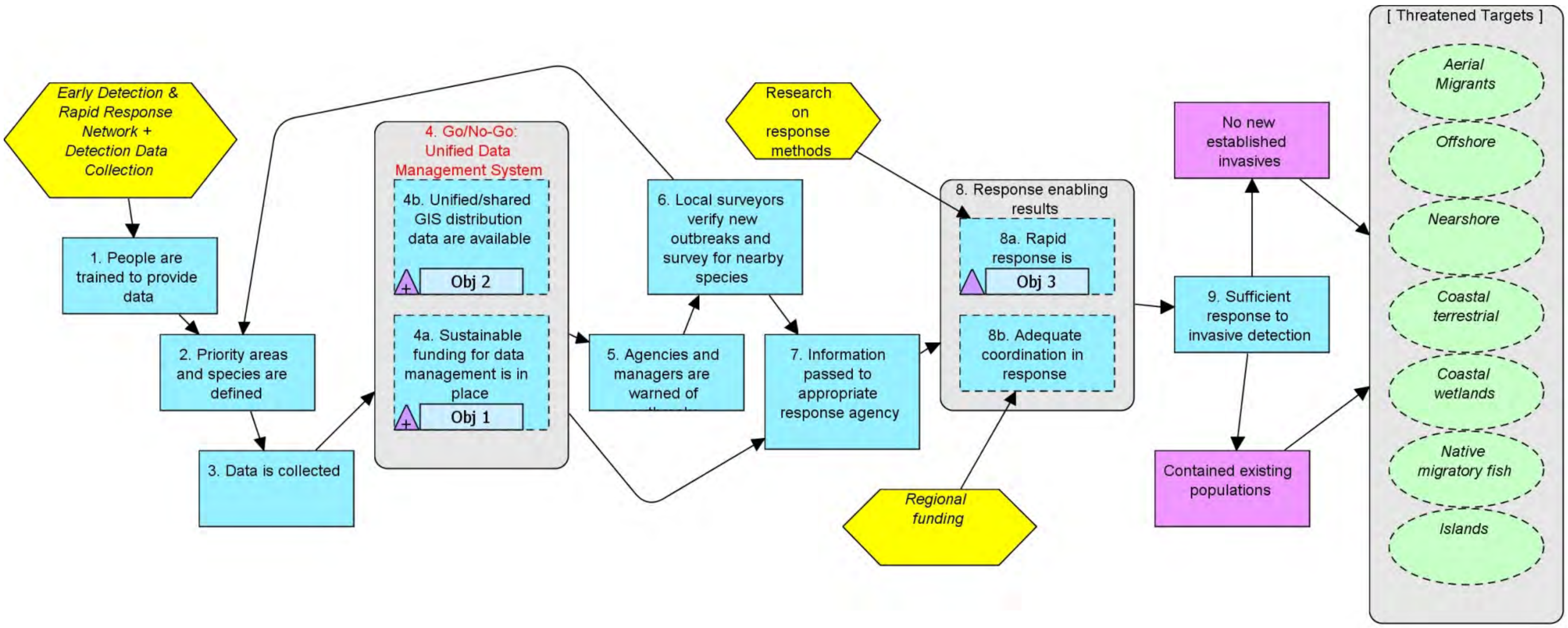

Figure 30: Results chain for the early detection and rapid response network strategy for Lake Michigan invasive species.

Likely participating agencies and organizations

Great Lakes Early Detection Network participants, including the Midwest Invasive Plant Network; State Departments of Natural Resources, Departments of Agriculture, Coastal Management Programs, and others; Federal agencies including National Park Service, USDA Forest Service, USGS, USACE, U.S. EPA, and others; NGOs including The Nature Conservancy and local conservancies, and many others.

6.4. Coastal conservation: Preventing incompatible development and shoreline alterations

The nearshore waters, shoreline, and coastal uplands of Lake Michigan 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 purchase for protection. The single most important anthropogenic factor impacting the Nearshore Zone and Coastal Terrestrial Systems is shoreline alteration from housing, urban development, and shoreline hardening and the resulting physical alteration of the land-water interface (SOLEC 2009).

During the strategy workshop in Chicago, a total of 21 different strategies were identified to address the threat of shoreline development. These 21 strategies were then condensed into eight strategies. Although all eight strategies are important to addressing the threat of incompatible shoreline development, we were only able to fully develop the top priority strategy: the use of coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes. We anticipate the other strategies will be developed as additional resources become available in the future.

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 22. Five Lake Michigan conservation targets, 1) Aerial Migrants, 2) Nearshore Zone, 3) Coastal Terrestrial, 4) Coastal Wetland, and 5) Islands, 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.

The primary drivers contributing to the increased negative impacts of housing, urban development and shoreline alterations on the Lake Michigan coastal zone can be divided into 10 main categories: 1) lack of political will, 2) lack of comprehensive coastal plans, 3) lack of implementation of existing plans, 4) lack of participation in planning by coastal landowners, 5) high 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) uncertainty of future lake levels.

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 21 different strategies were developed (Table 18).

Table 18: List of strategies identified to address housing/urban development and shoreline alterations along Lake Michigan..

Strategies
Implement new controls at point of property sale
Point of property sale education
Identify appropriate BMP's/actions for landowners
Identify opportunities to connect offshore windfarm development with coastal restoration
Work with port authorities to restore idle lands
Economic revitalization of urban areas
Incentivize coordinated planning
Develop and implement collaborative watershed plans that integrate green infrastructure principles
Identify connections between stormwater management activities and restoration opportunities; include the need to plan for increases in run-off due to climate change
Integrate natural resource information into planning efforts
Workforce development for Green Infrastructure (landscape architects, architects, engineers, planners)
Identify the relationship between natural resource conservation and job development
Document and convey the economic growth benefits of ecosystem services
Identify ecological significant places across the lake
Evaluate existing decision support tools
Develop user friendly software packages to evaluate the tradeoffs of land and water based decisions
Develop common language and standardized metrics for ecological restoration and monitoring activities
Develop policies and regulations to improve the management of coarse sediment transport
Create policies to remove shoreline hardening
Integrate Great lakes issues into K-12 curriculum
Outreach and education focused on coastal ecology

These 21 strategies were then combined into a set of eight aggregated strategies based on common themes such as economics, policy, collaboration, and tools (Table 19).

Table 19: List of grouped strategies to address housing/urban development and shoreline alterations along Lake Michigan. 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 and implement collaborative planning efforts that integrate green infrastructure principles	Tier 1
Work with port authorities to restore idle lands-economic revitalization	Tier 2
Point of property sale education and regulations	Tier 2
Policies to manage sentiment transport/remove shoreline armoring	Tier 2
Development of user-friendly decision support tools development and outreach	Tier 2
Targeted workforce development	Tier 2
Document and convey economic growth benefits/jobs of eco-services	Tier 2
Opportunities to connect offshore windfarms with eco-restoration	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. After a quick deliberation about prioritization, the Coastal Conservation Group came to a consensus that the most important strategy to focus on was, “Develop and implement collaborative planning efforts that integrate green infrastructure principles.” It is important to point out, that the vast majority of participants in the Coastal Conservation Group were from in the greater Chicago region where the highest concentration of impervious surfaces, urbanization, industrialization, and brownfields occur in the Lake Michigan region. This probably played a strong role in influencing green infrastructure as the top strategy.

6.4.2. Strategy 1: Use coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes

This strategy attempts to address the disconnection between land use activities and policies that occur at the municipal scale and Lake Michigan’s coastal biodiversity and ecological processes that occur at multiple scales. Lake Michigan’s coastline spans four states and includes 10 regional planning commissions and hundreds of local communities. Based on “home-rule,” each of these local communities has the authority to develop their own master land use plans, functional plans, and zoning ordinances. The home-rule policy in conjunction with a strong desire for increased tax base, leads to a large number of land-based decisions that are made in isolation from one another and other planning efforts. In addition, these decisions are often made with inadequate information about the biodiversity features and supporting ecological processes of the coastal zone.

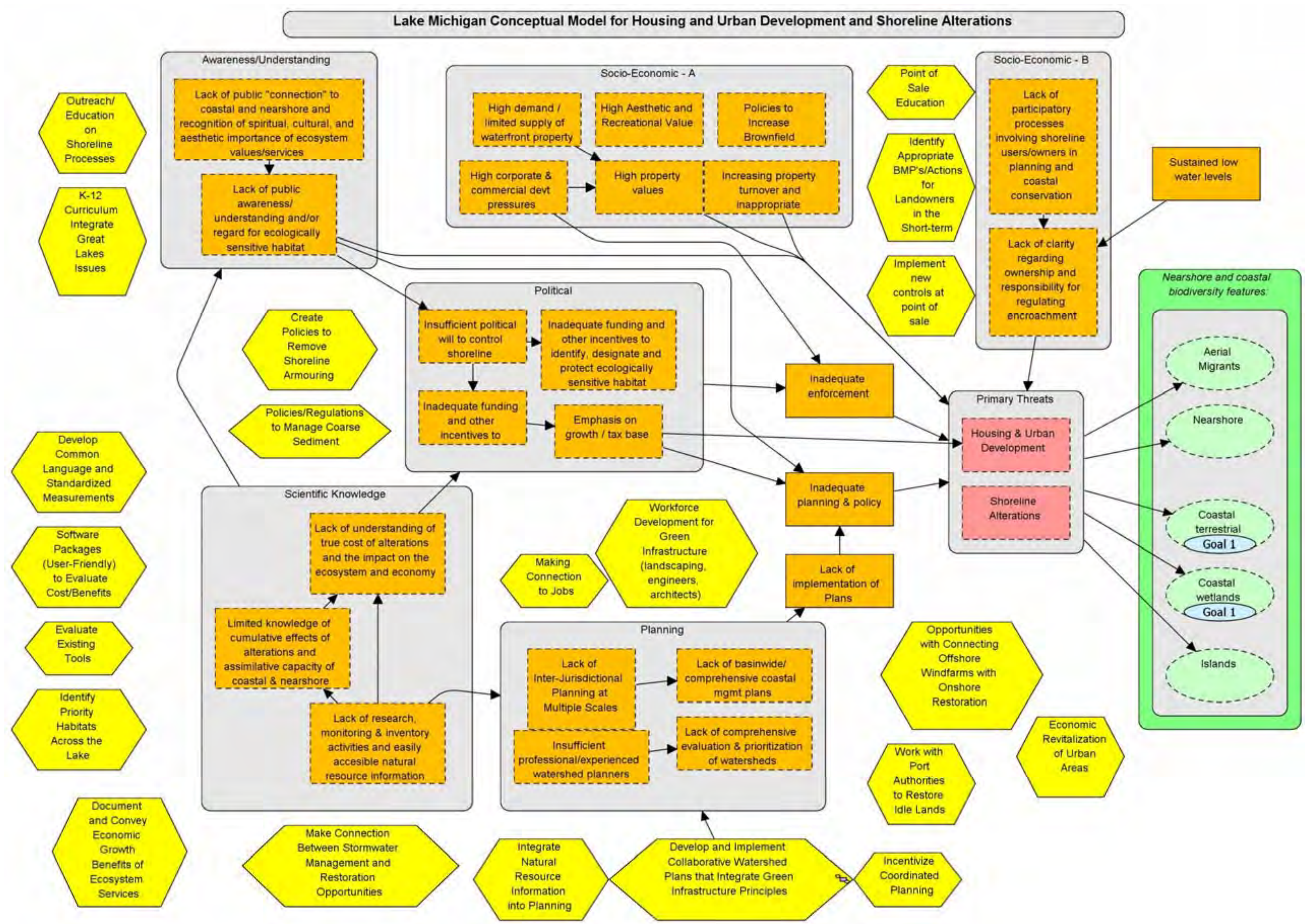

Figure 31: Conceptual model of the housing and urban development and shoreline alterations threats in Lake Michigan.

Strategic actions

1. Identify and contact local champions.
2. Inventory existing land use plans, functional plans, and zoning ordinances to identify those without Natural Resource Elements.
3. Identify economic advantages of collaboration.
4. Make natural resources information readily accessible.
5. Identify a water quality measure that resonates with coastal communities.
6. Identify and promote success stories.
7. Make connections between coastal biodiversity and human welfare.
8. Conduct periodic surveys.
9. Establish and provide regional technical assistance.

Results, objectives and measures

The foundation of this strategy is based on making high quality coastal information easily accessible and targeting areas with high potential for success. The results chain (Figure 32) also incorporates six additional strategies that are important to the success of the coordinated land use planning strategy: 1) technical assistance and training, 2) incentives for multi-jurisdictional planning, 3) coastal outreach and education, 4) integrating green infrastructure principles into local land use planning activities, and 5) developing and implementing a comprehensive shoreline softening program. The successful integration of coastal conservation targets into local plans, and implementation of these plans are key intermediate results of this strategy. If successful, this strategy will lead to future development that is located away from priority coastal areas, incorporates low impact design principles, and enhances coastal biodiversity and supporting processes.

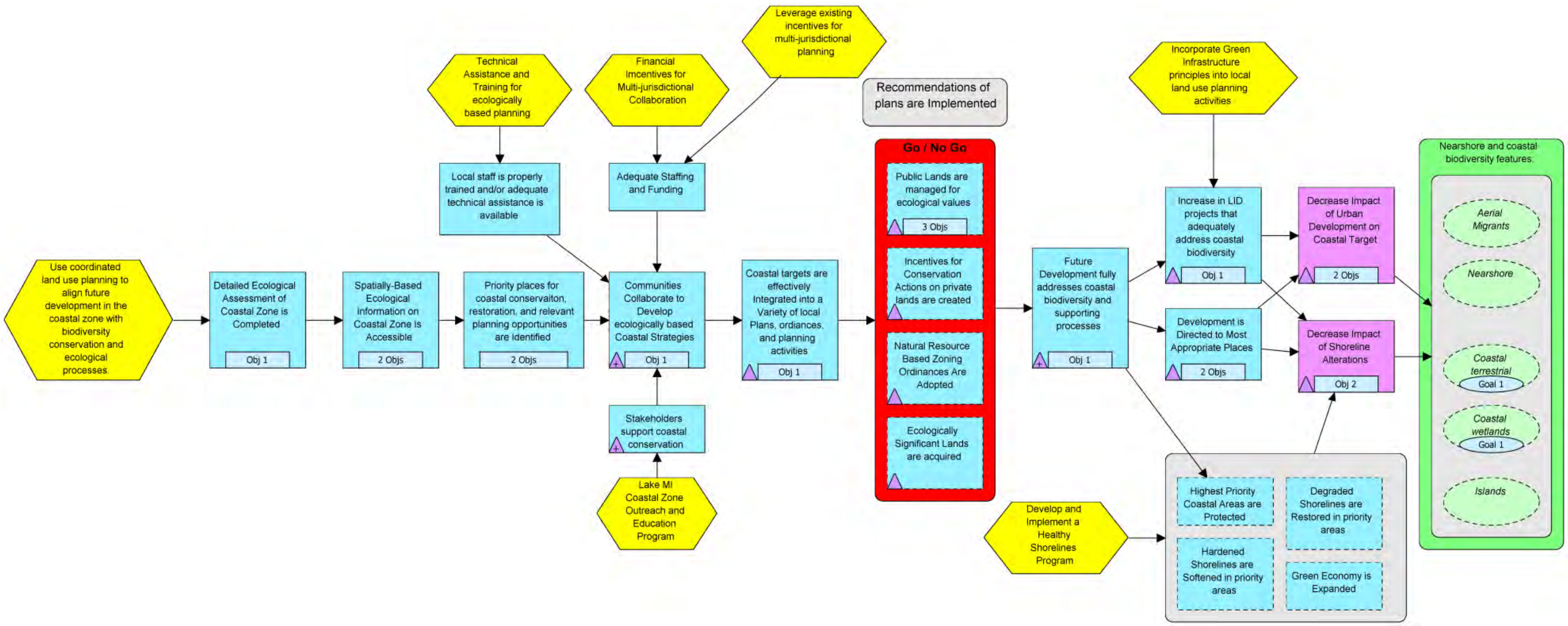

Figure 32: Results chain for the strategy to use coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological.

Result 1: Detailed ecological assessment of coastal zone is completed.

Objective 1: Spatially based analysis of biodiversity in Coastal zone is completed by fall of 2012.

Result 2. Spatially-based ecological information on coastal zone is accessible.

Objective 2: Identification of priority places in coastal zone for meeting conservation targets and goals (including threats analysis), is completed by 2013.

Objective 3: Spatially based ecological information on Lake MI coastal zone is accessible via the World Wide Web by middle of 2014.

Result 3. Priority places and relevant planning opportunities are identified around the Lake.

Objective 4: Land Use Plan assessment of local units of government completed by 2014.

Objective 5: Coastal conservation/restoration plans from around Lake are summarized by 2014.

Result 4. Communities collaborate to develop ecologically based coastal strategies.

Objective 6: By 2020, > 50% of coastal communities in significant biodiversity areas are actively involved in at least one collaborative effort to protect/restore coastal targets.

- Measure 1: Percent of Lake MI coastal communities directly involved in large scale conservation planning efforts.
- Measure 2: Number of applications to green infrastructure grants (state and federal).
- Measure 3: Number of data sharing agreements to access coastal information.

Objective 7: By 2020, 80% of coastal stakeholders support the conservation of Lake Michigan's coastal zone.

- Measure 1: Percent of municipalities that agree to sign a voluntary agreement to maintain and support the long-term health of the Lake Michigan coastal zone.
- Measure 2: Percent of residents in the coastal zone that support coastal conservation.
- Measure 3: Percent of businesses in coastal zone that support coastal conservation.

Result 5. Coastal targets are effectively integrated into a variety of local plans, ordinances, and planning activities.

Objective 8: By 2025, >50% of municipalities have effectively integrated coastal targets into master land use plans.

- Measure 1: Number of local land use plans that have integrated coastal targets and objectives as well as adaptive management.

Result 6. Public Lands are managed for ecological values.

Objective 9: By 2022, 50% of large public land holdings with significant natural features in coastal zone are managed for ecological values.

Objective 10: By 2020, all public lands in the coastal zone that contain significant natural features have a management plan that addresses coastal biodiversity and supporting processes.

- Measure 1: Area of public lands managed for conservation of coastal targets.
- Measure 2: Number of public land management plans that address coastal biodiversity and supporting processes.

Objective 11: By 2030, 50% of significant biodiversity areas on public land have some sort of legal designation to prevent future habitat degradation.

Result 7: Incentives for conservation action are created.

- Measure 1: Number of incentives that promote conservation.

Result 8: Ecologically significant lands are acquired.

- Measure 1: Area of ecologically significant lands acquired.

Result 9: Natural resource based zoning ordinances are adopted.

- Measure 1: Total number of natural resource-friendly ordinances/policies adopted per coastal community.
- Measure 2: Percent of coastal communities that have adopted at least one natural resource friendly ordinance.

Result 10: Future development fully addresses coastal biodiversity and supporting processes.

Objective 12: by 2030, 100% of all development proposals in the coastal zone are assessed for their impacts on coastal biodiversity and supporting processes as part of the formal approval process.

- Measure 1: Percent of development proposals assessed for impacts to coastal biodiversity and supporting processes.
- Measure 2: Percent of coastal communities that require development proposals to assess potential impacts to coastal biodiversity and supporting processes.

Result 11: Increase in low impact development.

Objective 13: By 2025, 100% of new development projects effectively integrate Low Impact Development (LID) principles that take into account coastal biodiversity and supporting ecological processes.

- Measure 1: Number of development proposals that effectively integrate LID principles.

Result 12: Development is directed to most appropriate places.

Objective 14: By 2030, 80% of high priority coastal areas are protected.

Objective 15: By 2025, 25% of priority restoration sites in the coastal zone are in the process of being restored.

- Measure 1: Area of critical habitat protected/restored.

Threat Reduction Result 1: Decrease impact of urban development on coastal targets.

Objective 16: Decrease existing impervious surface in the coastal zone by x % where it will have the biggest impact (numbers will differ by coastal assessment unit- TBD).

Objective 17: Increase current level of ecological connectivity in the coastal zone by xxx (numbers will differ by coastal assessment unit - TBD).

- Measure 1: Percent of existing impervious surface by coastal watershed.

Threat Reduction Result 2: Decrease impact of shoreline alterations on coastal targets.

Objective 18: By 2030, 20% or less of the Lake Michigan shoreline will be in hardened condition (numbers will differ by coastal assessment unit - TBD).

- Measures 1: miles of hardened shoreline.

Priority or opportunity areas for implementation

- Chicago-Gary and other large metropolitan areas in the coastal zone.
- Calumet Core Initiative: http://www2.illinois.gov/gov/millennium-reserve/Pages/default.aspx .

Related strategies and initiatives

- Lake Erie Biodiversity Conservation Strategies for Coastal Conservation– building a business case for Great Lakes conservation; Develop a comprehensive education/outreach shoreline softening program (in development).
- Illinois Lake Michigan Implementation Plan (in progress).
- Coastal & Estuarine Land Conservation Plans (CELCPs):
  - MI http://www.michigan.gov/documents/deq/deq-ess-clm-DraftCELCP-May07_211204_7.pdf .
  - WI: ftp://doaftp04.doa.state.wi.us/doadocs/WI%20CELCP%20Plan%20-%20Final%20web.pdf .

- IN: http://www.in.gov/dnr/lakemich/6136.htm .

- IL DNR Coastal Management Program Document: http://www.dnr.illinois.gov/cmp/Pages/documentation.aspx .
- Chicago Wilderness Biodiversity Recovery Strategy.
- The Indiana Lake Michigan Coastal Program of the IN DNR report "*A Synthesis of Environmental Goals and Objectives: Plans and Strategies for Indiana's Lake Michigan Region*" provides a comprehensive review of coastal conservation plans and initiatives that cover all or portions of the Indiana coastal zone: http://www.in.gov/dnr/lakemich/6037.htm .
- Great Lakes Restoration Initiative Action Plan, Nearshore goal 2 and Habitat goal 3: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf.

Likely participating agencies and organizations

- Regional Planning Agencies
- Municipal Planning Organizations
- Lake Michigan Watershed Academy
- U.S. EPA
- State Coastal Management Programs
- State Heritage Programs
- State Fish and Wildlife Agencies
- State Sea Grant Programs

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

We have developed a broad strategy to address the impacts of urban water pollution, namely to create incentives and the governmental structure to support increasing the implementation of green infrastructure practices throughout the Lake Michigan basin.

6.5.1. Priority Strategies

Of the many potential strategies identified by participants in the strategy workshop (see conceptual diagram, Figure 33), two were selected as having the greatest potential impact and feasibility: Green Infrastructure, and Strengthen NPS Management (Table 20). As participants began to explore assumptions and refine the intermediate results in the results chain exercise (Figure 25), we initially focused on the Green Infrastructure strategy, but recognized that ineffective management of NPS regulations is a substantial barrier to implementation of green infrastructure practices, as is explained in more detail below. Hence, the two strategies were merged into one more comprehensive strategy. In addition, to improve the likelihood of implementing green infrastructure practices, the group also developed another strategy that comprised increased, targeted training and incentives.

Table 20: Priority strategies for urban non-point and point source pollutants in Lake Michigan. 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 Rank
Green infrastructure: promoting and implementing green infrastructure practices	Tier 1
Strengthen NPS management: remove barriers and provide incentives for managing non-point source pollutants	Tier 1
Source reduction (emerging contaminants): improve monitoring and promote product substitutions for emerging contaminants	Tier 2
Valuation of biodiversity and ecosystem services: develop valuations for and raise awareness of ecosystem services impacted by urban NPS pollutants	Tier 2
Collaborative Vision, Framework: promote and implement a more collaborative vision and approach for managing urban NPS, and develop a framework for NPS management at multiple scales	Tier 2
Accounting system for externalities: (need to describe)	Tier 2
Cleaner energy: promote clean energy technology and energy conservation	Tier 2
Climate adaptation: develop and promote adaptation strategies for urban areas	Tier 2

6.5.2. Strategy 1: Promote and Implement Green Infrastructure and Strengthen NPS Management

As mentioned briefly above, the two strategies with the highest priority—Green Infrastructure and Strengthen NPS Management—were merged into one strategy that includes components addressing the development, promotion, standards, and incentives for increasing the implementation of green infrastructure practices throughout the Lake Michigan basin.

Currently, water quality standards in the Lake Michigan basin are established by the states, with oversight by the U.S. EPA under Section 303 of the Clean Water Act (CWA http://www.epa.gov/lawsregs/laws/cwa.html). Standards include designated uses such as swimming, wading, public water supply, and habitat for aquatic species, and for Great Lakes watersheds are higher than those called for in the CWA. Point source discharges into surface waters are regulated and permitted through the National Pollutant Discharge Elimination System (NPDES), and if regulated point sources do not meet water quality standards, the responsible party, such as a municipality or industrial facility, must establish a Total Maximum Daily Load based on the capacity of the receiving surface water to accommodate the discharge and still meet water quality standards.

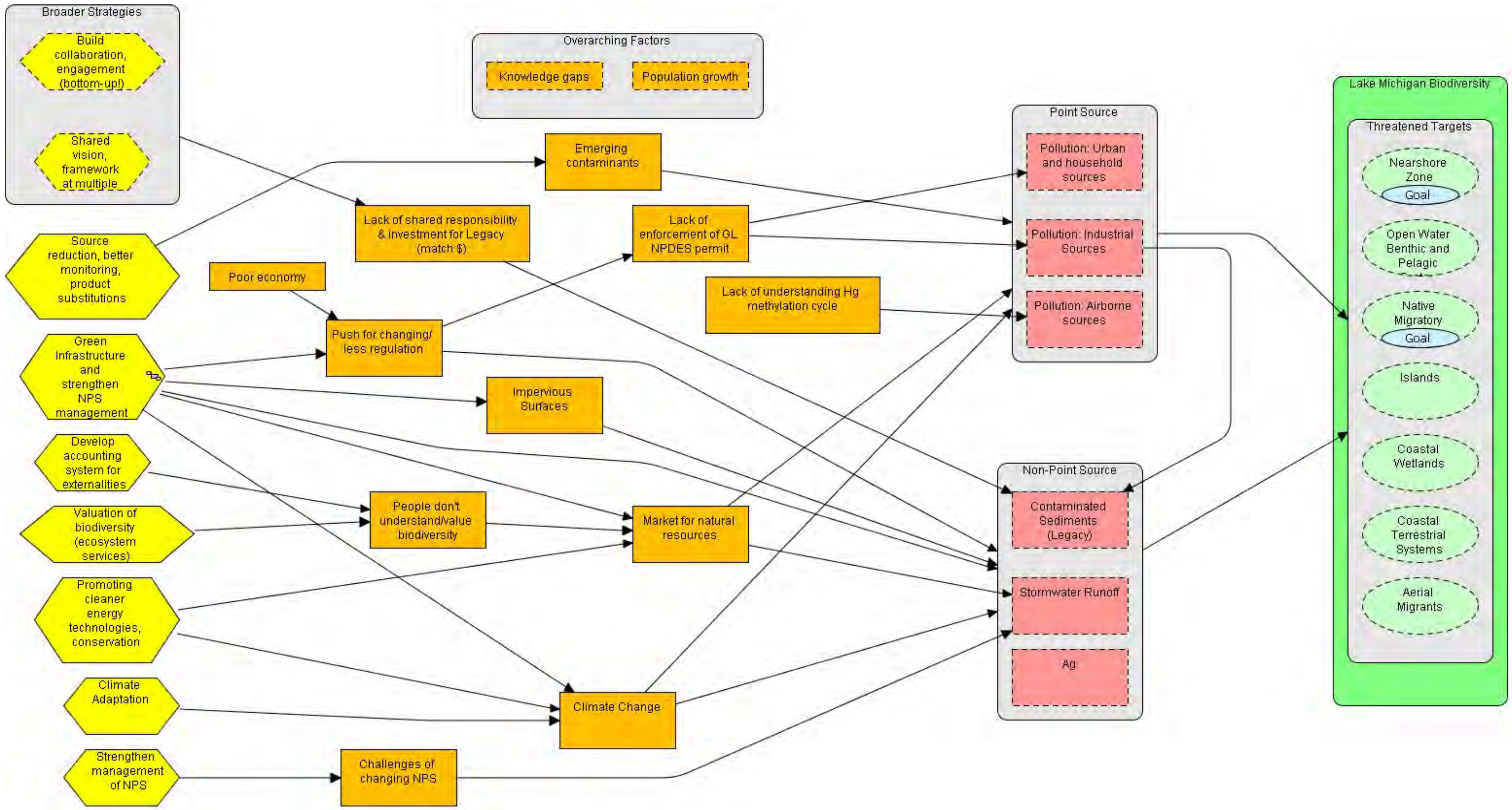

Figure 33: Conceptual model of urban point and non-point sources of pollution in Lake Michigan.

Complementary to this approach, NOAA and EPA have a suite of Management Measures required of Coastal States to address these issues. The Coastal Zone Act Reauthorization Amendments—section 6217—requires states that have an approved Coastal Zone Management Program to develop Coastal Nonpoint Pollution Control Programs (see EPA website: http://water.epa.gov/polwaste/nps/czara.cfm). All four states in the Lake Michigan basin now have approved CZM programs and are required to meet measures specified by these amendments.

As many older communities in the Great Lakes were built with combined sewer and stormwater management systems, and these systems occasionally overflow during storm events (a Combined Sewer Overflows or CSO), the CSO Control Policy is another regulatory mechanism that shapes local and stormwater codes because municipalities are usually the largest permit holders and the largest dischargers. Therefore, municipal ordinances and building codes are a key mechanism for managing stormwater in urban and near urban environments. How municipalities set and meet standards within their codes and ordinances may vary. For example, some cities set standards based on volume control from impervious surfaces, while others implement minimization of site disturbance and require reductions in impervious surfaces. These standards may be met through performance-based (added flexibility) or prescriptive control measures stipulated in municipal stormwater and development codes. Zoning is another way in which cities can manage stormwater flows and volumes and meet water quality requirements. Stormwater best management practices (BMPs) are often prescribed because monitoring for non-point-source pollutant concentrations is a formidable challenge.

Incorporating green infrastructure as a stormwater management approach to meet water quality standards is increasing around the Great Lakes. Even so, there are barriers to adopting green infrastructure practices for managing urban runoff and municipal or industrial point sources, such as the lack of consistency between guidance and encouragement of green infrastructure for stormwater management by regulators (U.S. EPA or states) and the enforcement of specific requirements outlined in NPDES permits. Green infrastructure practices lack acceptance in some areas, and this perspective has weakened the implementation of green infrastructure in NPDES permits and stormwater/development codes and ordinances. One reason for this challenge, sometimes cited by cities, is the hesitation on behalf of regulators to accept green infrastructure as a substitute for conventional infrastructure in meeting NPDES standards and measures for compliance. Consequently, cities have limited incentive to invest in green infrastructure not knowing whether they will be in compliance of their permit.

Secondly, municipal building, zoning, development and stormwater codes and ordinances are often based on historical engineering standards, which are tried and true in terms of safety, stormwater management effectiveness and cost. Green infrastructure is not a comprehensive solution, nor can it be implemented effectively in every location due to soil constraints, urban density, climate, and so on. However, revisions to codes and ordinances for stormwater, development, landscaping, utilities, parks, and other land uses can improve the implementation of green infrastructure to manage stormwater for water quality and potential biodiversity impacts.

The sheer number and diversity of agencies that are involved in stormwater management also contributes to the complexity of implementing innovative green infrastructure practices. To address this issue, the U.S. EPA has created the Water Quality Scorecard (http://www.epa.gov/smartgrowth/water_scorecard.htm) to help cities identify and remove barriers to implementing green infrastructure through revising and creating new codes, ordinances and incentives across all relevant departments and at a variety of scales of implementation. However, before cities will be willing to make revisions, they will likely wait for the U.S. EPA and NPDES administrators to move forward on creating more acceptability of green infrastructure for meeting performance or water quality standards in their NPDES permits. Clearly, coordination between municipalities and regulators—whether U.S. EPA or the states—to address this barrier is an important first step in advancing green infrastructure practices.

Strategic actions

1. Review and amend codes as needed.
2. Identify and reduce barriers to implementation.
3. Promoting Green Infrastructure Practices, and require communities to explain why they aren't using green infrastructure, thereby increasing demand.

Results, objectives and measures

The actions listed above would lead to several intermediate results, ultimately leading to a reduction in impacts from point and non-point source pollutants from urban areas, and ultimately improving biodiversity of the Nearshore Zone and Native Migratory Fish conservation targets (Figure 34).

Non-point source results

Result 1: Local codes and ordinances encourage and promote green infrastructure. This result is identified as a “go-no-go” scenario for achieving the potential biodiversity outcomes associated with the green infrastructure strategy. As described above, overcoming regulatory barriers will require coordination among regulators and managers, yet many cities around the U.S. are beginning to take on the challenge. Several Great Lakes cities including some within the Lake Michigan watershed are now updating codes and ordinances to better accommodate green infrastructure.

Objective 1: By 2020, all MS4 communities have updated local codes, ordinances, zoning, and/or by-laws that influence storm water management to at least allow if not mandate use of green infrastructure to meet or surpass NPDES permit requirements by a designated time.

- Measure 1: Proportion of MS4 communities that have enabling code.

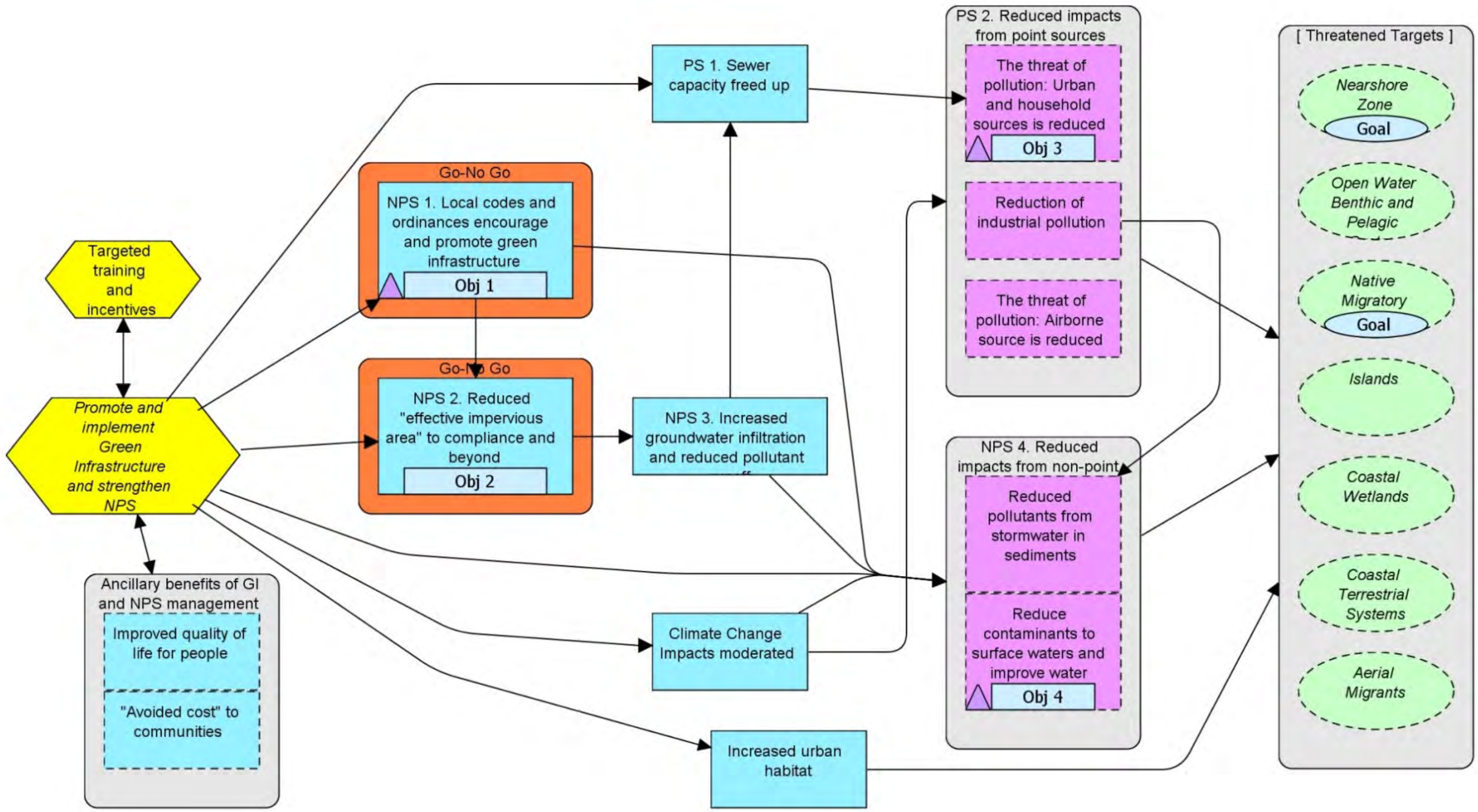

Figure 34: Results chain for priority strategy Promote and implement green infrastructure and strengthen NPS management.

Result 2: Reduced "effective impervious area" to compliance and beyond. The wording of this result reflects a consensus among the experts involved in compiling this strategy that simple compliance with regulations for impervious surface area will not be sufficient to meet water quality goals, and that implementing green infrastructure practices will lead to economic and public health benefits that will provide incentives for further use of the tactic, enabling municipalities to surpass regulatory goals. Also implicit in the result is that some seemingly pervious surfaces are in fact effectively impervious, especially during storm events, in that they have very little capacity to allow infiltration to groundwater.

> *Objective 2: By 2020, all 8-digit Hydrologic Unit Codes will be at or below 10% effective impervious surfaces and there will be no net increases in effective impervious surfaces within any of these basins.* [Note: it may be impossible to achieve this objective in some 8-digit HUCs in the Southern Basin, so this objective should be considered for refinement as the LMBCS is updated.]

Result 3: Increased groundwater infiltration and reduced pollutant runoff. This result is a key outcome of green infrastructure practices—that precipitation and runoff will increasingly fall on or flow to pervious surfaces and infiltrate to groundwater, leading to reduced pollution of surface waters, including Lake Michigan.

Result 4: Reduced impacts from non-point sources. This group of results has two components—reduced pollutants from storm water and reduced contaminants to surface waters and improve water quality.

> *Objective 4: Reduce Total Suspended Phosphorus (TSS) in Municipal Separate Storm (MS4) water by at least 40% by 2014.* This objective is in effect in Wisconsin now, and the deadline there is 2013. The effectiveness will be measured relative to 2004 levels, which are prior to the installation of storm water BMPs. In some communities, new construction must meet 80% reduction in TSS.

- Measure 1: Estimated TSS based on Source Load Allocation Management Model (SLAMM) model.

Point source results

Result 1: Sewer capacity freed up. The rationale for this result is that as green infrastructure practices are increasingly installed, precipitation and runoff will increasingly infiltrate into groundwater, placing less demand on sewer systems.

Result 2: Reduced impacts from point sources. This group of results comprises reduced point-source pollution from household, industrial, and airborne sources.

> *Objective 3: By 2020, reduce frequency and volume of CSO's by an amount commensurate with effective impervious area reduction.*

- Measure 1: Frequency and volume of CSO’s (5-year running average of CSO frequency and volume per municipality and rolled up to the appropriate HUC).

Other results of this strategy

Result 1: Climate Change Impacts moderated. Experts noted that as green infrastructure installations increase, it is likely that some aspects of climate change and its impacts may be moderated. Possible examples include carbon sequestration, localized cooling through increased shade and evapotranspiration, and mitigation of impacts from high-intensity storms, which are projected to increase in frequency.

Result 2: Ancillary benefits of Green Infrastructure and NPS management. This result includes the improvements in quality of life for people in urban areas and the avoided costs to communities that would follow increased implementation of green infrastructure and improved NPS management.

Result 3: Increased urban habitat. Green infrastructure projects are likely to provide new habitat for urban wildlife of many types including birds, small mammals, insects and other invertebrates, reptiles, and amphibians.

Priority or opportunity areas for implementation

TBD.

Related strategies and initiatives

- The Lake Michigan LaMP (U.S. EPA 2008), summarizes the EPA's Green Infrastructure Policy and lists the benefits of green infrastructure on pages 6-9; www.epa.gov/glnpo/michigan.html . It also suggests several next steps that relate to the strategy described above, including:
    - Develop an Impaired Waters Strategy (P 1-1 in Subgoal 1: Can we all eat any fish?)
    - Continue Watershed Academy to ensure land use and planning take account of source water issues protection needs (P 2-1 in Subgoal 2: Can we drink the water?)
    - Promote measures that will reduce or eliminate pollution sources at Great Lakes beaches (P 3-1 in Subgoal 3: Can we swim in the water?)
    - Identify open space multi-use opportunities and tools for such things as flood retention parks and open space with commuter bike trails, among others (P 5-1 in Subgoal 5: Does the public have access to abundant open space, shoreline, and natural areas, and does the public have enhanced opportunities for interaction with the Lake Michigan ecosystem?)
    - Assist development of Green: Marina, Highway, and Golf Course programs for the basin to reduce inputs of nutrients, pesticides, and other pollutants into basin waters, AND Promote basin-wide opportunities for green areas that sequester carbon (P 6-1 in Subgoal 6: Are land use, recreation, and economic activities sustainable and supportive of a healthy ecosystem?)
    - Reduce pollutant loads with effective pollution control measures with a focus on nutrients and mercury (P 7-1 in Subgoal 7: Are sediments, air, land, and water sources or pathways of contamination that affect the integrity of the ecosystem?)

- The U.S. EPA Office of Wastewater Management offers a suite of information, including case studies from around the Great Lakes, for Green Infrastructure and storm water management: www.epa.gov/npdes/greeninfrastructure and http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf .

- Lake Michigan cities that have implemented stormwater management BMPs and have set quantitative goals for reduction of runoff and/or standards for new construction include Milwaukee, WI, Chicago, IL, and Grand Rapids, MI. For more information, see Green CiTTs (Cities Transforming Towards Sustainability) report, a source for stormwater management data for individual cities: http://www.glslcities.org/greencities/stormwater/Stormwater%20Management%20Report_English_Final2_Updated_June11.pdf .

- Wisconsin Storm Water Regulations Summary-Fact Sheet (as it relates to green infrastructure, exemptions and prohibitions): http://dnr.wi.gov/runoff/pdf/rules/Final_NR151_non-ag_FS_Oct_2011.pdf .

- Wisconsin Administrative Codes NR 216 Storm Water Permitting and NR 151 Runoff Mgmt: http://docs.legis.wisconsin.gov/code/admin_code/nr/216.pdf and http://docs.legis.wisconsin.gov/code/admin_code/nr/151.pdf .

- Wisconsin Administrative Code NR 105 Surface Water Quality Criteria and Secondary Values for Toxic Substances (Per Vicky's Request): http://docs.legis.wisconsin.gov/code/admin_code/nr/105.pdf .

- Wisconsin Technical Standards (Construction & Post Construction) to meet the NR 216 and NR 151 Wis. Admin. Codes: http://dnr.wi.gov/runoff/stormwater/techstds.htm .

- 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*.”: http://www.glpf.org/funded-projects/improving-water-management-great-lakes-basin.

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

Likely participating agencies and organizations

Municipalities, regional councils of governments, and regulating agencies are all likely to be key participants in this strategy—and many already are. Others include water and sewerage districts, State Departments of Natural Resources and Environmental Management/Quality, Coastal Zone Management Programs, and the Lake Michigan Watershed Academy.

6.6. Restoration of the offshore fisheries in Lake Michigan

In Lake Michigan, the native prey base for top offshore fish predators—historically dominated by seven coregonid species (the ciscos) —is largely absent today due to population crashes and extirpations that occurred in the 20th century. Cisco historically occurred throughout the lake and were a major component of this prey base, but are now almost extirpated in Lake Michigan except for a remnant population in Grand Traverse Bay. We identified five possible strategies to support restoration of the offshore fish and fisheries. All are priorities lakewide. In the workshop, we further developed two of these strategies to address the needs of the Offshore Zone. The first is to restore cisco in Lake Michigan and the second is to assure that funding for lamprey control continues at current levels at least.

6.6.1. Priority strategies

We need to implement a restoration strategy because native prey have been unable to recover on their own. Their population numbers are very low, a result of historic overfishing, as well as increased predation from invasive species. In turn, lake trout have a diet dominated by the exotic alewife. Alewife contains high levels of thiaminase which causes thiamine deficiency in lake trout, resulting in poor reproductive survival. The influence of these factors is shown in the conceptual model (Figure 35). The model shows the interrelationships among fisheries management decisions, past fishing, current fishing, invasive species, sportfishing, and emerging issues such as offshore wind towers to the current stresses on the offshore food web. We note that any restoration effort will need to be mindful of balancing harvest and stocking, as well as the treaty rights and sea lamprey control. In addition, fisheries managers should evaluate habitat conditions, water quality, and the status of the base of the food web, and additional strategies should be considered, should these factors prove to be a barrier to native offshore fisheries recovery. Should we be successful in raising population sizes of prey, it may be necessary to enact protections and/or revisit existing harvest agreements.

Table 21: Priority strategies for restoration of the offshore fisheries of Lake Michigan. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to restore the offshore fisheries of Lake Michigan.

Fisheries Restoration Strategies	Priority
Cisco restoration	Tier 1
Sea lamprey treatments, barriers, pheromones	Tier 1
Deepwater coregonid restoration	Tier 2
Lake trout stocking (increase rates, bring in different morphotypes, offshore refuge stocking)	Tier 2
Educating the public on a more stable and diverse fishery	Tier 2

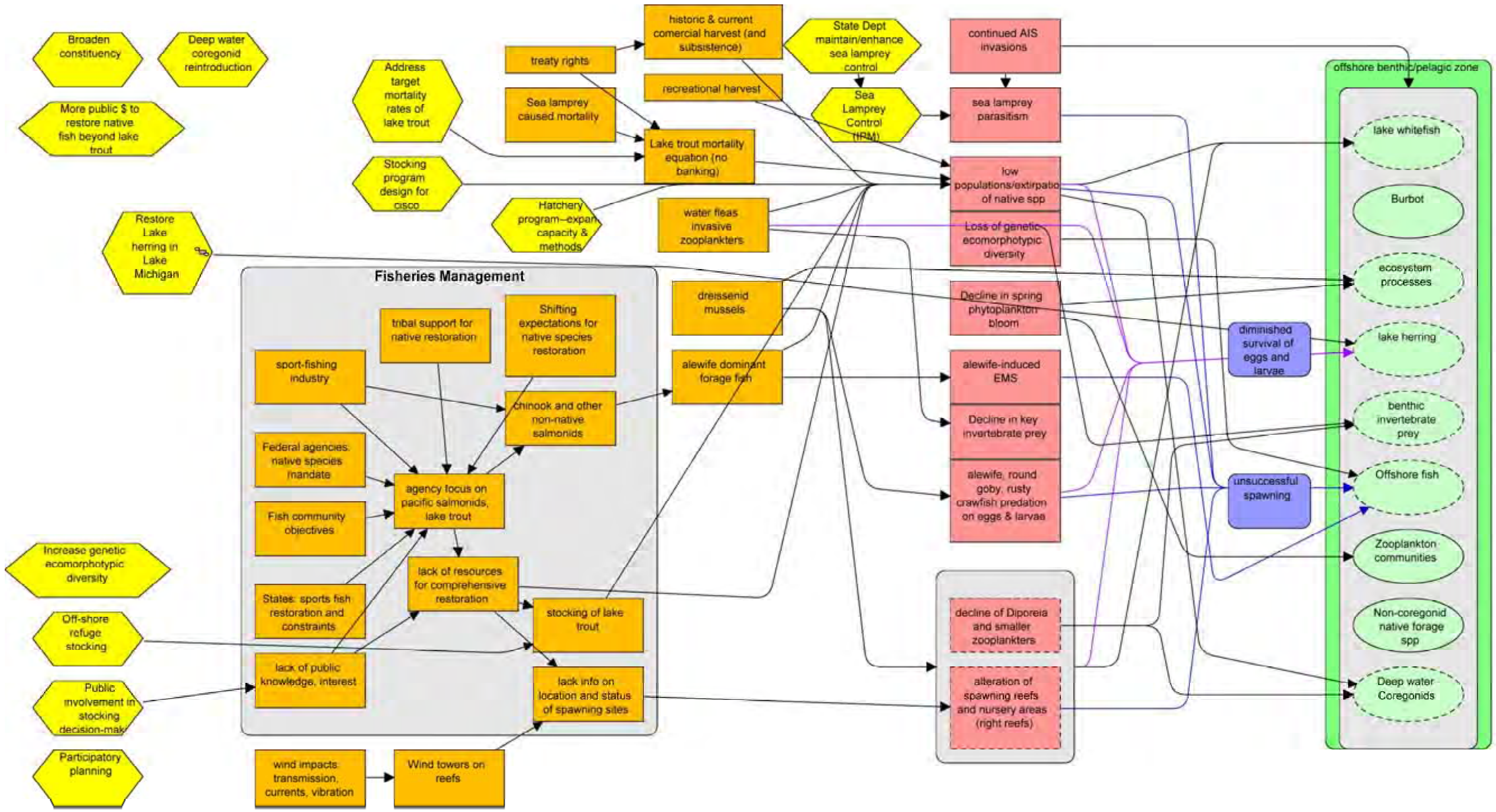

Figure 35: Conceptual model of the offshore food web in Lake Michigan

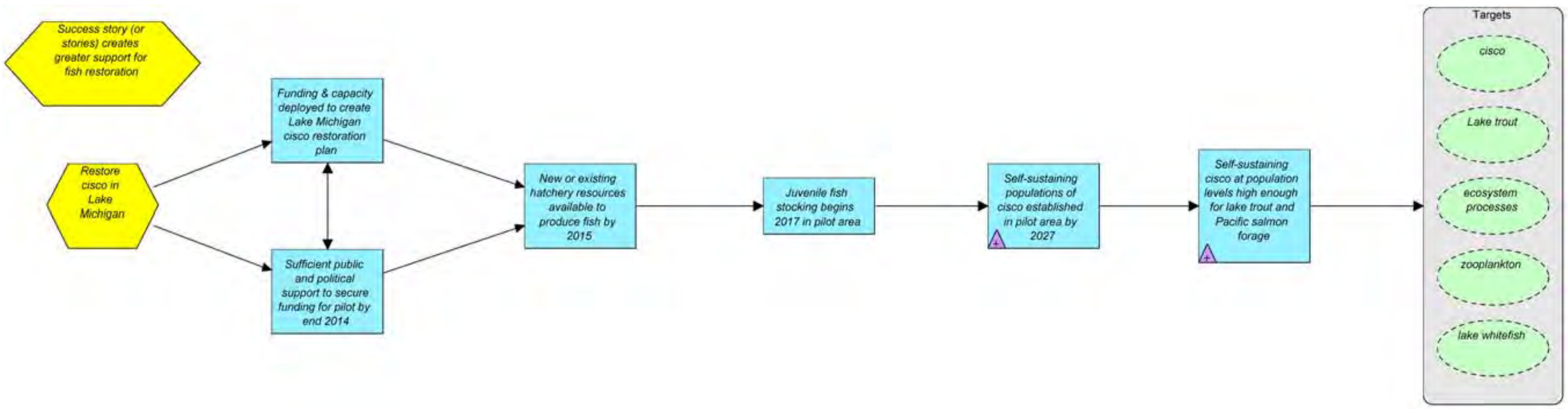

Figure 36: Results chain for restoring Cisco in Lake Michigan

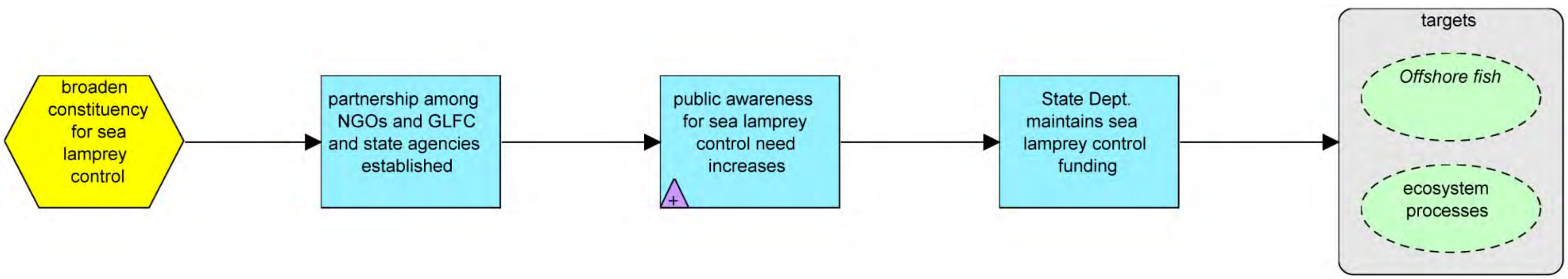

Figure 37: Results chain for Sea Lamprey control in Lake Michigan

6.6.2. Strategy 1: Restore Cisco (*Coregonus artedi*) in Lake Michigan

Fisheries managers are interested in enhancing the populations of native prey, and at the strategy workshop representatives of federal, state and tribal agencies crafted a strategy to restore cisco in Lake Michigan. The strategy is to restore cisco in Lake Michigan by 2035, as indicated by self-sustaining populations that provide sufficient forage for lake trout and Pacific salmon. This strategy would benefit from an accompanying communications strategy to build stakeholder support and to share successes.

Given the governance of fishery management in the Great Lakes, it will be necessary to engage the Lake Michigan Committee of the Great Lakes Fishery Commission as a first step in establishing this strategy. The entities responsible for fishery management in the Great Lakes coordinate their actions through the guidance of the Joint Strategic Plan for the Management of Great Lakes Fisheries (GLFC 2007), which is administered by the Great Lakes Fishery Commission. The planning process will be an opportunity to challenge two assumptions behind this strategy, first that cisco is the correct fish to focus on and that Green Bay is the right initial location for re-introduction. Green Bay was discussed as a logical potential location for re-establishment and the results chain's objectives specifically mention Green Bay as a restoration site. There are three factors that support the selection of Green Bay: 1) Green Bay historically maintained the highest densities of cisco, 2) Green Bay appears to have overwintering habitat conditions that are much-improved over the conditions when its populations crashed (Madenjian et al. 2011), and 3) Green Bay is far from Grand Traverse Bay where the only remnant population occurs. However, any location for restoration is contingent upon the planning steps that would precede it, so Green Bay as the location for starting rehabilitation efforts is subject to change. In the planning process, we also recommend that the potential restoration of deep water coregonids be considered.

While fisheries managers have native fish restoration as a stated goal (Eschenroder et al. 1995), management decisions and spending are balanced against stocking of introduced salmon, highly valued by the sport fishing industry. Resources for native fish restoration needs to be increased to achieve healthier Lake Michigan fisheries, and especially for the long-term restoration of self-sustaining lake trout populations. The sport fishers and the industry that support them represents a very important stakeholder group that will need to be engaged in implementation of any restoration strategy.

Strategic actions

1. Engage the Lake Michigan Committee of the Great Lakes Fishery Commission to request they appoint a task group to develop a plan to restore cisco in Lake Michigan.

2. Conduct asset-based mapping to identify the objectives and needs of all key stakeholders/constituencies.

3. Complete a contemporary retrospective analysis of cisco (revisit research by T. N. Todd. i.e. Todd et al 1981).

4. Agencies conduct uniform, coordinated outreach to stakeholders.

5. Complete hatchery plan to assess capacity and how it will be used.

Results, objectives and measures

To restore cisco in Lake Michigan, workshop participants laid out a sequence of six results. Each result involves numerous specific actions. If these actions were discussed in the workshop they are included in the list above or the details on each outcome below.

Result 1. Funding and capacity deployed to create Lake Michigan cisco restoration plan.

Objective 1: Complete Lake Michigan cisco restoration plan by 2014.

The planning process will need to begin by the Lake Michigan Committee of the GLFC appointing a task group (by Lake Michigan Committee), followed by garnering funding, holding meetings, completing a contemporary retrospective analysis, detailed analyses and planning itself—including development of monitoring program and measures. Such a plan would address:

- Actions
- Justifications
- Risks (genetics, Grand Traverse population)
- Costs
- Benefits (economic, ecological, cultural)
- Evaluation of pilot locations
- Participation by agencies, academics, other partners, some key stakeholders

Result 2. Sufficient public and political support is in place to secure funding for pilot stocking effort.

Objective 2: By the end of 2014, funding is secured for pilot stocking effort.

Having a plan helps to get congressional support, but there will need to be policy engagement to get there. This objective will be reached by involving key stakeholders (e.g., organized fisheries, NGOs) in the plan development and addressing their needs and values.

Result 3. New or existing hatchery resources available to produce fish by 2015.

To get the hatchery capacity changes will likely require reallocation of resources (USFWS) rather than new resources, for example, raising cisco at a facility that is no longer raising lake trout.

Result 4. Juvenile fish stocking begins 2017 in Green Bay (or alternate pilot location).

The intervening time is needed to collect gametes in the Fall (2016) for release some time in 2017. Also would have to have the hatcheries effectively raising herring.

Result 5. Self-sustaining populations of cisco established in Green Bay (or alternate pilot location) by 2027.

This time period allows for repeated stocking and adaptive management as results are monitored. A milestone for self-sustaining populations would be evidence of naturally reproduced individuals in the population (note: this does not mean there is a self-sustaining population yet).

Result 6. Self-sustaining cisco at population levels enough for lake trout and Pacific salmon.

This final objective would involve stocking other key areas of the lake if needed. The populations in Green Bay (or alternate pilot location) could be a source for the rest of Lake Michigan. Monitoring would include ecological measures for cisco including age structure of the parent stock and proportion that is naturally reproduced. The goal is to have a multi-age structured parental stock with sustained recruitment and a shift in lake trout diet to greater than 50% cisco.

Priority or opportunity areas for implementation

Currently, the water quality conditions in Green Bay have improved to the point that the bay is a sound place for a pilot stocking program.

Related strategies and initiatives

- Cisco restoration efforts in Grand Traverse Bay.
- Cisco stocking on Lake Huron.
- Cisco rehabilitation efforts in Lake Ontario.
- Great Lakes Fishery Commission Fish Community Objectives.
- Lake Michigan Integrated Fisheries Management Plan (2003-2013) – WI DNR (Goal 1, Objective B – Protect and restore native species) [doesn't mention cisco specifically – but does mention issues with alewife].
- Great Lakes Restoration Initiative Action Plan, Habitat goal 1: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf .

Likely participating agencies and organizations

Lake Michigan Committee, Great Lakes Fishery Commission; U.S. Fish and Wildlife Service; U.S. Geological Survey; Wisconsin, Michigan, Illinois and Indiana Departments of Natural Resources; tribes; sportfishing associations.

6.6.3. Strategy 2 (Possible strategy): Broaden constituency for Sea Lamprey control

The U.S. State Department allocates funding to sea lamprey control as it is governed by an international treaty. The Great Lakes Fishery Commission (GLFC) has the largest budget of all the fisheries commissions, funded by the State Department at approximately $20 million/year. If this funding were to erode, it would undermine conservation efforts in the Great Lakes. The funding for the GLFC has been reduced, but the governing body reallocates funding to maintain the sea lamprey control program, pulling funding from other management and research priorities.

Currently, the constituencies that actively lobby Congress for sea lamprey control include state resource agencies, the GLFC secretariat and sport-fishing groups. However, a much broader constituency actually benefits from sea lamprey control efforts including restaurant and bar owners, convention and visitors bureaus, the tourism industry, and conservation NGOs.

While the need for sea lamprey control was a headline issue in the 1950s, it has receded from public view and is underappreciated by legislators and anglers. The concern needs to be on par with the concern for preventing the Asian carps from getting established in the Great Lakes. Sea lamprey control is a powerful aquatic invasive species control success story.

We need to spread the message – "Don't forget about sea lamprey control; nothing else matters if that falls away."

Results, objectives and measures

This strategy is only partially developed. The key steps in the results chain are:

1. Partnership among NGOs and Great Lakes Fishery Commission and state agencies established.
2. Public awareness for sea lamprey control need increased.
3. State Department maintains and/or enhances sea lamprey control funding.

Priority or opportunity areas for implementation

This strategy requires coordination across the Great Lakes and applies everywhere.

Related strategies and initiatives

- Great Lakes Fishery Commission – Joint Strategic Plan for Management of Great Lakes Fisheries (rev. 2007).
- Great Lakes Restoration Initiative Action Plan, Invasive Species goals 3 and 5: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf .

Likely participating agencies and organizations

Great Lakes Fishery Commission; sportfishing associations, chambers of commerce.

6.7. Improve habitat connectivity by reducing the impact of dams and other barriers

Dams and barriers in Lake Michigan are considered significant threats to Migratory Fish as well as Nearshore Zone, Coastal Wetland, and Coastal Terrestrial 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 Michigan tributaries, but also dikes which isolate coastal wetlands from other nearshore habitats.

6.7.1. Priority strategies

A conceptual model depicting the causative linkages, contributing factors, and opportunities for dams and barriers can be found in Figure 38. Four Lake Michigan conservation targets, Migratory Fish, Nearshore Zone, Coastal Wetland Systems and Coastal Terrestrial Systems, are threatened by dams and barriers through a 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 Michigan are dams and poorly installed road-stream crossings. 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, 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, resulting in threats to public health and safety. We developed two strategies specifically to address first barrier (mostly dams) and road stream crossings in a comprehensive way that can be applied at multiple scales of decision making.

Each of these strategies would provide benefits to Lake Michigan (Table 22), but not all strategies were selected for development. Two comprehensive strategies were selected for lakewide emphasis, including 1) a decision tool for barrier removal and 2) improved road-stream crossing BMPs (2). Several other specific strategies were incorporated into these (1a-1c, 2a-2c).

Table 22: Priority strategies for dams and barriers in Lake Michigan.

Dams and Barriers Strategies	Priority rank
Decision tool for dam removal/passage enhancement applicable at any scale	1
Rate dams and barriers on metrics of ecological significance, economics, risks, opportunities, etc.	1a
Have watershed management plans include Lake Michigan priorities	1b
Streamline permitting for barrier removal/improvement	1c
Improve road-stream crossing BMPs	2
Influence existing road/stream barriers through regulation	2a
Involve economic stakeholders; link environment w/ economy	2b
Increase knowledge of road-stream crossing BMPs	2c
Outreach to increase understanding of funding options and benefits	--
Funding assistance to governments to upgrade culverts	--
Create demonstration sites for municipal leaders	--
Prevent future barriers to connectivity	--

6.7.2. Strategy 1: Increase connectivity to Lake Michigan through development and use of a comprehensive lowest barrier decision tool

This strategy is intended to bring together a wide variety of data and information that includes pressures to keep barriers and pressures to remove barriers into one decision tool. Pressures to keep barriers, combined with uncertainty as to which barriers are the most important to remove; have impeded progress in removing dams and other barriers. The decision tool would provide a means for prioritization and decision making based on a comparison of costs and benefits. If the tool is widely accepted by management and funding agencies and stakeholders, it would result in shared regional priorities for barrier removal and could be used by dam owners locally in making informed decisions. Cost-benefit comparisons would also be beneficial in providing better information to the public, in ensuring restoration funds are well spent, and in streamlining project permitting.

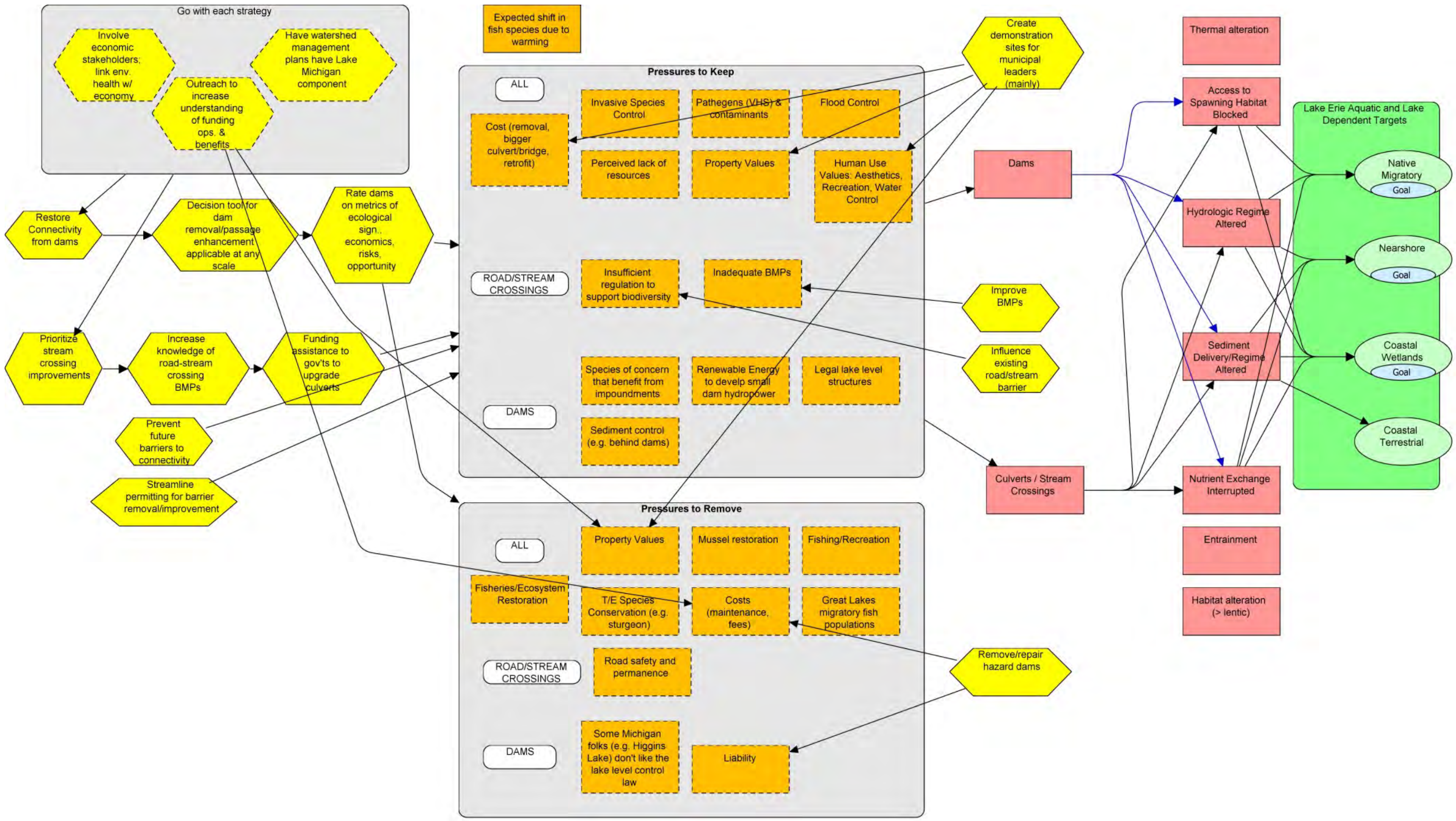

Figure 38: Conceptual model depicting the causative linkages, contributing factors, and opportunities for addressing the impacts of dams and barriers in Lake Michigan

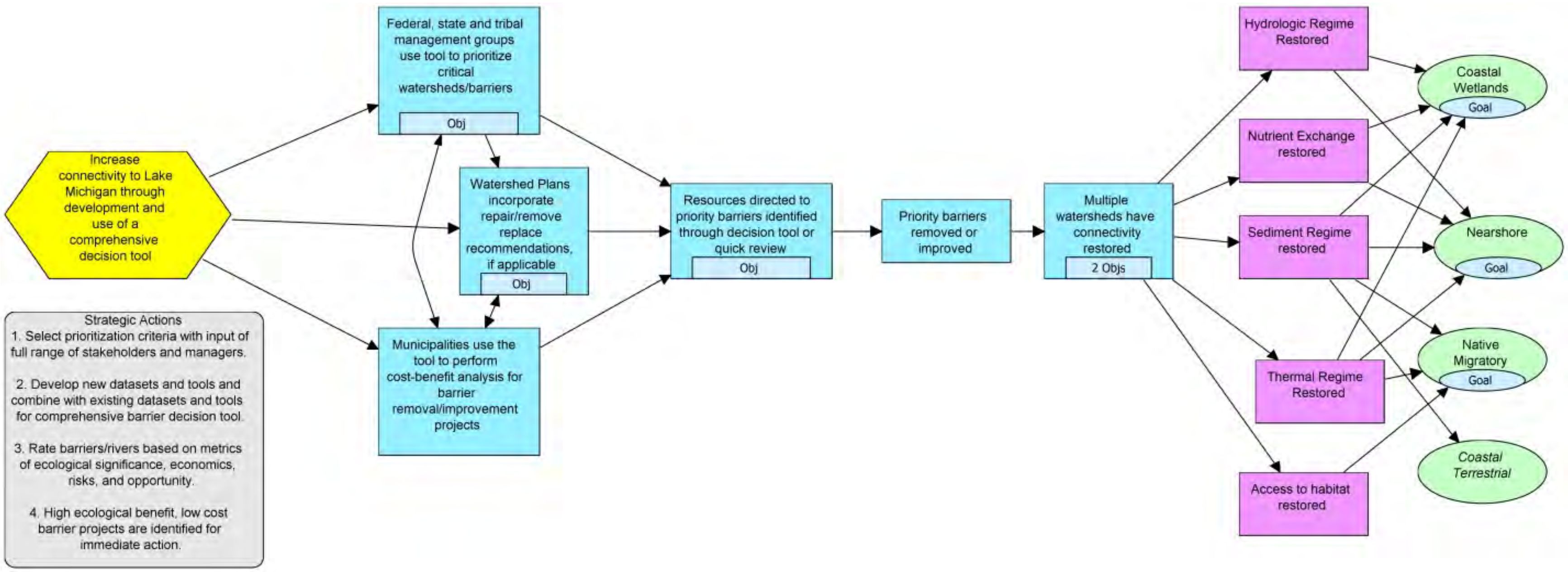

Figure 39: Results chain for a strategy to address dams and barriers threats in Lake Michigan by increasing connectivity to the lake by developing a multi-scale decision tool focusing on costs and benefits of first barrier removal.

Strategic actions

1. Select prioritization criteria with input from full range of stakeholders and managers.
2. Develop new datasets and tools and combine with existing datasets and tools for comprehensive barrier decision tool.
3. Rate barriers/rivers based on metrics of ecological significance, economics, risks, and opportunity.
4. High ecological benefit, low cost barrier projects are identified for immediate action.
5. 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 39).

Result 1. Management groups across the lake use tool to prioritize critical watersheds/barriers.

Objective 1: By 2015 management groups (federal, tribal, state) would use the decision tool to set priorities for connectivity restoration across Lake Michigan 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.

Building on existing tools if possible, this tool would be developed to evaluate the costs and benefits of dam or other barrier removal at multiple scales, including across a larger geographic area (e.g. lakewide) to prioritize among dam/barrier removal projects, as well as for local evaluations, including for individual dams.

The tool should answer the question: What are the relative costs and benefits of removing, keeping/maintaining, or mitigating (e.g., passage structure) a particular barrier, or even set of barriers since some calculations will differ if multiple dams are addressed? The answer should include consideration of lake-wide values such as: how much walleye or sturgeon habitat would become accessible, or how many migratory species will benefit?

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 Michigan 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, Great Lakes Fish and Wildlife Restoration Act, Great Lakes Fishery and Ecosystem Restoration Program (GLFER), National Fish and Wildlife Foundation (NFWF).

Result 5. Priority barriers are removed or improved.

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

Result 6. Multiple watersheds have connectivity restored.

Objective 4: *By 2020, 25% of the length/area of all types of habitats are connected to Lake Michigan.*

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

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 through more effective projects that face fewer obstacles, therefore saving money and potentially resulting in additional resources overall. 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 Michigan LaMP Objectives.
- Great Lakes Fishery Commission Lake Michigan Fish Community Objectives.
- 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.
- Aquatic Connectivity is one of four focal issues of the Sustain our Great Lakes program of the National Fish and Wildlife Foundation.
- Great Lakes ecological connectivity project: http://www.greatlakeslcc.org/about-lcc-projects/2011-projects/fy11-07/.
- Great Lakes Fishery Commission Lake Michigan Technical Committee, Habitat Working Group, Great Lakes Aquatic Connectivity Project: http://conserveonline.org/workspaces/streamconnect .
- Great Lakes Restoration Initiative Action Plan, Habitat goal 2: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf .

Likely participating agencies and organizations

Great Lakes Fishery Commission, U.S. Fish and Wildlife Service, U.S. Forest Service, State fisheries agencies, tribal agencies, university researchers, USGS, EPA, The Nature Conservancy, watershed groups.

6.7.3. Strategy 2: Increase Connectivity at Road-Stream Crossings at a Large Scale

This strategy is to leverage existing funds, conduct targeted education and outreach, and influence policy to increase the adoption of best practices for constructing road-stream crossings to restore connectivity in the most important watersheds in terms of their biological significance. Climate change is an important element to consider as standards are developed, as projections suggest higher peak flows, and lower low flows as the current warming trend continues.

Strategic actions

1. Create a common vision among organizations and establish knowledge/experience sharing.
2. Seek to leverage existing funds by requiring that grant funds include cost-sharing from road agencies.
3. Identify priorities for stream crossing improvements based on connectivity restored, species benefitting, ecosystem benefits, cost, feasibility and potential risks (aquatic invasive species).

4. Complete an economic analysis that addresses the question of long term benefits and avoided costs, and communicate results to road managers, resource management agencies, and state lawmakers.

5. Document ecological justification for higher road-crossing standards and seek acceptance by management agencies.

6. Establish demonstration projects in key watersheds and share results with road managers, resource management agencies, and state lawmakers.

Results, objectives and measures

There are three main paths to reaching the main outcome of increasing riverine connectivity. The first path does not require increased resources, but instead would introduce cost-sharing to leverage existing funding levels further for more projects. The second path relies more on education and outreach to convince road agencies of the importance of improved road stream crossings, including working with them to determine to what extent the added short-term costs are recouped in the long-term. The third path outlines the results needed to both raise regulatory standards for road-stream crossings and to increase funding allotted to these types of projects. Together, these paths lead to increased connectivity and would be measured by their impact on key species in sub-regions of each lake.

Result 1. Managers and stakeholders agree to focus restoration on priority watersheds and crossings.

While the outcomes that follow are really those related to implementation, development of priority locations to focus resources and subsequent acceptance of those priorities is critical to ensure that funding and educational efforts are targeted to areas that will provide the most benefits and least costs.

Result 2. Local demonstration projects of the justification for higher road-crossing standards are in place.

These demonstration projects will help in reaching out to road managers, resource management agencies, or lawmakers in convincing them that improved road stream crossings are necessary.

Result 3. More projects are funded through increased leverage of existing resources (e.g., cost-sharing)

Objective 1: number of high-quality crossing replacement projects doubles in priority watersheds by 2020.

Given that we may not succeed in garnering new funding for road-stream crossing improvements, we need a way to leverage existing funds. Since road agencies have to spend a certain amount to repair culverts and bridges anyway, these funds could be used to leverage funds that are available to benefit passage and other ecosystem values. Road managers would still experience substantial cost savings through reduced failure and maintenance, while providing more services from local streams and rivers and allowing existing funds to be used for a greater number of projects.

Result 4. Education and outreach efforts increase understanding of benefits of best practices among road agencies/departments.

Getting better information out to road agencies in priority areas can facilitate improved crossings. It may also contribute to improved policies.

Result 5. Lawmakers are convinced that higher standards need to be employed for road-stream crossings.

Result 5a. Regulatory standards have been raised for crossing projects.

With successful outreach, economic analysis and resource management agencies or lawmakers seeing the need for higher standards, new regulations would be possible. This result is not necessary to accomplish increased adoption but may prove the most effective for causing wide-spread adoption of best practices.

Result 5b. Funding for road-stream crossing best practices increased.

This may result from priority setting, from lawmakers seeing the value of best practices and wanting to expand the practice, and having new regulations that call for increased funding levels.

Objective 2: funding for priority watersheds doubles by 20XX.

Result 6. Adoption of best practices for crossings increased, particularly in priority areas.

Objective 3: a 20% improvement in connectivity in priority watersheds by 2020.

Objective 4: priority watersheds at least 80% connected by 2040.

Priority or opportunity areas for implementation

There has been significant work conducted in this area in Green Bay watersheds, including multiple education outreach workshops and development of tools to identify priority problem road-stream crossings. There have also been major efforts to address problem road-stream crossings in the northwest Lower Peninsula of Michigan. However, a basinwide prioritization effort would help to further refine priority locations for this strategy.

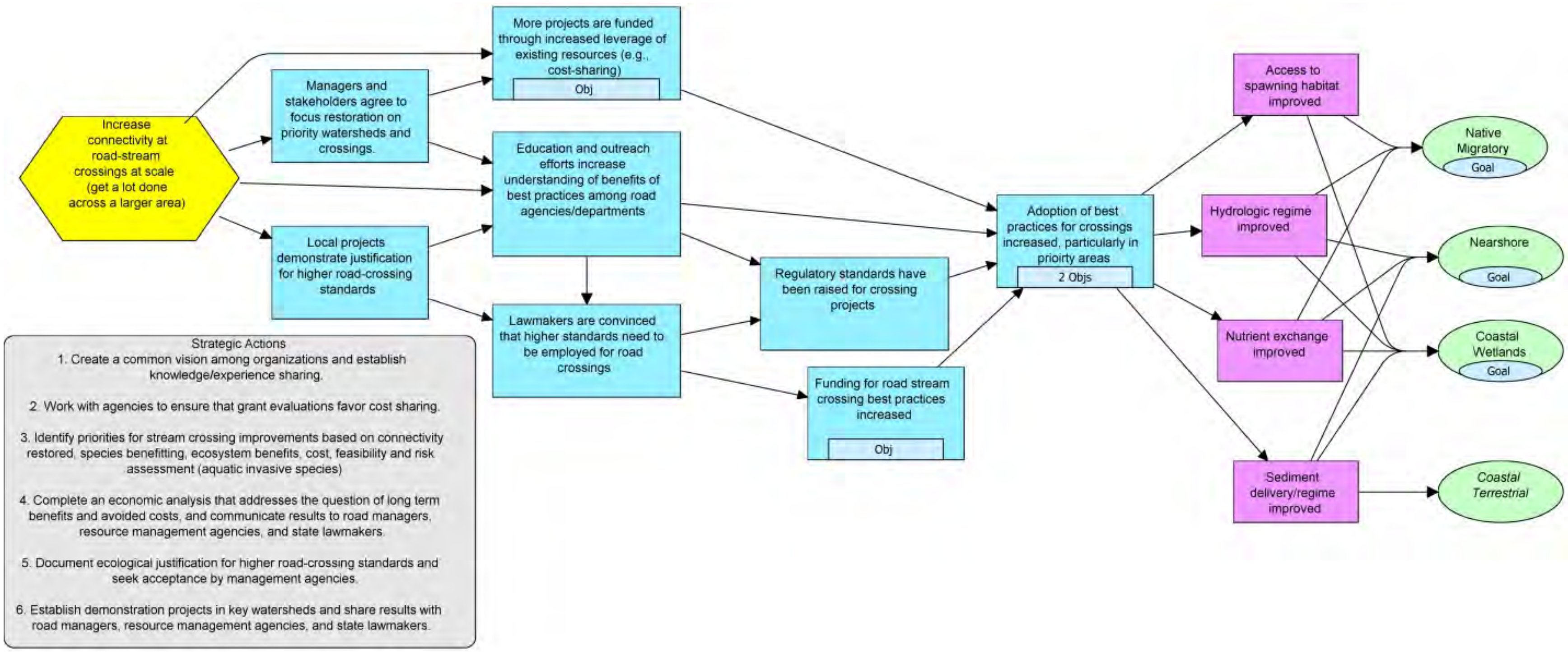

Figure 40: Results chain for a strategy to address dams and barriers threats in Lake Michigan by increasing connectivity at road-stream crossings.

Related strategies and initiatives

- Great Lakes Fishery Commission Lake Michigan Technical Committee, Habitat Working Group, Great Lakes Aquatic Connectivity Project: http://conserveonline.org/workspaces/streamconnect.
- Great Lakes ecological connectivity project: http://www.greatlakeslcc.org/about-lcc-projects/2011-projects/fy11-07/.
- The Great Lakes Basin Fish Habitat Partnership strategic priorities include (Great Lakes Basin Fish Habitat Partnership 2010)
- Great Lakes Information Management and Delivery System (led by TNC and USGS, funded by USFWS through the Upper Mississippi and Great Lakes Landscape Conservation Cooperative).
- Aquatic Connectivity is one of four focal issues of the Sustain our Great Lakes program of the National Fish and Wildlife Foundation.
- Significant momentum in dealing with problem road-stream crossings in the northern lower peninsula of Michigan (Conservation Resource Alliance and partners).
- Great Lakes Restoration Initiative Action Plan, Habitat goal 2: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf.
- Section 6217 Coastal Management Plans; for example, the Indiana 6217 plan includes best practices for road construction and inventory and evaluate dam impacts: http://www.in.gov/dnr/lakemich/files/6217_Final.pdf .

Likely participating agencies and organizations

State fisheries agencies, U.S. Fish and Wildlife Service, U.S. Forest Service, Great Lakes Fishery Commission, tribal agencies, The Nature Conservancy, Conservation Resource Alliance, watershed groups, university researchers, USGS, EPA, NRCS, conservation districts.

7. SPATIAL PRIORITIZATION OF CONSERVATION ACTIONS

Earlier in this report, we evaluated the viability of certain biodiversity indicators at the assessment and reporting unit scales for Lake Michigan. Although these analyses provide an overall assessment of the health of conservation 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 Michigan for the conservation of biodiversity. These areas are rated based on two primary factors: 1) biodiversity significance[11] 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 targets (Coastal Terrestrial and Coastal Wetlands).

The same analysis was not applied to the remaining five targets: Offshore Zone, Nearshore Zone, Native Migratory Fish, Aerial Migrants, and Islands. The Offshore Zone target is limited by threats that cannot be addressed through place based conservation action. The Nearshore Zone 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) 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 Michigan from this study are presented in this chapter.

7.1. Coastal Terrestrial System

7.1.1. Description

An analysis of biodiversity significance was completed for each coastal watershed unit[12] 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 Michigan coastal terrestrial environment. Biodiversity significance was measured by the following five factors: 1) coastal shoreline complexity, 2)

[11] 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.

[12] 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

richness of globally rare terrestrial species (G1-G3[13]), 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 23).

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. 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 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 (Table 24). The scores from each of the six factors were summed to produce an aggregated terrestrial condition score for each coastal watershed unit.

Table 23: 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

[13] G ranks reflect an assessment of the condition of the species or ecological community across its entire range (NatureServe 2012):
G1 (Critically Imperiled)—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2 (Imperiled)—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
G3 (Vulnerable)—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

Table 24: 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/100km	>300	250-300	200-250	150-200	100-150	30-100	0-30	0

7.1.2. Results

The coastal terrestrial biodiversity scores for Lake Michigan ranged from 0 to 22 out of a possible 35 points with a mean score of 9.9. Coastal watershed unit 15, located on the eastern coast of the Door Peninsula in the Central Basin, received the highest score (Figure 42). Other units that fell into the very high category for coastal terrestrial biodiversity included units 1, 2, 3, 15, 25, and 40.

The coastal terrestrial condition scores ranged from 3 to 37 out of a possible 42 points, with a mean score of 21.9. The eight coastal watershed units with the highest scores are all located in Michigan, and seven of these are in the Upper Peninsula (Figure 43). The five units located along the northern shore of Green Bay received the highest scores. Other top scoring units included units 1, 2, 3, 4, 8, and 34.

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. Three of the units with high terrestrial biodiversity scores, units 1, 2, and 3, also had high terrestrial condition scores. All three are located in the Upper Peninsula of Michigan. The only unit with a high biodiversity value and very low condition score is unit 25 located in the Chicago region. This unit is home to the highest population, building, and road density in the entire Lake Michigan Basin. Although this highly urbanized environment poses major obstacles, there appears to be opportunities for meaningful ecological restoration.

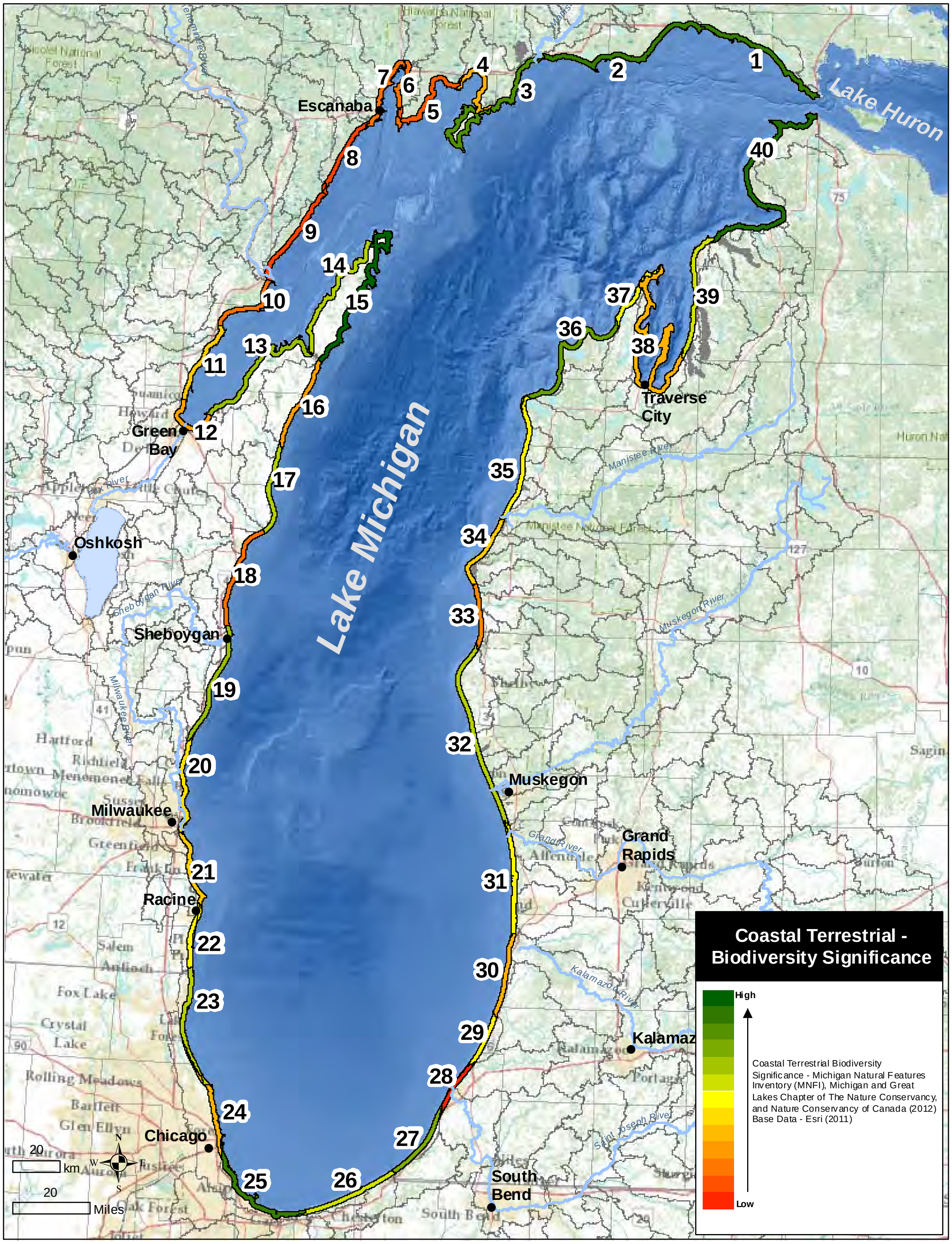

Figure 41: Coastal Terrestrial significance

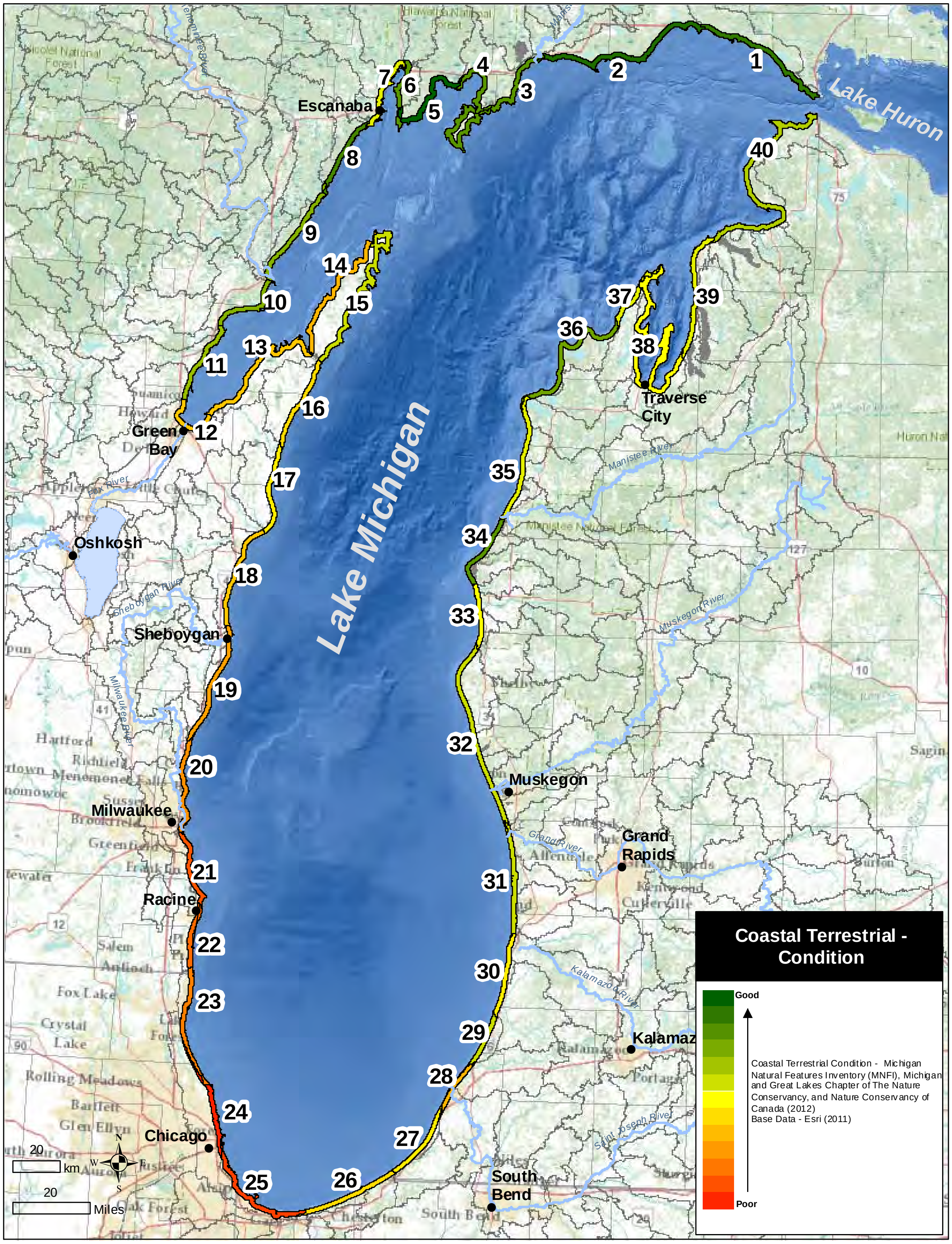

Figure 42: Coastal Terrestrial condition

7.2. Coastal Wetlands

7.2.1. 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 Michigan 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 (Table 25). Similar to the terrestrial analysis, the scores from each of the five factors were summed to produce an aggregated 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 (Table 26). The scores from these two factors were summed to produce an aggregated wetland condition score for each coastal watershed unit.

Table 25: 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 26: 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%

7.2.2. Results

The scores for the wetland biodiversity analysis ranged from 0 to 15 out of a possible 35 points, with a mean score of 3.5 (Figure 43). The only coastal watershed unit to score in the very high category was unit 1 located in the Upper Peninsula of Michigan. The next two highest scoring coastal watershed units are unit 40, located in the northwest tip of the Lower Peninsula, and 10, located in the southwest corner of Green Bay. All three of these units contain large intact coastal wetlands of major ecological significance.

The wetland condition scores for Lake Michigan ranged from 0 to 12 out of a possible 14 points, with a mean score of 5.4 (Figure 44). Unit 3 located in the Garden Peninsula received the highest wetland condition score in Lake Michigan. Other units with high wetland condition scores include unit 1, 5, 8, 9, 34, and 35.

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.

Unit 5, located in the Upper Peninsula was the only unit to score high for both coastal wetland biodiversity value and condition. This unit contains some very significant wetlands, such as the Pt. Aux Chenes wetland complex, and a large percentage of its contributing watersheds are under public ownership. Both Unit 10 and Unit 40 in the northern portion of Lake Michigan had somewhat high biodiversity scores but relatively low condition scores. These two units may be good areas to employ wetland mitigation strategies to protect the existing coastal wetland resources from further degradation.

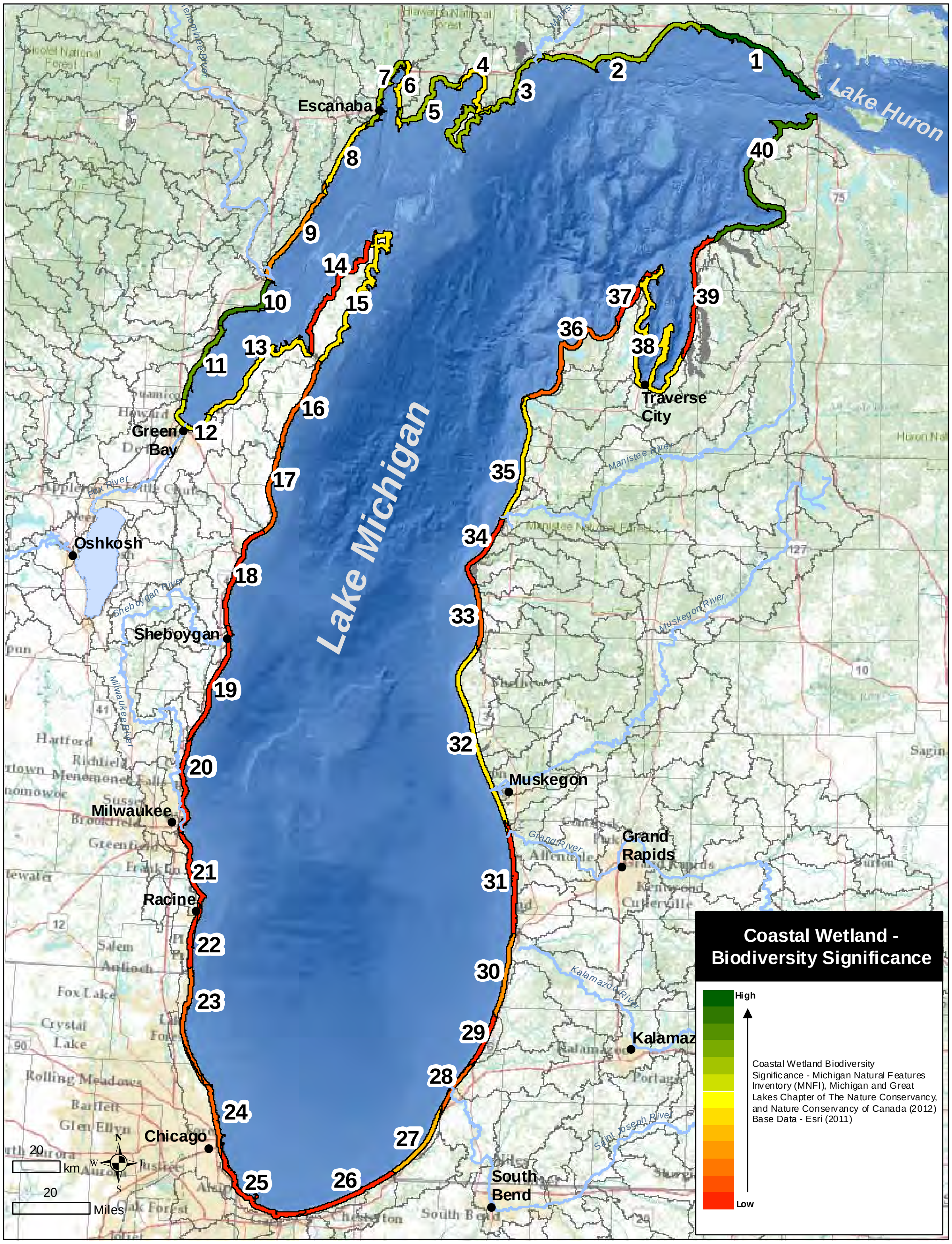

Figure 43: Coastal Wetlands significance

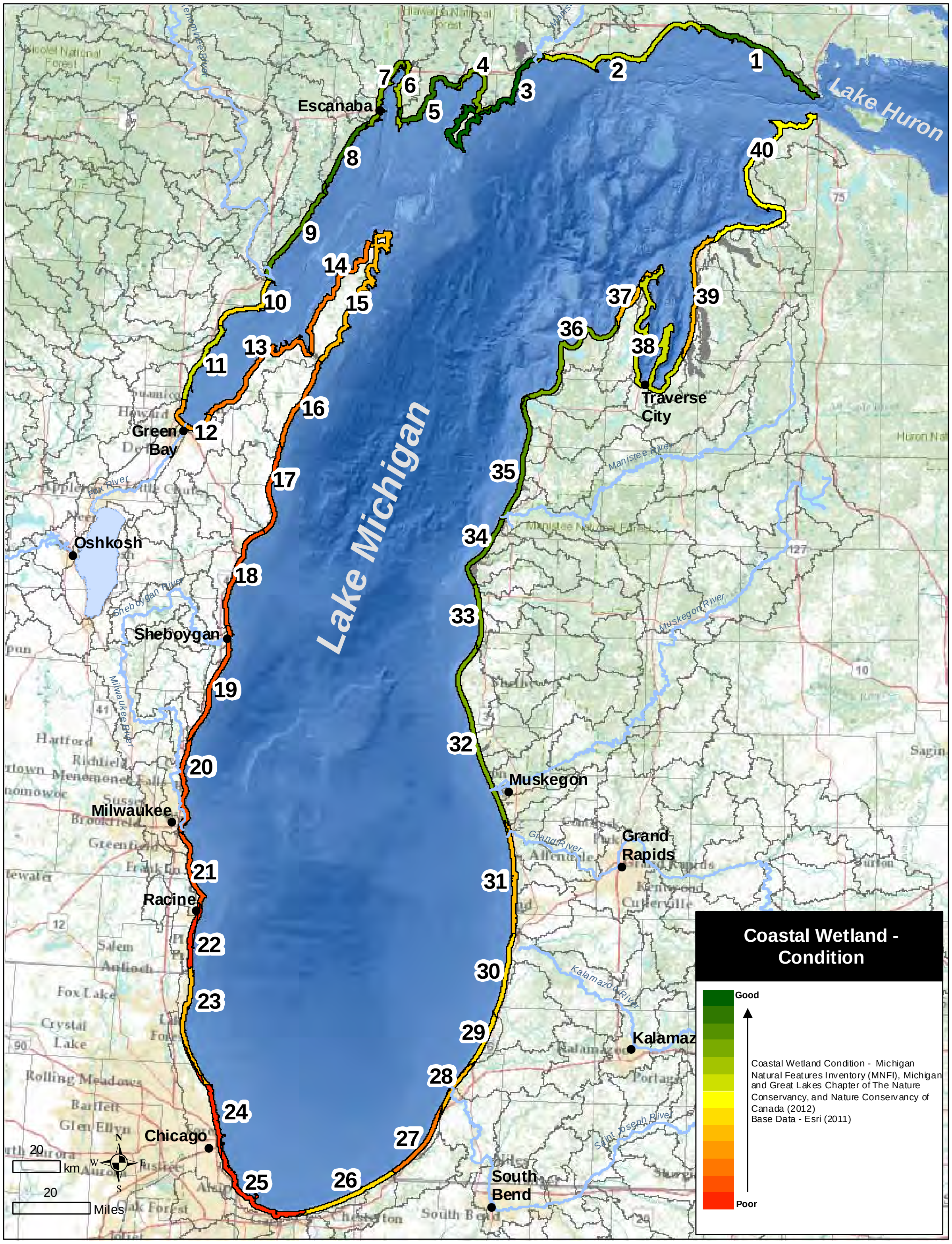

Figure 44: Coastal Wetlands condition

7.3. Islands

7.3.1. 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 (2010), there are 726 islands in Lake Michigan, totaling 34,818 ha.

Lake Michigan 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 (Please refer to Henson et al. 2010 for more details).

7.3.2. Results

The majority of islands in Lake Michigan are concentrated in the northern portion of the lake close to the mainland. According to Henson et al. (2010), key islands for biodiversity conservation in Lake Michigan are Beaver, Washington, Garden, and Hog Islands (Figure 45). Beaver Island is the largest island in the basin. Beaver and Washington Islands are considered to be the most threatened due to residential and recreational development pressures.

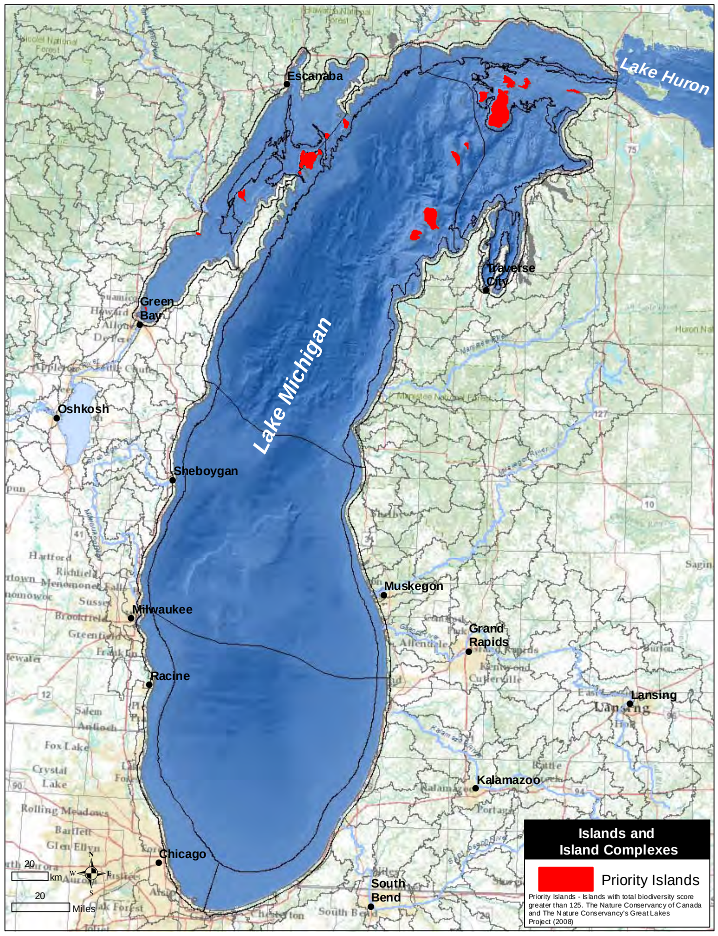

Figure 45: Lake Michigan priority islands

7.4. Aerial Migrants

7.4.1. 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). 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 based 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.

7.4.2. Results

Preliminary results of the modeling study suggest that the Lake Michigan Basin provides spring stopover habitat across the lake for waterfowl with a high concentration of good habitat found in nearshore areas and in the Green Bay region. In addition, there appears to be good stopover habitat for shorebirds along the southeast shore of the lake (see Figure 20 in the description of the Aerial Migrants target). Much of the nearshore coastal terrestrial area is predicted to provide good landbird stopover habitat. For more detailed information about the study, please refer to the report authored by Ewert et al. (2012).

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

The primary purpose of the LMBCS is to develop biodiversity conservation strategies for Lake Michigan and the surrounding coastal zone. Though the goal of these strategies is to improve the health of and abate the key threats to Lake Michigan'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 Michigan coastal area, we employed the concept of ecosystem services, using the framework developed by the Millennium Ecosystem Assessment (MEA 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, 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 Michigan, we next constructed a digital survey using Survey Monkey and invited Lake Michigan managers and experts to rate the importance of each ecosystem service to the people that benefit from Lake Michigan and its coastal area[14] by assigning each service to one of three 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 Michigan;
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 Michigan;
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 Michigan.

We subsequently resurveyed the same audience to assess the potential impact of the highest priority biodiversity conservation strategies—as identified by the LMBCS—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 states, completed the first phase of the survey. State agency representatives comprised the largest single group of participants, followed by NGOs, Federal agencies, regional planning agencies, and academic institutions (Table 27). Participation within particular affiliation categories was mostly consistent from the first to second phases of the survey, except for notable drops in state agency and NGO representation, and an increase in Sea Grant representatives. Notably absent from the survey participants are coastal residents and people who are employed in private commercial or industrial sectors affiliated with Lake Michigan.

[14] 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 27. Participants in the Lake Michigan ecosystems services assessment surveys.

Affiliation Category	Phase 1	Phase 2
State Agencies	18	9
NGOs	11	4
Federal Agencies	6	4
Regional Planning Commission	6	1
Academic Institutions	4	4
Regional NGOs (e.g., Chicago Wilderness)	3	
County Agencies	2	1
Heritage	2	
Tribal	1	2
AOC Public Advisory Committees	1	1
Ecological Consultant	1	1
Bi-national Agency (e.g., IJC or Great Lakes Fishery Commission)	1	
Sea Grant		4
Grand Total	56	31

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 ecosystem 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 28). 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 Michigan were also the top ten in an identical assessment for Lake Erie, completed as part of the Lake Erie 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 Michigan survey also completed the first survey for Lake Erie—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.

Table 28. Ten highest ranked ecosystem services, based on a survey of people engaged in conservation and management of Lake Michigan (see Appendix J for the full list of ecosystem services, scores and ranks).

Rank	Service	Score
1	Provisioning Services - Fresh Water (Water supply)	162
2	Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	158
3	Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	158
4	Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	158
5	Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	154
6	Cultural Services - Aesthetic values (Aesthetics)	152
7	Supporting Services - Water cycling (Soil moisture storage)	150
8	Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	149
9	Cultural Services - Sense of place	142
10	Supporting Services - Nutrient cycling (Nutrient storage)	142

Thirty one participants, representing Federal and State agencies from all four states, 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. The average effect of strategies on ecosystem services ranged from strongly positive to slightly negative (Table 29). On average three sets of strategies (Urban NPS, Coastal, Ag NPS) had a relatively high estimated impact across all ecosystem services, followed by coastal conservation strategies and reducing agricultural non-point source pollutants (Table 29). These three strategies were also thought to be the most beneficial to ecosystem services in Lake Erie, though in slightly different order (Pearsall et al. 2012), suggesting that watershed and coastal strategies could be very rewarding with respect to benefits derived from the lake. Restoration of offshore fisheries was predicted to have the least benefit to ecosystem services, even registering slightly negative predicted effects on water cycling and climate regulation. Other than these two negative effects, the biodiversity conservation strategies were predicted to enhance all of the top ten ecosystem services.

From a services perspective, recreation and tourism (cultural service) and habitat (provisioning service) received the highest overall predicted benefits, especially from the invasive species, coastal conservation, and connectivity strategies. Primary production (supporting service) would benefit from the invasive species, agricultural NPS reduction, and offshore fisheries restoration strategies; aesthetic values (cultural service) were predicted to improve as a result of coastal conservation, invasive species, and urban NPS reduction strategies. Other ecosystem services were predicted to benefit less, especially climate regulation (regulating service) and water cycling (supporting service).

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 Michigan Biodiversity Conservation Strategy included services from each of the four categories – provisioning, regulating, cultural and supporting – indicating that Lake Michigan provides a broad variety of values to these stakeholders. The top ten ranked services for Lake Michigan were identical to the top ten for Lake Erie, 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 Urban NPS, Coastal, and Agriculture NPS 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, Michigan and Erie, 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 29. Average effect of biodiversity conservation strategies on the ten most important ecosystem services in Lake Michigan. 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 agricultural non-point source pollution; Invasives = preventing and reducing the impact of invasive species; Coastal = Coastal conservation: preventing incompatible development and shoreline alteration; Urban NPS = reduce the impacts of urban non-point and point source pollutants; Offshore = restoration of the offshore fisheries in Lake Michigan; and Connectivity = improve habitat connectivity by reducing the impacts of dams and barriers.

Ecosystem Services	Strategies						
	AgNPS	Invasives	Coastal	Urban NPS	Offshore	Connectivity	Average response of ecosystem service across all strategies
Cultural Services - Aesthetic values (Aesthetics)	0.97	1.13	1.55	1.17	0.43	1	1.04
Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	1.07	1.48	1.48	1.16	1.27	1.16	1.27
Cultural Services - Sense of place	0.67	0.97	1.29	1	0.73	0.73	0.9
Provisioning Services - Fresh Water (Water supply)	1.31	0.45	0.52	1.17	0	0.43	0.64
Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	0.38	0.23	0.72	0.83	-0.04	0.55	0.45
Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	1.31	0.41	0.87	1.35	0.04	0.53	0.75
Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	1.24	1.52	1.48	1.1	1	1.48	1.3
Supporting Services - Nutrient cycling (Nutrient storage)	1.21	0.84	0.86	1.13	0.43	0.89	0.89
Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	1.33	1.43	0.86	0.97	1.27	1	1.14
Supporting Services - Water cycling (Soil moisture storage)	0.69	0.21	0.68	1.07	-0.07	0.71	0.55
Average effect of strategy across all ecosystem services	1.02	0.87	1.03	1.09	0.51	0.85	0.89

9. IMPLEMENTING BIODIVERSITY CONSERVATION: RECOMMENDATIONS FOR A COLLABORATIVE, ADAPTIVE APPROACH

9.1. Introduction

The LMBCS presents key components of a common vision for the conservation of Lake Michigan 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 LMBCS based on the experience of TNC and its partners implementing biodiversity conservation strategies for Lake Ontario (Lake Ontario Biodiversity Strategy Working Group 2009) and Lake Huron (Franks Taylor et al. 2010), 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 LMBCS and affirms common vision and priorities

For the strategies in the LMBCS to be successfully implemented, it is critical that the Lake Michigan LaMP adopt the LMBCS 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 LMBCS (Lake Ontario LaMP Work Group and Technical Staff, 2011). This process would be best served by expanding stakeholder engagement that can build ownership, support and investments by the greater Lake Michigan 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 Michigan 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 process 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, the Lake Michigan LaMP and its associated public bodies) organized and structured appropriately to successfully implement and achieve the goals and outcomes of the strategy or will it require restructuring? Some recommendations for an effective structure include:

- Strengthen and support a "backbone" entity (*sensu* Kania and Kramer 2011) with appropriate staff and the necessary authority (decision maker) to effectively lead, coordinate, and manage the implementation of the strategies. Many of the strategies in the LMBCS 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 LMBCS. 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 that are specific to geography, thus requiring local solutions (e.g., urban and rural non-point source pollution), or basin-wide specific issues that require a 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 LMBCS based on their own actions and their ability to influence others.

    - Build support and participation among local-regional elected officials to identify points of alignment and areas that falls within their jurisdiction and responsibility that are integral to the success of the priority strategies identified in the LMBCS.

9.2.3. Develop an implementation plan and employ an adaptive management approach

Successfully implementing the biodiversity conservation recommendations in the LMBCS will require that leaders, decision makers and stakeholders around the Lake Michigan 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 LMBCS 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, p. 28)

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 Michigan 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. In order to achieve the greatest measurable impact on Great Lakes health for dollars spent, we submit a final recommendation to aligning U.S. EPA funding to achieve LaMP priority outcomes. This includes appropriate funding and staffing of EPA-GLNPO—the division of EPA charged with management of the Lake Michigan LaMP—and previous recommendations to more fully engage stakeholders.

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APPENDIX A: PROJECT COORDINATION

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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.”

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 MICHIGAN 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 Green Bay, which is physically disjunct from the rest of Lake Michigan 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 the accepted depth that distinguishes nearshore from offshore in each lake (30 m). 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 five reporting units and seventeen assessment units, nested hierarchically as depicted in Figure 1.

Reporting units: Lake Michigan does not have universally recognized basins. Studies of the bathymetry of the lake have led to the identification of major features in the lake (e.g., NOAA study at http://www.ngdc.noaa.gov/mgg/greatlakes/lakemich_cdrom/html/geomorph.htm) including basins, ridges, and groups of islands. The proposed stratification of the lake into four basins and Green Bay has some commonalities with the NOAA study. Boundaries between reporting units are generally defined by circulation patterns, as determined by Beletsky et al. (1999), and consistent with the Great Lakes Aquatic Gap Analysis Aquatic Lake Units (Figure 2). However, the specific boundary locations were also highly informed by bathymetry, existing boundaries between coastal reaches, element occurrence distribution patterns, and large tributary influences. The Northern Basin unit is not so much a basin as a bathymetrically diverse area of reefs and islands known as the Islands Area, with a deepwater channel running through the Mackinac Strait. Green Bay stands as a reporting unit due to its separation from the Central Basin by the Door Peninsula, Garden Peninsula and the chain of islands lying between them; it includes the Whitefish Channel and Fan. The Central Basin includes the Two Rivers Ridge and Door-Leelenau Ridge and Chippewa Basin. The Mid-Lake Plateau is a recognizably shallower, though still offshore, submerged moraine feature, and the Southern Basin corresponds pretty well to the South Chippewa basins, as well as dominant circulation patterns.

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.

Challenges: Green Bay is usually considered a nearshore feature, but it has a convoluted area of offshore depth that is mapped as a distinct assessment unit.

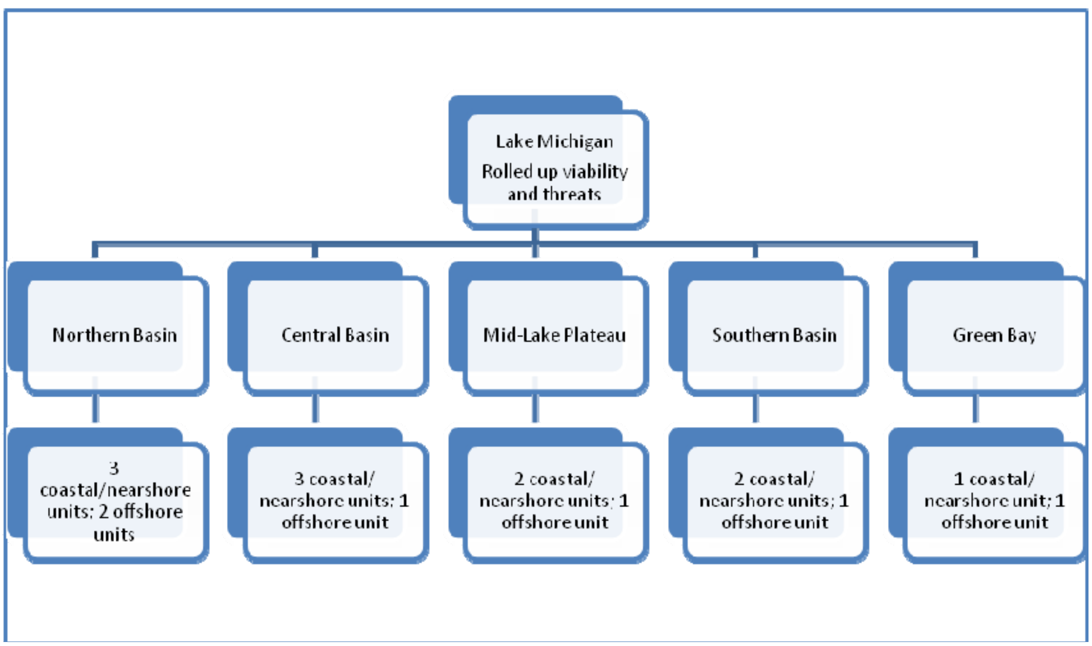

Figure 1. Conceptual diagram of reporting and assessment units in Lake Michigan.

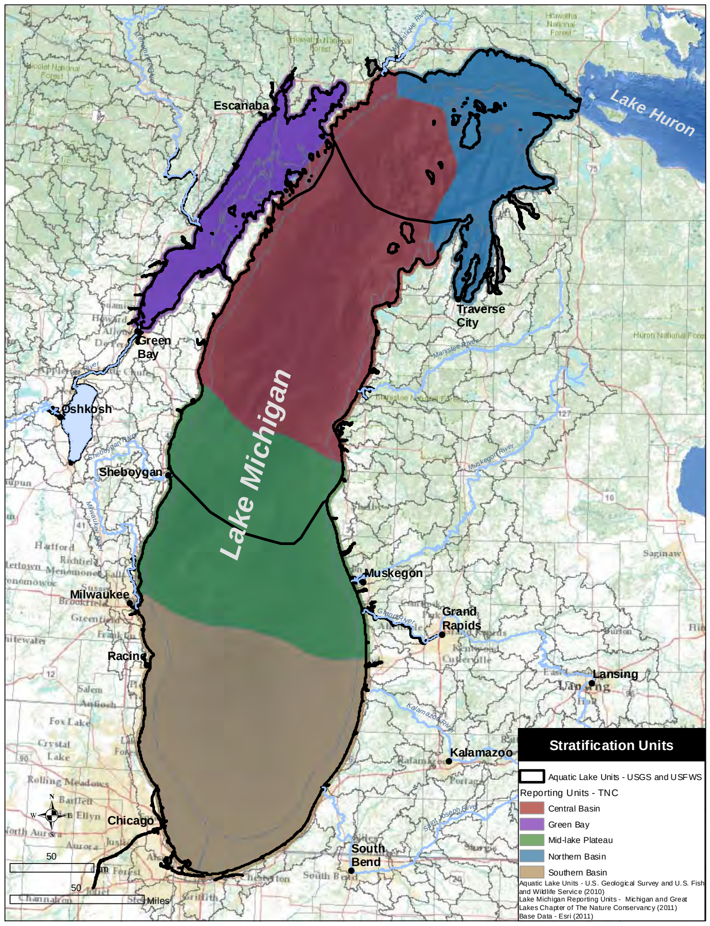

Figure 2. Aquatic Lake Units (ALUs) in Lake Michigan (McKenna and Castiglione 2010), overlain on LMBCS reporting units.

References Cited

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Rodriguez, K.M., and R.A. Reid. 2001. Biodiversity investment areas: rating the potential for protecting and restoring the Great Lakes ecosystem. Ecological Restoration 19:3:135-144.

TNC. 2007. Priority Geographies for Coastal and Watershed Biological Values. Map

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 Michigan 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)
	NB	Northern Basin
	CB	Central Basin
	GB	Green Bay
	MLP	Mid-Lake Plateau
	SB	Southern Basin
AU		Assessment unit (see Appendix D: Stratification)

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
TBD	To be determined

Open Water Benthic and Pelagic Ecosystem

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Benthic macroinvertebrate community structure	Dreissenid mussel biomass (density in kg/ha)	current densities (2012)	trend decreasing for 5+ years	low presence	not in lake	RG	NB	101	(RG)
								CB	201	(RG)
								GB	301	(RG)
								MLP	401	(RG)
								SB	501	(RG)
Condition	Benthivore fish Population size & dynamics	Coregonids: lake whitefish – biomass trend	decreasing trend across all management units	decreasing trend for sampling period (1985 to present) across most management units or stable-but stabilized below time series average	stable or increasing trend for most management units	stable or increasing across all management units	RG	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)
Condition	Benthivore fish Population size & dynamics	Coregonids: lake whitefish – recruitment trend	decreasing trend across all management units	decreasing trend for sampling period (1985 to present) across most management units or stable-but stabilized below time series average	stable or increasing trend for most management units	stable or increasing across all management units	RG	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Mid-level prey abundance	lake-wide prey biomass from bottom trawl	at low, or trend decreasing for 5+ years	trend increasing for 5+ years	sufficient forage biomass to support top predators (i.e., no growth impediments to top predators)	TBD	RG	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)
Condition	Mid-level prey composition	Proportion native prey in biomass	<25%	25-50%	>50%	predominantly native	EK	NB	101	43% (IA)
								CB	201	43% (IA)
								GB	301	43% (IA)
								MLP	401	43% (IA)
								SB	501	(IA)
Condition	Native macroinvertebrates	Diporeia -- Density of individuals in grab samples, >90 m depth (#/m^2)	<500 / m^2	500 - 1000 / m^2	>1000 - 2000 / m^2	>2000 / m^2	EK	NB	101	(EK)
								CB	201	(EK)
								GB	301	(EK)
								MLP	401	(EK)
								SB	501	(EK)
Condition	Native macroinvertebrates	Diporeia -- Density of individuals in grab samples, 30 - 90 m depth (#/m^2)	<500 / m^2	500 - 1000 / m^2	>1000 - 4000 / m^2	>4000 / m^2	EK	NB	101	(EK)
								CB	201	(EK)
								GB	301	(EK)
								MLP	401	(EK)
								SB	501	(EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Native macroinvertebrates	Mysis – Mean density of individuals in vertical net tows at night (#/m^2) at depths greater than 100m	levels depressed for mulit-year period (4 years)	levels are significantly lower than (or much higher than) several year average	levels within range of multi-year time series	Mysis densities increasing - but within upper historical limits	RG	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)
Condition	Phytoplankton - primary productivity	Phytoplankton abundance - mean daily integrated primary production (mgC/m^2/day) during spring isothermal mixing period	TBD	levels are significantly lower than (or much higher than) several year average	levels within range of multi-year time series	TBD	RG	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)
Condition	Predator fish species population size	Lake trout: Young of the year density (#individuals/hectare)	0	anything north of 0 - given the history of the restoration program	>2 - 10/ha	>10/ha	ER	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)
Condition	Top predator population dynamics	Proportion of wild Lake Trout in sample	<5 spawning phase adults per 100m of net and/or <10% are wild	5-10 spawning phase adults per 100m of net and 10-25% wild	>10-20 spawning phase adults per 100m of net and >25%-60% wild	> 20 spawning phase adults per 100m of net of which >60% are wild	EK	NB	101	(EK)
								CB	201	(EK)
								GB	301	(EK)
								MLP	401	(EK)
								SB	501	(EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Zooplankton community structure	Bythotrephes average annual abundance relative to prey	>50% greater than prey abundance	25-50% greater than prey abundance	balanced with prey abundance		RG	NB	101	(IA)
								CB	201	(IA)
								MLP	201	(IA)
								GB	301	(IA)
								SB	501	(IA)
Landscape Context	Water quality	Total Phosphorous (Spring)	TBD	> 7 ug/l, or too low (lower limit not yet determined)	<7 ug/l	TBD	ER	NB	101	(IA)
								CB	201	(IA)
								GB	301	(IA)
								MLP	401	(IA)
								SB	501	(IA)

Nearshore Zone

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Community architecture	Mean Dreissena density	>1000 m^{-2}	200-1000 m^{-2}	50-200 m^{-2}	<50 m^{-2}	ER	NB	111	(IA)
									112	(IA)
									113	(IA)
								CB	211	(IA)
									212	(IA)
									213	(IA)
								GB	311	(IA)
								MLP	411	(IA)
									412	(IA)
								SB	511	(IA)
									512	(IA)
Condition	Community architecture	Native fish species richness	<40% of fish spp anticipated are collected w/in 5-year window	40-60% of fish spp anticipated are collected w/in 5-year window	>60-80% of fish spp anticipated are collected w/in 5-year window	>80% of fish spp anticipated are collected w/in 5-year window	RG	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Community architecture	Smallmouth bass population relative abundance	Less than ½ of representative populations meeting goals for relative abundance/ CPUE	½ to ¾ of representative populations meet goals for relative abundance/ CPUE	At least ¾ of representative populations meeting goals for relative abundance/ CPUE & remaining populations at >80% of goal	Each representative population meeting goals for relative abundance/ CPUE	EK	NB	111	(EK)
									112	(EK)
									113	(EK)
								CB	212	(RG)
									213	(EK)
								GB	311	(RG)
Condition	Food web linkages	Hexagenia mean density in fine sediments (3 yr average)	<40	100-40	200-100	300-200	ER	GB	311	<40 (RA)
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	NB	111	133.41 (IA)
									112	93.37 (IA)
									113	4.67 (IA)
								CB	211	18.45 (IA)
									212	4.2 (IA)
									213	29.9 (IA)
								GB	311	72.52 (IA)
								MLP	411	31.69 (IA)
									412	32.89 (IA)
								SB	511	43.66 (IA)
									512	328.58 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Spawning habitat quality and accessibility	Percentage of historic spawning reefs available as quality spawning habitat	<25% available and high quality	25-50% available and high quality	50-75% available and high quality	>75% available and high quality	RG	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Landscape Context	Coastal and watershed contribution	Artificial Shoreline Hardening Index	>40%	>30 - 40%	20 - 30%	<20%	EK	NB	111	18.6 (IA)
									112	10.6 (IA)
									113	7.7 (IA)
								CB	211	17.6 (IA)
									212	7.5 (IA)
									213	23.2 (IA)
								GB	311	14.5 (IA)
								MLP	411	26.4 (IA)
									412	37.1 (IA)
								SB	511	35.3 (IA)
									512	59.3 (IA)

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	<40	40 - 60	<60 -80	>80	EK	NB	111	69.8 (IA)
									112	70.3 (IA)
									113	89.9 (IA)
								CB	211	83.2 (IA)
									212	93.1 (IA)
									213	41.5 (IA)
								GB	311	68.5 (IA)
								MLP	411	47.8 (IA)
									412	22.1 (IA)
								SB	511	32.3 (IA)
									512	23.1 (NS)
Landscape Context	Coastal and watershed contribution	Percent natural land cover within 2 km of shoreline	<25	25 - 50	>50 - 75	>75	EK	NB	111	59 (IA)
									112	64 (IA)
									113	93.7 (IA)
								CB	211	78.5 (IA)
									212	88.9 (IA)
									213	49.2 (IA)
								GB	311	65.4 (IA)
								MLP	411	72.1 (IA)
									412	28.9 (NS)
								SB	511	58.3 (IA)
									512	13.5 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Water chemistry	Soluble Reactive Phosphorus	>0.7 µgP/l	>0.4- 0.7 µgP/l	0.2-0.4 µgP/l	<0.2 µgP/l	ER	NB	111	NA
									112	NA
									113	NA
								CB	211	(NS)
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	~.260 (NS)
								SB	511	NA
									512	NA
Landscape Context	Water quality	5-year Average Spring isothermal Chlorophyll-a concentration (µg/L)	<0.25 or >4.0	0.25-0.5 or 3.0-4.0	0.5-1.0 or 2.0-3.0	1.0-2.0	ER	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
			<3 or >14	3-4 or 12-14	4-5 or 10-12	5-10		GB	311	NA
			<0.25 or >4.0	0.25-0.5 or 3.0-4.0	0.5-1.0 or 2.0-3.0	1.0-2.0		MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

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	NB	111	NA
									112	NA
									113	NA
								CB	211	80% (IA)
									212	NA
									213	>80% (IA)
			>75%	50-75%	25-50%	<25%		GB	311	NA
			>80	>30 - 80	15 - 30	<15		MLP	411	NA
									412	>80% (IA)
								SB	511	71-94 (IA)
									512	>80 around Milwaukee; 12-72 to the South in IL (IA)
Landscape Context	Water quality	Total Phosphorus concentrations (µg/L)	>10	7 - 10	5 - 7	<5	ER	NB	111	(IA)
									112	(IA)
									113	(IA)
								CB	211	(IA)
									212	(IA)
									213	(IA)
								GB	311	NA
								MLP	411	(IA)
									412	(IA)
								SB	511	(IA)
									512	(IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Water quality	Upland Sediment Contributions (tons/ac/yr)	>0.125	0.075-0.125	0.025-0.075	<0.025	ER	NB	111	0.076 (IA)
								NB	112	0.099 (IA)
								NB	113	0.010 (IA)
								CB	211	0.040 (IA)
								CB	212	0.005 (IA)
								CB	213	0.078 (IA)
								GB	311	0.048 (IA)
								MLP	411	0.055 (IA)
								MLP	412	0.143 (IA)
								SB	511	0.100 (IA)
								SB	512	0.142 (IA)
Size	Population size & dynamics	Average *Diporeia* densities number/m^2	<500	500 – 1500	>1500 - 3500	>3500	ER	NB	111	<<500 (IA)
									112	<<500 (IA)
									113	<<500 (IA)
								CB	211	<<500 (IA)
									212	<<500 (IA)
									213	<<500 (IA)
								GB	311	<<500 (IA)
								MLP	411	<<500 (IA)
									412	<<500 (IA)
								SB	511	<<500 (IA)
									512	<<500 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Size	Population size & dynamics	Average Native mussels richness per site	<1	1 - 2.9	3 - 9	>9	EK	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Size	Population size & dynamics	Biomass of crustacean zooplankton in early summer (mg/L)	TBD	TBD	TBD	TBD		NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Size	Population size & dynamics	Native mussel abundance	TBD	TBD	TBD	TBD		NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Size	Population size & dynamics	Yellow perch (annual biomass)	Lakewide annual yield <0.5 M kg	Lakewide annual yield of 0.5-0.9 M kg	Lakewide annual yield of 0.9-1.8 M kg	Lakewide annual yield of >1.8 M kg	ER	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Size	Population size & dynamics	Yellow perch population status	Yellow perch populations well-below historical average, with little recruitment	Yellow perch populations below historical average	Yellow perch populations at or above historical average	Yellow perch populations well above historical average		NB	111	(NS)
									112	(NS)
									113	(NS)
								CB	211	(NS)
									212	(NS)
									213	(NS)
								GB	311	(NS)
								MLP	411	(NS)
									412	(NS)
								SB	511	(NS)
									512	(NS)

Native Migratory Fish

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Access to Spawning Areas	Percentage of Accessible Headwater Stream Habitat (Shreve Link 1-2)	<25%	25-50%	>50-75%	>75%	EK	NB	111	3.3 (IA)
									112	7.8 (IA)
									113	52.1 (IA)
								CB	211	17.7 (IA)
									212	4.4 (IA)
									213	36 (IA)
								GB	311	14.7% (IA)
								MLP	411	16.3 (IA)
									412	38.3 (IA)
								SB	511	27.4 (IA)
									512	16.6 (IA)
Landscape Context	Access to Spawning Areas	Percentage of Accessible Creek Habitat (Shreeve Link 3-30)	<25%	25-50%	>50-75%	>75%	EK	NB	111	0 (IA)
									112	7 (IA)
									113	65.3 (IA)
								CB	211	16.9 (IA)
									212	0.7 (IA)
									213	20.5 (IA)
								GB	311	14.1% (IA)
								MLP	411	19.3 (IA)
									412	30.3 (IA)
								SB	511	21.9 (IA)
									512	8.6 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Access to Spawning Areas	Percentage of Accessible Small River Habitat (Shreeve Link 31-700)	<25%	25-50%	>50-75%	>75%	EK	NB	111	43.1 (IA)
									112	33.1 (IA)
									113	93.5 (IA)
								CB	211	23.7 (IA)
									212	2.2 (IA)
									213	44.1 (IA)
								GB	311	13.1% (IA)
								MLP	411	13.8 (IA)
									412	37.5 (IA)
								SB	511	17.6 (IA)
									512	12.3 (IA)
Landscape Context	Access to Spawning Areas	Percentage of Accessible Large River Habitat (Shreeve Link >700)	<25%	25-50%	>50-75%	>75%	EK	GB	311	7.4% (IA)
								MLP	411	43.1 (IA)
								SB	511	79.5 (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	NB	111	(RG)
									112	(RG)
									113	(RG)
								CB	211	(RG)
									212	(RG)
									213	(RG)
								GB	311	(RG)
								MLP	411	(RG)
									412	(RG)
								SB	511	(RG)
									512	(RG)
Size	Population size & dynamics	Lake sturgeon status across tributaries	<50% of historic rivers with connected remnant runs or No river with large (750+ mature adults) population	>50% of historic rivers with connected remnant runs or 1 rivers (depending upon reporting unit) with large (750+ mature adults) population	>50% of historic rivers with connected remnant runs and 1 rivers (depending upon reporting unit) with large (750+ mature adults) population	>75% of historic rivers with connected remnant runs and >1 rivers (depending upon reporting unit) with large (750+ mature adults) population	ER	NB	111	0 of 1 (IA)
									112	NA
									113	1 of 1* (IA)
								CB	211	2 of 2 (2 remnant) (IA)
									212	2 or 2 (2 remnant) (IA)
									213	0 of 1 (IA)
								GB	311	4 of 15 (3 remnant, 1 large) (IA)
								MLP	411	2 of 2 (2 remnant) (IA)
									412	0 of 3 (IA)
								SB	511	2 of 2 (2 remnant) (IA)
									512	0 of 3 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Size	Population size & dynamics	Status of lake whitefish 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	NB	111	10% (EK)
									112	40% (EK)
									113	10% (EK)
								CB	211	(EK)
									212	(EK)
									213	60% (EK)
								GB	311	45% (EK)
								MLP	411	45% (EK)
									412	10% (EK)
								SB	511	0% (EK)
									512	0% (EK)
Size	Population size & dynamics	Status of northern pike 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	NB	111	10% (EK)
									112	40% (EK)
									113	60% (EK)
								CB	211	40% (EK)
									212	60% (EK)
									213	45% (EK)
								GB	311	40% (EK)
								MLP	411	50% (EK)
									412	20% (EK)
								SB	511	25% (EK)
									512	10% (EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
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	CB	211	75% (EK)
									212	10% (EK)
									213	10% (EK)
								GB	311	30% (EK)
								MLP	411	40% (EK)
									412	10% (EK)
								SB	511	45% (EK)
									512	10% (EK)
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	NB	111	10% (EK)
									112	40% (EK)
									113	40% (EK)
								CB	211	70% (EK)
									212	10% (EK)
								GB	311	60% (EK)
								MLP	411	35% (EK)
									412	10% (EK)
								SB	511	24% (EK)
									512	10% (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	NB	111	25% (EK)
									112	40% (EK)
									113	60% (EK)
								CB	211	70% (EK)
									212	25% (EK)
									213	60% (EK)
								GB	311	60% (EK)
								MLP	411	40% (EK)
									412	50% (EK)
								SB	511	30% (EK)
									512	30% (EK)

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 Integirty						NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Condition	Abundance and diversity of wetland-dependent bird species	Marsh Bird IBI	0 - 2.5	2.6 - 5.0	5.1 - 7.5	7.6 - 10	OR	NB	111	NA
									112	NA
									113	NA
								CB	211	10.57 (NS)
									212	NA
									213	NA
								GB	311	12.31 (NS)
								MLP	411	5.24 (NS)
									412	NA
								SB	511	8.87 (NS)
									512	5.54 (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	NB	111	100 (IA)
									112	38 (IA)
									113	100 (IA)
								CB	211	100 (IA)
									212	78 (IA)
									213	100 (NS)
								GB	311	68 (IA)
								MLP	411	50 (IA)
									412	100 (IA)
								SB	511	100 (IA)
									512	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	EK	NB	111	63 (IA)
									112	37 (IA)
									113	67 (IA)
								CB	211	58 (IA)
									212	37 (IA)
									213	75 (NS)
								GB	311	30 (IA)
								MLP	411	41 (IA)
									412	NA
								SB	511	49 (IA)
									512	46 (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	NB	111	NA
									112	NA
									113	NA
								CB	211	3.35 (IA)
									212	NA
									213	3.25 (IA)
								GB	311	NA
								MLP	411	3.49 (IA)
									412	NA
								SB	511	2.72 (IA)
									512	NA
Condition	Macroinvertebrate quality	Invertebrate IBI	Extremely degraded	Degraded or moderately degraded	Moderately impacted or mildly impacted	Reference condition	OR	NB	111	NA
									112	NA
									113	(IA)
								CB	211	NA
									212	(IA)
									213	(NS)
								GB	311	(IA)
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

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	RG	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Condition	Species composition / dominance	% Coverage of Phragmites	>50	50 - 20	<20 - 5	<5	EK	NB	111	NA
									112	NA
									113	NA
								CB	211	4.37 (IA)
									212	NA
									213	NA
								GB	311	6.16 (IA)
								MLP	411	5.38 (IA)
									412	NA
								SB	511	3.86 (IA)
									512	0 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Condition	Species composition / dominance	Wetland macrophyte index	≤2	3	4	5	OR	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	2.68 (IA)
								MLP	411	2.32 (IA)
									412	NA
								SB	511	NA
									512	NA
Landscape Context	Connectivity among communities and ecosystems	Percent natural land cover in watershed	<40	40 - 60	>60 - 80	>80	ER	NB	111	69.82 (IA)
									112	70.28 (IA)
									113	89.87 (IA)
								CB	211	83.21 (IA)
									212	93.13 (IA)
									213	41.45 (IA)
								GB	311	68.52 (IA)
								MLP	411	47.84 (IA)
									412	22.11 (IA)
								SB	511	32.25 (IA)
									512	23.11 (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 500m of mapped wetlands	<20	20 - 40	>40 - 70	>70	EK	NB	111	72.67(IA)
									112	ND
									113	94.13 (IA)
								CB	211	62.70 (IA)
									212	76.97 (IA)
									213	48.67 (IA)
								GB	311	70.83 (IA)
								MLP	411	59.20 (IA)
									412	ND
								SB	511	59.83 (IA)
									512	75.54 (IA)
Landscape Context	Water level regime	Annual peak water level trend	Monotonic increase or decrease for 10 years in a row	Monotonic increase or decrease for any 7 years in a 10-year window	Monotonic increase or decrease for no more than 6 years in a 10-year window		OR	NB	111	Longest monotonic trend is 3 yrs (IA)
									112	
									113	
								CB	211	
									212	
									213	
								GB	311	
								MLP	411	
									412	
								SB	511	
									512	

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Water level regime	January - July water level increase	< 0.30 m for 9 consecutive years	< 0.30 m for any 7years in a 9-year window	< 0.30 m for no more than 6 years in a 9-year window		OR	NB	111	< 0.3 m for 5 years in last 9 ('03 – '11) (IA)
									112	
									113	
								CB	211	
									212	
									213	
								GB	311	
								MLP	411	
									412	
								SB	511	
									512	
Landscape Context	Water level regime	March - June water level increase	> 0.36 m for 3 consecutive years	> 0.36 m for any year within 3-year window	0.36 m or less for 3 consecutive years		OR	NB	111	> 0.36 m for 1 year in last 3 (IA)
									112	
									113	
								CB	211	
									212	
									213	
								GB	311	
								MLP	411	
									412	
								SB	511	
									512	

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Landscape Context	Water level regime	Mean growing season water level (Apr-Sep)	Maintained at or above 177.65 or below 175.0 m for a period of 5 consecutive years	Maintained at or above 177.65 or below 175.0 m for any 3 years within a 5-year window	Maintained between 175.0 and 177.65 m for any 3 years within a 5-year window		OR	NB	111	Between 175.0 and 177.65 for 5 years running; (IA)
									112	
									113	
								CB	211	
									212	
									213	
								GB	311	
								MLP	411	
									412	
								SB	511	
									512	
Landscape Context	Water quality	Water Quality Index (WQI) for wetland quality	-3 to -1	> -1 to 0	>0 to 1	>1 to 3	OR	NB	111	NA
									112	NA
									113	NA
								CB	211	-0.37 (IA)
									212	NA
									213	-0.71 (IA)
								GB	311	-0.12 (IA)
								MLP	411	-0.13 (IA)
									412	NA
								SB	511	-1.36 (IA)
									512	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current value (Source)
Size	Size / extent of characteristic communities / ecosystems	Wetland area	Greater loss from current area	Some loss from current area	Current area	Historic area	RG	NB	111	62 ha (IA)
									112	(EK)
									113	1448 ha (IA)
								CB	211	1966 ha (IA)
									212	913 ha (IA)
									213	442 ha (IA)
								GB	311	6125 ha (IA)
								MLP	411	2335 ha (IA)
									412	0 ha (IA)
								SB	511	804 ha (IA)
									512	5 ha (IA)

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	EK	NB	101	NA
									111	100% (IA)
									112	NA
									113	58% (IA)
								CB	201	82% (IA)
									211	NA
									212	100% (IA)
									213	NA
								GB	301	NA
									311	60% (IA)
								MLP	412	NA
								SB	512	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	EK	NB	101	NA
									111	0% (IA)
									112	NA
									113	43% (IA)
								CB	201	56% (IA)
									211	NA
									212	14% (IA)
									213	NA
								GB	301	NA
									311	60% (IA)
								MLP	412	NA
								SB	512	NA

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	NB	101	0 (IA)
									111	0 (IA)
									112	0 (IA)
									113	1641.38 (IA)
								CB	201	754.61 (IA)
									211	0 (IA)
									212	499.17 (IA)
									213	0 (IA)
								GB	301	0 (IA)
									311	3007.17 (IA)
								MLP	412	0 (IA)
								SB	512	0 (IA)
Condition	Landscape pattern (mosaic) & structure	House density on island (number of buildings / km^2)	>40	21 - 40	11 - 20	<10	EK	NB	101	0 (IA)
									111	1.14 (IA)
									112	0 (IA)
									113	4.97 (IA)
								CB	201	0.35 (IA)
									211	0 (IA)
									212	1.14 (IA)
									213	11.81 (IA)
								GB	301	0 (IA)
									311	13.29 (IA)
								MLP	412	0 (IA)
								SB	512	0 (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	NB	101	0 (IA)
									102	0 (IA)
									111	98.03 (IA)
									112	97.86 (IA)
									113	94.58 (IA)
								CB	201	97.36 (IA)
									211	0 (IA)
									212	98.12 (IA)
									213	84.05 (IA)
								GB	301	0 (IA)
									311	73.63 (IA)
								MLP	412	0 (IA)
								SB	512	0% (IA)
Condition	Soil / sediment stability & movement	Artificial Shoreline Hardening Index	>40	>20 - 40	10 - 20	<10	EK	NB	111	7.5 (IA)
									112	NA
									113	7.5 (IA)
								CB	201	7.5 (IA)
									211	NA
									212	7.5 (IA)
									213	7.5 (IA)
								GB	301	NA
									311	12.37 (IA)
								MLP	412	NA
								SB	512	NA

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	NB	101	NA
									111	NA
									112	NA
									113	NA
								CB	201	NA
									211	NA
									212	NA
									213	NA
								GB	301	NA
									311	NA
								MLP	412	NA
								SB	512	NA
Landscape Context	Conservation status	Percentage of high-ranked islands that are in conservation status	<20	20 - 40	>40 - 70	>70	ER	NB	101	NA
									111	NA
									112	NA
									113	88 (IA)
								CB	201	89.1 (IA)
									211	NA
									212	NA
									213	32.3 (IA)
								GB	301	NA
									311	0 (IA)
								MLP	412	NA
								SB	512	NA

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	NB	111	30% (IA)
									112	38% (IA)
									113	79% (IA)
								CB	211	72% (IA)
									212	78% (IA)
									213	97% (IA)
								GB	311	86% (IA)
								MLP	411	74% (IA)
									412	75% (IA)
								SB	511	46% (IA)
									512	81% (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	NB	111	63% (IA)
									112	37% (IA)
									113	49% (IA)
								CB	211	58% (IA)
									212	38% (IA)
									213	50% (IA)
								GB	311	42% (IA)
								MLP	411	41% (IA)
									412	43% (IA)
								SB	511	49% (NS)
									512	45% (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	NB	111	3551.96 (IA)
									112	4196.67 (IA)
									113	1563.43 (IA)
								CB	211	3402.67 (IA)
									212	2024.06 (IA)
									213	2399.97 (IA)
								GB	311	3368.18 (IA)
								MLP	411	4182.68 (IA)
									412	5228.23 (IA)
								SB	511	6468.89 (IA)
									512	11644.33 (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	NB	111	66.41 (IA)
									112	90.31 (IA)
									113	12.32 (IA)
								CB	211	44.31 (IA)
									212	13.47 (IA)
									213	33.74 (IA)
								GB	311	51.75 (IA)
								MLP	411	75.33 (IA)
									412	145.22 (IA)
								SB	511	166.27 (IA)
									512	1254.88 (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	NB	111	57.92 (IA)
									112	64.81 (IA)
									113	93.70 (IA)
								CB	211	78.22 (IA)
									212	89.35 (IA)
									213	48.64 (IA)
								GB	311	65.10 (IA)
								MLP	411	71.98 (IA)
									412	27.89 (IA)
								SB	511	58.31 (IA)
									512	13.09 (IA)
Condition	Soil / sediment stability & movement	Artificial Shoreline Hardening Index	>40%	>20 - 40%	10 - 20%	<10%	EK	NB	111	18.61 (IA)
									112	10.56 (IA)
									113	7.66 (IA)
								CB	211	17.59% (IA)
									212	7.5% (IA)
									213	23.2% (IA)
								GB	311	14.51 (IA)
								MLP	411	26.35 (IA)
									412	37.05 (IA)
								SB	511	35.31 (IA)
									512	59.32 (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	NB	111	133.41 (IA)
									112	93.37 (IA)
									113	4.67 (IA)
								CB	211	18.45 (IA)
									212	4.2 (IA)
									213	29.92 (IA)
								GB	311	72.34 (IA)
								MLP	411	31.69 (IA)
									412	32.89 (IA)
								SB	511	43.66 (IA)
									512	328.58 (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	NB	111	50.44 (IA)
									112	71.34 (IA)
									113	89.41 (IA)
								CB	211	66.24 (IA)
									212	78.24 (IA)
									213	27.72 (IA)
								GB	311	65.24 (IA)
								MLP	411	52.64 (IA)
									412	15.59 (IA)
								SB	511	36.67 (IA)
									512	13.85 (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%	<30%	EK	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	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	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									212	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	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	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA
Landscape Context	Anthropogenic disturbance	Average distance of suitable waterfowl habitat from disturbance factor (m)	<100	100 - <200	>200	> 250	ER	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	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	NB	111	6 (IA)
									112	5 (IA)
									113	8 (IA)
								CB	211	6 (IA)
									212	10 (IA)
									213	5 (IA)
								GB	311	7 (IA)
								MLP	411	6 (IA)
									412	4 (IA)
								SB	511	8 (IA)
									512	4 (IA)
Landscape Context	Habitat availability	Percentage of 2 km shoreline area that is suitable habitat for landbirds	<10	10 - 30	>30 - 50	>50	OR	NB	111	61 (IA)
									112	68 (IA)
									113	89 (IA)
								CB	211	68 (IA)
									212	87 (IA)
									213	78 (IA)
								GB	311	81 (IA)
								MLP	411	70 (IA)
									412	53 (IA)
								SB	511	68 (IA)
									512	35 (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	NB	111	28 (IA)
									112	24 (IA)
									113	47 (IA)
								CB	211	22 (IA)
									212	41 (IA)
									213	46 (IA)
								GB	311	44 (IA)
								MLP	411	19 (IA)
									412	28 (IA)
								SB	511	29 (IA)
									512	25 (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	NB	111	NA
									112	NA
									113	NA
								CB	211	NA
									212	NA
									213	NA
								GB	311	NA
								MLP	411	NA
									412	NA
								SB	511	NA
									512	NA

APPENDIX F: INDICATOR DESCRIPTIONS

5-year average spring isothermal Chlorophyll-a concentration (µg/L)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone`

Description: Chlorophyll-a is a measure of phytoplankton productivity in a lake. It is an important measure, because high chlorphyll-a concentrations indicate eutrophic conditions and if they are too low, it can indicate that nutrient concentrations may be too low to support desired fisheries.

Basis for Assessing Indicator: Ratings are based on relationships in Mida et al. (2010) and H. Bootsma (pers. comm). The potential for chlorophyll-a concentrations to be too low has not been of concern in the past, but given recent concerns about excessive oligotrophication in the offshore, the chlorophyll –a indicator ratings included both upper and lower bounds.

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: For previous biodiversity conservation strategies, we have obtained data from Bird Studies Canada, who has coordinated surveys on hundreds of marsh routes in the Great Lakes for up to 15 years through the volunteer based Marsh Monitoring Program (Archer and Jones 2009). There are very few coastal wetlands in Lake Michigan that are surveyed through this program, so there was insufficient data to evaluate the status of this indicator. We recommend updating the status of this indicator through the ongoing Great Lakes wetland surveys mentioned above.

Annual peak water level trend

KEA (Type): Water level regime (Landscape Context)

Target: Coastal Wetlands

Description: This indicator reflects some of the projected wetland impacts of long-term changes in water level regime. Great Lakes water levels are naturally dynamic, varying seasonally, annually, and over multi-year cycles. Coastal wetland vegetation zones shift in response to water level, but long-term changes that exceed historic ranges of variability can result in losses or gains in wetland area, structure, and composition. The trend in annual peak water level can influence the availability of food for fish (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options, indicator LMH-03 (IUGLS 2011, p 72). We obtained annual peak water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA GLERL) and then graphed these data to evaluate the length of increasing and decreasing trends over the past 10 years.

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

Description: Percent of shoreline protected with artificial structures (e.g., sea walls, rip rap) to prevent erosion. Shoreline hardening disrupts natural nearshore coastal processes that drive erosion and sediment transport, and therefore the nature and extent of Nearshore Zone habitats and community structure of Great Lakes shorelines (Meadows et al. 2005, Mackey 2008, Morang et al. 2011, Morang et al. 2012). 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). 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 hardening 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 *Diporeia* densities number per m^2

KEA (Type): Population size & dynamics (Size)

Target: Nearshore Zone

Description: *Diporeia* spp. are benthic amphipods that are extremely important in the diets of many fish species and they have been called a "*a keystone organism in the cycling of energy between lower and upper trophic levels*" (Nalepa et al. 2009, p. 467) . However, their populations have crashed over the last fifteen years, which is of substantial concern for the food web of Lake Michigan (Nalepa et al. 2009).

Basis for Assessing Indicator: Indicator ratings are based on relationships in Nalepa et al. (2009) and Hondorp et al. (2005). Current status is based on data in Nalepa et al. (2009).

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 mussels richness per site

KEA (Type): Population size & dynamics (Size)

Target: Nearshore zone

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). Though Lake Michigan mussel data is limited (EC and EPA 2009), some limited historic data, the known importance in Lake Erie, and habitat conditions in portions of Lake Michigan indicate that many areas likely provided important habitat for a wide variety of mussel species. Historically, mussel populations in Lake Michigan may have provided for dispersal, colonization, or recolonization, of mussel populations among tributaries. Given the imperiled status of many river populations in the basin, this source of colonization—if available—could prove important (as in Sietman et al. 2001).

Basis for Assessing Indicator: Lake Michigan mussel data is limited (EC and EPA 2009), so indicator ratings are a best guess. They are loosely based on the ratings provided by experts for the Lake Erie Biodiversity Conservation Strategy, but were adjusted with lower expectations since limited historic data would indicate that a typical nearshore area in Lake Erie likely had higher mussel richness than Lake Michigan nearshore areas.

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, 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.

Biomass of crustacean zooplankton in early summer (mg/L)

KEA (Type): Population size & dynamics (Size)

Target: Nearshore

Description: Zooplankton are an important food source for all nearshore fish species for at least part of their life cycle. Both the overall biomass and structure of zooplankton assemblages is important.

Basis for Assessing Indicator: There currently doesn't seem to be any consistent nearshore zooplankton monitoring across the lake that would provide data to help develop an indicator that integrates zooplankton biomass.

Bythotrephes average annual abundance relative to prey

KEA (Type): Zooplankton community structure (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Bythotrephes is an invsive zooplanktor that has been a significant driver of change to the offshore food web since its introduction in the 1980's (Vanderploeg et al. 2012). Bythotrephes disrupts the foraging of other zooplanktors and adds stress to the native zooplankton that are already stressed by decrease food availability due to other factors. Overall, bythotrephes presence is correlated to lower zooplankton biomass. Also small mid-level prey fish cannot inject bythotrephes because of its tail spine. (Vanderploeg et al. 2012).

Basis for Assessing Indicator: Ratings are based on rough guess. Measurement is based on Vanderploeg et al. (2012)

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. They have experienced excessive grown in Lake Michigan (and other Great Lakes) in recent years and have received considerable attention from frustrated 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 Bootma (per. comm.). Current status of Cladophora standing crop is based on Greb et al. (2004), Bootsma et al. (2005), Bootsma (unpublished data), and some anecdotal information from Bootsma (pers. comm.).

Coregonids: lake whitefish – biomass trend

KEA (Type): Benthivore fish 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 Michigan. These fish are still important commercially and to the tribes. Biomass is an overall indicator of population size

Basis for Assessing Indicator: This indicator is based on the Core team interpretation of assessment results presented by management unit in the 2011 Status Report - Modeling Subcommittee, Technical Fisheries Committee. 2011. Technical Fisheries Committee Administrative Report 2011: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan, with recommended yield and effort levels for 2011. http://www.michigan.gov/greatlakesconsentdecree; It is important to note that LWF are not evenly distributed throughout Lake Michigan and so I was out to capture the general trend.

Coregonids: lake whitefish – recruitment trend

KEA (Type): Benthivore fish 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 Michigan. These fish are still important commercially and to the tribes. Recruitment is a measure of reproductive success - how many reproducing fish came from the previous generation

Basis for Assessing Indicator: This indicator is based on my interpretation of assessment results presented by management unit in Modeling Subcommittee, Technical Fisheries Committee (2011); It is important to note that LWF are not evenly distributed throughout Lake Michigan and so we were out to capture the general trend.

Diporeia -- Density of individuals in grab samples, >90 m depth (number/m^2)

KEA (Type): Native macroinvertebrates (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Diporeia are a zooplanktor that used to be the dominant forage for mid-level prey fish in Lake Michigan. This indicator is included because the status of diporeia is an indicator of major changes in the Lake Michigan food web. (see Vanderploeg et al. 2012).

Basis for Assessing Indicator: Rating thresholds and current values are based on personal communication with Tom Nalepa. See Nalepa et al. 2009 for collection methods.

Diporeia -- Density of individuals in grab samples, 30 - 90 m depth (number/m^2)

KEA (Type): Native macroinvertebrates (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Diporeia are a zooplanktor that used to be the dominant forage for mid-level prey fish in Lake Michigan. This indicator is included because the status of diporeia is an indicator of major changes in the Lake Michigan food web. (see Vanderploeg et al. 2012).

Basis for Assessing Indicator: Rating thresholds and current values are based on personal communication with Tom Nalepa. See Nalepa et al. 2009 for collection methods

Dreissenid mussel biomass (density in kg/ha)

KEA (Type): Benthic macroinvertebrate community structure (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Dreissnid musslels are responsible for massive changes to the offshore food web in 4/5 Great Lakes.

Basis for Assessing Indicator: The trend in density is based on information presented by Madenjian et al 2012 based on bottom trawls. The methods in Nalepa et al. 2009 offer a more accurate density measure. However, the bottom trawls are done every year and may be a more available source of information.

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 2011).

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.

Hexagenia mean density in fine sediments (3 yr average)

KEA (Type): Food web linkages (Condition)

Target: Nearshore Zone

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, Boase et al. 2011), yellow perch (Price 1963, Clady and Hutchinson 1976), and walleye (Ritchie and Colby 1988). Experts indicated that *Hexagenia* in Lake Michigan were only a significant component in Green Bay, so they were only included as an indicator for that assessment unit.

Basis for Assessing Indicator: Indicator ratings and current status are based on Edsall et al. (2005) and EC and EPA (2009, p. 127).

House density on island (number of buildings/ km^2)

KEA (Type): Landscape pattern (mosaic) & structure (Condition)

Target: Islands

Description: This indicator is intended to reflect 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: We used census block data (U.S. Census Bureau 2000) to provide an estimate of housing density for each island. 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 is intended to reflect 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: We used census block data (U.S. Census Bureau 2000) to provide an estimate of housing density within each watershed. Housing unit density per square kilometer was calculated for each census block. The census block data were then combined with the 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.

Invertebrate Index of Biotic Integrity (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 LMBCS, average invertebrate IBI values could be calculated for a limited number of assessment units (see Appendix E). 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 LMBCS. 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 Michigan.

January - July water level increase

KEA (Type): Water level regime (Landscape Context)

Target: Coastal Wetlands

Description: This indicator reflects the frequency with which the seasonal increase in January – July water levels falls below normal levels. The amplitude of this water level increase is important to maintaining abundance of native fish (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options, indicator LMH-04 (IUGLS 2011, p 72). We obtained water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA 2012) and then graphed these data to evaluate the amount of water level increase in each of the past nine years.

Lake sturgeon status across tributaries

KEA (Type): Population size & dynamics

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, Rutherford et al. 2004). Historically, they were an important ecological and economic component of the Lake Erie fish community (Zollweg et al. 2002, Rutherford et al. 2004). However, their populations were decimated by overfishing, dam construction, and habitat degradation (Rutherford et al. 2004). Lake sturgeon populations are estimated at only one percent of their historic abundance (Tody 1974 cited in Rutherford et al. 2004).

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, by experts felt that 750 was a more reasonable number to expect for most tributary populations.

Lake trout: Young of the year density (individuals/ha)

KEA (Type): Predator fish species population size (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator would show if lake trout were naturally reproducing and the eggs were surviving. This is the goal of lake trout recovery.

Basis for Assessing Indicator: Rating thresholds and measures are based on Bronte et al. (2008) and Dexter et al. (2011)

Lakewide prey biomass from bottom trawl

KEA (Type): Prey availability (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Total prey biomass is an indicator of the ability of Lake Michigan to support top predators including native lake trout and burbot, as well as introduced salmonids. The level of preyfish biomass is of particular concern in the management of pacific salmonid stocking. Levels are nowhere near the GLFC goals.

Basis for Assessing Indicator: Current measures from the USGS (Madenjian et al. 2012) annual bottom trawl data.

March - June water level increase

KEA (Type): Water level regime (Landscape context)

Target: Coastal Wetlands

Description: This indicator reflects the frequency with which the seasonal increase in March - July water levels exceeds normal levels. The amplitude of this water level increase is important to maintaining diversity of native fish (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options, indicator LMH-09 (IUGLS 2011, p 72). We obtained water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA 2012) and then graphed these data to evaluate the amplitude of water level increase in each of the past three years.

Marsh Bird Index of Biotic Integrity (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 hundreds of marsh routes in the Great Lakes for up to 15 years through the volunteer based Marsh Monitoring Program (2009). These surveys include coastal wetlands in roughly half of the assessment units in Lake Michigan. Using ArcMap, we calculated the average of the Marsh Bird IBI values for all marsh routes in each assessment unit.

Mean Dreissena density

KEA (Type): Community architecture (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 nuiscance *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.

Mean growing season water level (Apr-Sep)

KEA (Type): Water level regime (Landscape Context)

Target: Coastal Wetlands

Description: This indicator reflects the frequency with which the mean growing season water level falls below 175.0 m. This level reflects an interpretation of the range in mean growing season water levels below or above which bulrush habitat will be severely reduced (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options, indicators LMH-05 and LMH-06 (IUGLS 2011, p 72). We obtained water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA 2012) and then graphed these data to evaluate the amount of water level increase in each of the past five years.

Mysis – Mean Density of individuals in vertical net tows at night (number/m^2) at depths greater than 100m

KEA (Type): Native macroinvertebrates (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: *Mysis relicta* is a large zooplantor in Lake Michigan and is a primary food source for sculpin, coregonids and burbot.

Basis for Assessing Indicator This indicator reflects the challenge of setting a "good" level for a species that fluctuates a lot in population size and does so in response to many variables. It appears that *Mysis relicta* densities are steady based on a conversation with Steve Pothoven (NOAA - Muskegon). Current Value based on Pothoven et al. (2000) and Pothoven et al (2004).

Native fish species richness

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

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

Basis for Assessing Indicator: We are still working with D. Clapp in developing this indicator using fish assemblage data collected in yellow perch trawl surveys.

Native mussel abundance

KEA (Type): Population size & dynamics (Size)

Target: Nearshore Zone

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 macroinvertabrates and help to stabilize sediments—especially in sandy areas, such as those that dominate along the eastern side of Lake Michigan.

Basis for Assessing Indicator: Lake Michigan 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 Michigan nearshore.

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 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 (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 averaged that percentage by assessment unit.

Percent natural land cover in watershed

KEA (Type): Coastal and watershed contribution

Target: Nearshore Zone

KEA (Type): Connectivity among communities and ecosystems

Target: Coastal Wetlands

Description: The amount of natural land cover within the watershed contributing to a Nearshore Zone reach. There are substantial data indicating that the percent of development within the contributing watershed of the 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). This water quality affects the coastal wetlands within the nearshore zone as well.

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: Expert opinion and literature-based criterion (Robinson et al. 1995).

Percent natural land cover within 2 km of shoreline

KEA (Type): Coastal and watershed contribution (Landscape Context)

Target: Nearshore Zone

KEA (Type): Size / extent of characteristic communities / ecosystems (Condition)

Target: Coastal Terrestrial Systems

Description: The amount of natural land cover within 2 km of Lake Michigan. 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: As with watershed land use, most published studies are generally insufficient for identifying thresholds in impacts. As a result, we utilized the same thresholds used for watershed impacts derived from data in Lougheed et al. (2001) and Niemi et al. (2009). Ideally these ratings would be based on more data and evaluation of relationships between percent development and biotic community metrics (e.g., IBIs, ordination axes); future research on these relationships are 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 is intended to reflect the degree of connectivity between coastal wetlands and adjacent upland natural communities. Many wetland fauna, such as snakes and turtles, depend on this upland – wetland connection for different activities including foraging, nesting, and hibernating. Wetlands with greater connectivity to upland natural communities are better able to support these species.

Basis for Assessing Indicator: Using ArcMap, we buffered each coastal wetland polygon in the Great Lakes Coastal Wetland Consortium data layer by 500 m, and then calculated the percentage of each buffer area occupied by natural land cover types, using the NOAA CCAP data. The ratings for this indicator are based on expert opinion.

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 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 Michigan. 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 accessible creek habitat (Shreeve Link 3-30)

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 Michigan. Creeks are small streams with a Shreeve link (Shreeve 1966) of 3-30.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of creeks within each assessment unit that were connected to Lake Michigan (i.e., that were not isolated from Lake Michigan by dams). Indicator ratings were quartiles of the proportion of creeks that are currently connected to Lake Michigan.

Percentage of accessible headwater stream habitat (Shreeve Link 1-2)

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 1981, Becker 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 Michigan. Streams with a Shreeve link (Shreeve 1966) of 1-2 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 Michigan (i.e., that were not isolated from Lake Michigan by dams). Indicator ratings were quartiles of the proportion of headwater streams that are currently connected to Lake Michigan

Percentage of accessible large river habitat (Shreeve Link >700)

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 Michigan basin, all large rivers flow directly into Lake Michigan. Large Rivers are rivers with a Shreeve link (Shreeve 1966) of >700. 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 Michigan (i.e., that were not isolated from Lake Michigan by dams). Indicator ratings were quartiles of the proportion of large rivers that are currently connected to Lake Michigan.

Percentage of accessible small river habitat (Shreeve Link 31-700)

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 Michigan. Small rivers are rivers with a Shreeve link (Shreeve 1966) of 31-700.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of small rivers within each assessment unit that were connected to Lake Michigan (i.e., that were not isolated from Lake Michigan by dams). Indicator ratings were quartiles of the proportion of small rivers that are currently connected to Lake Michigan.

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)

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 Blueprint (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.

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: Expert opinion.

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: Expert opinion.

Percentage of historic spawning reefs available as quality spawning habitat

KEA (Type): Spawning habitat quality and accessibility (Condition)

Target: Nearshore Zone

Description: Despite their fairly small footprint, nearshore spawning reefs are critical areas for recruitment of several nearshore and offshore fish species, including walleye, yellow perch, lake trout, and lake whitefish. However, they have experienced significant degradation due to navigation and channelization, sedimentation, lake level changes, and high densities of invasive egg predators (Rutherford et al. 2004).

Basis for Assessing Indicator: Nearshore reefs do not seem to have been systematically mapped for Lake Michigan and data are not available to assess the proportion of reefs that should be in high quality to maintain quality fisheries. Therefore the indicator ratings and current status have not been developed for this indicator.

Phytoplankton abundance - mean daily integrated primary production (mgC/m^2/day) during spring isothermal mixing period.

KEA (Type): Phytoplankton - primary productivity (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator was included to represent primary productivity in Lake Michigan.

Basis for Assessing Indicator: For detailed information on methods please see Fahnenstiel et al. (2010)

Proportion native prey in biomass

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, including deepwater sculpin, slimy sculpin, ninespine stickleback, and bloater in the prey fish biomass rather than the current status of dominance by three invasive species – alewife, round goby and rainbow smelt.

Basis for Assessing Indicator: The ratings are based on recent bottom trawls as described in Madenjian et al. (2012).

Proportion of wild lake trout in sample

KEA (Type): Top predator population dynamics (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Lake trout is a key top predator for Lake Michigan and the focus of restoration efforts. This particular indicator was suggested by Chuck Madenjian who estimates this from the annual bottom trawl data (personal communication from Chuck Madenjian).

Basis for Assessing Indicator:

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).

Smallmouth bass population relative abundance

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

Description: Smallmouth bass are a major component of the nearshore fish community (and the fisheries economy) in northern Lake Michigan (Eshenroder et al. 1995, Kaemingk et al. 2012, Rutherford et al. 2004). Smallmouth bass populations have been impacted by habitat degradation and degraded water quality in Lake Michigan (Rutherford et al. 2004), so their populations represent a good indicator that is highly socio-economically relevant. While smallmouth bass are an important component of northern Lake Michigan nearshore fish assemblages, experts indicated that it is a minor component in much of southern Lake Michigan, so it was not included as an indicator for assessment units in the southern portions of the lake.

Basis for Assessing Indicator: Ratings for this indicator are generally qualitative, because no good quantitative measure was available for evaluation across assessment units. Current status is based on expert input from R. Claramunt, D. Clapp, & T. Galarowicz; but were supported by recent studies (Kaemingk et al. 2012, T. Galarowicz unpublished data).

Soluble Reactive Phosphorus

KEA (Type): Water chemistry (Landscape Context)

Target: Nearshore Zone

Description: Soluble Reactive Phosphorus (SRP) is a form of dissolved phosphorus and is generally the form that is most readily available to algae (Bootsma et al. 2012). As such, it is a very important form of phosphorus in determining nuisance algal potential, particularly given the complex biological spiraling of phosphorus in the lake (Hecky et al. 2005, Bootsma et al. 2012). Lake Michigan is experiencing problems with excess phosphorus in the nearshore zone, while also experiencing such low phosphorus in the Offshore Zone that lower trophic levels seem to have collapsed and there are concerns about a collapse in offshore fishery populations (Bunnell et al. 2009). So while lower phosphorus loading would help to address problem Cladophora growth in the nearshore, it could compound the oligtrophication that is occurring in the offshore food web, further impacting the base of the offshore food web (Bootsma et al. 2012). It should be noted that while most monitoring programs measure SRP in the upper water column, what is really important to address the Cladophora problem is the concentrations down near the substrate, which tend to be higher concentrations (H. Bootsma, pers. comm.).

Basis for Assessing Indicator: Current status of SRP was based on Tomlinson et al. (2010) and H. Bootsma (unpublished data), but SRP data was not available for much of the lake.

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 LMBCS, but should be available beginning in 2013.

Status of lake whitefish across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Historically, lake whitefish spawned in several lake Michigan tributaries, including the Menominee River where they occurred in “great numbers,” as well as the Muskegon River, the Cedar River, Whitefish River, Elk River, Manistique River, Kalamazoo River, and St. Joseph River (Goodyear et al. 1982, O’Neal 1997, Rozich 1998, Wesley and Duffy 1999, 2005, Madison and Lockwood 2004). These spawning runs were disrupted by dam construction, lumbering activities, and other pollutants by the late 1800’s to such an extent that tributary spawning was virtually absent across the lake (Goodyear et al. 1982). In more recent years, some tributary spawning runs have begun to recover, particularly in the Menominee River where whitefish recruitment is providing significant contributions to Green Bay whitefish populations (Hansen et al. 2012).

Basis for Assessing Indicator: Experts agreed that the status of current populations relative to historic conditions was a logical measure of viability, with the proportion 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 lake whitefish spawning runs, so the current status was based on the opinions of expert fisheries biologists across the lake.

Status of northern pike across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Historically, lake whitefish spawned in several lake Michigan tributaries, including the Menominee River where they occurred in "great numbers," as well as the Muskegon River, the Cedar River, Whitefish River, Elk River, Manistique River, Kalamazoo River, and St. Joseph River (Goodyear et al. 1982, O'Neal 1997, Rozich 1998, Wesley and Duffy 1999, Madison and Lockwood 2004, Wesley 2005). These spawning runs were disrupted by dam construction, lumbering activities, and other pollutants by the late 1800's to such an extent that tributary spawning was virtually absent across the lake (Goodyear et al. 1982). In more recent years, some tributary spawning runs have begun to recover, particularly in the Menominee River where whitefish recruitment is providing significant contributions to Green Bay whitefish populations (Hansen et al. 2012).

Basis for Assessing Indicator: Experts agreed that the status of current populations relative to historic conditions was a logical measure of viability, with the proportion 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 lake whitefish spawning runs, so the current status was based on the opinions of expert fisheries biologists across the lake.

Status of shorthead redhorse across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Shorthead redhorse are one of several Lake Michigan 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, Burroughs et al. 2010) 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 data was available at a broad scale on white sucker spawning runs, so the current status was based on expert opinion.

Status of walleye across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: : Walleye are important ecologically and economically in Lake Michigan (Schneeberger 2000, Rutherford et al. 2004) and tributary spawning populations provide a major component of Lake Michigan's walleye population (Mion et al. 1998, Schneeberger 2000, Rutherford et al. 2004). However, walleye populations are much lower than historically due to dam construction and habitat degradation (Rutherford et al. 2004)

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. Since no consistent lakewide data was available on walleye spawning runs, the current status was based on expert opinion.

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 based on expert opinion.

Total Phosphorous (Spring)

KEA (Type): Water quality (Landscape Context)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Total Phosphorous is one indicator of the trophic status of the lake. Concerns have been raised that total P is too low in Lake Michigan - and work will need to be done to determine what a lower bound should be.

Basis for Assessing Indicator: Current ratings are based on measures presented in Mida et al. (2010). The rating scale is based on SOLEC indicator #111

Total Phosphorus concentrations (μg/L)

KEA (Type): Water chemistry (Landscape Context)

Target: Nearshore Zone

Description: Phosphorus is an important measure of trophic state and keeping phosphorus below target levels is important to maintain natural trophic conditions (e.g., oligotrophic or mesotrophic, depending upon where you are in the lake) and avoid nuisance algae problems (EC and EPA 2009). Total phosphorus has been measured for decades in the Great Lakes and has been a predominant measure of Phosphorus as an indicator, though more recently dissolved phosphorus (or soluble reactive P) has become an increasingly important indicator.

Basis for Assessing Indicator: Little total phosphorus data was accessible for the nearshore (most long-term monitoring seems biased toward the offshore), but some data was utilized from Greb et al. (2004) and more qualitative information was taken from EC and EPA (2009).

Upland Sediment Contributions (tons/ac/yr)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone

Description: Excessive sedimentation from upland sources that are delivered to the nearshore can degrade or alter physical habitat, including changes in shoreline configuration (e.g. bars, shoals) and loss of exposed coarse substrates, such as gravel, cobble, or even sand. As a result, many nearshore organisms are impacted by excessive upland sediment contributions.

Basis for Assessing Indicator: Data used to develop current status was from the High Impact Targeting (HIT) System (Ouyang et al. 2005, http://35.9.116.206/hit2/home.htm), which uses soil type, topography, land use, and proximity to streams to predict sediment delivery to stream systems. Indicator ratings were developed through examination of predicted sedimentation rates across the basin and comparing the distribution in that data against other datasets, in particular Robertson (1996), as reproduced in Figures 5.4 and 5.5 in U.S. EPA (2000), and Heidelberg University's tributary data from Lake Erie (http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data).

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, but some in Lake Michigan.

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 Michigan, data exist for four of the eleven assessment units. 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

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 wetland viability for a particular area. There is a SOLEC indicator in development—Coastal Wetland Landscape Extent and Composition—that is scheduled to be ready for SOLEC 2014, but we could find no references that cite the amount of coastal wetland loss relative to what would be expected for a particular area.

Basis for Assessing Indicator: The ratings for this indicator are qualitative, the amount of loss or gain expressing the amount of loss or gain relative to the current area. 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. We assigned status ranks based on expert opinion (Dennis Albert, Oregon State University, pers. comm.).

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. Fish data are being collected as part of the basin-wide coastal wetland surveys, and should be available by 2013 to enable updating of this indicator status (Matthew Cooper, Notre Dame University, pers. comm.).

Basis for Assessing Indicator: We obtained data for some assessment units in Lake Michigan, and used ArcMap to calculate average values of the WFI for each of these assessment units. 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 the two assessment units that contained wetlands that had been sampled. We used ratings from Croft and Chow-Fraser (2007). Macrophyte data are being collected as part of the basin-wide coastal wetland surveys, and should be available by 2013 to enable updating of this indicator status (Matthew Cooper, Notre Dame University, pers. comm.).

Yellow perch population status

KEA (Type): Community architecture (Size)

Target: Nearshore Zone

Description: Yellow perch are an extremely important component of the Lake Michigan nearshore fish community. They interact with a wide variety of fish and invertebrates as both prey and predator, they are important as an indicator of ecological health, and they are extremely import to regional fisheries (Clapp and Dettmers 2004, Wilberg et al. 2005) often dominating the harvest of recreational anglers in the region (Bence and Smith 1999).

Basis for Assessing Indicator: There are many techniques used to monitor yellow perch populations in Lake Michigan. The Lake Michigan Yellow Perch Task Group (Clapp and Dettmers 2004) evaluates a variety of measures and metrics to determine the status of perch across the lake (Makauskas and Clapp 2012). As a result, we did not settle on any single measure to determine yellow perch status, but rather ratings and status are based on the task group reviews (Makauskas and Clapp 2012, Breidert 2011, D. Clapp pers. comm.).

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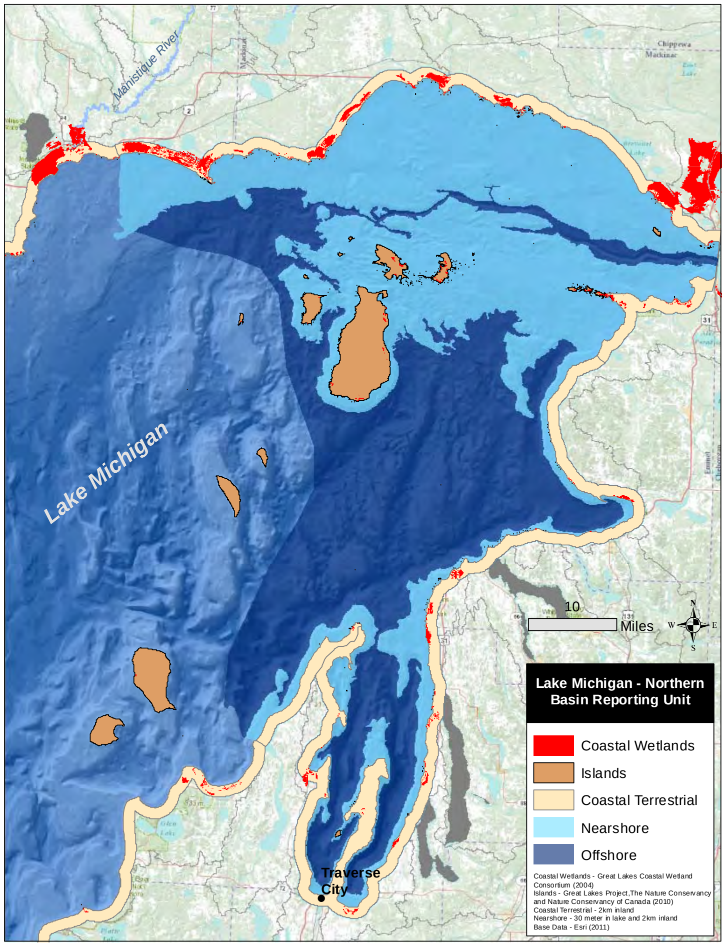
APPENDIX G: REPORTING UNITS: DESCRIPTION, VIABILITY AND THREATS

1. Northern Basin



Shoreline length	**709 km**
Coastal area (2km inland)	9,433 km^2
Baymouth/barrier beach	5%
Bedrock	6%
Cliff/bluff	3%
Cobble/gravel	1%
Artificial shoreline:	0%
Sandy Beach/dunes	84%

Viability and Threat Summary

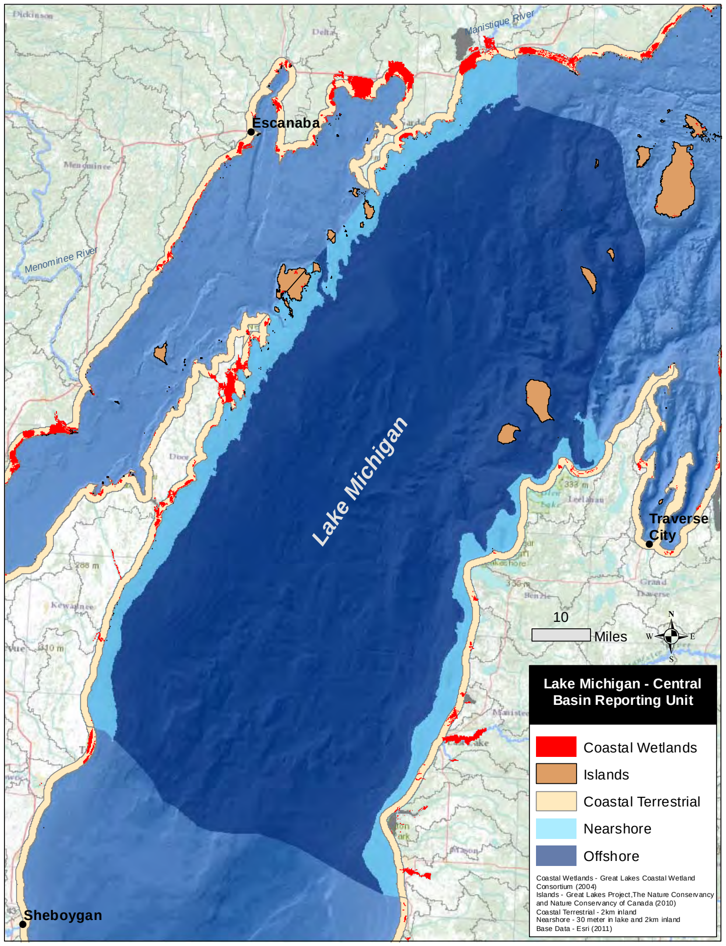
Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	High
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Good	Very High
Islands	Good	High
Native Migratory Fish	Fair	High
Offshore Zone	Fair	High
Lakewide	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Invasive Non-Native Aquatic Species		High	High	High	High	High	High	Very High
Invasive non-native terrestrial species	High	Medium	Medium	Low	Medium	High	High	High
Dams & Other Barriers		High			Not Specified	Medium	High	High
Climate change: Habitat shifting & alteration	Medium	Medium	Medium	Medium	High	Medium	High	High
Contaminated sediments: (should this be incorporated into viability?)	Medium		High	Not Specified	High	Medium	Medium	High
Mining & Quarrying	Medium		Medium		Low	Medium	Medium	Medium
Incompatible fisheries management	Not Specified	Medium	Medium	Medium	Medium	Medium	Low	Medium
Shoreline Alterations	Medium		Not Specified		Medium	Medium	Medium	Medium
Pollution: Urban and household sources	Medium	Medium	Medium	Not Specified	Medium	Medium	Medium	Medium
Pollution: Ag and forestry sources		Medium		Medium	Medium	Medium	Medium	Medium
Recreational activities	Medium		High			Medium	Medium	Medium
Housing & Urban Development	Medium		Medium		Not Specified	High	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Diking of wetlands		Medium			Medium	Medium	Medium	Medium
Non-renewable energy	Medium				Medium	Medium	Medium	Medium
Pollution: Industrial sources				Medium	Medium	Medium		Medium
Renewable Energy	Medium	Not Specified	Medium		Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Medium	Medium		Low	Medium	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium	Medium
Climate Change: Temperature extremes or drought	Low							Low
Summary Target Ratings:	High	High	High	High	High	Very High	Very High	Very High

2. Central Basin



Shoreline length	**566 km**
Coastal area (2km inland):	8,833 km^2
Baymouth/barrier beach:	10%
Bedrock:	21%
Cliff/bluff:	17%
Cobble/gravel:	0%
Artificial shoreline:	1%
Sandy Beach/dunes:	45%

Viability and Threat Summary

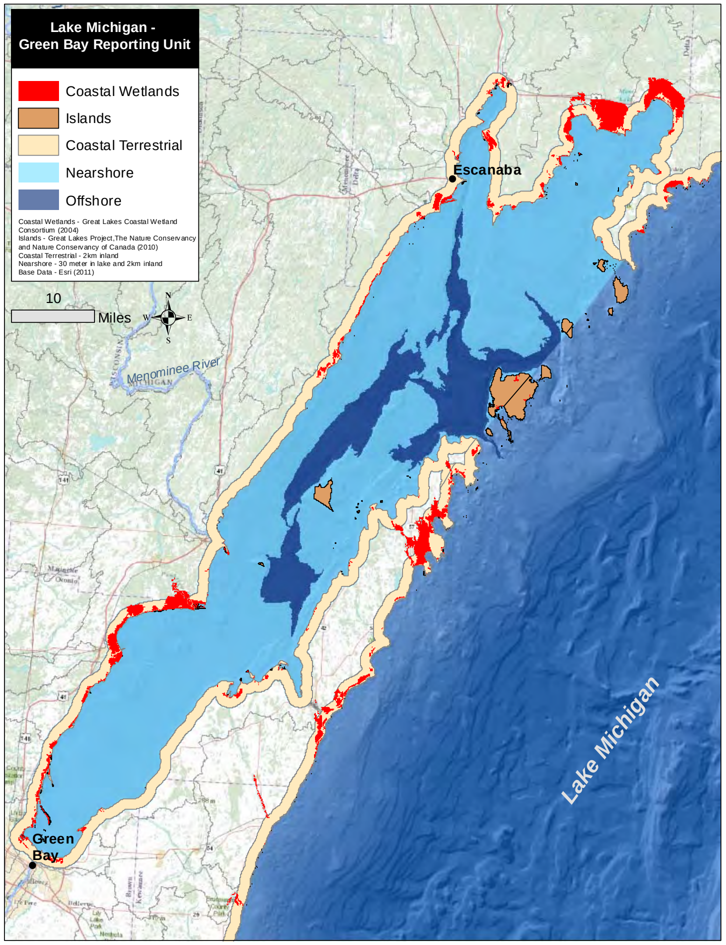
Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	High
Coastal Terrestrial Systems	Fair	High
Coastal Wetlands	Good	Very High
Islands	Good	Medium
Native Migratory Fish	Fair	High
Offshore Zone	Fair	Medium
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Invasive Non-Native Aquatic Species		High	Medium	High	High	Medium	High	High
Invasive non-native terrestrial species	Medium	Low		Low	Medium	High	High	High
Housing & Urban Development	Medium		High		Not Specified	Medium	Very High	High
Climate change: Habitat shifting & alteration	Medium	Medium	Medium	Medium	Medium	High	Very High	High
Incompatible fisheries management	Not Specified	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Shoreline Alterations	Medium		Not Specified		Medium	Medium	Medium	Medium
Pollution: Urban and household sources	Low	Medium		Not Specified	Low	Medium	Medium	Medium
Pollution: Agriculture and forestry sources		Medium	Medium	Low	Medium	Medium	Medium	Medium
Dams & Other Barriers		Medium			Not Specified	Medium	Medium	Medium
Recreational activities	Medium		Low		Medium	Medium	Medium	Medium
Agriculture: Annual and Perennial Nontimber Crops						High		Medium
Diking of wetlands		Medium			Medium	Low	Low	Medium
Non-renewable energy	Low				Medium	Medium	Low	Medium
Pollution: Industrial sources				Medium	Medium	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Renewable Energy	Medium	Not Specified	Medium		Low	Medium	Medium	Medium
Contaminated sediments	Low		Low	Not Specified	Medium	Low	Medium	Medium
Navigation & Recreational Dredging & Blasting	Low	Medium		Low	Medium	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium	Medium
Mining & Quarrying	Low		Low		Low	Medium	Low	Low
Summary Target Ratings:	Medium	High	High	Medium	High	High	Very High	Very High

3. Green Bay



Shoreline length:	**709km**
Coastal Area (2km inland):	9,338km^2
Baymouth/barrier beach:	8%
Bedrock:	17%
Cliff/bluff:	5%
Cobble/gravel:	1%
Artificial shoreline:	3%
Sandy Beach/dunes:	53%

Viability and Threat Summary

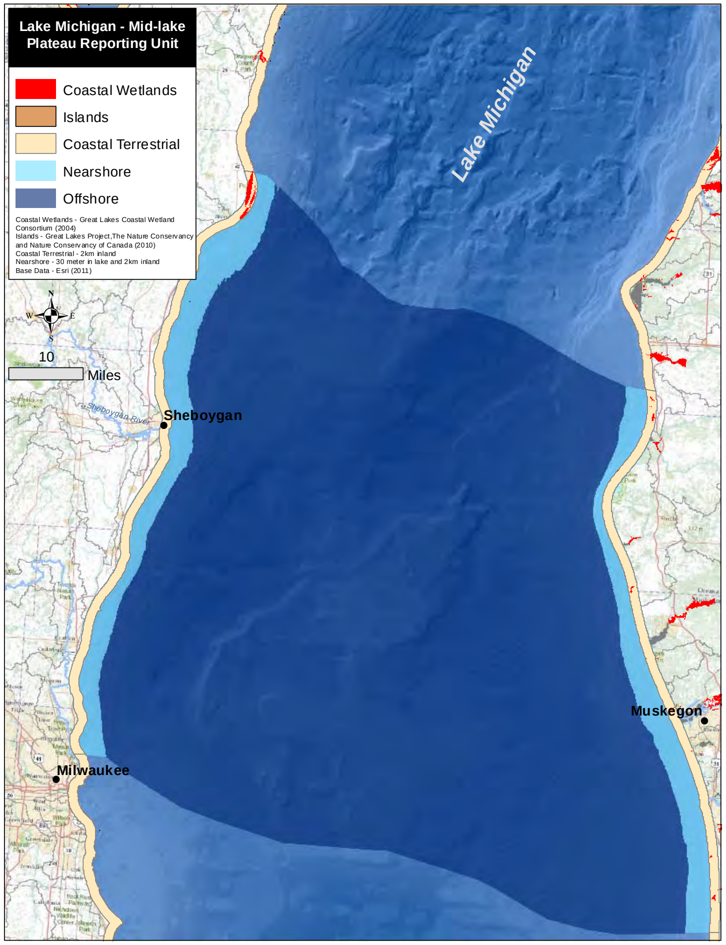
Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	Medium
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Good	High
Islands	Good	High
Native Migratory Fish	Fair	High
Offshore Zone	Fair	Medium
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Invasive Non-Native Aquatic Species		High	High	High	High	High	High	Very High
Invasive non-native terrestrial species	High	Medium	Medium	Low	Medium	High	High	High
Housing & Urban Development	Medium		Medium		Not Specified	High	High	High
Incompatible fisheries management	Not Specified	Low	Low	Medium	Low	Medium	Medium	Medium
Shoreline Alterations	Medium		Not Specified		Medium	Medium	Medium	Medium
Pollution: Urban and household sources	Medium	Medium	Low	Not Specified	Medium	Medium	Medium	Medium
Pollution: Agriculture and forestry sources		Medium			High	Medium	Medium	Medium
Dams & other Barriers		High			Not Specified	Low	Medium	Medium
Recreational activities	Low		Low		Medium	Low	Medium	Medium
Climate change: Habitat shifting & alteration	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium
Agriculture: Annual & Perennial Nontimber Crops	Medium					High		Medium
Diking of wetlands		Medium			Medium	Medium	Low	Medium
Pollution: Industrial sources				Medium	Medium	Medium	Medium	Medium
Renewable Energy	Low	Not Specified	Medium		Low	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Contaminated sediments	Low		Medium	Not Specified	Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Low	Low		Low	Low	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium	Medium
Mining & Quarrying	Low		Low		Low	Low	Low	Low
Non-renewable energy	Low				Low	Low	Low	Low
Summary Target Ratings:	High	High	Medium	Medium	High	Very High	High	Very High

4. Mid-Lake Plateau



Shoreline Length:	**272 km**
Coastal Area (2km inland):	5,354 km^2
Baymouth/barrier beach:	13%
Bedrock:	0%
Cliff/bluff:	35%
Cobble/gravel:	0%
Artificial shoreline:	3%
Sandy Beach/dunes:	46%

Viability and Threat Summary

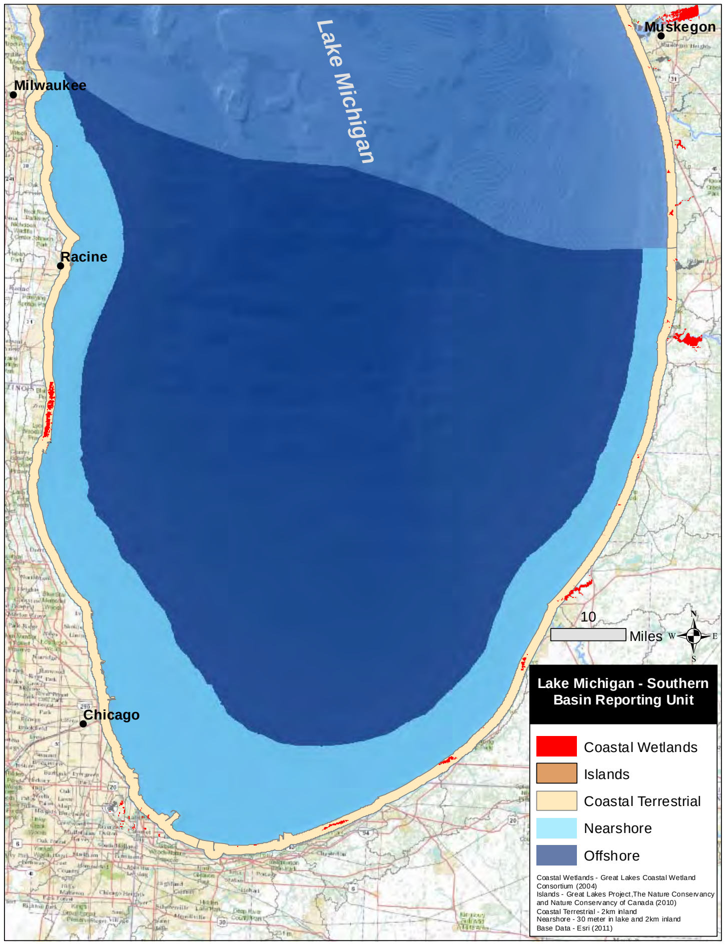
Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	Medium
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Fair	High
Islands	Good	Medium
Native Migratory Fish	Fair	High
Offshore Zone	Fair	Medium
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Invasive Non-Native Aquatic Species		High	Medium	High	High	Medium	Medium	High
Climate change: Habitat shifting & alteration	High	Medium	Medium	Medium	High	High	High	High
Mining & Quarrying	Low		Low		Low	Medium	Medium	Medium
Incompatible fisheries management	Not Specified	Medium	Low	Medium	Medium	Medium	Medium	Medium
Shoreline Alterations	Medium		Not Specified		Medium	Medium	Medium	Medium
Pollution: Urban and household sources	Low	Medium	Low	Not Specified	Medium	Medium	Medium	Medium
Pollution: Agriculture and forestry sources		Medium		Low	Medium	Medium	Medium	Medium
Invasive non-native terrestrial species	Medium	Medium	Medium		Low	Medium	Medium	Medium
Dams & Other Barriers		High			Not Specified	Medium	Medium	Medium
Recreational activities	Low		Low		Low	Medium	Medium	Medium
Housing & Urban Development	Medium		Medium		Not Specified	High	Medium	Medium
Agriculture: Annual & Perennial Nontimber Crops						High		Medium
Diking of wetlands		Medium			Low	Medium	Medium	Medium
Pollution: Industrial sources				Medium	Medium	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Renewable Energy	Low	Not Specified	Medium		Medium	Medium	Medium	Medium
Contaminated sediments	Low		Low	Not Specified	Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Low	Medium		Low	Medium	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Low	Low	Medium	Medium	Medium
Non-renewable energy	Low				Low	Low	Low	Low
Summary Target Ratings:	Medium	High	Medium	Medium	High	Very High	High	Very High

5. Southern Basin



Shoreline length:	**447 km**
Coastal Area (2km inland):	7,120 km^2
Baymouth/Barrier beach:	10%
Bedrock:	0%
Cliff/bluff:	38%
Cobble/gravel:	0%
Artificial shoreline:	28%
Sandy Beach/dunes:	22%

Viability and Threat Summary

Target	Viability Status	Threat Status
Nearshore Zone	Fair	Very High
Aerial Migrants	Fair	High
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Fair	Very High
Islands	Good	High
Native Migratory Fish	Poor	High
Offshore Zone	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
Shoreline Alterations	Medium		Not Specified		High	High	High	High
Pollution: Urban and household sources	Medium	Medium	Medium	Not Specified	High	High	High	High
Pollution: Agriculture and forestry sources		Medium		Medium	Medium	High	High	High
Invasive Non-Native Aquatic Species		High	Medium	High	High	High	High	High
Invasive non-native terrestrial species	High	High	High	Low	Medium	High	High	High
Housing & Urban Development	Medium		High		Not Specified	High	High	High
Climate change: Habitat shifting & alteration	High	Medium	High	Medium	High	High	High	High
Pollution: Industrial sources				Medium	High	High	High	High
Mining & Quarrying	Low		Low		Low	Medium	Medium	Medium
Incompatible fisheries management	Not Specified	Medium	Low	Medium	Medium	Low	Medium	Medium
Dams & Other Barriers		High			Not Specified	Medium	Medium	Medium
Recreational activities	Medium		Medium		Medium	Medium	Medium	Medium
Diking of wetlands		Medium			Medium	Medium	High	Medium
Non-renewable energy	Low				Low	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Renewable Energy	Medium	Not Specified	Medium		Medium	Medium	Medium	Medium
Contaminated sediments	Medium		Low	Not Specified	Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Medium	Medium		Low	Medium	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium	Medium
Agriculture: Annual & Perennial Nontimber Crops						Medium		Low
Summary Target Ratings:	High	High	High	High	Very High	Very High	Very High	Very High

APPENDIX H: CLIMATE TRENDS FOR LAKE MICHIGAN, 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 coastal areas and Great Lakes islands will serve as climatic refugia for species that are highly stressed by increasing summer temperatures, and this "service" can potentially be added to factors used to determine where to prioritize our conservation investments. 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 inhabiting the coastal areas.

Temperature as a driver of impacts on Lake Michigan

In addition to acting as a direct stressor on species 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). While we would expect increases in water temperatures as air temperatures increase, summer surface water (defined as the upper 30 m) temperatures in the upper Great Lakes, including Lake Michigan, are currently increasing even faster than air temperatures (Austin and Colman 2007, see Table 1). 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). While highly variable from year to year, ice cover on Lake

Michigan has been declining at an average rate of 2% a year from 1973-2010, leading to an overall reduction in annual ice area of 77% (Wang et al. 2011). 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 Colman 2007, 2008, Dobiesz and Lester 2009). As the example of surface water temperature changes suggest, understanding and planning for temperature change impacts on the species, ecosystems, and processes of Lake Michigan is a challenge, as we need to think about both the potential impacts of temperatures increasing at an accelerating rate, and about the potential for feedback loops, exceedance of critical thresholds, and the potential for tipping points, defined as dramatic shifts in an ecosystem in response to an incremental change.

Table 1: Estimated rate of change in summer (July-September) temperature (T), duration of the stratified period, and increase in wind speed for two locations in Lake Michigan from 1979-2006 (Source: Austin and Colman 2007, Table 1).

	Air T increase (°C/decade)	Surface water T increase (°C/ decade)	Start of the stratified season (days per decade earlier)	Increase in wind speed (meters/second per decade)
Northern site	0.74 ± 0.29	0.78 ± 0.36	5.8 ± 8.2	0.44 ± 0.07
Southern site	0.38 ± 0.29	0.51 ± 0.34	14.2 ± 5.5	0.30 ± 0.07

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. Researchers predict the duration of stratification by estimating when surface waters will go above and below about 4°C (McCormick and Fahnenstiel 1999). Given the information above on increases in surface water temperatures, we should expect increases in the duration of the stratified period in Lake Michigan, and indeed this duration has already increased by more than two to four weeks since the late 1970s (Table 1, data from Austin and Colman 2007). Although projections for future changes in stratification are not currently available for Lake Michigan, estimates for the end of this century for Lake Huron suggest that we could see increases in duration of 40-50 days by the 2050s, and 60-90 days by the 2080s relative to the 1980s (Trumpickas et al. 2009).

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, but some shallow water bodies will exhibit oxygen-poor "dead zones" because shallow water warms more rapidly, and warmer water holds less oxygen and leads to increases in respiration rates for aquatic species. As warming continues, and we see increases in the intensity of peak storms (see below) that bring more nutrients into the water that promote algal blooms (and contribute to low oxygen levels after they die and decay below the thermocline), we should expect a higher risk of oxygen depletion (hypoxia) in the shallow bays of the Great Lakes region such as Green Bay.

Warming temperatures in the Great Lakes region can also affect another important process that shapes Great Lakes habitats, especially in the coastal zone: The characteristics of winds, which drive currents, and influence the degree and extent stratification. 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 (Austin and Colman 2007, 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). While this research team did not calculate a percentage change for wind speed increases observed on Lake Michigan, they are also increasing, and magnitudes are similar to those reported for Lake Superior (Austin and Colman 2007, see Table 1 above). 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. However, the many changes in the Green Bay ecosystem that have occurred due to the wind direction changes observed (i.e., reduction in the amount of mixing with the rest of Lake Michigan, weakened stratification) emphasize the importance of understanding and anticipating wind-related impacts (Waples and Klump 2002).

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 "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).

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 further reduced the ability of natural systems to absorb storm impacts, especially in coastal areas 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) using 23 GCMs reported a median value for projected changes by 2050 of a 0.23m drop for all three emissions scenarios they tested (low-B1, medium-A1B, and high-A2). However, this work suggested a wide range of possible futures, as the “lowest” 5% of model runs suggest a drop of 0.79 to 0.94m or more by 2050, and the “highest” 5% of runs suggest increases of 0.15 – 0.42m (B1 – A2 scenarios) by 2050. 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 a meter of water to the lake levels relative to the old method, so final projections for two models were about a 1 m drop, or a 0.4 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 0.55 m drop for the same time period using the original version of the model, 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

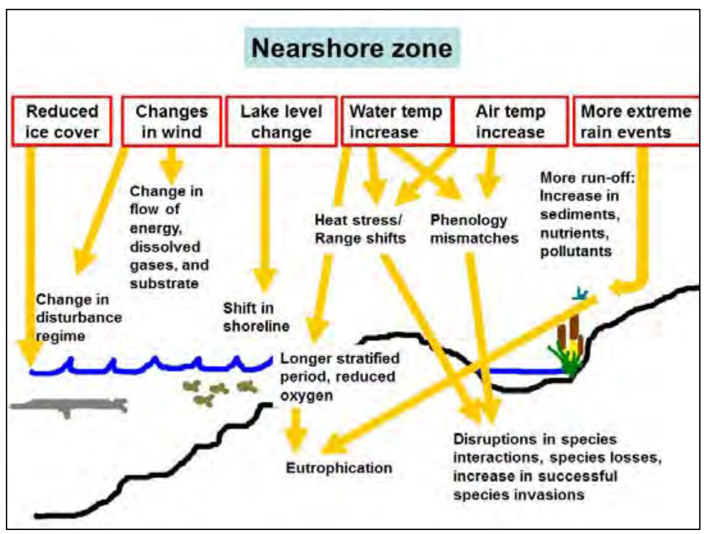
In terms of implications for biodiversity features, the direct impacts of temperature increases are primarily considered a threat because they are happening at such fast rates, and many species are not likely to be able to adapt, either due to limitations in physiology or mobility, or because anthropogenic changes in habitat seriously hinder adaptive responses. 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.

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 Michigan basin are of concern for several reasons. First, the rapid changes in climate described above are taking place in the context of a wide range of other impacts on these ecosystems, most notably habitat loss and fragmentation, such as coastal development, and the presence of dams and barriers. Even in areas where we have large expanses of intact ecosystems, increasing temperatures can make wetland habitats more fragmented as some patches dry out, an impact that can be accelerated if lake levels decline. Second, range and abundance changes are of concern because species that are not able to disperse will have the added stress of species from lower latitudes (both native and non-native invasive) invading their habitats. So, individuals at the southern end of their species' range have the potential to be stressed both by climatic conditions that are becoming less and less favorable, and by species that move in from warmer areas and are less challenged by the same climatic factors. The species moving in may directly compete for key resources, and also may contribute to the decline of resident species by spreading diseases and parasites. Third, we are concerned about range and abundance shifts because species movements will often be independent of shifts of other species. We expect species to shift independently, as the set of constraints that describe the habitat and ecological niche for each species (factors like water temperature, food availability, sediment type, and stream flow characteristics) is unique. In effect, we expect to see the "tearing apart" of sets of species that typically interact, and many of these interactions may be critical to the survival one or more of the interacting species.

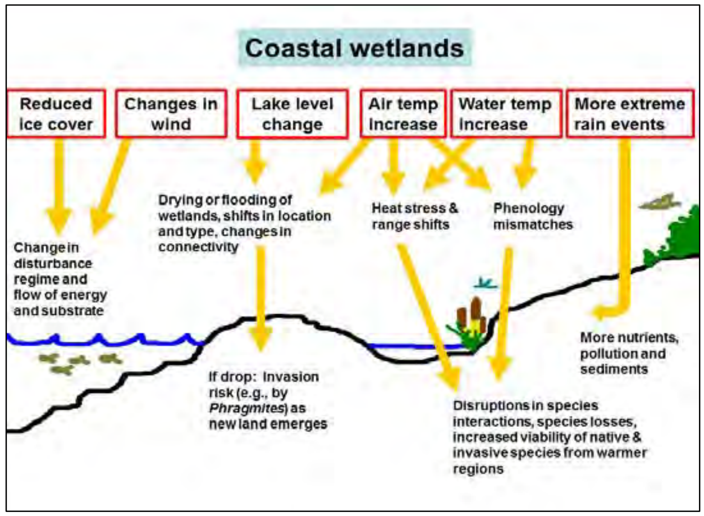
Concern about key species interactions also leads us to examine the potential for phenological mismatches, or disparate changes in the timing of seasonal events. For many organisms, seasonal changes in temperature act as cues that trigger transitions in the species' seasonal cycle, such as metamorphosis (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.

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. Habitats along the northern shore of Lake Michigan are analogous to systems on mountain tops; there is no habitat to the north that species can shift toward without crossing inhospitable areas. Other key concerns include stresses related to invasive species; for example, if lake levels do drop, many newly exposed areas will be at risk of invasion from *Phragmites* and other non-native invasive plants. Coastal terrestrial systems are also likely to be exposed to higher drought stress in the summer, and more intense rain events, which may lead to erosion and reduced viability of sensitive coastal systems like wetlands. Further, changes in wind and current patterns are likely to lead to changes in key physical processes that shape coastal communities. As with all of our conservation features, there is also the potential for phenological mismatches that reduce the viability of key species.

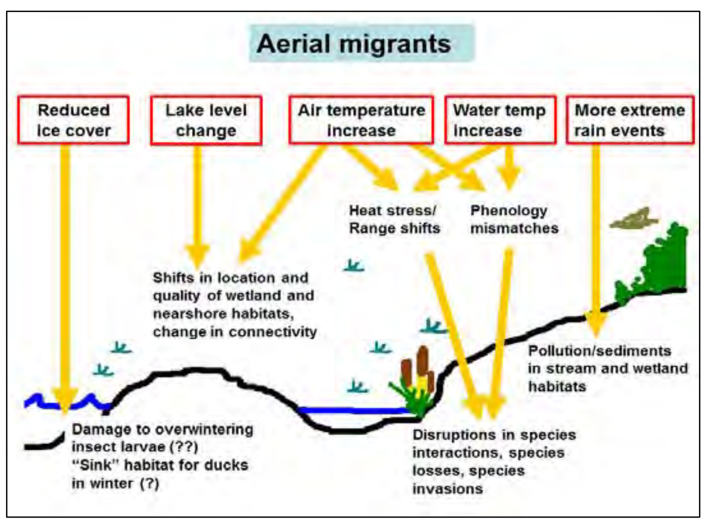
Nearshore Zone. Key concerns in the Nearshore Zone aquatic ecosystem include impacts related to hypoxia, as warmer water temperatures and a longer stratified period are expected to lead to higher summer oxygen depletion. These areas may also show phenological mismatches that influence food web dynamics,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



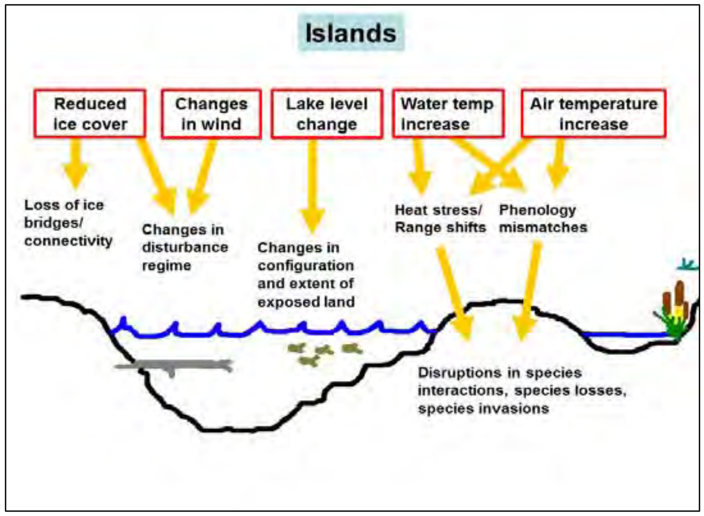
In addition to the aquatic environment, shoreline configuration, seasonal and decadal water level fluctuations, and bedrock geology, climate plays a significant role in structuring and maintaining Coastal Wetlands. Climate change, through warmer air temperatures, increases in evaporation, and changes in precipitation and snow cover, is expected to significantly alter the hydrology over the next 50 years, relative to the last 150 years (Mortsch et al., 2006). Changes in the mean lake level, annual range, and seasonal cycle as well as the timing, amplitude, and duration of water levels are expected to occur, although there is high uncertainty regarding the magnitude, timing, and direction of changes (see above). Of the possible changes, the most critical impact is projected to result from 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.



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

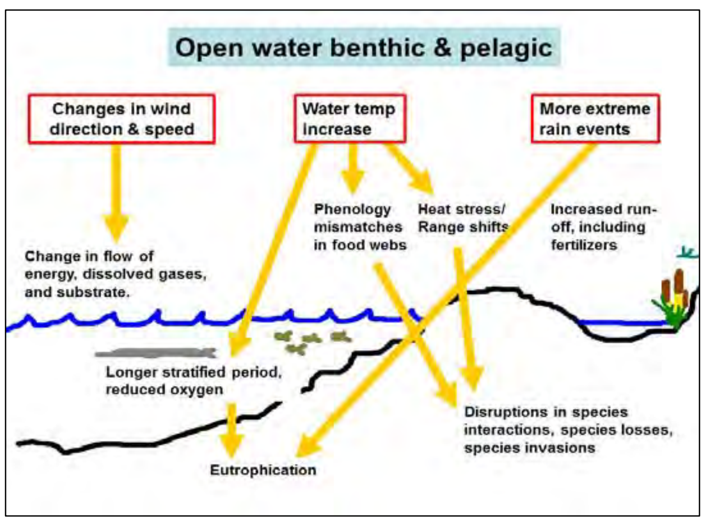


responses by species that are key elements of habitat or food sources.

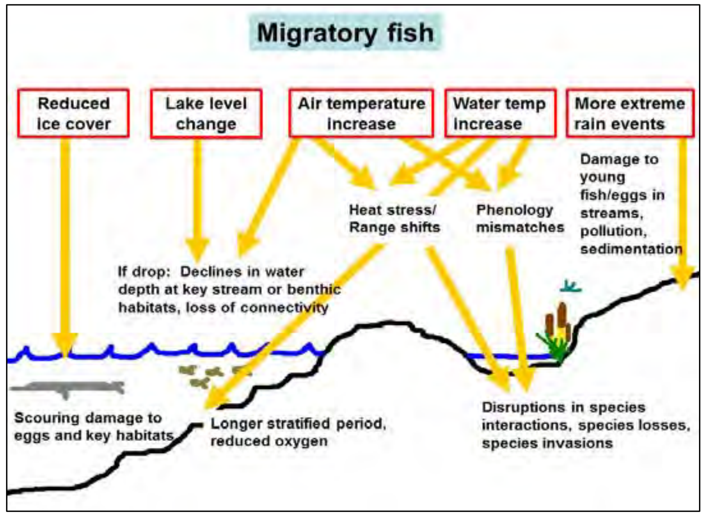


Islands are also expected to be at risk due to climate change impacts, largely due to concerns about the lack of connectivity for species that can't fly or swim (e.g., plants, some insects and reptiles) that would potentially benefit from northward movement. Also, changes in ice cover and duration (e.g., 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 Ecosystems 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 Michigan 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 food webs (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.



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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?)

Instructions:

- Using a flip chart, create a table including one column for strategies and three additional columns for potential impact, feasibility, and total.
- Begin ranking your strategies in terms of potential impact by giving the strategy you think is likely to have the greatest impact the highest ranking (e.g., a 6 if you have 6 strategies), and the one with lowest impact the lowest ranking (see box below for criteria for rating strategies).
- Continue ranking remaining strategies for potential impact
- Repeat process for feasibility
- Add scores for potential impact and feasibility
- Strategy with the highest total score is the best strategy

Criteria for Rating Strategies:

Potential Impact - If implemented, will the strategy lead to desired changes in the situation at your project site?

- **Very High** - The strategy is very likely to completely mitigate a threat or restore a target.
- **High** - The strategy is likely to help mitigate a threat or restore a target.
- **Medium** - The strategy could possibly help mitigate a threat or restore a target.
- **Low** - The strategy will probably not contribute to meaningful threat mitigation or target restoration.

Feasibility - Would your project team be able to implement the strategy within likely time, financial, staffing, ethical, and other constraints?

- **Very High** - The strategy is ethically, technically, AND financially feasible.
- **High** - The strategy is ethically and technically feasible, but may require some additional financial resources.
- **Medium** - The strategy is ethically feasible, but either technically OR financially difficult without substantial additional resources.
- **Low** -The strategy is not ethically, technically, OR financially feasible.

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
Provisioning Services - Fresh Water (Water supply)	162	1
Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	158	2
Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	158	3
Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	158	4
Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	154	5
Cultural Services - Aesthetic values (Aesthetics)	152	6
Supporting Services - Water cycling (Soil moisture storage)	150	7
Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	149	8
Cultural Services - Sense of place	142	9
Supporting Services - Nutrient cycling (Nutrient storage)	142	10
Cultural Services - Inspiration	141	11
Cultural Services - Educational values	136	12
Cultural Services - Cultural heritage values	135	13
Provisioning Services - Food (Wild game)	128	14
Regulating Services - Air quality maintenance (Air purification, visibility)	124	15
Regulating Services - Water regulation (Flood mitigation)	124	16
Cultural Services - Cultural diversity	116	17
Cultural Services - Spiritual and religious values	116	18
Cultural Services - Knowledge systems	115	19
Regulating Services - Erosion control	109	20
Regulating Services - Storm protection	106	21
Cultural Services - Social relations	105	22
Supporting Services - Production of atmospheric oxygen	104	23
Provisioning Services - Genetic Resources	103	24
Supporting Services - Soil formation and retention (Soil renewal, renewal of soil fertility)	102	25
Regulating Services - Regulation of human diseases	91	26
Provisioning Services - Fiber (Timber production)	87	27
Regulating Services - Pollination (Pollination)	87	28

Regulating Services - Biological control (Pest control)	85	29
Provisioning Services - Fuel/energy (Hydro-electricity)	83	30
Provisioning Services - Ornamental Resources	74	31
Provisioning Services - Biochemicals, natural medicines, and pharmaceuticals (Medicines)	71	32

APPENDIX K. RELATIONSHIP OF LAKE MICHIGAN BIODIVERSITY CONSERVATION STRATEGIES TO THE GREAT LAKES RESTORATION INITIATIVE ACTION PLAN AND OTHER PLANS AND INITIATIVES.

Crosswalk of Lake Michigan biodiversity conservation strategies with GLRI Action Plan

Toxic Substances and areas of concern

Great Lakes Restoration Initiative Action Plan		LMBCS	
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.		
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		LMBCS	
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.		
	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.		

Great Lakes Restoration Initiative Action Plan			LMBCS
Goals	Objectives	Strategies	Objectives
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.	Agreements among Great Lakes States for Invasive species in Lake Michigan	▪By 2013, all ten Great Lakes states and provinces will reach agreement on risk assessment tools for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These tools would need to be based on the latest science. By 2013, all ten Great Lakes states and provinces will reach agreement on a structure for coordination for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture) By 2014, all ten Great Lakes states and provinces will reach agreement on minimum protective regulations related to at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These regulations would need to be science based and linked to the risk assessment tools mentioned in Result 1 above.

Great Lakes Restoration Initiative Action Plan		LMBCS	
Goals	Objectives	Strategies	Objectives
3. The spread of invasive species, by means of recreational activities, connecting waterways, and other vectors, beyond their current range is prevented.			
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.	Early detection and rapid response network for invasive species in Lake Michigan	By 2013, sustainable funding for all components of data management infrastructure is in place. Currently, network pieces are in place and linked through GLEDN, but need sustainable funding. By 2013, all lakewide data systems are compatibly linked and accessible for both upload and download from one site. This system will enable both online mapping and interactive input and editing of data by qualified users. By 20XX , for all species listed in the unified database, accepted and effective control protocols exist.
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

<table>
<tr><th colspan="2">Great Lakes Restoration Initiative Action Plan</th><th colspan="2">LMBCS</th></tr>
<tr><th>Goals</th><th>Objectives</th><th>Strategies</th><th>Objectives</th></tr>
<tr><td rowspan="3">1. The introduction of new invasive species to the Great Lakes basin ecosystem is eliminated, reflecting a “zero tolerance policy” toward invasives.</td><td rowspan="2">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.</td><td>Agreements among Great Lakes States for invasive species in Lake Michigan</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>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.</td><td></td><td></td></tr>
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Great Lakes Restoration Initiative Action Plan			LMBCS
Goals	Objectives	Strategies	Objectives
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.	Agreements among Great Lakes States for invasive species in Lake Michigan	▪By 2013, all ten Great Lakes states and provinces will reach agreement on risk assessment tools for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These tools would need to be based on the latest science. ▪By 2013, all ten Great Lakes states and provinces will reach agreement on a structure for coordination for at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture) ▪By 2014, all ten Great Lakes states and provinces will reach agreement on minimum protective regulations related to at least one of the four potential pathways (shipping, live trade, boat/rec, horticulture). These regulations would need to be science based and linked to the risk assessment tools mentioned in Result 1 above.

Great Lakes Restoration Initiative Action Plan		LMBCS	
Goals	Objectives	Strategies	Objectives
3. The spread of invasive species, by means of recreational activities, connecting waterways, and other vectors, beyond their current range is prevented.			
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.	Early detection and rapid response network for invasive species in Lake Michigan	By 2013, sustainable funding for all components of data management infrastructure is in place. Currently, network pieces are in place and linked through GLEDN, but need sustainable funding. This objective has two measures. ▪By 20XX , for all species listed in the unified database, accepted and effective control protocols exist.
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		LMBCS	
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.		
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.		
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.		

Great Lakes Restoration Initiative Action Plan		LMBCS	
Goals	Objectives	Strategies	Objectives
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.		
	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		LMBCS	
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.	Lake Michigan road-stream crossing – increase connectivity at road-stream crossing at a large scale	
	By 2014, a baseline will be established for total suspended solids loadings from targeted tributaries.	Promote and implement green infrastructure and strengthen NPS management	Reduce Total Suspended Phosphorus (TSS) in Municipal Separate Storm (MS4) water by at least 40% by 2014. This objective is in effect in Wisconsin I now, and the deadline there is 2013. The effectiveness will be measured relative to 2004 levels, which are prior to the installation of storm water BMPs. In some communities, new construction must meet 80% reduction in TSS.

Great Lakes Restoration Initiative Action Plan		LMBCS	
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.	Market Mechanisms: Nutrient Trading	By 2015, a location has been identified that meets the criteria for a watershed market and willing buyers have been identified. ▪By 2016, required resources have been secured to initiate at least one project in the Lake Michigan basin to test use of markets to implement agricultural conservation practices.

Habitat and wildlife protection and restoration

Great Lakes Restoration Initiative Action Plan		LMBCS	
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.		
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.	Use Coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecoligcal processes	▪By 2022, 50% of large public land holdings with significant natural features in coastal zone are managed for ecological values ▪By 2020, all public lands in the coastal zone that contain significant natural features have a management plan that addresses coastal biodiversity and supporting processes
		Increase Connectivity to Lake Michigan through Development and Use of a Comprehensive Lowest Barrier Decision Tool	▪By 2015 management groups (federal, tribal, state) would use the decision tool to set priorities for connectivity restoration across Lake Michigan 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 2025 all applicable watershed plans have incorporated the recommendations for addressing barriers generated through the prioritization process.

Great Lakes Restoration Initiative Action Plan		LMBCS	
Goals	Objectives	Strategies	Objectives
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.	Use Coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes	▪By 2030, 80% of high priority coastal areas are protected. ▪By 2025, 25% of priority restoration sites in the coastal zone are in the process of being restored.
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.	Use Coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes	▪By 2020, >50% of coastal communities in significant biodiversity areas are actively involved in at least on a collaborative effort to protect/restore coastal targets. ▪By 2025, >50% of municipalities have effectively integrated coastal targets into master land use plans
	By 2014, 30 habitat-related beneficial use impairments will be delisted across the Areas of Concern.		

Great Lakes Restoration Initiative Action Plan		LMBCS	
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.	Use Coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes	▪Spatially based analysis of biodiversity in Coastal zone is completed by fall of 2012 ▪Identification of priority places in coastal zone for meeting conservation targets and goals (including threats analysis), is completed by 2013 ▪Spatially based ecological information on Lake MI coastal zone is accessible via the World Wide Web by middle of 2014 ▪Land Use Plan assessment of local units of government completed by 2014 ▪Coastal conservation/restoration plans from around Lake are summarized by 2014 ▪By 2030, 100% of all development proposals in the coastal zone are assessed for their impacts on coastal biodiversity and supporting processes as part of the formal approval process

Accountability, education, monitoring, evaluation, communication and partnerships

Great Lakes Restoration Initiative Action Plan		LMBCS	
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		LMBCS	
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 and Initiatives
Reducing the impact of agricultural non-point source pollutants	Development of a communications network within the agricultural community	▪Lake Michigan LaMP Subogal 2, Subgoal7 ▪Michigan Agriculture Environmental Assurance Program ▪Great Lakes Conservation Effects Assessment Project(CEAP) ▪Institute of Water Research(MSU) High Impact Targeting ▪The Conservation Technology Information Center at Purdue University ▪Conservation Agriculture Systems Alliance (CASA0 ▪GLRI Action Plan Near shore goal 5, ▪Section 6217 Coastal Management Plans
	Market mechanisms: nutrient trading	▪ Lake Michigan LaMP Subgoal 2, Subgoal 7 ▪Michigan Agriculture Environmental Assurance Program ▪Great Lakes Conservation Effects Assessment Project (CEAP) ▪Ohio EPA Water Quality Trading Program ▪Ohio River Water Quality Trading Project ▪Maryland Nutrient Trading Program ▪GLRI Action Plan Near shore goal 5 ▪The U.S Army Corps of Engineers(USACE)
Preventing and reducing the impact of invasive species (aquatic and terrestrial	Agreements among great lakes states for invasive species in Lake Michigan	▪GLRI Action Plan, Focus Area 2:Invasive Species, Goal 1. Objective to establish 8 state ANS management plans ▪Lake Michigan LaMP, Subgoal 8
	Early detection and rapid response network for invasive species in Lake Michigan	▪GLRI Action Plan, Focus Area 2: Invasive Species, Goal 1, Objective to establish 8 state ANS management plans ▪Lake Michigan LaMP, Subgoal 8

Strategies	Priority Strategies	Related strategies and Initiatives
Coastal conservation: preventing and reducing the impacts of incompatible development and shoreline alterations	Use coordinated land use planning to align future development in the coastal zone with biodiversity conservation and ecological processes	▪Lake Erie Biodiversity Conservation Strategies for Coastal Conservation ▪Illinois Lake Michigan Implementation Plan (in progress) ▪Coastal & Estuarine Land Conservation Plans (CELCPs) ▪IL DNR Coastal Management Program Document ▪Chicago Wilderness Biodiversity Recovery Strategy ▪The Indiana Lake Michigan Coastal Program of the IN DNR report "A synthesis of environmental goals and objectives: plans and strategies for Indiana's Lake Michigan region" ▪GLRI Action Plan, Near shore goal 2 and habitat goal 3
Reducing the impacts of urban non-point and point source pollutants	Promote and implement green infrastructure and strengthen NPS management	▪The Lake Michigan LaMP (U.S EPA 2008) pages 6-9 ▪The U.S EPA Office of Wastewater Management ▪Lake Michigan cities that have implemented stormwater management BMPSs and have set quantitative goals for reduction of runoff and/or standards for new construction include Milwaukee, Chicago and Grand Rapids, see Green CITTS ▪Wisconsin storm water regulations summary fact sheet ▪Wisconsin administrative Codes NR 216 storm water permitting and NR 151 runoff management ▪ Wisconsin administrative Code NR 105 surface water quality criteria and secondary values for toxic substances ▪ Wisconsin Technical Standards to meet NR 216 and NR 151 Wis. Administration Codes ▪Great Lakes united Study funded through the Great Lakes Protection Fund ▪GLRI Action Plan, Toxics goal 2
Restoration of offshore fisheries	Restore Cisco in Lake Michigan	▪ Cisco restoration efforts in Grand Traverse Bay ▪Cisco stocking on Lake Huron ▪Cisco rehabilitation efforts in Lake Ontario ▪Great Lakes Fishery Commission Fish Community Objectives ▪Lake Michigan Integrated Fisheries Management Plan (2003-2013)-WI DNR (Goal 1, Objective B) ▪GLRI Action Plan, Habitat goal 1

Strategies	Priority Strategies	Related strategies and Initiatives
	Broaden constituency for Sea Lamprey control	▪Great Lakes Fishery Commission- Joint Strategic Plan for Management of Great Lakes Fisheries ▪GLRI Action Plan, Invasive Species goals 3 and 5
Improving habitat connectivity by reducing the impact of dams and other barriers	Increase connectivity to Lake Michigan through development and use of a comprehensive lowest barrier decision tool	▪ Lake Michigan LaMP Objectives ▪Great Lakes Fishery Commission Lake Michigan Fish Community Objectives ▪Aquatic Connectivity is one of four focal issues of the Sustain our Great Lakes program of the National Fish and Wildlife Foundation ▪Great Lakes ecological connectivity project ▪Great Lakes Fishery Commission Lake Michigan Technical Committee, Habitat Working Group, Great Lakes Aquatic Connectivity Project ▪GLRI Action Plan, Habitat goal 2
	Increase connectivity at road-stream crossing at a large scale	▪Great Lakes Fishery Commission Lake Michigan Technical Committee, Habitat Working Group, Great Lakes Aquatic Connectivity Project ▪Great Lakes ecological connectivity project ▪Great Lakes Information Management and Delivery System (led by TNC and USGS, funded by USFWS through the Upper Mississippi and Great Lakes Landscape Conservation Cooperative) ▪Aquatic Connectivity is one of four focal issues of the Sustain our Great Lakes program of the National Fish and Wildlife Foundation ▪Significant momentum in dealing with problem road-stream crossings in the northern lower peninsula of Michigan (Conservation Resource Alliance and partners) ▪Great Lakes Restoration Initiative Action Plan, Habitat goal 2 ▪Section 6217 Coastal Management Plans; for example, the Indiana 6217 plan includes best practices for road construction and inventory and evaluate dam impacts