2016

State of the Strait: Coordinating Conservation in the St. Clair-Detroit River System

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STATE of the STRAIT

Coordinating Conservation in the St. Clair-Detroit River System 2016

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Based on the 2015 State of the Strait Conference held at Eastern Michigan University, Ypsilanti, Michigan, USA

Suggested citation: Francoeur, S., J. Ciborowski, J. Gannon, D. Kashian and K. Kahl, eds. 2016. State of the Strait: Coordinating Conservation in the St. Clair-Detroit River System. Great Lakes Institute for Environmental Research, Occasional Publication No. 9,
University of Windsor, Ontario, Canada
ISSN 1715-3980

Report also available at: www.stateofthestrait.org

Acknowledgements

The biennial State of the Strait Conference is a collaborative effort of numerous Canadian and U.S. agencies, institutions, and organizations. Any binational effort covering such a broad scope, by nature, requires considerable collaboration and many contributions. The 2015 State of the Strait Conference and this report would not be possible without the generous support of our many sponsors. We gratefully acknowledge the following supporters:

- Detroit River Canadian Cleanup
- Eastern Michigan University
- Environment Canada
- Friends of the Detroit River
- International Joint Commission, Great Lakes Regional Office
- International Wildlife Refuge Alliance
- Michigan Department of Environmental Quality
- University of Michigan-Dearborn
- University of Windsor
- U.S. Fish and Wildlife Service
- Wayne State University

The management and direction of this project was handled by the State of the Strait Steering Committee made up of the following members:

- Raj Bejankiwar, International Joint Commission
- Mary Bohling, Michigan Sea Grant
- Jan Ciborowski, University of Windsor, Conference Co-Chair
- Anna Cook, U.S. Fish and Wildlife Service
- Jesse Gardner-Costa, University of Windsor
- Richard Drouin, Ontario Ministry of Natural Resources
- Steve Francoeur, Eastern Michigan University, Conference Co-Chair
- John Gannon, USGS Great Lakes Science Center (retired)
- Orin Gelderloos, University of Michigan-Dearborn
- John Hartig, U.S. Fish and Wildlife Service
- Katherine Kahl, The Nature Conservancy
- Donna Kashian, Wayne State University
- Ethan Lowenstein, Eastern Michigan University
- Greg Norwood, U.S. Fish and Wildlife Service

- Bill Parkus, Southeast Michigan Council of Governments
- Claire Sanders, Detroit River Canadian Cleanup
- Chad Segrist, Detroit Institute of Technology
- Michelle Selzer, Michigan Department of Natural Resources and Environment
- Katherine Stammler, Essex Region Conservation Authority
- Lisa Voelker, Eastern Michigan University
- Bill Welsh, Eastern Michigan University
- YichunXie, Eastern Michigan University

We would also like to extend our gratitude to those who shared their data and research through presentations, posters, displays and discussions. Their thought-provoking work was key to the overall success of the conference, as well as essential to our understanding of the current status of the St. Clair-Detroit River system.
In addition, we would like to take all those who attended the conference, including local citizens, environmental and conservation organizations, researchers, students, and government and industry representatives who all played an important role in the success of the conference.

Special thanks are extended to Meg Castro, Eastern Michigan University Event Planning Office, and the student volunteers from Eastern Michigan University's Biology Department for their assistance with the conference.

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1.0 Introduction

The State of the Strait is a one-day conference held every two years that brings together government managers, researchers, students, environmental and conservation organizations, and concerned citizens from the United States and Canada to assess ecosystem status and provide advice to improve research, monitoring and management. Themes explored by past conferences include: status and trends of the Detroit River ecosystem (2001), monitoring for sound management (2004), status and trends of key indicators (2006), ecological benefits of habitat modification (2009), use of remote sensing and GIS in management (2011), and ecological endpoints and management targets (2013).

The seventh biennial State of the Strait conference was held on December 9, 2015 at Eastern Michigan University in Ypsilanti, Michigan. The theme for the 2015 conference was "Coordinating Conservation in the St. Clair-Detroit River System". A total of 12 oral presentations, 8 poster presentations and a 5-member discussion panel (see conference program in Section 6) highlighted some of the current conservation efforts and management plans in the St. Clair-Detroit River system. The goal of the conference was to summarize the results of existing projects and to facilitate cooperation and harmonization in the development of future projects.

The St. Clair-Detroit River system is comprised of the southern end of Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, and the western basin of Lake Erie. Located at the center of the Great Lakes, the St. Clair-Detroit River system connects the upper and lower Great Lakes and is ecologically and economically significant to the region.

The St. Clair-Detroit River system provides habitat for over 65 species of fish, and serves as a major fish migration corridor. It is part of an internationally-important migration corridor for waterfowl and other migratory birds, and contains some of the largest and most diverse wetlands remaining in the region. For example, the St. Clair delta is one of the most biologically diverse ecosystems in North America and has been designated a wetland of international importance by the United Nations. At the same time, the St. Clair-Detroit River system is one of the busiest navigation corridors in the United States, a major international trade route, and a center of industrial development. It is home to the highest density of commercial ports anywhere in the Great Lakes region, and is a major source of drinking water for over 5 million residents of Michigan, Ohio and Ontario.

Multiple, sometimes conflicting uses of the St. Clair-Detroit River system for waste disposal, water withdrawals, shoreline development, shipping, recreation and fishing have resulted in numerous environmental stresses to the system, including the effects of contaminated sediments, the introduction of non-native species, hardening of shorelines and infilling of coastal wetlands, construction of shipping channels, and urban sprawl. This has resulted in the designation of six U.S.-Canada Great Lakes Water Quality AgreementAreas of Concern (AOC) within the region, the highest concentration of AOCs anywhere in the Great Lakes.

The ecological significance and often-conflicting economic uses of the St. Clair-Detroit River system make it an area that is actively managed by multiple local, state, provincial, federal, and international government agencies and non-governmental organizations. There is a need to share information, monitoring techniques, indicators and goal-setting approaches in order to better coordinate conservation planning, funding and implementation toward shared outcomes if we are to achieve maximal benefit from the resources invested.

This report summarizes the presentations and key findings from the 2015 State of the Strait conference. Extended abstracts for oral presentations and posters are presented. Along with a summary, the State of the Strait Steering Committee has prepared recommendations for enhancing the coordination of existing and future management activities in the St. Clair-Detroit River system identified at the conferences.

2.0 Summary and Recommendations

Encouraging! Who can't be encouraged by the breadth and depth of conservation and restoration planning and activities and projects being undertaken in the St. Clair-Detroit River system and western Lake Erie upon perusal of the abstracts of oral and poster sessions presented at the State of the Strait Conference? Professionals, interested citizens and student attendees heard seven resource management and planning initiatives, most of them involving binational communication and cooperation. Six presentations concerned urban forest, wetlands, and coastal habitat conservation and restoration, and six more addressed protection and restoration of aquatic organisms and habitats.

Industrialization, agriculture and municipal development of the St. Clair-Detroit River system destroyed or degraded natural habitats throughout the region on both sides of the border over several hundred years. Yet today, thanks to improvements in environmental quality brought about by regulatory programs and changes in municipal and industrial practices towards environmentally sustainable economic development, challenges and opportunities for conservation and restoration abound. It is indeed encouraging to report on improvements in fish and wildlife conservation efforts in the midst of one of the Great Lakes' major municipal and industrial corridors.

The conference was successful in providing a forum for networking and sharing of information on urban, coastal, wetland, and aquatic conservation and restoration in the St. Clair-Detroit River system and western Lake Erie; but can we make strides beyond sharing of information? What are the challenges and opportunities in better coordinating activities, making best use of available financial and human resources, and striving towards common conservation goals and desired outcomes? To that end, the panel discussion during the conference addressed where we'd like to be in five years. What advancements can be made in five years to towards focused, measurable conservation and restoration implementation in the St. Clair-Detroit River system and western Lake Erie?

These are the common themes and recommendations arising from the conference:

<u>Align Common Goals, Outcomes and Indicators.</u> Adaptive management, even if not explicitly stated, was a common thread among the various resource planning and implementation activities presented at the conference. The elements of adaptive

management in a conservation and restoration context are:

- Set goals and implement projects designed to achieve those goals.
- Monitor how the species, habitats, systems or functions respond.
- Refine or adjust the project based on monitoring results.
- Repeat refinements, adjustments and monitoring until goals are met.

Continuation of adaptive management as a common practice should be encouraged, but there also is merit in regularly reviewing the goals set to achieve ultimate outcomes of the various initiatives, then checking for alignment among regional ecological, social and economic initiatives and asking:

- Are there incompatibilities?
- Can some goals be refined for better alignment of outcomes?
- Are monitoring programs and indicators sufficiently developed and aligned to track goal attainment?
- How are project status and goal attainment being disseminated among practitioners, funders, planners and policy-makers to enable regional, focused action toward shared conservation goals and outcomes?

Recommendation: Given the various conservation and human-wellbeing target- and goal-setting initiatives underway in the St. Clair- Detroit River system and western Lake Erie, including: 1) the Lake Erie Biodiversity Conservation Strategy; 2) the St. Clair-Detroit River System Initiative (SCDRS); 3) The Nature Conservancy's western Lake Erie coastal conservation visioning (optimization analysis); and 4) the Upper Midwest & Great Lakes Landscape Conservation Cooperative's coastal Landscape Conservation Design, we should look across these regional initiatives for opportunities to ensure agreement around common goals, monitoring efforts, indicators and outcomes, in order so that we may create and implement plans most effectively.

<u>"Top-down" and "Bottom-up Programs".</u> Many of the conservation and restoration activities in the St. Clair-Detroit River system and western Lake Erie are "top-down" programs, i.e., formal agreements between governments, such as Remedial Action Plans (RAPs) in the Areas of Concern (AOCs) and the Lake Erie Lakewide Action and Management Plan (LAMP) under the auspices of the U.S.-Canada Great Lakes Water Quality Agreement. Others involve agreements to coordinate among non-governmental organizations and academic institutions. The State of the Strait Conference and SCDRSare examples of "bottom-up" activities, whereby interested individuals got together without mandates or agreements to organize the binational stakeholders. Such "bottom-up" initiatives are to be encouraged because personal drive and enthusiasm often sustain activities while "top-down" programs sometimes come and go with changes in political priorities.

Recommendation: Seek opportunities to leverage and support "bottom-up" initiatives to augment and mutually reinforce "top-down" conservation programs in the St. Clair-Detroit

River system and western Lake Erie.

Conservation and Restoration Communication. With such a vibrant conservation community, it behooves all involved to find better communication methods to share lessons learned so that success stories can be adopted and adapted elsewhere. In this regard, there are also benefits in transforming data and information into a form that is more easily understood by the public, funders, and decision-makers. The Blue Accounting Framework has been established as a binational forum to do just that.

Recommendation: Consider using the Blue Accounting Framework (http://glc.org/projects/water-econ/blue-accounting/) and the evolving Great Lakes Inform (https://greatlakesinform.org/) platform for a binational, centralized way of sharing conservation knowledge, data, project tracking, and goal status information on the St. Clair-Detroit River system and western Lake Erie.

Habitat Restoration. There was a time not so many decades ago that the St. Clair-Detroit River system and western Lake Erie were considered so polluted and habitats so degraded that the thought of restoration was considered hopeless. Today, environmental conditions have improved to the extent that habitat restoration has become a reality. Binationally, the Detroit River International Wildlife Refuge has provided the umbrella for many successful habitat conservation initiatives, especially in the lower Detroit River region. On the U.S. side, thanks to the Great Lakes Legacy Act, the worst toxic sediment hot spots are being remediated. Since 2010, the Great Lakes Restoration Initiative has provided the necessary funding for many habitat conservation projects in the St. Clair-Detroit River system and western Lake Erie. On the Canadian side, Environment and Climate Change Canada has used a Sediment Quality Index (SQI) to guide toxic sediment removal in the locations where the greatest benefit to the ecosystem is likely to be achieved. Furthermore, Environment and Climate Change Canada through its Great Lakes Sustainability Fund has funded many habitat conservation and restoration projects in the Areas Of Concern. The numerous coastal projects along the Canadian side of the Detroit River conducted by the Essex Regional Conservation Authority and other partners are helping to address erosion problems while concurrently creating terrestrial and aquatic habitats.

Recommendation: Keep up the momentum of progress in the St. Clair-Detroit River system and western Lake Erie by maintaining and enhancing programs and funding for habitat protection and restoration.

Land-Water Linkages. Historically, most water quality investigations were conducted mainly in the open waters of lakes where conditions were considered to be more homogeneous and water samples were thought to be generally representative of lakewide conditions. In contrast, water quality conditions in rivers and wetlands and in the nearshore zones of lakes were believed to be too variable and complex to obtain representative samples. Furthermore, environmental assessments on land, in wetlands, and in rivers and lakes were conducted separately with little or no coordination. Today, as illustrated by many of the conference presentations, advances in water quality sampling techniques, statistical design and training of scientists are allowing for better integration of land and water investigations with the potential for improved ecosystem understanding and guidance for sound resource management and decision making.

Recommendation: Encourage an ecosystem approach to scientific investigations on species and habitat conservation and restoration in the St. Clair-Detroit River system and western Lake Erie with emphasis on land-water linkages to inform resource management and decision-making.

Youth Involvement. A regular feature of the State of the Strait Conferences has been to invite student groups to attend the conferences, listen to the presentations, participate in the discussions and interact with the other attendees. Future conservation progress will largely depend on instilling a sense of environmental ethics and stewardship among the younger generation. There are many opportunities for the public, including students, to participate in citizen science monitoring of wildlife, plants and habitats in the St. Clair-Detroit River system and western Lake Erie that can help instill a land ethic and sense of place, ultimately enabling achievement of our conservation goals.

Recommendation: Identify citizen science environmental monitoring activities in the St. Clair-Detroit River system and western Lake Erie, and then encourage students and other young people to participate in them.

3.1 Greak Lakes Blue Accounting - Delivering Information, Supporting Collaboration

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Introduction

The Great Lakes region is a large, unique basin comprised of complex and diverse ecosystems under intense pressure from human impacts. Its vast size and complexity, along with the myriad local, regional and national agencies and organizations working across eight U.S. states and two Canadian provinces, make it difficult to understand or measure how human actions and resource use impact the basin. Federal, state, provincial and local agencies, along with non-profit organizations have invested billions of dollars in programs to improve the Great Lakes with the goal of creating a healthy and sustainable ecosystem that supports a broad range of human uses, economic activities and natural resource conservation. Measured individually and locally, many of these programs are successful in addressing specific, small-scale issues. However, Great Lakes leaders and decision-makers across the region do not have a cohesive medium to communicate how much progress is being made toward their goals. Consequently, they also lack the information they need to prioritize efforts and investments.

The Blue Accounting initiative will provide Great Lakes leaders a means to understand the progress against goals for the Lakes spanning healthy aquatic ecosystems, sustainable human uses, social values and quality of life. Blue Accounting will bring together expert working groups (collaboratives) to establish shared goals on the path toward these desired outcomes and define measures of progress (metrics) toward these goals. Each metric will require selection and combination of data from various sources from which the Blue Accounting initiative will build an information management platform to maintain and deliver these metrics.

The Blue Accounting Program

Across the eight U.S. states and two Canadian provinces of the Great Lakes basin, many organizations, agencies and individuals are working to address challenging conservation problems on a variety of scales. Federal, state and provincial agencies, along with local and municipal governments and non-profit organizations are collectively investing hundreds of millions of dollars each year in programs intended to conserve and restore the Great Lakes ecosystem. However, because these programs are initiated and funded by many different entities and are measured within that entity or on a small scale, the Great Lakes region lacks a basin-wide view of the progress being made toward large-scale, overarching desired outcomes.

Major bi-national programs like those initiated by the International Joint Commission and the Great Lakes Water Quality Agreement, and the major investments made by the U.S. through the Great Lakes Restoration Initiative, have associated goals and indicators intended to inform ecological progress in the Great Lakes basin. But even those goals and indicators do not address the need for a holistic view of our expectations and needs for the Great Lakes on environmental, economic and cultural dimensions. As a result, elected and appointed leaders across the Great Lakes basin lack reliable and concise information they need to understand the extent to which progress is being made, thoughtfully set priorities, allocate resources and adapt as needed.

At their 2013 summit, the Great Lakes governors and the premier of Ontario passed a resolution calling for a comprehensive approach to monitoring Great Lakes water resources. At the subsequent request of the Council of Great Lakes Governors, the Great Lakes Commission created an advisory workgroup to develop a regional monitoring strategy. This bi-national workgroup was drawn from across the Great Lakes basin and included 25 members representing governments from Canada and the United States (from federal to local scales); the three bi-national lakes commissions; industries including foods, power and shipping; expertise in hydrology, water quality indicators, water accounting, gathering local perspectives and bi-national governance.

The resulting Blue Accounting report, delivered to the governors and premiers in April 2014, is available at http://bit.ly/BlueAccounting. It establishes the Blue Accounting value proposition in stating,

"Realizing the value and competitive advantage in the Great Lakes water system requires a Great Lakes Blue Accounting Process: a new collaborative, issue-based process that is anchored in a common agenda, development of common strategies, and optimized investments in information infrastructure."

The Blue Accounting initiative, which was envisioned and initiated by the report, will provide Great Lakes leaders a means to understand the progress being made across the region toward shared desired outcomes for the Lakes spanning healthy aquatic ecosystems, sustainable human uses, social values and quality of life. It is a four-pronged strategy to:

- enable the Great Lakes community to create a consensus-based set of desired goals for Great Lakes water resources management;
- identify a set of strategic actions and performance metrics for evaluating the effectiveness of the those actions;
- determine the quantity and types of data and information needed to support the selected process metrics; and

- optimize investments in a regional information infrastructure to support more effective and efficient delivery of information to decision makers, leading to more effective and efficient resource management.

This is a long-term initiative of strategic importance to the Great Lakes basin and its residents. The Great Lakes Commission has formed a partnership with The Nature Conservancy to lead the effort and, together, we are receiving broad support from leaders, agencies and funders across the basin. It is clear there is a unique opportunity, at this time, to establish the means to give Great Lakes leaders the information they need to make strategic management decisions. We have Great Lakes agencies (e.g., Great Lakes Restoration Initiative, Government Accounting Office), organizations (Great Lakes Advisory Board), and even scientists (IJC's Science Priority Committee) calling for increased attention to information management and delivery. Moreover, we have elected officials who recognize this problem and understand that Blue Accounting is an essential part of the solution.

Implementing Blue Accounting – Three Core Strategies

The working group that developed the Blue Accounting report identified nine desired outcomes for the Great Lakes region, spanning healthy aquatic ecosystems, sustainable human uses, social values and quality of life. They described a process for establishing collaboratives to lead the work for each desired outcome. These collaboratives will convene to develop shared regional goals contributing to the desired outcome and measures of progress against those goals.
As with all new ventures, there is a relatively short window of opportunity to demonstrate the value of the services this program will provide to key Great Lakes leaders. The Blue Accounting team, led by the Commission and the Conservancy will quickly establish an information platform that demonstrates the value of Blue Accounting services by working on real issues that are priorities for the region. Early success in these demonstrations will help the team secure the long-term political and financial support needed for sustained operation. We have established three strategies, described below, that will demonstrate the value of Blue Accounting quickly and effectively.

Strategy 1: Establish a program to support information management and delivery for strategic decision-making for the Great Lakes

To become a permanent resource for the Great Lakes, the team will create the enabling conditions for the Blue Accounting program: a set of cross-boundary, multi-jurisdictional and region-wide services to support information management and delivery. At the center of the program's ability to deliver these services are the activities of issue-specific work collaboratives charged with establishing shared basin-wide goals and strategies and determining appropriate measures of progress against those goals. The Blue Accounting staff from the Commission and the Conservancy will provide a range of services to the collaboratives and will support the adaptive management processes to improve and adapt their goals and metrics as conditions change.

Strategy 2: Build Blue Accounting Information Management Systems

A well-designed information management system will enable the collaboratives to collect, aggregate, deliver and archive the data required to create the metrics; and provide user experiences that make it easy for non-technical users to quickly and easily find the information they need.

The team will develop and maintain the information systems required to deliver these services for the collaboratives and the end-users of Blue Accounting metrics. There are substantial information management systems in place to build upon. The Commission has been delivering information about the Great Lakes on a broad scale for over 20 years through the Great Lakes Information Network (glin.net) and the Conservancy's Great Lakes Inform system (greatlakesinform.org) provides a strong platform for information management for collaboration and adaptive management programs. The Blue Accounting initiative will build upon and combine these two systems, adding capabilities to manage data and metrics for individual issues.

Strategy 3: Support issue-specific collaboratives to set basin-wide goals and develop information management and delivery strategies
The Blue Accounting team will support and provide information management and delivery services for issue-based collaboratives focused on three distinct desired outcomes described in the Blue Accounting report:

- Healthy, diverse and connected habitats – Human activity has interrupted many of the river and stream networks between the lakes and the tributaries in the Great Lakes basin. The scope of the issue is large and widespread and, while connectivityis recognized as integral to the health of freshwater systems, resource managers throughout the Great Lakes are concerned about tradeoffs in restoring connectivity. The connectivity collaborative will create shared goals and strategies for the reconnection of these networks that balance these pressures to remove and keep barriers in place and measure progress towards these goals.
- Healthy and abundant wildlife – The Great Lakes are probably the most heavily-invaded freshwater ecosystem in the world, with food webs dominated by non-native aquatic invasive species (AIS) that have altered ecosystem services and functions. The economic impacts on Great Lakes businesses and households are conservatively estimated to cost hundreds of millions annually. Preventing and managing AIS is critical to the desired outcome of healthy and abundant wildlife in the Great Lakes. The Blue Accounting program will help support the AIS collaborative to establish shared goals and performance metrics to assess the success of closing AIS pathways and both surveillance and response programs.
- Safe and sustainable domestic water supply – The Great Lakes region faces multiple challenges in delivering high-quality water to its citizens and businesses while ensuring healthy ecosystems. Even in a region with a seemingly limitless supply of clean, fresh water, recent problems in Flint, Michigan, and Toledo, Ohio, teach us that supplying reliable and safe water is not simple or guaranteed. Public water suppliers have limited ability to manage or influence the quality or quantity of source water yet must deliver clean, safe water to each of their customers while managing the effects of aging

infrastructure. Furthermore, their water sources interact with environmental influences that directly affect the quality and quantity of available water. Recognizing these myriad point and non-point influences on water sources, this Blue Accounting pilot program will create goals and metrics for water supply as an integrated system and will help track progress towards desired outcomes for source water quality within the watershed.

Working with the Blue Accounting team, collaboratives will establish shared goals and strategies, define performance metrics for each of these issues, and identify data sources from which the metrics can be created and maintained. The Blue Accounting team will facilitate data retrieval and storage, and metric creation and delivery to the desired decision-makers.
The Blue Accounting pilot programs addressing these first three issues are the beginning of a long journey for the Great Lakes region. On this journey, we will learn and adapt to the changing requirements of each issue and the information needs of Great Lakes decision-makers. Each step will provide more and better information about our progress towards the many desired outcomes we have for the region: our social values and desired quality of life; our need to sustain human uses of resources across the region; and our interest in maintaining healthy aquatic ecosystems. In the long term, the processes and systems created by the Blue Accounting program will become accepted practice in managing the region – an integral part of setting priorities and allocating resources to achieve our shared desired outcomes.

3.2 Lake Erie's Biodiversity Conservation Strategy

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Introduction

The Lake Erie Biodiversity Conservation Strategy (Pearsall et al. 2012) highlights the conservation features that represent the biodiversity of the lake, identifies the key threats to these features, and articulates long-term actions to conserve them. It was developed over a two-year planning process that involved over 190 people from 87 organizations around the basin who are concerned about and responsible for safeguarding the health and sustainability of Lake Erie's biodiversity and inhabitants. The project was led by The Nature Conservancy (TNC), Nature Conservancy Canada (NCC), and the Michigan Natural Features Inventory (MNFI), with strong connections to the binational Lake Erie Lakewide Action and Management Plan (LAMP).

Background

The 1987 amendment of the 1978 Canada-US Great Lakes Water Quality Agreement (Government of the United States and Government of Canada 1987) called for the development of Lakewide Management Plans for each Great Lake. Development of the Lake Erie Lakewide Management Plan (LaMP) began in the early 1990s and the first Lake Erie LaMP was released in 2000 (Lake Erie LaMP 2000). The revised 2012 Water Quality Agreement (Government of the United States and Government of Canada 2012) includes commitments to maintain the Lakewide Action and Management Plans (LAMPs) for each Great Lake. The change-of-name recognized the need for implementation and action going forward.

The Lake Erie LAMP is a long-term ecosystem based framework for the binational management of Lake Erie. The spatial extent includes Lake Erie proper, including the upstream connecting channel, nearshore areas, embayments and river mouths, as well as the entire lake basin with respect to watershed influences on the lake. The LAMP is overseen by the binational Lake Erie Partnership, which is comprised of representatives from federal, provincial and state agencies, conservation authorities, NGOs, and academia. The United States Environmental Protection Agency (US EPA) and Environment and Climate Change Canada (ECCC) are the federal co-leads of the Partnership. It is collaborative in nature and provides a forum for ongoing discussion and resolution by which collaborative, lakewide goals, objectives and action planning are developed.

Starting with Lake Ontario in 2007, the US EPA and ECCC have invested in the development of BCSs for each Great Lake (Pearsall et al. 2014). Strategies have now been developed, by or in close association with the LAMPs, for Lake Ontario (2009), Lake Huron (2010), Lake Erie and Lake Michigan (2012), and Lake Superior (2015). Collaborative goal setting and strategy implementation in the Great Lakes is challenging, and it was determined that the LAMPs held the greatest potential for supporting such collaboration given that they regularly bring together stakeholders to coordinate action and will continue to do so in the future (Pearsall et al. 2014).

Strategy Development
The development of the Lake Erie BCS was initiated in 2011 and the technical report was released in January 2013. Funding was provided by US EPA (GLRI grant to TNC) and ECCC (support to NCC).

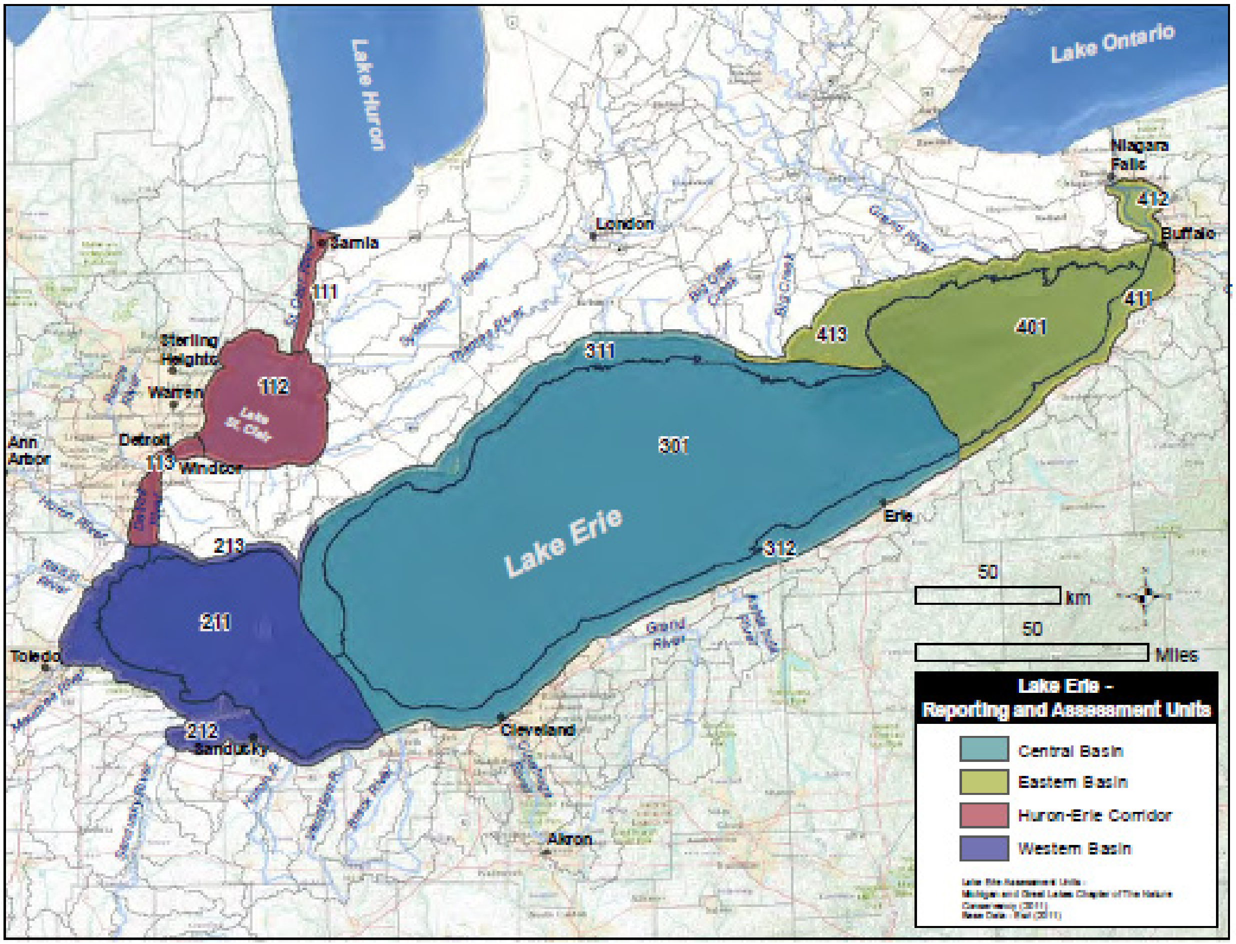
Development of the Lake Erie BCS followed the TNC's Conservation Action Planning process (TNC 2007), which includes the following four steps: a) defining the project; b) developing conservation strategies and measures; c) implementing conservation strategies and measures, and d) using the results to adapt and improve future strategies. The development of all Great Lakes BCSs focused on the first two steps of the CAP process.

A. Defining the Project
1. <u>People</u>
The project was led by The Nature Conservancy, Nature Conservancy Canada and Michigan Natural Features Inventory. A core team managed the project, and guidance was provided by a binational Steering Committee comprised of 60 members from 36 organizations. Overall, the two-year process involved 190 people from 87 organizations. Communications occurred via regular conference calls, webinars, email communications, surveys, quarterly project updates, project websites, strategy development workshop, attendance at meetings of the Lake Erie Public Forum and other related groups.

2. <u>Scope</u>
The scope the Lake Erie Biodiversity Conservation Strategy was consistent with the Lake Erie LAMP scope, comprising the ecological systems and species within the lake itself, the connecting channels, the immediate coastal area (extending roughly 2 km inland from the shoreline), and the watersheds of the tributaries to the extent that they affect the biodiversity of the lake. One difference from the LAMP scope is the inclusion of the upper Niagara River above Niagara Falls. That was done because of the strong biological link between the upper Niagara River and the east basin of Lake Erie.

Lake Erie has considerable regional variation in ecology, economics and land use, and this variation has implications for the status of biodiversity, the threats that impact biodiversity, and the effectiveness of conservation strategies. In order to address this variability and to provide greater resolution to the assessments of viability and threats to biodiversity, Lake Erie was stratified into 4 Reporting Units that reflect the accepted sub-basins within Lake Erie: Eastern Basin, Central Basin, Western Basin and the St. Clair-Detroit River System (comprised of St. Clair

River, Lake St. Clair and the Detroit River). The Reporting Units were further broken down into 13 Assessment Units, which separate out nearshore and offshore areas, and in the case of the upstream connecting channel, distinguish the individual components of the corridor.



B. **Developing Strategies and Measures**

3. <u>Focal Targets</u>

The next step was to select biodiversity conservation targets, which can be ecological systems, natural communities, species, or groups of species. The suite of targets is assumed to represent the biodiversity of Lake Erie. These were selected based on targets that had previously been selected by the Lake Ontario and Lake Huron conservation strategies, as well as other assessments of Lake Erie and complemented by the input from the project core team, steering committee, and other partners.

Lake Erie Biodiversity Targets:	
1.	Open water benthic and pelagic ecosystem: offshore waters deeper than 15 m
2.	Nearshore zone: waters <15 m in depth, including the coastal margin
3.	Native migratory fish: fishes that migrate to complete part of their life cycle (e.g., walleye, sturgeon, suckers)
4.	Coastal wetlands: wetlands with historic and current hydrological connectivity to and direct influence from Lake Erie
5.	Connecting channels: the St. Clair Detroit River System and upper Niagara River
6.	Islands: including both naturally formed and artificial islands
7.	Coastal Terrestrial Systems: upland systems within 2 km of the shoreline
8.	Aerial Migrants: all types of migrating birds, insects and bats dependent on Lake Erie

4. Viability Assessment

The next step was to assess the status of the biodiversity targets through an assessment of viability. This answered the question "How is the biodiversity of Lake Erie, as represented by the focal targets, doing?

This was done by, first, identifying key ecological attributes and indicators for each target. These were compiled from the Lake Ontario and Lake Huron BCSs, SOLEC reports, and a literature review. Next, best available data were used to estimate the current value of the indicators and to assign each indicator a viability rank of poor, fair, good or very good. Thresholds to define the rankings were based on best available information and expert opinion. The viability assessment was done at the assessment unit level, which was the finer scale breakdown of the basins.

5. Threats Assessment

The next step was to identify the threats that are affecting the biodiversity targets and determining how serious those threats are.

The core team compiled a list of threats from the Lake Ontario and Lake Huron BCSs, relevant regional plans, and other initiatives and reports including the Lake Erie LAMP. The Steering Committee provided additional suggestions to complete the list. An online survey was developed and 275 experts (agency staff, academics, private consultants, etc.) were invited to rate the scope, severity and irreversibility of each threat to each biodiversity target within each reporting unit. Of the 18 threats that were included in the survey, 9 had a Very High or High ranking in at least one reporting unit.

In general, the threats that were identified through this process are consistent with other studies, including the Lake Erie LAMP, which identifies many of these threats as causes of beneficial use impairments.

Aggregated Critical Threats:	
1.	Invasive Species
2.	Non-Point Source Pollution
	a. Agricultural NPS
	b. Urban NPS
3.	Housing and Urban Development, coupled with Shoreline Alternations
4.	Dams and Barriers
5.	Climate Change*

**Climate change was deemed to be a cross-cutting threat and therefore was considered as part of all strategies and not as a stand-alone strategy*

6. Strategies

Five high priority biodiversity conservation strategies were developed via a December 2011 workshop that brought together 71 experts from academia, NGOs and government agencies. The goal of the strategies is to improve the health of the biodiversity targets and/or reduce the threats.

Biodiversity Conservation Strategies:	
1.	Reducing the impact of Agricultural NPS pollutants
2.	Preventing and reducing the impact of invasive species (aquatic and terrestrial)
3.	Coastal conservation: preventing incompatible development and shoreline alterations
4.	Reducing the impact of urban NPS and PS pollutants
5.	Connecting channels: the St. Clair Detroit River System and upper Niagara River
6.	Improving habitat connectivity by reducing the impact of dams and other barriers

Breakout groups analyzed the factors contributing 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. Multiple strategies were developed for each of the five higher-level strategies; the ones ranked as the highest priority were developed in detail. This included the development of objectives and strategic actions and measures for tracking progress.

C. Next Steps

The next steps in the CAP process are implementation and analysis of results to adapt and improve (adaptive management). The Lake Erie LAMP Partnership is in the process of adopting the vision and priority strategies and developing regional plans for implementation, with the goal of incorporating the biodiversity conservation into the long-term, ecosystem based framework for the binational management of the Lake Erie ecosystem.

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3.3 The St Clair Detroit River System Initiative: The Collective Impact, the Common Agenda and a Thriving Ecosystem

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The international waters of the St Clair Detroit River System (SCDRS) include portions of southern Lake Huron, the St. Clair River, Lake St Clair, the Detroit River and the western basin of Lake Erie (Figure 1). The System forms part of the international boundary that separates Canada from the United States of America. Water from over 17,000 km2 (MacLennan et al., 2003) of inland watershed and three upper Great Lakes (Superior, Michigan and Huron) flow through the SCDRS into Lake Erie at a rate of about 120 billion gallons per day (454 million m3/d; http://scdrs.org).

Figure 1. SCDRS Initiative Project Area. Stretching from the southern shore of Lake Huron to the western basin of Lake Erie, the Initiative focuses on the strait itself and its connection to the lakes.

The System is complex and reflects the cultural, ecological, economic and jurisdictional realities of the region. Unfortunately, the long-term use of the system for waste disposal, water withdrawals, shoreline development, shipping, urbanization, recreation and fishing has impacted the ecosystem and its environmental services to the region. Deterioration of water quality, habitats and biodiversity, as well as proliferation of invasive species, reflect an ecosystem in need of improvement to restore lost benefits to people.

In 2004, The Huron-Erie Corridor Initiative (HECI) was proposed by U.S. Geological

Survey Great Lakes Science Centre (USGS-GLSC) to formulate and address high priority research questions affecting the aquatic resources and habitats of the System. Over time, this voluntary consortium of researchers and resource managers successfully cultivated an effective working relationship among various federal, provincial, state, First Nations, academic, and private sector groups leading to the first ever U.S. / Canada fish habitat restoration project in the Great Lakes (http://scdrs.org), SCDRS Steering Committee, 2014). Building on this success, a formal process based on a "common agenda" was proposed. In 2013, the HECI was transformed into the St Clair Detroit River System Initiative. (http://scdrs.org) and SCDRS Steering Committee, 2014)

At the core of the SCDRS Initiative is the recognition that managing an international-boundary water system is complex, requiring consideration of jurisdictional responsibilities at the federal, provincial/state, First Nation and municipal levels. The SCDRS Initiative is designed to take advantage of that complexity by focusing government programs and resources (people, knowledge, expertise and funds) better known as the "collective impact" towards a "common agenda." As defined by Kania and Kramer (2011) the collective impact requires a "…long-term commitment by important actors from different sectors to a common agenda for solving a specific problem." Success of a collective impact initiative requires "…that actions are supported and shared by a measurement system, mutually reinforcing activities, and ongoing communication and are supported by a backbone organization." (Kania& Kramer 2011).

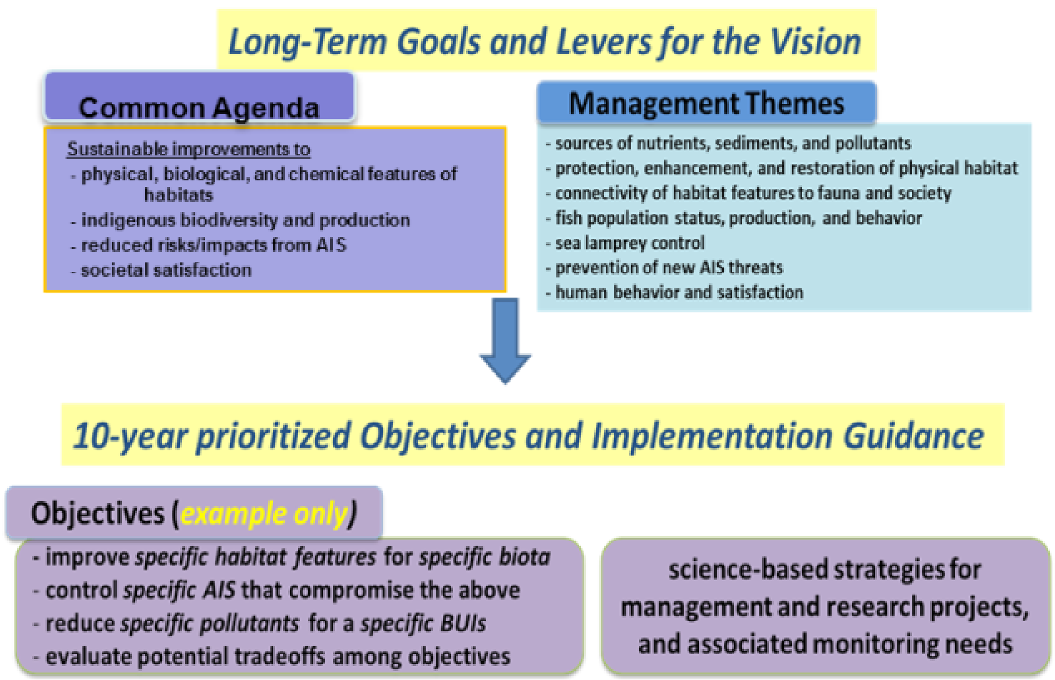

Figure 2. SCDRS flow chart used to develop the Common Agenda for the St Clair Detroit River System Initiative.

The common agenda for the SCDRS is built on the shared vision of "a thriving ecosystem managed with science-based principles and broad social support, providing desired environmental services for the region and the Great Lakes basin" (SCDRS Steering Committee, 2014) (Figure 2). Collective actions are governed by a volunteer Partnership Agreement, which provides part of the backbone organization and structure. The purpose of the Partnership is to coordinate research and management efforts that collectively will achieve measurable progress towards the shared vision. Under the SCDRS Initiative, the common agenda is defined as the restoration, protection and sustainability of the System. It is based on the principles of adaptive management and coordinated consensus based decisions that are guided by science, assessment and evaluations that lead to improvements in:

- physical, biological and chemical features of habitat
- production and biodiversity of indigenous species
- prevention or mitigation of negative impacts from AIS
- societal satisfaction in the system.

The current SCDRS Partnership includes a multi-disciplinary team of resource managers, scientists and stakeholders representing 30 different organizations (http://scdrs.org). Together through a variety of surveys, workshops and annual meetings, the SCDRS Partnership has developed a set of mutually agreed upon goals and objectives (Tables 1 and 2). The expectation of the collective impact is not for all members of the SCDRS Partnership to work on the same goal, but for participants to work towards the particular goals and objectives that are best suited to their mandate, knowledge and expertise.

To better link resource management and science priorities, the SCDRS Partnership is developing a Science and Monitoring Plan. The foundation of the plan will be based on an adaptive management approach to common agenda projects. By comparing a set of working hypotheses that reflect the current state of knowledge along with tested research hypotheses, it is anticipated that over time resource managers will be able to make more informed decisions. Knowledge about the current state of the system will be provided through on-going monitoring actions. Monitoring will also provide the data needed to develop targets and endpoints that will allow the SCDRS Partnership to measure progress towards outcomes.

Table 1. Five management priorities.

Biodiversity Conservation Strategies:	
1.	Address beneficial use impairments by undertaking actions needed to de-list the Detroit River AOC and St Clair River AOC in both countries
2.	Improve water quality through reductions in pollutants from SCDRS sources
3.	Increase the overall biodiversity through protection and improvements to a connected mosaic of habitats in the system
4.	Increase production of indigenous fish stocks through the protection and improvement to functional habitat in the system
5.	Reduce impacts on habitats, biodiversity and fisheries from Aquatic Invasive Species threats

Table 2. Prioritized list of objectives and expected outcomes of actions needed to achieve management priorities (table continued on following page).

Priority	Objective (Action Needed)	Expected Outcomes	Indicator
1,3,4	Complete habitat improvement projects to remove loss of fish and wildlife habitat BUI	Completion of targeted habitat projects as per AOC habitat plans; pre/post monitoring protocol for projects	# of projects completed
2	Reduce loadings from regulated and unregulated sources of Total Phosphorus/ Dissolved Reactive Phosphorus (TP/DRP)	Fewer and lower concentrations of contaminants, nutrients and nuisance algae; reduced loading to Lake Erie, more SAV, greater fish diversity	TP/DRP loads from SCDRS sources including tributaries
2	Identify contaminants of concern (e.g., pharmaceuticals and personal care products, microplastic); determine sources, and develop load reductions strategies	Fewer and lower concentrations of contaminants of concern (e.g., pharmaceuticals and personal care products, microplastic)	Loads of contaminants form SCDRS sources, including tributaries
3	Increase riparian complexity/ connectivity through increased softened shoreline and native riparian vegetation	More reptiles & amphibians, shorebirds, waterfowl, and fish species in shoreline areas	Number of Acres/Hectares protected/ improved; species richness
3,4	Increase continuous area of functional wetland and their connectivity to the SCDRS	Increased biodiversity and fish production in wetland areas	Number of Acres/ Hectares protected/ improved; species richness; larval fish densities; fish population dynamics

Table 2, continued.

3,4	Increase amount and quality of river spawning habitat	Improve biodiversity and fish production	Number of Acres/ Hectares protected/ improved; species richness; larval fish densities; fish population dynamics
3,4	Identify and protect critical habitat area for rare species including river mouth habitats and connectivity with tributaries	Increase abundance and distribution of Threatened & Endangered species/ Species-at-Risk; increase production of YOY fishes	Acres protected/ improved; rare species presence
5	Develop surveillance monitoring for AIS based on habitat requirements and availability	Improve detection and assessment programs for developing effective risk management actions	Estimated detection probabilities by species and gear type
5	Implement preventative strategies through information/ education programs and management of potential sources and pathways (e.g., ballast water, live release etc.,)	Prevent introduction of new species	# of people/groups contacted; compliance rates with Ballast Water plans; # of new species by vector over time

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3.4 Developing a Shared Vision for Coastal Conservation in Western Lake Erie

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Introduction

The coastal ecosystems of the western Lake Erie basin (WLEB) – including the nearshore, coastal wetlands, islands, coastal terrestrial systems, tributaries, and the Detroit River – support regionally and globally significant biodiversity (Pearsall et al. 2012). These ecosystems also provide multiple services including world-renowned fishing, hunting, and migratory bird-watching opportunities, many of which contribute important revenues to the region (Allan et al. 2015). Despite these natural assets, the WLEB has been severely degraded due to the effects of high human population densities, intensive agriculture, and significant shoreline hardening (Allan et al. 2013, Allan et al. 2015). Anthropogenic impacts have degraded natural habitat and water quality, reduced native plant and wildlife populations, and diminished many ecological services. There is a resounding call to prioritize conservation action in the Great Lakes (Great Lakes Interagency Task Force 2014). Conservation actions will need to meet measurable ecological goals and sustain the multiple nature-based activities that contribute positively to the region's coastal communities and their economies. Since it is impractical to manage the entire 150-mile (240 km) length of the coastal region, conservation practitioners must understand which stretches of the coast are the highest priority for conservation activities that benefit both ecological systems and people.

In developing a shared conservation vision for the coastal area of the WLEB, our primary objective was to develop a spatially-explicit conservation plan that identifies optimal locations for conservation and restoration actions to meet ecological goals while maintaining or enhancing human well-being values at the lowest financial or social cost. We adopted ecological conservation targets from the Lake Erie Biodiversity Conservation Strategy (LEBCS; Pearsall et al. 2012), and then developed a process for integrating human well-being values into biodiversity conservation planning that can serve as a model for other areas. Second, we employed data not typically used in conservation planning and developed an innovative approach to incorporating social values, which will benefit and complement priority- setting efforts across regional conservation, planning and business sectors. Finally, we examined the influence of human well-being values on the conservation plan in terms of locations of priority areas and the total area and cost required to meet goals established in the LEBCS. The mapped outputs of this work comprise the Western Lake Erie Coastal Conservation Vision (WLECCV). The WLECCV benefitted from the input of managers and other partners in Ontario, Michigan, and Ohio, and the process is now being expanded by the Upper Midwest/Great Lakes Landscape Conservation Cooperative (LCC) to cover the US side of the St. Clair – Detroit River System and Saginaw Bay. We hope to expand this approach into adjacent coastal areas of Ontario and Ohio as well.

Methods

Our project area includes the Detroit River, the entire nearshore of the WLEB (i.e., the waters of the western Basin), and its coastal area up to 25 km inland from the shoreline, as defined in the Lake Erie Biodiversity Conservation Strategy (LEBCS; Pearsall et al. 2012) (Figure 1).

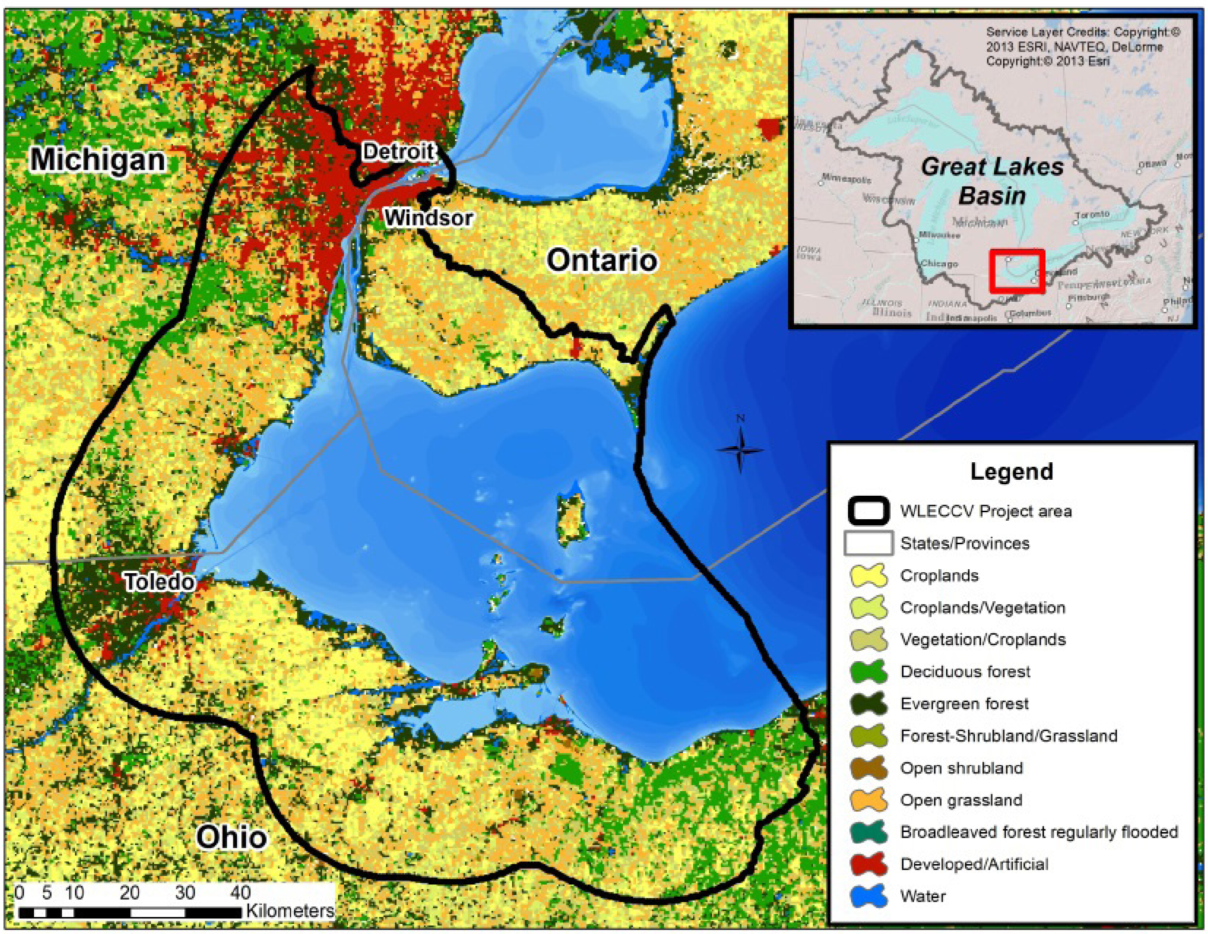

Figure 1.Scope of the Western Lake Erie Coastal Conservation Vision (WLECCV).

Within this area, we utilized the spatial conservation planning software Marxan with Zones (Watts et al. 2009, hereafter “MarxanZ”) to identify areas for conservation actions that benefit ecological and human well-being goals. MarxanZ allows mapping of distinct spatial zones for different kinds of activities. The primary components of a MarxanZ analysis include a planning unit framework (10-ha hexagons covering the entire study area), a suite of features (i.e., ecological targets and human well-being values), and costs.

Ecological and Human Well-being Features

We adopted the LEBCS conservation targets (Pearsall et al. 2012) except for the Open Water Benthic and Pelagic System (which refer to parts of the lake that are >15 m deep; not present in WLEB). We also updated the Aerial Migrants targets based on revised migratory bird stopover maps and new scoring criteria (Ewert et al. 2012). We then obtained or developed spatial data to represent these targets; the data layers comprised ecological features in the MarxanZ analysis (Table 1).

We identified human well-being values by first adopting an established framework based on Smith et al. (2013) and Lovelace et al. (2011). We then identified locally relevant social, cultural, and economic values through reviews of related plans and completion of localized anthropological fieldwork. We tied these values to the framework and associated them with important ecosystem services identified as in surveys conducted for the LEBCS. Finally, we retained those services and values that were likely to be affected by coastal restoration and conservation actions. We then obtained or developed geospatial data that could be used to spatially represent these services and values; these became our human well-being features (Table 2).

Table 1. Ecological targets (from Pearsall et al. 2012) and representative data layers (features) used in the WLECCV. More information on the methods, data layers and sources are available at http://nature.ly/WLEcoastalvision.

Ecological Targets	Representative Data Layers (Features)
Nearshore Zone: *waters less than 15 m in depth, including the coastal margin*	Nearshore Fish Habitat, Walleye Spawning Sites (lake)
Native Migratory Fish: *Lake Erie fishes with populations that require tributaries for a portion of their life cycle, including Lake Sturgeon, Walleye, suckers and Sauger*	Walleye Spawning Sites (tributaries), Walleye Stream Potential Habitat
Coastal Wetlands: *wetlands with historic and current hydrologic connectivity to, and direct influence by, Lake Erie*	Potential Coastal Wetlands,
Coastal Terrestrial Systems: *upland systems within ~2 km of the shoreline*	Coastal Terrestrial Biodiversity Significance

Aerial Migrants: *migrating birds, insects, and bats dependent on the Lake Erie shoreline*	Coastal Landbird Habitat, Inland Restorable Landbird Habitat, Shorebird Habitat, Nearshore Waterfowl Habitat, Inland Waterfowl Habitat
Connecting Channels *(St. Clair Detroit River System?)*	Potential Coastal Wetlands, Detroit River Spawning Sites (sturgeon, whitefish, walleye) Detroit River Walleye Habitat
Islands: *including both naturally formed and artificial islands*	Coastal Terrestrial Biodiversity Significance

Table 2. Human well-being values and representative data layers (features) used in the WLECCV. More information on the methods, data layers and sources are available at http://nature.ly/WLEcoastalvision.

Human Well-being Values	Representative Data Layers (Features)
HEALTH: *physical and psychological human health + access to quality food and water, air quality*	Drinking water intakes (Lake Erie), Drinking water intakes (inland), Beaches, Parks & recreation lands, Trails, Birding visits; popularity of birding spots
SPIRITUAL AND CULTURAL FULFILLMENT: *opportunity to meet spiritual and cultural needs + Recreational (cultural) places and activities*	Hunting areas, Recreational boating, Recreational fishing (Lake Erie), Recreational fishing (stream), Shipwrecks (dive sites)
LIVING STANDARDS: *wealth, income levels, housing and food security + housing, economic security, equity, job satisfaction, property values, employment security*	Birding visits; popularity of birding spots, Commercial fishing
CONNECTION TO NATURE: *the innate emotional affiliation of humans to other living organisms + Recreational (natural) places and activities, park lands, beach quality, scientific resources, coastal development, aesthetics*	Birding visits; popularity of birding spots, Hunting areas, Water access sites

Goals for the ecological features were adopted from the LEBCS (Pearsall et al. 2012), with some exceptions. We reviewed all county planning documents throughout the project area and interviewed key stakeholders, and found no objective basis for setting goals for human well-being features. As an alternative, we established goals by surveying regional stakeholders at three workshops held in Monroe Michigan, Toledo Ohio, and Essex Ontario. The MarxanZ software sought to meet all these goals while minimizing costs.

Costs

To reflect the varied and substantial costs of conservation and restoration, we developed seven cost layers, four of which are characterized in monetary values derived from local projects, and three of which are cost indices reflecting landscape attributes that affect the feasibility of effective conservation (Table 3). We calculated these costs for every 10-ha hexagon in the planning unit framework.

Table 3.List and descriptions of the costs of conservation and restoration in the WLECCV. More details, including data sources, on the cost layers are available at http://nature.ly/WLEcoastalvision.

Cost (units)
Land value ($): *average land value in the WLEB coastal area*
Wetland restoration ($): *The average cost of restoring coastal wetlands in the WLEB*
Phragmites treatment ($): *Cost estimate for removing the invasive common reed (Phragmitesaustralis)*
Marinas (Index): *Index representing marina size. Areas with marinas and lots of boat traffic would make coastal restoration more difficult.*
Lake Erie and Detroit River Stress Index (Index): *Index representing 34 stressors that likely have an impact on biota and ecosystem dynamics*
Landbird habitat restoration ($): *Cost of restoring bird habitat based on land cover and the cost of planting trees*
Walleye stream habitat improvement cost (Index): *Index representing the difficulty of restoring walleye habitat in streams*

Results

The most important areas for coastal conservation on land are concentrated within 3-4 km of the shoreline and in a few areas further inland, such as southern Wayne County, Michigan and southwest of Amherst, Ohio, where many of the ecological and human well-being features are located (Figure 2). The coastal wetlands and coastal terrestrial biodiversity significance features are located along the coast and exert strong influence on the conservation vision. Inland priority areas are centered around existing or restorable landbird stopover habitat and along trails.

The most important aquatic areas in Lake Erie as delineated by Marxan are concentrated in the waters of Ohio and Michigan, corresponding to areas highly valued for recreational fishing and recreational boating as well as supporting numerous walleye spawning areas (Figure 2). Recreational fishing is of far greater importance in the U.S. than in Ontario, while commercial fishing is more important in Ontario.

Setting high goals for human well-being values resulted in a 4.3% increase in both the amount of land (from 71,190 to 72,440 acres) and an 18.7% increase in the cost of conservation (from $16.9B to $20.1B) required to meet goals for ecological targets, relative to not including human well-being at all. The spatial arrangement of high value areas (i.e., “Top 10%” as shown on the map in Figure 2) was also affected; areas associated with trails and local parks were pulled into the vision as high value areas to meet human well-being goals, though their contribution to ecological goals was comparatively small. This result reflects the tradeoffs related to broad scale land use planning and conservation, while also supporting the idea that conservation can support both ecological goals and human well-being.

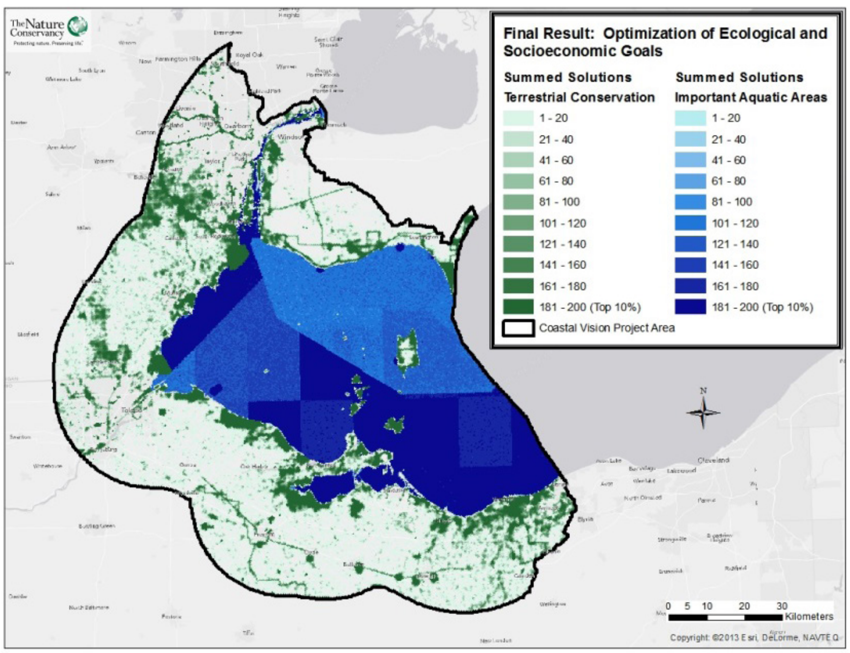

Figure 2. Distribution and extent of areas for coastal conservation and restoration that would best achieve ecological goals and enhance human well-being in western Lake Erie. In MarxanZ, the Summed Solutions represents the number of times out of 200 runs that a particular planning unit was selected as part of the solution. Planning units selected more often are considered more important.

Discussion and Conclusions

Historically, successful regional conservation efforts were driven by science-based goals for important features of ecological systems. It is increasingly recognized that incorporating human values into conservation planning increases the chances for success by garnering broader project acceptance. However, while goals for ecological attributes are typically based on well-established ecological knowledge and the tenets of conservation biology, methods for defining quantitative goals goals for human well-being values are lacking (Adams et al. 2014). Our approach of identifying regionally important human values, datasets to represent them, and establishing specific goals based on stakeholder outreach and survey is innovative and has been demonstrated elsewhere (e.g., Adams et al. 2014). To our knowledge, ours is the first application of this approach in the Great Lakes, and it could be applied to other areas. Indeed, the Upper Midwest/Great Lakes LCC is now undertaking a Landscape Conservation Design following this approach for the U.S. coast of the St Clair – Detroit River System and Saginaw Bay.

This work has created a process for integrating human well-being values into biodiversity conservation planning to:

- complement priority-setting efforts across regional conservation, planning and business sectors;
- serve as a model for other areas of the Great Lakes and beyond; and
- define total area and cost required to meet regionally-vetted ecological goals and thus priority areas to target for maximum impact.

The primary outcome of this work demonstrates a method for identifying the best places for conservation actions that not only achieve multiple conservation goals but also incorporate places and things that people value. Detailed maps, data, methods and supporting materials can be found at http://nature.ly/WLEcoastalvision.

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3.5 The Upper Midwest and Great Lakes Landscape Conservation Cooperative and Coastal Wetland Conservation Design

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Landscape Conservation and the Landscape Conservation Cooperative Network
There is an increasing recognition that future conservation success requires thinking about and addressing conservation issues at broader spatial and longer temporal scales than historically (National Academies of Sciences, Engineering, and Medicine 2015). Challenges like a rapidly changing climate and an increasing global population that is raising the demand for food, water, and space is creating changes to the pattern of land use and cover across large ecological regions. These issues cross-jurisdictional boundaries exceeding the responsibility of any individual agency or program (Millard et al. 2012). Therefore, a new 21st century conservation paradigm built around shared governance concepts like collective impact (Kania and Kramer 2011), multi-disciplinary science, and adaptive resource management (National Ecological Assessment Team 2006, Williams and Brown 2012) is necessary. In 2010, the U.S. Department of Interior established a network of Landscape Conservation Cooperatives (LCC) as a forum for the conservation community to carry out this paradigm.

Landscape Conservation Cooperatives are self-directed cooperatives composed of state, federal, non-governmental, Tribal, and other organizations and agencies with a vision of landscapes sustaining natural and cultural resources for current and future generations. To pursue this vision, LCCs identify and work on shared natural resource priorities. Collaborative science-based planning processes like Landscape Conservation Design (LCD) are used to define, design, and inform landscape conservation strategies. These strategies, when collectively delivered, improve progress toward natural resource goals and objectives. LCCs develop science-based decision support tools to place actions into context at multiple scales. Measuring the effectiveness of the collective actions and unforeseen changes to the landscape are used to refine the strategies.

The Upper Midwest and Great Lakes LCC (UMGL LCC), directed by a 30 member executive level steering committee with representatives from across the Upper Midwest and Great Lakes region, is using this approach within several priority focus areas including coastal conservation issues. The steering committee established a Coastal Conservation Work Group (CCWG), composed of various program leaders, technical experts, academics, and others to carry out the process.

Conservation of Great Lakes Coastal Wetlands

Over time, many historic Great Lakes coastal wetland areas have been damaged or converted to other uses. This is particularly true for much of the coastal wetland area on the Lower Great Lakes. These historic changes were considered necessary because they allowed for productive human uses like farming, but it came at a cost to the benefits wetlands provide. Coastal wetlands of the Great Lakes are home to an abundance of fish, wildlife and plants. People also use these areas for a variety of recreational pastimes such as hiking, hunting, fishing, and bird watching.

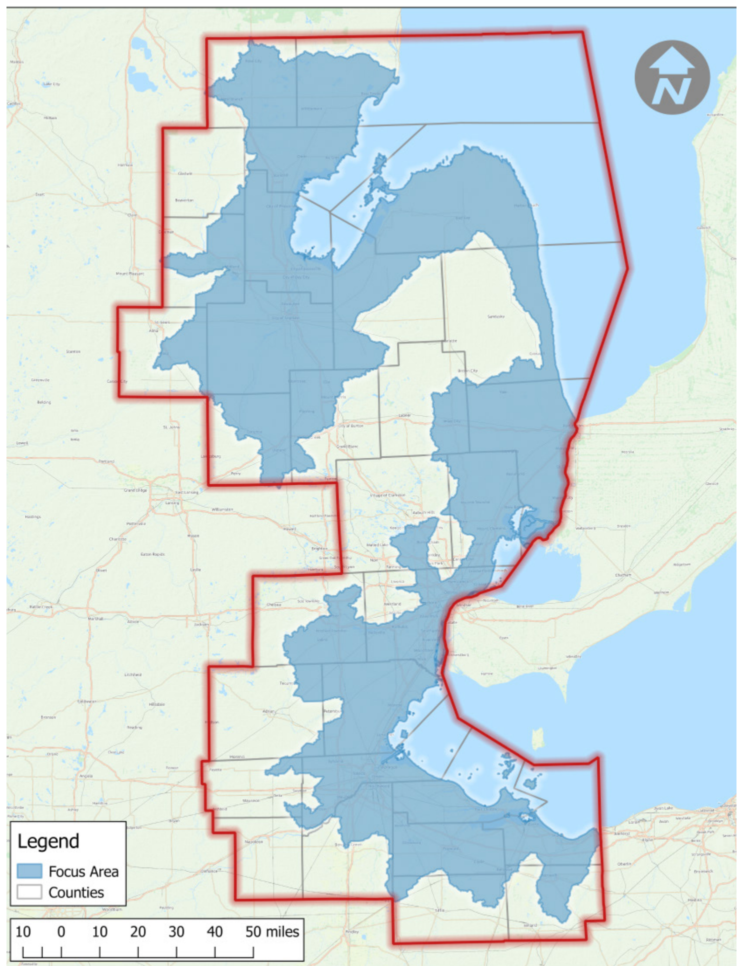

Figure 1. Initial geographic focus area for the Upper Midwest and Great Lakes LCC Coastal Conservation Working Group's landscape conservation design process.

Economically, coastal wetlands protect important infrastructure from storms and associated flooding. For decades, conservation agencies have worked to restore, enhance, and protect wetlands to reverse wetland losses and recover the benefits. These efforts have occurred with an absence of regional goals and general lack of coordination across the Great Lakes basin hampering the conservation community's ability to strategically provide multiple benefits across the coastal wetland system. Several important questions should be addressed through a large-scale, coordinated effort. How many restored and protected wetland acres are enough? For what purposes should conservation target? What system of coastal wetland areas and features are predicted to maintain these benefits under a changing climate and landscape? How much will it cost to attain conservation goals? The answers to these questions, incorporated into a conservation design, help conservation agencies, organizations, and funders target resources to the highest priority locations and actions.

An LCD effort spearheaded by the Coastal Conservation Work Group (CCWG) of the UMGL LCC is uncovering answers to these questions in a collaborative and structured way. The effort will initiate in an area that spans Saginaw Bay in Lake Huron to Western Lake Erie (Figure 1), with intent to build up to a larger Great Lakes basin-wide approach.

The Landscape Conservation Design Process

A collaborative conservation planning and design process is complex with many activities, processes, and contributors. To simplify communicating about the process the CCWG has broken the process into 4 basic elements: kickoff, planning, design, and strategy.

Kickoff

During the kickoff element the process starts with agreement on the overall conservation goal. This an open-ended and broad statement of desired future conditions that conveys the purpose, but does not define measurable units. It is also during this element that capacity is identified to facilitate, organize, and serve as the "bridging" entity between science and the management community.

Planning

The planning element builds upon the conservation goal by clearly defining the geographic scope and selecting specific conservation targets, indicators, and goals.

Conservation design

This is the scientific assessment element. Using the best available information, the landscape is characterized for conservation targets in current and projected future conditions. Analytical tools such as scenario planning, optimization, and prioritization help identify areas that could attain goals for individual and multiple targets and where actions directed at targets may conflict.

Spatial data in the form of maps, geodatabases, and geographically based decision support tools provide visual representations that allow one to envision the best places to conduct conservation. Decision support tools should be developed with specific treatments in mind that produce a desired response of the conservation target. Decision support tools aid decisions by providing relevant information in a single format and location that allows comparisons to be made in a simple form. These tools can be used individually or in combination to help direct activities. However they do not supplant the decision-maker. People, rather than data and information, make decisions.

Devise strategy

Using information and decision tools from the previously described elements, the amount, configuration, and type of actions necessary to attain the conservation objectives are identified. This also includes an assessment of recent conservation actions, the current capacity for action, opportunities and constraints, and strategies for funding.

While there is a logical sequence to the processes, specific activities within the elements are not linear and iterations will occur between elements and across the entire process as new information is gained and collaborators become involved.

Status of Great Lakes Coastal Wetland LCD

Kick-off and planning elements

For the Great Lakes coastal wetland LCD, the CCWG defined the goal as conserving Great Lakes coastal wetlands that ensure sustainable ecological and human wellbeing conservation targets. The Open Standards for Conservation terminology (Conservation Measures Partnership 2013) was adapted for this process because The Nature Conservancy used this terminology in development of the Lake Erie Biodiversity Conservation Strategy (Pearsall et al. 2012) and Western Lake Erie Vision (The Nature Conservancy 2016) and these products are being built upon and incorporated into the broader LCD process.

To identify an initial pool of conservation targets and indicators subject-matter experts from federal and state agencies, non-government organizations, and academics worked within two separate expert panels. The Ecological Functions Expert Panel reviewed literature to identify a list of meaningful targets and indicators in current Great Lakes or regionally specific conservation plans and documents. The draft ecological targets included: native migratory fish, native wetland fish, native coastal wildlife, invasive plants, biological integrity, landscape integrity, water quality, and shoreline buffering.The Human Wellbeing Expert Panel worked through a similar research and review process, but much less information was available for human wellbeing values. Several human wellbeing goal-setting frameworks were reviewed and based on the work by Smith and others (2013), the panel arrived at the following targets: human health, living standards, social cohesion, connection to nature, spiritual and cultural fulfillment, and safety and security.

In addition, the Expert Panels identified specific key ecological attributes, indicators, and some draft goals for conservation targets that had readily identifiable information.
In the spring of 2016, vetting and selection of conservation targets will occur during a series of workshops. These workshops are designed to capture input from conservation managers, funders, and scientists working on Great Lakes coastal wetlands within the local region. Also during these workshops, connections to planning, design, delivery, and activities of others will be discussed to ensure there is no duplication of effort and identify ongoing activities that can be incorporated into the process.

Conservation design element

Conservation design work has not officially started but the following describes a general approach for developing spatial tools for the LCD process. Spatial data, models representing distributions, and other relevant information will be compiled for the chosen set of targets for which quality data exists. The models and information around each target can be used individually, or in instances where multiple targets/indicators have similar needs and treatments, tools like Marxan (Ball et al. 2009) can be used to identify areas meeting multiple objectives at the lowest cost. There are many existing data sets and models available that can be compiled and rapidly deployed while new data and models are in development. The Nature Conservancy's Western Lake Erie Vision Marxan analysis provides a good starting point for expansion and is an example of a readily available product that can used while new data, models, and tools are in development.

An increasing interest of the conservation community is the concept of resilience (Ludwig et al. 1997). Identifying locations and strategies that provide long-lasting conservation benefits are important for wise investments. Care should be taken when considering resilience of a system as naturally dynamic as Great Lakes coastal wetlands. Changes in Great Lakes water levels can have a large influence on the ecological functions and values at individual sites at any one point in time. The system should be viewed as a whole under various water-level change scenarios to identify possible deficiencies in maintaining desired conditions across the system.
Several important data sets and decision support tools are already in development. In particular, the LCC is funding the development of a decision support tool that compares the ecological "health" of existing Great Lakes coastal wetlands based on basin-wide coastal wetland monitoring data collected by the Great Lakes Coastal Wetland Monitoring Project (Burton et al. 2008). This tool will help make comparisons among existing wetlands for several ecological indices and other attributes.

The LCC is also supporting the identification and attribution of potentially restorable Great Lakes coastal wetlands. Using LiDAR derived digital elevations, soil survey information, existing land use/cover data and other spatially explicit data, researchers with the U.S. Geological Survey are identifying the specific areas that could be hydrologically connected to the Great Lakes and providing an index of the potential restorability to a Great Lakes coastal wetland. As such, this product provides an estimate and a spatially explicit depiction of the available opportunities to add coastal wetland acres. Based on the position in the landscape and attributes (e.g., size, shape, and juxtaposition) of the potential wetlands the contribution to conservation objectives from restoring these areas can be estimated.

Lastly, the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) provides data on land-use/land-change and landscape trends (NOAA Office for Coastal Management 2016). Other NOAA data, including information from the Digital Coast will be useful to the LCD process.

Strategy element

The first conversation on strategy development will occur during the late-summer/early-fall 2016. This will include a look at initial spatial data and analysis and draft decision support tools. Additionally, a conversation about delivery approaches and programs will identify the capacity available to deliver various strategies. The intent is to the start the conversation. Ideally, the current knowledge base and tools can be used to put a conservation strategy in place, while new information is being generated. In this manor, the LCD process and products should not be static. Instead, a continual collaborative relationship between on-the-ground management, policy, and science providers will add efficiency to a basin-wide coastal wetland conservation adaptive management framework.

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3.6 Assessment of Nutrient/Eutrophication Dynamics in Western Lake Erie

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The following extended abstract was prepared using the project proposal written by the full project team (see list). Some minor details may have changed from the original over the course of the project.

Project Summary
In recent years, nutrient loading to the western basin of Lake Erie has been recognized as a pivotal component in the re-occurrence of harmful and nuisance algal blooms throughout the lake and hypoxia in the Central Basin. Through a combination of in situ experiments, laboratory studies, and modeling, our project will improve current understanding of the roles of external and internal nutrient loading, especially as influenced by weather forcing events. Outputs and outcomes will include development of nutrient mass budgets for the western basin, including internal cycling, and improved understanding of the causes of harmful algal blooms (HABs).

Project Background
During the 1960s, Lake Erie experienced huge algal blooms, low-oxygen waters, and fish kills reflecting the effects of significant eutrophication. Research and predictions of empirical and computer ecosystem models (e.g., Vollenweider 1976; Schelske and Stoermer 1971; Charlton 1980; Di Toro and Connolly 1980) identified phosphorus control as the best means of controlling eutrophication. Target levels for phosphorus loading were determined by binational collaborative programs that led to the implementation of the Great Lakes Water Quality Agreement (IJC 1978) with a target annual total phosphorus (TP) loading of 11,000 metric tons and the International Joint Commission (IJC) recommended programs that would achieve those loads.

Phosphorus loadings declined steadily beginning in the late 1970s from over 25,000 metric tons/y (MTA) to their present levels of 8,000-12,000 MTA (Dolan and McGunagle 2001). Phytoplankton biomass and frequency of cyanobacterial blooms decreased (Makarewicz 1993), and oxygen depletion rates also declined (Bertram 1993).

Since the mid-1990s, Lake Erie has experienced water quality and ecosystem changes (Matisoff and Ciborowski 2005). For example, although TP loadings have remained at or below the target loading of 11,000 metric tons/y (except during wet years characterized by marked flood pulses), the extent of harmful (Microcystis) and nuisance (Cladophora) algal blooms has increased (Conroy et al. 2005), bottom waters in the Central Basin appear to have gone anoxic sooner in the late summer months, and the areal extent of the anoxia has increased relative to previous years (Rockwell and Warren 2003).

Project Approach

This project was funded by USEPA under the Lake Erie Cooperative Science and Monitoring Initiative (CSMI) via the Great Lakes Restoration Initiative. This proposal addresses all three sub-topics of interest to USEPA: 1) quantifying the internal nutrient (phosphorus, nitrogen, carbon) loads to the water column in the western basin; 2) evaluating the important factors of river hydrology and/or seasonality of loads to harmful algal bloom formation and dynamics in the western basin of Lake Erie, including the effects of storm and other meteorological/climatological forcing events (e.g., climate change); and 3) developing a nutrient mass budget for the western basin of Lake Erie, which includes sub-watersheds.

We will use a fine-scale model of the Western Basin to interpolate and extrapolate the point-in-space and point-in-time data we plan to collect into a system-level quantification of the relationship between external loadings of water, sediments, nutrients, and organic carbon and the ecological responses to loadings and other forcing functions in the Western Basin. This system-level synthesis will produce a better understanding of the cause-effect relationships on the nutrient/eutrophication problems in Lake Erie and an improved ability to make management and policy decisions to address those problems.

The project was broken into three sub-projects. A description of each sub-project follows:

Sub-Project 1: Quantifying the internal nutrient movement (flux) from sediment to the water column in the western basin

We will obtain estimates of the internal phosphorus (and to a more limited extent, nitrogen) movement from sediment to the water column using three different techniques: 1) lab-based core incubations using 2 different methods, 2) field-deployed benthic flux chambers, and 3) water column measurements collected before, during, and after resuspension events.

Internal nutrient movement is of concern due to its potential to be a source that may contribute to harmful algal blooms as they occur during the summer. For this reason, and because of the practicalities of large-lake operations, sampling will emphasize summer conditions; all field work will be conducted in summer 2014. The sampling locations reflect established lake monitoring programs of the University of Toledo, OSU Sea Grant/Stone Lab, and USGS Great Lakes Science Center and take advantage of the existing sampling history of those sites, representing the major regions, depths, and sediment types in the western basin.

Cores

Whole core incubations will be done on short cores collected from all the study sites. Sampling will be done using a gravity corer, a box corer, or short cores collected by SCUBA, as appropriate. The cores will be returned to the lab in their collection tubes and incubated at temperatures representative of bottom waters at the time of collection. Cores will be incubated under various oxygen concentrations to document how phosphorus flux is affected by overlying oxygen. Measurements of soluble reactive phosphorus and ferrous iron concentrations in the overlying water will provide one estimate of the flux from the sediment. Fickian diffusion calculations will be used to provide a second means of estimating the phosphorus flux from sediments and to relate the pore water phosphate, iron and other chemical profiles to the measured fluxes.

Flux chambers

Lake-bottom flux chambers will be constructed, and placed on the lake-bottom by divers using SCUBA. Bottom chambers will be emplaced long enough to enable the entrapped water to become anoxic. Divers will collect time series data by withdrawing sample aliquots through a port over a 72-h interval.

Water column measurements

The third approach to calculating phosphorus flux uses water column measurements. Measurements of pore water concentrations will be obtained by microsensors, and diffusive-equilibrium-in-thin-film (DET) techniques. Whereas microelectrodes collect data from the site of a single penetration of the sediments, DET provides more spatially robust measurements. The research team will also measure nutrient concentrations in the water column before, during, and after wind-driven resuspension events.

Researchers will use microsensors fabricated at the University of Toledo to measure the profiles of compounds such as dissolved oxygen, nitrate, and sulfate, many of which govern the release of SRP from sediments. These microsensor profiles as well as wet-chemistry analysis of sediments will allow us to elucidate the redox-dependent SRP release kinetics from sediments in the western and central basins of the Lake Erie under a range of oxygen conditions.

DET is a passive sampling technique in which a polyacrylamide hydrogel layer, comprised mostly of water, is placed in the sediment and allowed to equilibrate with dissolved species in the pore water (Davison et al. 2000). This method has been successfully employed for phosphate (Pagès et al. 2011) and iron (Roberson et al. 2008; Bennett et al. 2012). The DET technique provides estimates of very high resolution 2-dimensional pore water concentrations. The resulting 1-D phosphate porewater profiles and 2-D color maps of the phosphate concentrations permit the vertical, Fickian flux of phosphate to be calculated.

Because boats cannot be operated during wind-driven resuspension events, a Wetlabs Cycle P phosphate sensor will be deployed in the western basin in the summer of 2014. It will be programmed to collect a water sample every 2 hours and determine nutrient concentrations using a colorimetric wet chemistry method.

Nitrogen (N)

Microcystis, the primary cyanobacterial component of Lake Erie harmful algal blooms, preferentially takes up N species ($NH4+$> DON > $NO3-$; Chaffin and Bridgeman, 2014); and at times *Microcystis* (and *Planktothrix*) become N-limited in Lake Erie (Chaffin et al. 2013).

Tributary inputs of N consist almost entirely of NO3- and TKN, the less preferred forms of N; thus significant transformation of N in the sediment (i.e., remineralization to NH4+) could further feed HABs in the western basin. Alternatively, if denitrification (the transformation of NO3- to N2O and N2 gases) is readily occurring the sediments, then N could be permanently removed from Lake Erie and contribute to N limitation of *Microcystis* and the late-season species shift to the N-fixing *Anabaena* phytoplankton.

Water samples will be collected at selected locations and times for analysis of N species. Time series of samples will be collected from the cores and flux boxes. These samples will quantify the potential for internal N loading or removal and resolve how oxygen concentrations may affect the role of sediments as a source or a sink of N. In addition, by measuring multiple forms of N, we will be able to quantify significant N transformations.

Dreissenid mussels

In addition to sediments, dreissenid mussels are an important component of phosphorus and nitrogen cycling in Lake Erie. Although we do not propose to measure nutrient fluxes from dreissenids directly, we will combine literature-derived estimates of dreissenid P and N excretion with western Lake Erie dreissenid biomass and distribution maps for use in Subproject 3.

Subproject 2: Evaluating river hydrology and/or seasonality of nutrient loads in the western basin of Lake Erie, including the effects of meteorological and climatological forcing events

The central objective of Subproject 2 is the proper integration of models designed for different spatiotemporal scales in order to better evaluate the effects of changing land use, climate, and other factors on nutrient loads to western Lake Erie. We will couple a Bayesian Hierarchical SPARROW (BH-SPARROW) fit for the Great Lakes region and SWAT models calibrated for the Maumee and Sandusky River basins to quantify both N and P loadings.

We propose a Bayesian hierarchical SPARROW model that will allow spatially varying model coefficients to account for regional differences, as well as changes of nutrient source characteristics due to water quality management practices. Building upon the Bayesian SPARROW of Qian et al. (2005), the BH-SPARROW model for the Great Lakes Region will have varying coefficients to reflect differences in land use and other factors affecting nutrient generation. The project will take full advantage of the data available in the Great Lakes area and the flexible Bayesian hierarchical modeling approach to illustrate how a large regional SPARROW model can be downscaled to the Great Lakes Basin and then to basins of individual lakes. The BH-SPARROW will also be used to evaluate changes in nutrient loading on an annual scale.

While the BH-SPARROW model provides estimates of nutrient loadings over a large region at an annual scale, we will use the SWAT model for detailed analysis of two major river basins (Maumee and Sandusky) in the Western Basin of Lake Erie. The SWAT model is applied at a watershed scale to evaluate the effectiveness of various management practices under different future climate scenarios.

Both models will be used for TP and TN. Using historical data, we develop empirical relations between TN and various N species and between TP and various P species using a Bayesian hierarchical structural equation type of model (BHSEM). The BHSEM model will consider factors such as time, season, and watershed land use. By coupling these two models, we are able to assess the changes in the context of a larger spatial region and better understand the changes in nutrient loads to Lake Erie.

To model climate variations predicted over the next century, and the implications these will have on nutrient runoff control, we will integrate model climate data into the model simulations. Results will include flow, sediment, and key nutrient concentrations delivered to Lake Erie through the Maumee and Sandusky Rivers, including baseline and conservation model simulations, both under current and modeled climate regimes.

Finally, to support Sub-project 3, we will use the coupled model and approaches developed by the late Dave Dolan to determine phosphorus loads to the Western Basin in 2014 from all tributaries and other sources.

Sub-project 3: Developing a nutrient mass budget for the western basin of Lake Erie which includes sub-watersheds AND overall modeling synthesis

A fine-scale model of the Western Basin will be used to interpolate and extrapolate the point-in-space and point-in-time data collected in subprojects 1 and 2 into a system-level quantification of the relationship between external loadings of water, sediments, nutrients, and organic carbon and the responses to loadings and other forcing functions in the Western Basin. The model, called the Western Lake Erie Ecosystem Model (WLEEM), was developed over the last four years by LimnoTech specifically to address the types of questions posed by this project. WLEEM is a time-dependent, 3-D model that computes temporal and spatial profiles of water, sediment, nutrients, and plankton and benthos dynamics as a function of loadings from all major and minor watersheds, the Detroit River, and hydro-meteorological forcing functions. The model consists of two linked public domain models, EFDC (TetraTech 2007) and a modified version of RCA (HydroQual 2004).

Limnotech has also coupled EFDC with a wind-wave model (SWAN) (Delft University of Technology 2006) to facilitate simulation of wind-driven sediment resuspension as a source of internal sediment and phosphorus loading in the western basin. LimnoTech also customized RCA to include up to five phytoplankton functional groups; effects of Dreissenids on nutrient cycling, particle fate and transport, algal production, and water clarity; and a benthic algal functional group based on the Auer Great Lakes Cladophora Model (GLCM) (Auer, et al., 2010; Bierman, et al., 2005; DePinto, et al., 2009; LimnoTech 2010; LimnoTech 2013). This improved RCA framework is called the Advanced Aquatic Ecosystem Model (A2EM) and will be utilized for this project.

WLEEM will be applied to simulate nutrient and lower food web dynamics for the 2014 Cooperative Science Monitoring Initiative field year. Data collected as a part of this project as well as available data from other organizations will be used to develop model forcing functions (atmospheric conditions, tributary loads, boundary conditions, etc.) and for model corroboration.

The first objective, to quantify the magnitude of the internal nutrient load, will be addressed by evaluating the output of the A2EM sediment diagenesissubmodel and from wind-driven resuspension computed by the EFDC-SWAN model. The sediment diagenesissubmodel simulates the anoxic and oxic nutrient pore diffusion rates across the entire model domain. This submodel fully simulates the deposition, resuspension, and diffusion of nutrients to the sediment bed and all of the redox reactions that occur in the sediment bed. The magnitude of nutrient release estimated by the model will be compared against actual release rates measured as part of this project at sites across the basin. The integrated annual internal nutrient load will be compared against the external nutrient loads to determine if internal loading is a significant contributor to water column phosphorus concentration and ultimately to the development of HABs.

The second objective, to identify the important drivers of seasonal differences in HABs, will be addressed by using the model to isolate the influence of expected drivers by modifying the model input that corresponds to that driver. For example, the impact of river flow and loads from the Maumee River on HABs formation will be assessed by running a series of model simulations where the only change made between simulations is the flow and/or nutrient load of the Maumee River.

The third objective, to develop a nutrient mass balance budget including external loads from minor watersheds, will be accomplished by analyzing model output from the 2014 simulation. The sediment sub-model provides an estimate of the internal nutrient load including gross deposition, resuspension, and diffusion across the sediment water interface. Internal transformation of nutrients between various forms (available and unavailable; dissolved and particulate) will also be tracked by the model to allow for a complete tracking of nutrient sources to its ultimate impact on endpoints (such as HABs formation). Export of phosphorus from the basin is estimated by the model based upon the model-predicted concentration of nutrients at the boundary and the flow of water across the boundary as predicted by the NOAA GLCFS model for Lake Erie. The end result of this is a complete mass balance on all sources of nutrients in the water column as well as in the active sediment bed in western Lake Erie and a computation of the nutrients delivered from the Western Basin to the Central Basin of the lake.

The project completed a successful field season in 2014. Model development and analysis is in the final stages as of fall 2015. Members of the research team provided several presentations from this project at IAGLR 2015. The final report is expected in spring 2016 with numerous white papers in preparation.

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3.7 Connecting the Lakes - Completing their Assessment: Huron-Erie Corridor National Coastal Condition Assessment 2015

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The Huron-Erie Corridor (HEC) is the connecting channel between Lake Huron and Lake Erie, and includes the St. Clair River, Lake St. Clair, and Detroit River. This ecologically and economically significant system was not included in the 2010 U.S. EPA Office of Water National Coastal Condition Assessment (NCCA). In 2014, U.S. EPA conducted a pilot assessment of ecological conditions in the HEC which demonstrated the feasibility of assessing the HEC using NCCA methods and established baseline/temporal information. In 2015, the HEC was sampled as an enhancement to the NCCA of the Great Lakes survey. The NCCA provides statistically valid regional and national estimates of the condition of U.S. coastal waters and the Great Lakes. Sixty-one stations along the corridor were sampled for water quality, sediment quality, phytoplankton, algal toxins and benthic community composition to provide information on spatial variability of conditions throughout the corridor (Figure 1). Results are being analyzed with respect to landscape characteristics of adjacent watersheds. The combined corridor water quality data and landscape characterization form a demonstration and validation of a comprehensive assessment of the Great Lakes and their connecting channels. Results also will contribute to a coastal observing system that may be applied to all connecting corridors of the Great Lakes.

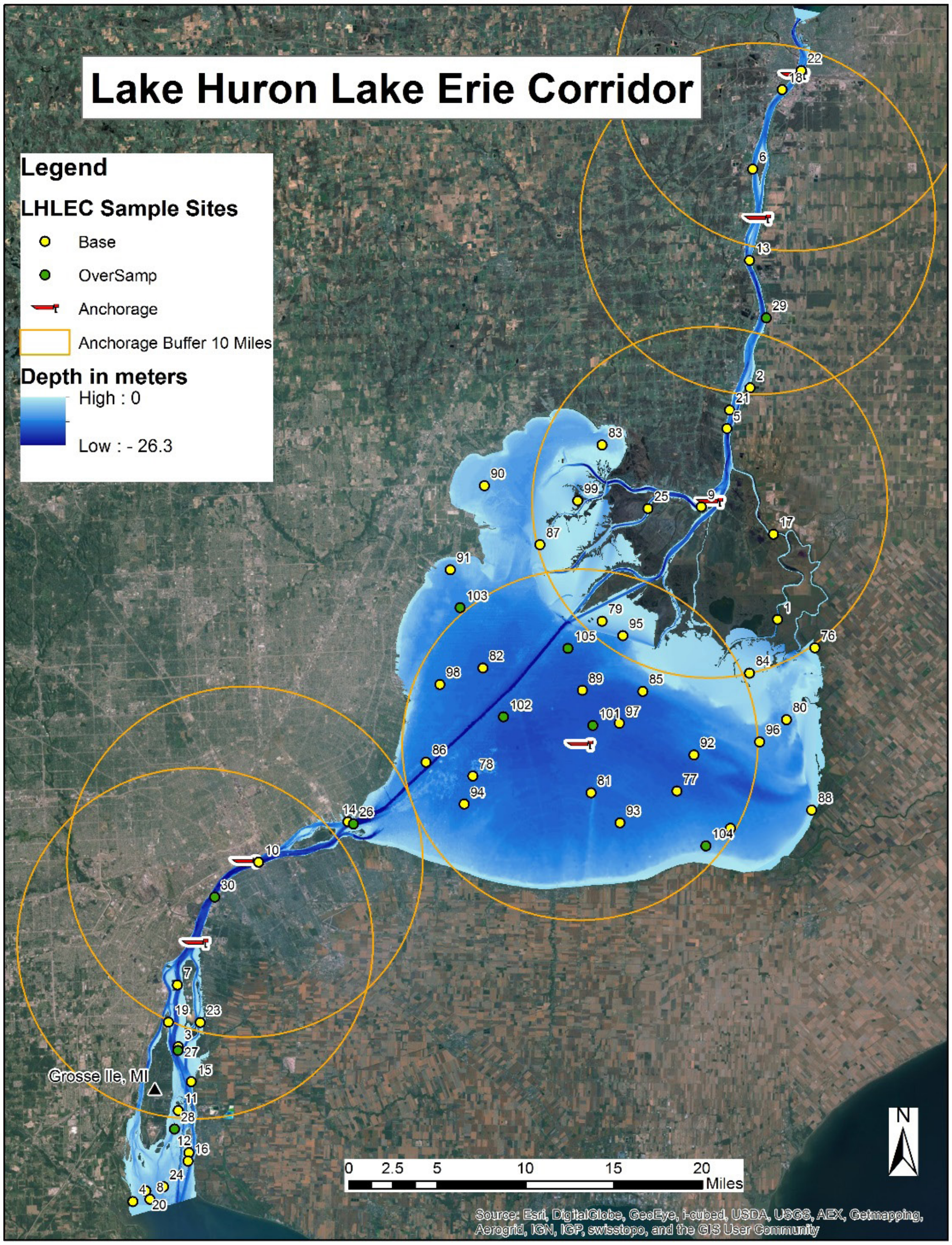

Figure 1. Pilot US EPA sampling stations located within the Huron-Erie corridor.

3.8 Linking Historical Studies and Biological Inventories to Evaluate Current Biodiversity and Improve Wetland Management in the St. Clair-Detroit River System

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Introduction

Members of our "Implementing Great Lakes Coastal Wetland Monitoring" project (called CWM) were requested to discuss biodiversity within the St. Clair-Detroit River System for State Of The Strait 2015, based on our 5 year (2011-2015) Great-Lakes wide study of the coastal marsh biota. Our sampling included plants, fish, birds, amphibians, invertebrates, as well as water quality. Sampling was conducted for CWM using a random sampling protocol to select sites and sampling plots, which provided a thorough biological overview of current conditions based on over 1000 coastal marshes (Figure 1). A more complete summary of protocols used by CWM and some of CWM's data products can be found on the web site: http://greatlakeswetlands.org.

However, because the CWM inventory does not provide a long-term perspective of the changing ecological conditions and overall biotic diversity of coastal wetlands, we decided to include in this State of the Strait presentation a discussion of earlier biological inventories of the St. Clair and Detroit Rivers as well. Hundreds of biological inventories have been conducted in the Great Lakes region, including many conducted within the St. Clair-Detroit River System. Michigan Natural Features Inventory's (MNFI) biodiversity database for all of Michigan has been summarizing these studies since roughly 1980, so we recommend utilizing it to provide time-depth for understanding the biodiversity of the St. Clair and Detroit Rivers (see the MNFI web site for more information: http://mnfi.anr.msu.edu/). MNFI's database includes recent, intensive biological inventories focused on both rare and common plant community and species along the rivers. An equivalent database exists for adjacent Ontario, but will not be summarized for this presentation.

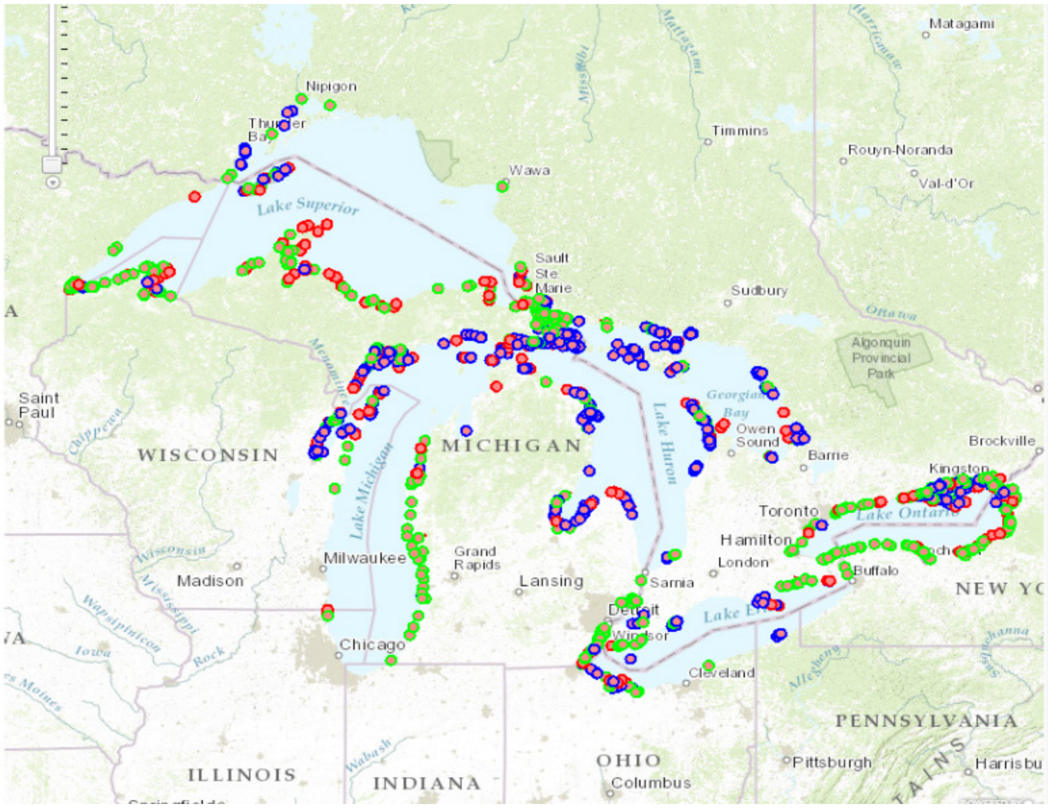

Figure 1. Map of Great Lakes coastal wetlands sampled between 2011 and 2015 by the Implementing Great Lakes Coastal Wetland Monitoring (CWM) sampling teams.

Historic overview

The St. Clair and Detroit River System has a long history of human land use that can be traced back to Native American Iroquoian cultures as far back as 1400 AD or earlier (Tanner 1987). Native American management with fire likely played a major role in establishment and maintenance on the extensive prairies and savannas that lined the rivers and extended inland at the time of the original government surveys in the early 1800s (Albert and Comer 2008). Native American's harvested a broad range of natural resources, including shell- fish, fish, waterfowl, and mammals, but the only species that was documented as overharvested was beaver, as a result of the intense fur trade with both the British and French. An early survey in 1837 along the Detroit River mentioned remnants of beaver dams and their probable past importance in the flat, wet landscape (Hubbard 1881), but there were few or no beavers encountered during the survey.

Biological Inventories

The earliest systematic biological inventories were conducted by the government land surveyors, who began their surveys in 1816 on the swamp and marsh filled landscape along Lake Erie and the Detroit River in southeastern Michigan (Albert and Comer 2008). We should not under-estimate the importance of these surveys, as they provide us with the most complete and systematic description of the topography, soils, hydrology, and vegetation along a one mile square grid for the entire state of Michigan. Their notes included tree species and size, and accurately mapped the boundaries between the plant communities, which included marshes, wet prairies, and swamp along the rivers, with clay uplands dominated by beech and sugar maple, and sand ridges dominated by oak forest or savanna. Figure 2 shows the St. Clair River delta, with its abundant marsh, wet prairie, and oak savanna. The surveyor notes and resultant maps have allowed change analysis to determine approximate conversion of original vegetation types to current vegetation types. For almost all plant communities, less than 2% of the original area remains, although prairies and savannas are much rarer still. Coastal marsh and swamp remain relatively common along portions of the rivers and the shorelines of Lakes St. Clair and Erie.

Early biological collections housed in Michigan's major universities document the diversity of flora and fauna associated with the original ecosystems within and along the rivers. These biological collections are included in MNFI's database of rare biota and high-quality natural communities (Figure 3). The figure shows the rare species and community occurrences along the St. Clair and Detroit Rivers. However, a closer examination of these records collected since 1980 show that nearly 75% of clam and mussel species have declined significantly in the rivers, and nearly 50 species of plant have not been seen in over 80 years - most of these plants are associated with either wet prairies or marshes. More than 98% of our wet prairies have been destroyed statewide, but the St. Clair and Detroit River corridors support some of the larger remnants of this globally rare community. There has been a severe decline in diversity of all aquatic groups, including fish, mussels, and clams, and also for coastal marsh birds.

MNFI also conducted surveys directed specific at Great Lakes coastal wetlands in 1987 and 1988 along the St. Clair and Detroit Rivers, and additional marsh surveys in the 1990s and early 2000s (Albert et al. 1988, Albert and Minc 2001). These early marsh surveys allow direct comparisons for many of our current 2011-2015 CWM surveys. A significant change was a major increase in invasive plant species dominance as water levels dropped and remained low from 1999 through 2013. The increase in invasive hybrid cattail (*Typha x glauca*) and common-reed (*Phragmites australis*) was especially dramatic in wetlands in Lake St. Clair, in the St. Clair River delta, and further north in Saginaw Bay. Both of these invasive species were already aggressive invaders in western Lake Erie and the Detroit River prior to the 1999 low-water conditions.

The early (1987-2004) marsh surveys by MNFI focused only on plants, while the 2011-2015 CWM surveys provide detailed faunal data as well. The number of invasive faunal species was higher in the southern Great Lakes (including the St. Clair and Detroit Rivers) than in the northern Great Lakes for both fish and invertebrates. Native bird and amphibian diversity was also found to be lower in CWM surveys of the southern Great Lakes.

The CWM surveys were less effective at documenting rare plant and animal species than MNFI's targeted surveys. This was to be expected as surveying for rare biota is most effective if it focuses on specific micro-habitats, and sometimes narrow periods of time, as for flight periods of rare moths, butterflies, or dragonflies. However, several rare plants were encountered, including American lotus (*Nelumbo lutea*) along the lower Detroit River. The survey also

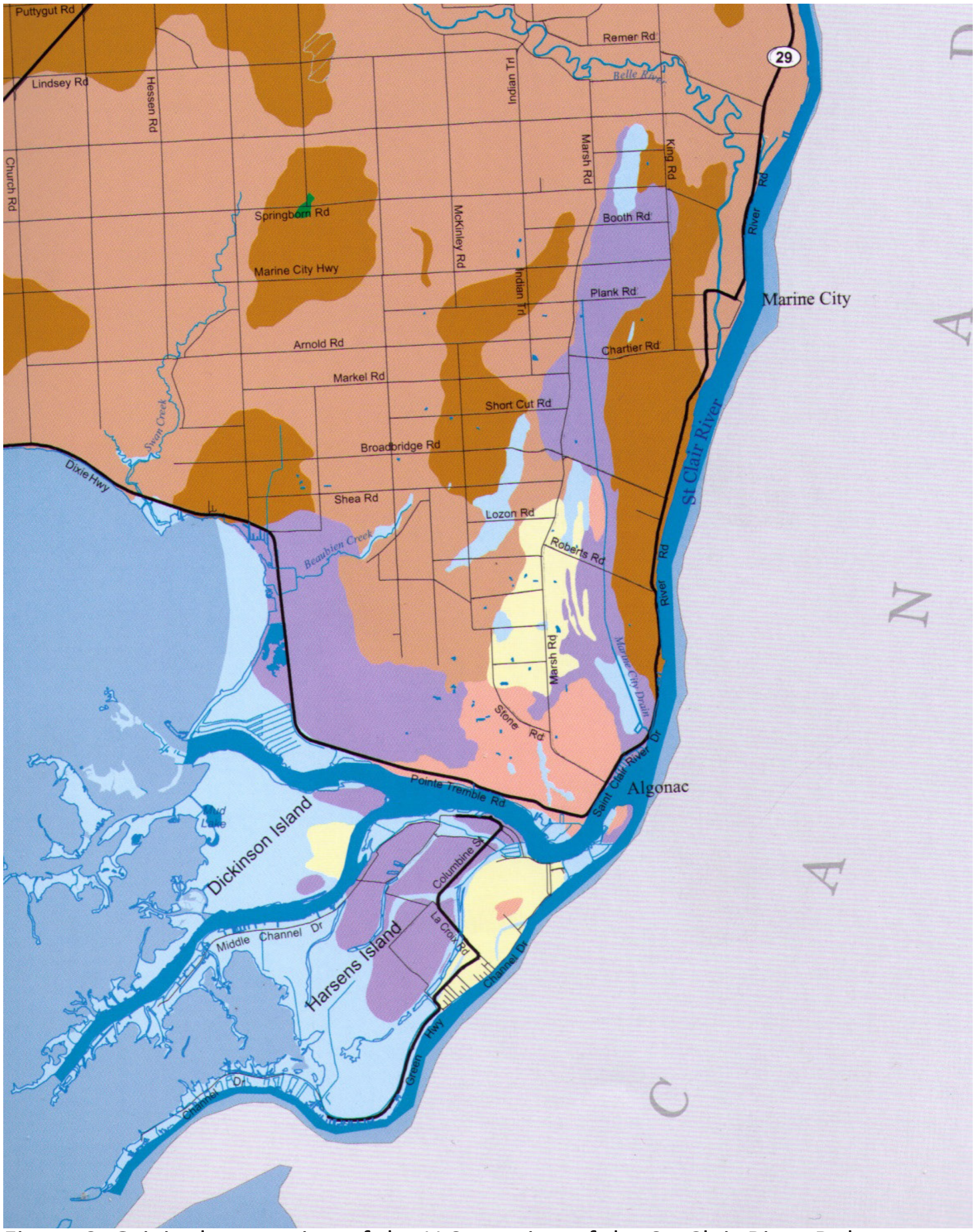

Figure 2. Original vegetation of the U.S. portion of the St. Clair River Delta.
Purple = wet prairie, yellow = oak savanna, blue = marsh,
orange = swamp forest, pinks = forest (map from Albert and Comer 2008).

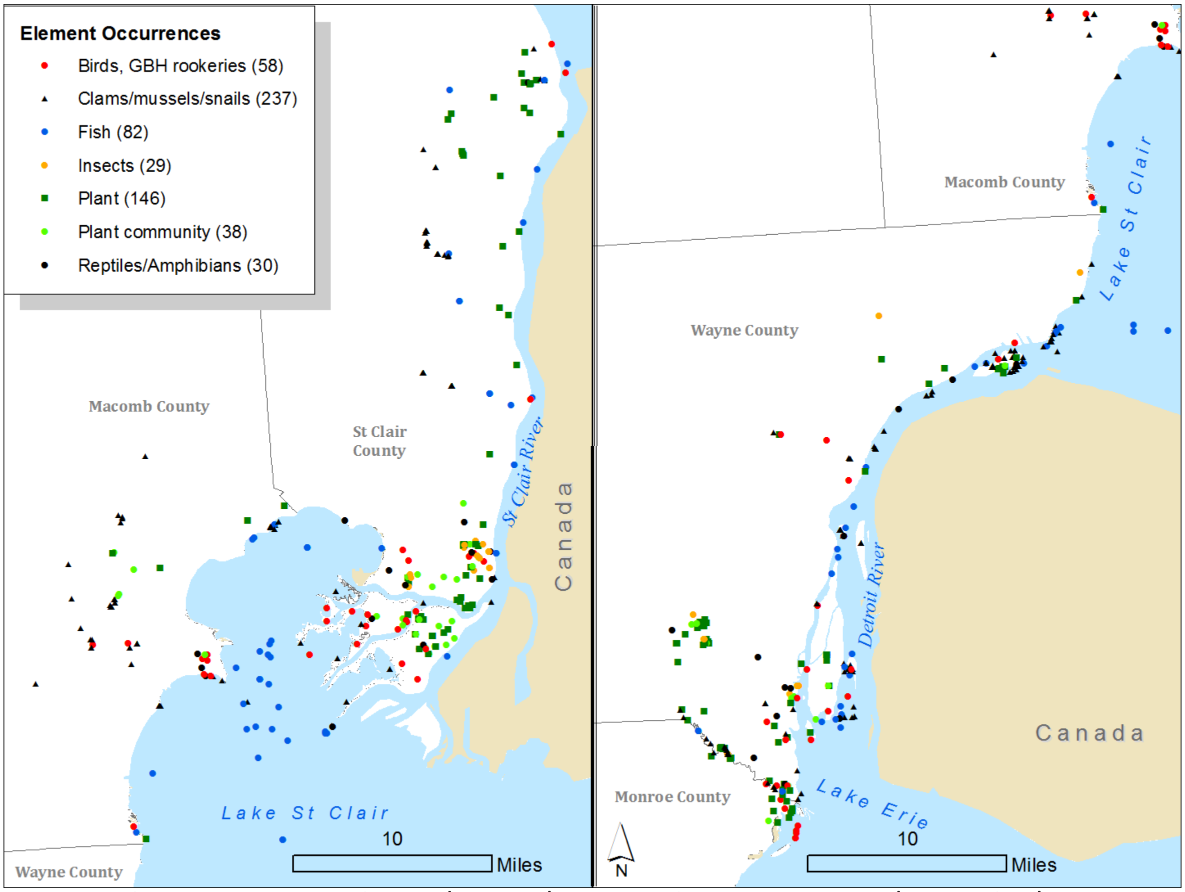

Figure 3. Rare species and natural community occurrences along or in the St. Clair and Detroit Rivers. Locational data include both historic and recent biological surveys in the Michigan Natural Features Inventory electronic database.

discovered a significant new site for globally rare lakeplain prairie at St. Johns marsh, in an area currently being proposed for diking by the Michigan DNR.

Most of our loss of biotic diversity can be linked to land-use changes. The CWM project collected water chemistry data that may improve our understanding of biodiversity loss, as analysis of the data collected between 2011 and 2015 proceeds. Probably one of the most direct recent causes in loss of biological diversity is increased coverage of invasive plant species, and the thousands of data points collected during the CWM study should allow us to document the relationship between water quality and invasive plant dominance. The effect of raking, disking, and plowing of coastal wetlands on native plant diversity was also documented by the CWM dataset – many disked and plowed wetlands were devoid of sediment-binding emergent wetland plants. Herbicide treatments of common reed were also regularly encountered in CWM sampling plots, and repeated sampling indicates that these treated areas were often replaced by both algal blooms and other invasive plants, reinforcing the assertion that other approaches to invasive plant control should be considered.

Summary

In summary, to understand the changing biodiversity along the St. Clair and Detroit Rivers it is probably more effective to combine the results of inventories of several different types, collected over a broad time period. In this presentation we are highlighting three inventories: the original government survey notes, MNFI's statewide long-term electronic database and inventories of rare biota, and the recent CWM Great-Lakes wide biotic inventories and database. The first of these, the original surveyors' notes, provide a broad picture of the plant communities and their spatial distribution along the rivers in the early 1800s. The second database and inventory, Michigan Natural Features Inventory's species-focused database, summarizes inventories from the early 1800s to the present, provides us with floral and faunal lists for our coastal ecosystems and locations of reference high-quality plant communities, and also provides a summary of which of these species have become rare due to habitat degradation or loss. A summary of these species and community inventories is maintained in MNFI's electronic database and ongoing field studies. And the third tool, the recent CWM inventories provide an intensive Great-Lakes wide sample collected simultaneously across all of the Great Lakes using the same protocols between 2011 and 2015. While rare species are under-represented in the CWM inventories, it probably provides the most accurate appraisal of common and invasive species of both plants and animals, and the potential for evaluating current habitat conditions. Combining these three inventories, and likely other similar studies from Ontario, provides us information for directing our ongoing restoration and management of aquatic and wetland ecosystems within the Straits.

Acknowledgements

Funding for the GLRI (CWM) study was provided by the Great Lakes National Program Office under the United States Environmental Protection Agency, grant number GL-00E00612-0.

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3.9 An Update on the American and Canadian Status of Beneficial Use Impairments in the Detroit and St. Clair River Areas of Concern

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The Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada was originally signed in 1972, then updated in 1978, 1983, 1987, and 2012. The Agreement established objectives and criteria for the protection, restoration and enhancement of water quality in the Great Lakes system. Annex 1 of the Agreement, defines an Area of Concern (AOC) as "a geographic area designated by the parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level" (GLWQA 2013). In 1987, 43 AOCs were designated throughout the Great Lakes in the United States and Canada (Figure 1) and were evaluated based on the list of 14 possible Beneficial Use Impairments (BUIs). As defined in Annex 1, a BUI is "a reduction in the chemical, physical, or biological integrity of the Waters of the Great Lakes sufficient to cause any of the following:

1. restrictions on fish and wildlife consumption;
2. tainting of fish and wildlife flavour;
3. degradation of fish and wildlife populations;
4. fish tumours or other deformities
5. bird or animal deformities or reproduction problems;
6. degradation of benthos;
7. restrictions on dredging activities;
8. eutrophication or undesirable algae;
9. restrictions on drinking water consumption, or taste and odour problems;
10. beach closings;
11. degradation of aesthetics;
12. added cost to agriculture or industry;
13. degradation of phytoplankton and zooplankton populations; and
14. loss of fish and wildlife habitat" (GLWQA 2013).

Figure 1. Map of All Great Lakes Areas of Concern in the United States and Canada

The Detroit River and St. Clair River are two of only five binational AOCs sharing jurisdiction between the United States and Canada.

The Detroit River AOC includes the entire 31 miles (51 km) the river from the mouth of the Lake St. Clair to the north end of Lake Erie; likewise the St. Clair River AOC encompasses the entire 40 miles (64 km) of the river from the mouth of Lake Huron down to and including the St. Clair River delta. Both rivers provide drinking water to thousands of people who call the area home in addition to valuable riverine and wetland habitat for many species of fish, birds and mammals. The rivers also support a wide variety of recreational activities including fishing, boating and swimming.

The Detroit and St. Clair Rivers were identified as AOCs for similar reasons. Extensive industrial, urban, and agricultural development resulted in the historical release of harmful legacy pollutants from industries including chemical manufacturers, petroleum refineries, paper plants, steel mills, and electrical power generating plants; bacteria from wastewater treatment plants; and agricultural runoff. This pervasive development contributed to significantly impaired water quality, contamination of sediment and degradation of benthic communities, body burden impacts to fish and wildlife, and loss of critical habitat. Since the signing of the Great Lakes Water Quality Agreement, American and Canadian governmental agencies, municipalities, industries, First Nations, and community groups have been working steadily to clean up, restore and revitalize both rivers. The following information highlights some of the recent successful remediation and monitoring actions undertaken on each side of both rivers.

Detroit River AOC – U.S. Side:

Loss of Fish and Wildlife Habitat and Degradation of Fish and Wildlife Populations BUIs:
In 2014, the Detroit River AOC Public Advisory Council (PAC) updated their plan to remove the *Habitat and Populations* BUIs. The plan includes a list of restoration projects which must be constructed and monitored. Projects on the plan are being implemented by multiple partners, and recent projects completed as part of this plan include the restoration of the Blue Heron Lagoon and South Fishing Pier on Belle Isle. Future construction projects that are in the design phase include Stony and Celeron Island restorations; Lake Okonoka on Belle Isle, and wetland restoration at Milliken State Park.

Degradation of Benthos BUI:
In 2012, the Detroit River PAC was provided funding for a project to gather and assess all available sediment data throughout the Detroit River on the U.S. side. This initial review of historical sediment data was necessary to determine appropriate areas for further investigation. Based on this early work, the EPA is currently characterizing all the identified areas of sediment contamination which will eventually lead to a list of sites to be remediated. The eventual sediment remediation will provide clean substrate for the benthic community and fish population and is expected positively impact fish and wildlife and other BUIs such as *Fish Tumors or Other Deformities, Bird or Animal Deformities or Reproduction Problems* and *Restrictions on Fish and Wildlife Consumption*.

Separate from the sediment mapping project, is an upcoming sediment remediation project currently in remedial design in the Upper Trenton Channel. Design is expected to be complete in 2016, with remediation likely to occur in 2017. This clean-up is expected to have a significant positive impact on the *Fish Tumours or other Deformities* BUI.

Detroit River AOC – Canadian Side:

Degradation of Benthos BUI:
Over the last several years, researchers at the University of Windsor sampled 73 sites for benthic invertebrates and sediment in order to determine whether contaminants are contributing to benthic toxicity. Results were very positive and it appears that sediment toxicity is not driving any impairment in the benthic community on the Canadian side of the Detroit River. Using these data, an assessment of the *Degradation of Benthos* BUI will be completed soon.

Bird or Animal Deformities or Reproductive Problems BUI:
A snapping turtle research project was conducted by Environment Canada in 2014 and 2015. Snapping turtle (*Chelydra serpentina*) eggs were collected and incubated. Hatching success

and deformity rates were assessed and found to be similar to a reference site outside the AOC. Mercury burdens in eggs were also similar to the reference site; results are pending for sum PCB burdens in eggs. The project will be repeated in 2016 and a tree swallow (*Tachycineta bicolor*) toxicology project will also be established in 2016.

Loss of Fish and Wildlife Habitat BUI:
Since 2000, over 320 hectares (790 acres) have been restored to Carolinian upland forest or tall grass prairie at numerous sites throughout the watershed. In addition, eight shoreline softening projects have occurred along the Detroit River and a Shoreline Design Manual was developed that describes the various options for shoreline restoration. This resource supports a growing effort to restore habitat diversity along the shoreline while achieving the primary erosion protection function. Next steps include prioritizing areas in the Detroit River for additional fish habitat restoration projects, such as installing breakwaters to create slow water areas for nursery habitat for many fish species.

Table 1.Current Status of Beneficial Use Impairments in the Detroit River AOC in the United States and Canada.

Detroit River AOC BUI Status		
Beneficial Use Impairment	U.S. Status	Canada Status
Restrictions on Fish and Wildlife Consumption	Impaired	Impaired
Tainting of Fish and Wildlife Flavour	Not Impaired (Removed in 2013)	Not Impaired (Removed in 2014)
Fish Tumours or Other Deformities	Impaired	Impaired
Degradation of Fish and Wildlife Populations	Not Impaired	Impaired
Bird or Animal Deformities or Reproduction Problems	Impaired	Impaired
Degradation of Benthos	Impaired	Impaired
Restrictions on Dredging Activities	Impaired	Impaired
Eutrophication or Undesirable Algae	Not Impaired	Not Impaired
Restrictions on Drinking Water Consumption or Taste and Odor Problems	Not Impaired (Removed in 2011)	Not Impaired (Removed in 2011)
Beach Closings	Impaired	Impaired (BUI Assessment Report Under Review)

Table 1, continued.

Degradation of Aesthetics	Impaired	Impaired (BUI Assessment Report Under Review)
Added Costs to Agriculture and Industry	Not Impaired	Not Impaired
Degradation of Phytoplankton and Zooplankton Populations	Not Impaired	Requires Further Assessment
Loss of Fish and Wildlife Habitat	Impaired	Impaired

St. Clair River AOC – U. S. Side:

Loss of Fish and Wildlife Habitat BUI:
In 2012, the St. Clair River AOC Binational Public Advisory Council (PAC) finalized their plan to remove the *Loss of Fish and Wildlife Habitat* BUI with a list of nine sites in need of restoration. Over the past four years, multiple projects have been completed including the Blue River Walk in Port Huron, the Living Shoreline project in Marysville, Port Huron North and South shoreline enhancements, the Marine City Drain habitat restoration project, the Krispin Drain habitat restoration project and the Middle Channel, Pointe aux Chenes, and Hart's Light Fish Spawning Reefs. Most recently the Cottrellville Township shoreline project has been completed which included the removal of a steel seawall replacing it with cobble and extensive rocky and woody habitat. One of the final projects is the restoration of Cuttle Creek, a tributary to the St. Clair River. This project included the removal of in-line pond and re-establishment of fish passage through a perched culvert barrier using natural channel design principles.

Beach Closings BUI:
Recently, in the Cities of Port Huron and Marysville, infrastructure updates have been implemented eliminating the sources of *E. coli* from combined sewer overflows, illicit connections and even wildlife such as Canada geese (*Branta canadensis*). Infrastructure improvements have eliminated sources of human pathogens and a green infrastructure project has reduced ideal habitat for Canada geese at the popular Chrysler Beach in Algonac. The *Beach Closings* BUI is currently under assessment and is expected to be removed in 2016.

Degradation of Benthos BUI:
In 2014, after a thorough review of all available sediment and benthic community data in the St. Clair River, the *Degradation of Benthos* BUI was removed. The assessment utilized the Sediment Quality Triad approach and examined all available sediment chemistry data, sediment toxicity data and macroinvertebrate community data. The findings indicated that there continues to be no evidence of sediment contamination significant enough to degrade the benthos or require further sediment characterization or sediment remediation.

Restrictions on Drinking Water or Taste and Odour Problems BUI:
The St. Clair River is unique in the potential for impacts to drinking water due to the fast

flowing waters of the river and the existence of several chemical manufacturing plants in Sarnia, Ontario. Currently, the EPA and MDEQ are working with St. Clair BPAC to assess the *Drinking Water* BUI using locally-derived delisting criteria based on the existing state and federal requirements for regulated facilities to have plans in place related to appropriate prevention, notification and response should a chemical spill occur.

St. Clair River AOC – Canadian Side:

Fish Tumors or Other Deformities BUI:
Brown bullheads (*Ameiurus nebulosus*) were collected and their livers extracted for analysis of liver tumours caused by exposure to contaminants. Fish were collected in 2013 and 2014 through collaboration between Walpole Island First Nation and Environment Canada. Over 50 fish have been collected and processed and are awaiting analysis; however, visual inspections were positive.

Loss of Fish and Wildlife Habitat BUI:
Habitat creation and restoration remains a priority, particularly in the southern region of the Canadian side of the AOC which was most heavily impacted by habitat loss. Since 1995, over 280 projects have been completed contributing 250 hectares (618 acres) of new or restored habitat. In addition, twelve shoreline restoration projects have been completed reducing shoreline erosion while improving habitat quality for aquatic animals and fish. Targets set for this BUI are quickly being approached.

Bird or Animal Deformities or Reproductive Problems BUI:
A research project on Walpole Island was completed in 2014 that saw the collection of Leopard Frogs (*Rana pipiens*). Frogs were visually inspected for deformities (e.g. missing limbs). The study was a collaborative effort, again between Walpole Island First Nation and Environment Canada. Results were positive and will be incorporated into a status assessment currently being prepared. Although the study has concluded, community members from Walpole Island plan to continue monitoring frog deformities in the future.

Degradation of Benthos BUI:
A major project slated for the Canadian side of the St. Clair River AOC involves the remediation of three sections of mercury-contaminated sediment along the shoreline. This project will directly support the *Restrictions on Fish and Wildlife Consumption* and the *Degradation of Benthos* BUIs. After extensive consultation, the recommendation to hydraulically dredge these locations was forwarded to the Federal and Provincial governments who are currently reviewing the recommendation and investigating funding options.

Table 2.Current Status of Beneficial Use Impairments in the St. Clair River AOC in the United States and Canada.

St. Clair River AOE BUI Status		
Beneficial Use Impairment	U.S. Status	Canada Status
Restrictions on Fish and Wildlife Consumption	Impaired	Impaired
Tainting of Fish and Wildlife Flavour	Not Impaired (Removed 2011)	Not Impaired (Removed 2011)
Fish Tumours or Other Deformities	Not Impaired	Requires Further Assessment
Degradation of Fish and Wildlife Populations	Not Impaired	Requires Further Assessment
Bird or Animal Deformities or Reproduction Problems	Impaired	Requires Further Assessment
Degradation of Benthos	Not Impaired (Removed 2014)	Impaired
Restrictions on Dredging Activities	Not Impaired (Removed 2011)	Impaired (BUI Assessment Report Under Review)
Eutrophication or Undesirable Algae	Not Impaired	Not Impaired
Restrictions on Drinking Water Consumption or Taste and Odor Problems	Impaired	Impaired
Beach Closings	Impaired (BUI Assessment Report Under Review)	Impaired (BUI Assessment Report Under Review)
Degradation of Aesthetics	Not Impaired (Removed 2012)	Not Impaired (Removed 2015)
Added Costs to Agriculture and Industry	Not Impaired (Removed 2012)	Not Impaired (Removed 2012)
Degradation of Phytoplankton and Zooplankton Populations	Not Impaired	Not Impaired
Loss of Fish and Wildlife Habitat	Impaired	Impaired

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3.10 A multi-chemical hazard metric predicts chironomid abundance in the Detroit River

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Abstract
Hazard quotients are commonly used with sediment quality guidelines (typically the probable effect concentration, PEC) to interpret site-specific sediment quality and potential toxicity to benthic communities. Methods to combine hazard quotients across pollutants into a single multi-chemical hazard score are generally non-standardized. This study contrasted three multi-chemical hazard score approaches, generated as the sum (*sumPEC*), average (*avgPEC*) and weighted average hazard quotient (*wtavgPEC*) for 13 priority chemicals in the Detroit River, to predict chironomid abundance in sediments of appropriate habitat. In addition, a novel hazard quotient approach (*HZD*), that uses both threshold effect and probable effect sediment quality guidelines and an assumed sigmoidal toxicity distribution, was developed to provide an alternative summed hazard score and compared with the above hazard indices. Multivariate analyses were used to define sediment habitat types and delineate habitats that support chironomid populations. For silt habitats, the *HZD* metric provided the best predictor of chironomid abundances followed by wtavgPEC. For low flow sand, *HZD* and *wtavgPEC*, provided comparable levels of prediction of chironomid abundance. Differences in chironomid abundance among habitats of similar contamination suggest differences in chemical bioavailability and sensitivity due to habitat-specific conditions. A contour map of hazard scores within the Detroit River was developed to delineate areas of low, intermediate and high potential for toxicity to benthic invertebrates.

Introduction
Sediment quality guidelines (*SQGs*) are used in conjunction with chemical concentration survey data as an initial step in the evaluation of degraded benthos

and to evaluate the suitability of prospective locations for use as reference sites with respect to chemical stressors (Long et al. 2006). Contaminated systems, such as the Detroit River Area of Concern, have historically received and/or continue to receive inputs of a variety of priority pollutants that include metals and organic contaminants. Each pollutant may have different sources and temporal patterns in loadings, environmental weathering, hydraulic focusing and environmental fate characteristics necessitating a multi-pollutant approach to hazard assessment. Effectively, areas that may be considered clean with respect to one or a group of pollutants, may be contaminated for others. As such, development of a multi-chemical hazard index is useful to provide a single score value on which to assess potential reference areas and delineate moderately contaminated and highly contaminated regions in the system.

The most common approach to hazard assessment applies hazard quotients, which is the ratio of chemical concentration in a sample relative to a *SQG* or reference toxicity concentration. Typically, the probable effect concentration (*PEC*) *SQG* value is used within the hazard quotient (Ingersoll et al. 2001). However, methods to combine hazard quotients across chemicals are non-standardized. Commonly, hazard quotients are summed across chemicals, averaged or generated as a weighted average to increase the weight of certain types of contaminants present in the mixture. Each of these methods can contribute to biases in the interpretation of overall hazard depending on their method of computation. These approaches also assume toxicity is linearly related to sediment contamination, whereas it is well known that mortality follows a sigmoidal relationship between toxicity and contamination. The objective of this research was to introduce an alternative toxicity index, defined here as the hazard score (*HZD*), which assumes sigmoidal toxicity and adopts a multi-point calibration for each pollutant based on threshold effect concentration *SQGs* (*TEC*) and PEC values. The new *HZD* metric and commonly applied multi-pollutant hazard indices were then compared against one another for their ability to predict chironomid abundance in appropriate Detroit River sediment types. The hazard indices generated from the most successful metric where then generated for the entire Detroit River to classify regions with high and low potential for degraded benthos.

Methods

Data from a 1999 survey of sediment chemistry and benthic community assessment were utilized for the study. Briefly, 136 sediment samples matched with benthic community assessment were collected throughout the Detroit River Area of Concern according to a stratified random sampling design as described in Drouillard et al. (2006) and Szalinska et al. (2006). Benthic invertebrates were assessed at each site by taking multiple grab samples via petite ponar until a standard volume of 2 L sediment was obtained. The preserved 2 L sample was sieved through a 500 µm mesh and macroinvertebrates were enumerated and identified to the species or family level depending on the taxa (Wood, 2004).

Habitat type of sediments was defined using a multivariate approach that considered site depth, bottom water velocity, sediment organic carbon content and grain size. The model identified five habitat types defined as: silt, high velocity sand, gravel, low velocity sand and mixed habitat. Discriminant function analysis assigned 124 of the above 136 stations into one of the 5 unique habitats with a 95% confidence. Subsequently, major benthic taxa were evaluated within groups of samples classified into each habitat type. Chironomidae were found in high abundance in silt and low flow sand. Amphipoda were in high abundance in gravel and high flow sand, while oligochaetes were present in all habitat types.

Chironomidae relative abundance was expressed as a field toxicity estimate by standardizing to organism abundance in sediment samples found to have the highest chironomid abundances for a given habitat type:

$$\textit{Field Toxicity(\%)} = \left(1 - \frac{1-A_x}{A_{high}}\right) * 100\%$$

Where A_x is the number of Chironomidae measured in a sediment sample at a given site and A_{high} is the mean abundance of Chironomidae determined in 5 sediments of the same habitat type which had the highest abundance of the indicator species.

Sediment chemistry data for arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, zinc, hexachlorobenzene (HCB), DDE, total PCBs and total PAHs were obtained from past survey data. For each pollutant and sediment sample, a hazard quotient was generated based on the pollutant specific *PEC-SQGs* reported by MacDonald et al. (2000). Multi-pollutant hazard indexes were generated according to three calculation schemes. The first, *sumPEC* represented the sum of hazard quotients for the 13 priority pollutants. The second, *avgPEC* was the mean hazard quotient across the 13 pollutants. The *wtavgPEC* followed the recommendation of Ingersoll et al. (2001) which gives a higher weighting to organic pollutants relative to metals:

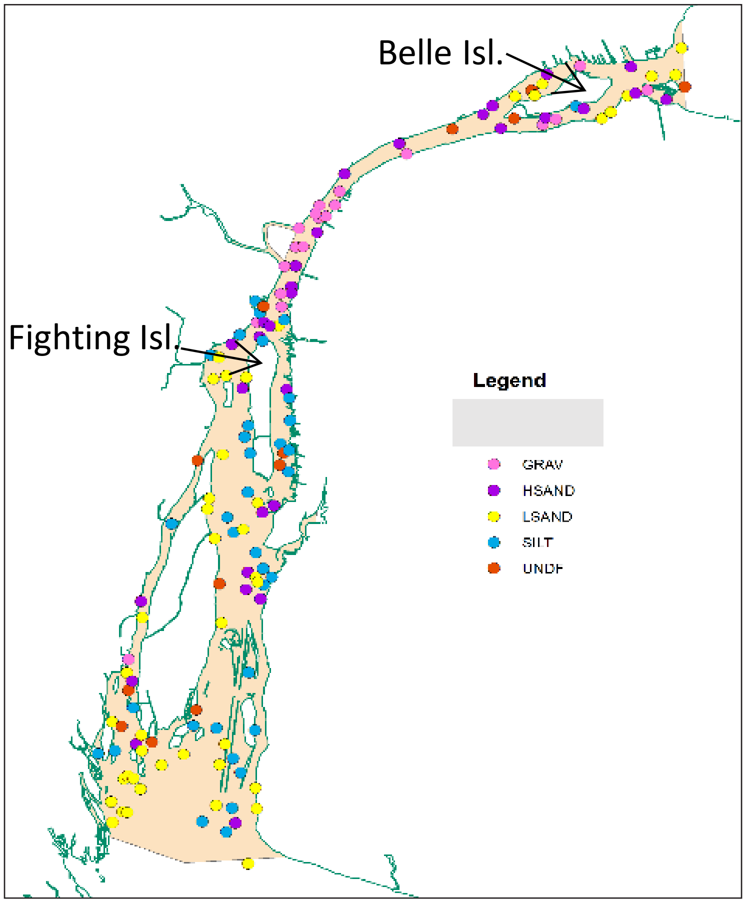
$$wtavgPEC = \frac{\sum_{i=1}^{n_{met}} \frac{PECQ_{x(metals)}}{n_{met}} + PECQ_{HCB} + PECQ_{DDE} + PECQ_{PCBs} + PECQ_{PAHs}}{.5}$$

Where n_{met} is the number of metals identified in the sample, PEC-$Q_{x(metals)}$ is the hazard quotient generated for each metal in the sample, *PEC-*Q_{HCB}, *PEC-*Q_{DDE}, *PEC-*Q_{PCBs} and *PEC-*Q_{PAHs} are the hazard quotients for each organic contaminant, respectively.

The HZD score was generated according to the following procedure. The TEC and PEC-SQG values were assumed to correspond to 5% and 50% toxicity, respectively. For each pollutant, a sigmoidal toxicity curve was forced to fit a sigmoidal model by fixing the 5% and 50% toxicity values at the TEC and PEC-SQG according to:

$$\textit{Toxicity(\%)} = \frac{100}{1+(A \cdot e^{-kC})}$$

where *A* is a fitted constant that determines the curvature of the dose-response curve, *k* is the chemical-specific toxicity coefficient and *C* is the measured sediment chemical concentration. The toxicity estimate above was modified by implementing a data censor rule to remove the possibility of adding a residual toxicity score based on fitted equations (i.e. solutions to the toxicity model yield a non zero intercept). If the concentration of a given chemical in a sample was less than *TEC*, a toxicity score of 0 was assigned for that chemical. The *HZD* score was



subsequently calculated as the sum of toxicity values determined at each site. In order to establish comparability of multi-chemical hazard metrics, all data were standardized to the same numerical scale. For *sumPEC*, *avgPEC* and *wtavgPEC*, the multi-chemical hazard index was multiplied by a value of 50. Thus, a hazard quotient equal to 1 for a given chemical establishes a 50% toxicity similar to the assumed PEC toxicity score used in the *HZD* computation. Finally, for all multi-pollutant indices, the cumulative toxicity estimate was capped at 100% toxicity. Goodness of fit tests were used to compare predicted toxicity (multi-chemical hazard metric) against field toxicity determined from relative chironomid abundances.

Figure 1. Locations of habitats in the Detroit River.

Results

Figure 1 summarizes sediment sampling locations and identifies each sampling location by habitat type. Sediments of the silt and low flow sand type were confined to the upper reach of the Detroit River (upstream of Belle Island) and in the lower reaches of the system, downstream of Fighting Island. Only sediments of the silt type and low flow sand type had sufficient abundances of chironomids and sufficient numbers of samples within each habitat type to compare organism abundance against toxicity score predictions.

Figure 2 provides goodness of fit test contrasts between predicted toxicity based on each multi-chemical hazard metric and field toxicity determined from the relative abundance of chironomids within silt-classified sediment samples. The *sumPEQ* and *avgPEC* provided overestimates and underestimates of the field abundances of chironomids. The *HZD* metric provided the highest coefficient of determination (R2 = 0.290) and a regression fit that more closely approximated the 1:1 relationship compared to other matrices. The *wtavgPEQ* metric yielded a coefficient of determination of 0.170 in goodness of fit tests, but tended to under predict toxicity for a larger number of sediment locations.

Figure 3 provides goodness of fit tests generated for chironomid abundance in low flow sand. For this habitat, the *HZD* and *wtavgPEC* yielded similar coefficients of determination (R2 = 0.270). The *HZD* goodness of fit regression generated a slope of 0.65 and was more similar in proximity to an expected slope of 1. The *wtavgPEC* yielded a goodness of fit slope of 0.39; implying that this index more commonly underestimated chironomid abundances.

Overall, the *HZD* metric provided the best estimate of chironomid toxicity, closely followed by wtavgPEC in low flow sand habitats.

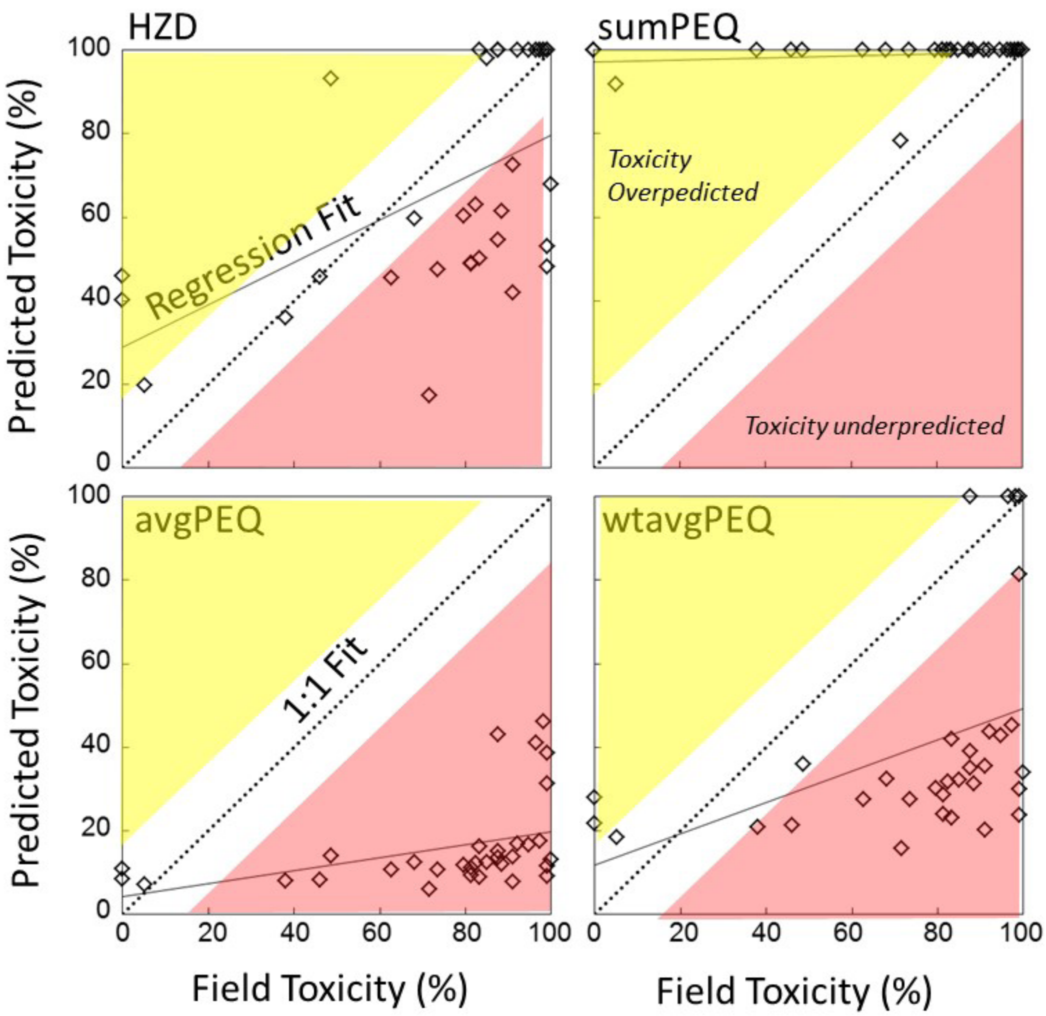


Figure 2. Goodness of fit tests for multi-chemical hazard metrics of chironomid abundance in silt.

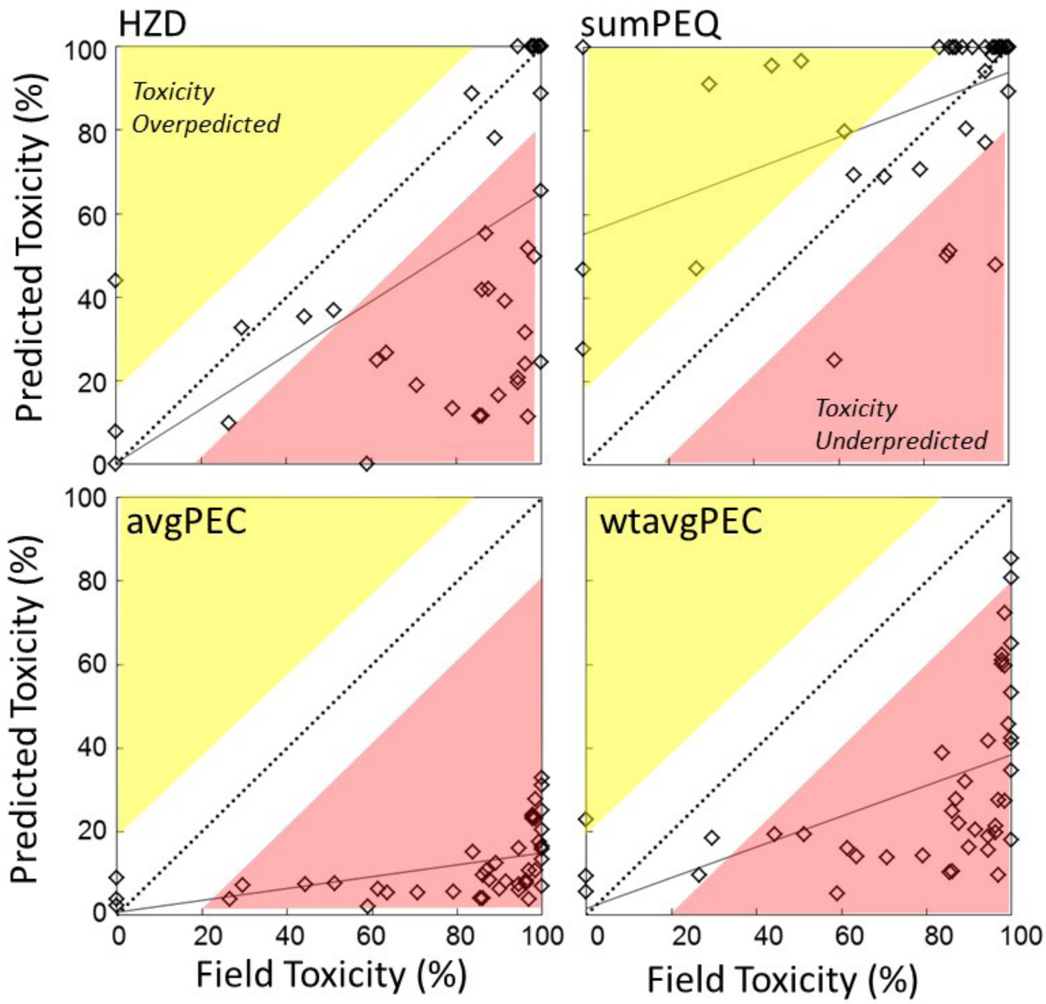


Figure 3. Goodness of fit tests for multi-chemical hazard metrics of chironomid abundance in low flow sand.

Discussion

Differences in toxicity predictions across hazard metrics are due to differences in their computation. Averaging hazard quotients across chemicals caused under prediction of field toxicity while summing hazard quotients caused over estimates of toxicity. Theses biases are expected to increase as more priority pollutants are added into the multi-chemical metric. The *wtavgPEC* provides an intermediate toxicity prediction relative to *sumPEC* and *avgPEC* by giving higher weight to organic pollutants and averaging the hazard quotient across metals. The *wtavgPEC* is expected to be more appropriate when organic contaminants contribute to a larger proportion of sediment toxicity and was found to be the second best predictor of chironomid abundances in the silt and low flow sand. The *HZD* metric uses a different computational approach. By forcing a sigmoidal toxicity distribution, the toxicity estimate generated by the *HZD* algorithm is always lower than a hazard quotient for a given chemical when sediment concentrations are between *TEC* and *PEC*. However, the algorithm produces a higher toxicity estimate compared to a hazard quotient when the sediment concentration is between *PEC* and

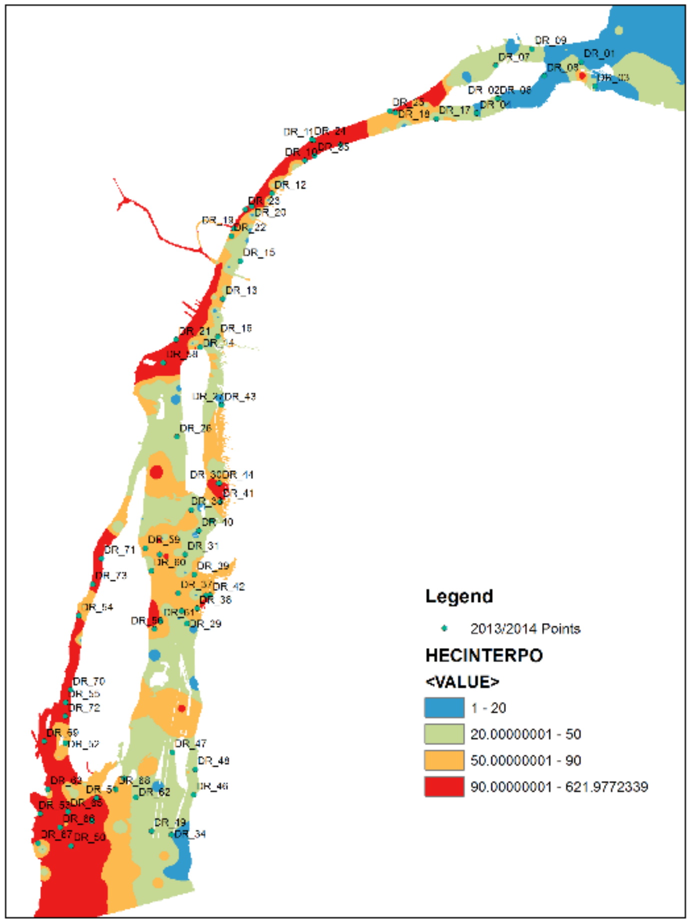


Figure 4. *HZD* score distributions in the Detroit River based on 1999 survey data.

approximately 2.3x *PEC*. When applied across multiple chemicals, *HZD* will yield lower toxicity estimates when several chemicals are less than *PEC* and generally higher toxicity estimates when multiple chemicals exceed their respective *PEC*.

The *HZD* provided the best overall predictor of chironomid abundances considered representative of field toxicity. A contour plot of *HZD* scores was applied to the Detroit River based on sediment chemistry results from 150 sampling stations described in Drouillard et al. (2006) and is summarized in Figure 4. Regions in blue reflect areas with *HZD* scores less than 20% and considered clean with respect to toxicity (in goodness of fit tests, all sites with *HZD*< 20% had high chironomid abundances). Stations with low potential for toxicity (20-50%) are presented in green, whereas stations with *HZD* between 50-90% and >90% are in orange and yellow, respectively. The majority of locations in Canadian waters of the Detroit River exhibited low to intermediate toxicity with the exception of the channelized area in proximity to the Ambassador Bridge. *HZD* values exceeding 90% were common in US waters at locations below Rouge River and in the Trenton Channel.

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3.11 Fish Habitat Restoration Efforts in the St. Clair-Detroit River System: with emphasis on Lake Sturgeon

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Project Description

Historically, the St. Clair and Detroit rivers supported a diverse and productive fishery. Lake sturgeon, walleye, and lake whitefish traveled to these rivers to spawn, depositing and fertilizing eggs in rocky areas with fast-flowing currents. Historic estimates of lake sturgeon abundance in Lake St. Clair ranged from 96,000 – 157,000 and between 294,000 – 1.16 million in Lake Erie (Haxton et al. 2014). However, beginning in 1874, both the St. Clair River and Detroit River were extensively modified. The river bottoms were dredged to create deep channels for large commercial ships. The dredging and disposal of dredged materials such as dirt, sediment and rocks, changed the flow of the river and damaged the natural limestone reefs where millions of fish spawned. These and other impacts including overfishing and shoreline development have dramatically reduced the populations of native fish, particularly lake sturgeon.

Despite the decline, the St. Clair and Detroit rivers continue to support one of the largest populations of lake sturgeon (near 50,000 fish; Chiotti et al. 2013) remaining in the Great Lakes, in part because most other large rivers have dams that block access to historical spawning areas. If the population is able to grow, it could help re-populate other parts of the Great Lakes.

Scientists conducted a detailed analysis of the damage done to historical spawning areas and searched for the few places where native fish still reproduce (Bennion and Manny 2011). A focus has been on sturgeon since they are listed as threatened or endangered by most of the Great Lakes states and Ontario. Prior to fish habitat restoration efforts, the remaining lake sturgeon spawned in only two locations in the St. Clair River (Manny and Kennedy 2002) and one in the Detroit River (Manny and Kennedy 2002; Caswell et al. 2004). Because very few natural rocky areas remain, sturgeon have been found depositing their eggs on some unusual materials. For example, coal cinders that were dumped in the river when ships unloaded near Algonac, Michigan, are used as spawning sites (Manny and Kennedy 2002). Many natural resource professionals believe that the recovery of native fish is limited by a lack of adequate spawning habitat, but that creating reefs that mimic the lost natural limestone reefs may help rebuild populations.

The goal of this work is to: 1) construct fish spawning reefs to enhance the productivity of native fish species, 2) remove the Detroit River and St. Clair River Areas of Concern beneficial use impairments based on the loss of fish and wildlife habitat and populations, and 3) improve understanding of fish communities and fish habitat restoration.

Methods

Site determination

Areas with strong currents and deep waters are ideal places to create spawning habitat for lake sturgeon. Scientists at the U.S. Geological Survey (USGS) developed a computer model using water depth and flows in the St. Clair and Detroit rivers to predict where lake sturgeon would spawn if the river bottom were suitable (Bennion and Manny 2014). Project partners used the model to identify high-priority places for constructing reefs and then selected specific locations without high levels of contaminated sediments or heavy boat traffic. At a potential reef site, underwater cameras and sonar are used to make sure the river bottom is hard and smooth and lacks desirable fish habitat that would be disturbed by reef construction. When possible, constructed reefs are placed close to known spawning areas and upstream of wetlands that could protect young fish after they hatch.

Biological response

A group of scientists study all life stages of the fish community prior to and after reef construction to evaluate the success of each reef. Egg mats are placed on the reefs to document egg deposition and to note which fish species are spawning and at what density. D-frame larval drift assessments are conducted to collect lake sturgeon larvae. D-frame nets are placed on the bottom of the river upstream and downstream of the reef in order to monitor larval catch rates. Juvenile fish assessment are conducted downstream of the reefs using electrofishing, hoop nets, and minnow traps. Adult and juvenile lake sturgeon are monitored using gill nets, setlines, and bottom trawls in each of the rivers and in western Lake Erie.

Figure 1. Map of completed spawning reef projects in the St. Clair and Detroit rivers (Photo credit – Michigan Sea Grant).

Results and Discussion

Reef construction

Since 2004, six spawning reefs totaling 12.4 acres have been constructed in the St. Clair and Detroit rivers (Figure 1). The Belle Isle Reef (2004), Fighting Island Reef (2008, expanded in 2013), and Grassy Island Reef (2015) have been constructed in the Detroit River, while the Middle Channel Reef (2012), Pointe aux Chenes Reef (2014), and Hart's Light Reef (2014) have been constructed in the St. Clair River.

Lake sturgeon spawning

Prior to reef construction, lake sturgeon eggs were only documented in the vicinity of one proposed reef restoration site, the Hart's Light Reef location. The density of lake sturgeon eggs collected prior to reef construction was 21 eggs/m2 on egg mats. In 2015, the first year after construction of the Hart's Light Reef, lake sturgeon eggs were again detected at the reef at a density of 6,481 eggs/m2 on egg mats. Lake sturgeon eggs have not been detected at the Belle Isle Reef location before or after construction. At all the other reef sites, no lake sturgeon eggs were detected prior to construction, but have been in subsequent years (Roseman et al. 2011). Table 1 summarizes the lake sturgeon egg data collected at each reef.

Larval production

Lake sturgeon larval drift assessments are conducted at each reef location; however, comparisons between upstream and downstream sites at each reef have only been made at the Fighting Island Reef site in the Detroit River and Middle Channel Reef site in the St. Clair River. Lake sturgeon larval drift was not assessed at the Belle Isle Reef site in the Detroit River, and data is currently being summarized for the reefs constructed in 2014. Upstream larval drift densities serve as a reference/control to compare with downstream site results. Mean CPUE (number of larvae/hour) was greater at sites directly downstream of the Fighting Island Reef sites when compared to sites upstream in 2012 and 2014 (Bouckaert 2013). Sampling at Fighting Island was not conducted in 2013. The collection of lake sturgeon larvae at upstream sites near the Fighting Island Reef suggests that successful lake sturgeon spawning is occurring elsewhere in the Detroit River. At the Middle Channel Reef in the St. Clair River, mean CPUE of lake sturgeon larvae was greater at upstream sites compared to downstream sites across all years of sampling (Bouckaert 2013; USGS, unpublished data). The variable size of larvae collected and development stage suggest spawning is occurring upstream of the Middle Channel Reef in the St. Clair River and at different times throughout the spring.

Table 1. Lake sturgeon egg presence/absence at reef locations in the St. Clair-Detroit River System prior to and after reef construction. The parenthesis in the first column denote the year in which the reef was constructed. The year in the post-assessment column indicate when lake sturgeon eggs were detected.

Reef	Pre-assessment	Post-assessment
Detroit River - Belle Isle (2004)	Absent	Absent
Detroit River - Fighting Is. (2008 & 2013)	Absent	2009, 2010, 2012, 2014, 2015
St. Clair River - Hart's Light (2014)	Present (21 eggs/m2)	2015 (6,481 eggs/m2)
St. Clair River - Pointe aux Chenes (2014)	Absent	2015
St. Clair River - Middle Channel (2012)	Absent	2012, 2013

Juvenile lake sturgeon

Juvenile lake sturgeon (< 1000 mm total length) have been collected in the St. Clair-Detroit River System and methodology is currently being developed to assess trends in juvenile sturgeon abundance over time. The annual CPUE (number of juvenile lake sturgeon/1000 hook hours) of juvenile lake sturgeon captured on setlines in the Detroit River has remained relatively consistent since 2011 (USFWS unpublished data). Juvenile lake sturgeon are commonly captured in "groups" (more than one at each location) suggesting a patchy distribution at habitats being selected at this life stage. These habitats are currently being identified and will be monitored on an annual basis to follow trends in juvenile abundance.

Adult lake sturgeon

Adult lake sturgeon assessments are conducted annually in the Detroit River, St. Clair River, and upper St. Clair River (southern Lake Huron). The current population estimate for the Detroit River is 4,068 (95% CI = 869 – 7,268), North Channel of the St. Clair River 11,720 (95% CI = 7,356 – 16,083), and upper St. Clair River 35,484 (95% CI = 25,939 – 45,030) (Chiotti et al. 2013). Based on these estimates the lake sturgeon population in the St. Clair-Detroit River System is one of the largest in the Great Lakes. Additional adult lake sturgeon data is currently being collected to provide better estimates of adult abundance. Due to the long maturation rate and life history strategy of lake sturgeon, it is difficult to observe trends in adult lake sturgeon abundance. The biological response of lake sturgeon resulting from the reefs is better assessed through collection of eggs, larvae, and juveniles. However, adult abundance does provide a long-term metric to assess the health of the Strait as well as a means to evaluate restoration endpoints for this species.

Summary

- 12.4 acres of hard rock substrate has been added to the St. Clair-Detroit River System for lithophilic broadcast spawning fish species such as lake sturgeon.
- Lake sturgeon spawning has been documented at four of the six spawning reefs created, therefore increasing the amount of suitable spawning habitat for this species.
- Lake sturgeon larvae have been collected downstream of constructed reefs; mean CPUE of larvae downstream of the Fighting Island Reef were greater than upstream sites, while mean CPUE was higher at upstream sites at the Middle Channel reef making results difficult to interpret when lake sturgeon spawning is taking place at other locations in these rivers.
- Methods to assess juvenile abundance and distribution are currently being developed and will be used to assess the state of lake sturgeon in the Strait. Annual mean CPUE of juvenile lake sturgeon in the Detroit River has remained relatively consistent since 2011.
- Adult lake sturgeon abundance will continue to be monitored in order to evaluate restoration endpoints for the Strait.

Lessons Learned

- Monitoring the biological response to the reefs is imperative to determine which physical factors favor native species restoration.
- Monitoring and evaluation are an important aspect of this work, allowing scientists to adapt techniques and guide future management efforts in an adaptive framework.
- A report titled “Science in Action: Lessons Learned from Fish Spawning Habitat Restoration in the St. Clair and Detroit Rivers” is available through the University of Michigan Water Center (Vaccaro 2016).

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3.12 Grass Carp Habitat Suitability, Establishment and Movement in the Detroit – St. Clair River Corridor

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Eighty-eight invasive species (45% plants, 22% fish) are documented to inhabit the Detroit-St. Clair River corridor (Huron-Erie Corridor, "HEC") and watersheds, including sea lamprey, round goby, Dreissenid mussels, and Viral Hemorrhagic Septicemia (VHS). Another 53 non-indigenous species have been identified as potential invaders, including the fish Northern Snakehead and Asian carp; an amphipod, killer shrimp; and an invasive plant, *Hydrilla verticillata* (henceforth, *Hydrilla*). The likelihood of successful establishment and spread by a nonindigenous species depends in part on availability of suitable habitat for reproduction and growth, and spread. Below, we report results of ongoing research to predict habitat suitability and movement of grass carp (*Ctenopharyngodon idella*) in the HEC. We also briefly discuss current and future actions needed to mitigate against grass carp invasion.

Grass carp are voracious herbivores that can eat from 20-40% of their body weight per day in aquatic vegetation. At high densities, they can remove virtually all aquatic vegetation in a lake. Because grass carp do not digest everything they eat, their egested material is nutrient rich and may stimulate algae growth, thus lowering water clarity. Grass carp pose a threat to native fishes such as sunfishes, bass and pike that depend on aquatic macrophytes for reproduction or nursery habitat, and to waterfowl that depend on macrophytes for food. Grass carp spawn in rivers and inhabit marshes and bays of lakes, thus could inhabit several habitat types in the Great Lakes basin if they establish breeding populations.

Grass carp were first imported to southern states in the US in the 1960s for aquatic macrophyte control. Widespread stocking of grass carp began in the early 1970s, and in the early 1980s, a procedure was developed to induce triploid carps using temperature or pressure shocking. In Lake Erie, sporadic but increasing numbers of diploid and triploid grass carp have been collected since the 1980s. In 2012, six diploid juvenile grass carp were collected in the Sandusky River tributary in western Lake Erie, indicating the species is reproducing naturally within the Great Lakes basin.

To determine use of tributary habitats for spawning, and potential rate of spread of grass carp in Lake Erie and the HEC, scientists from Michigan State University and Michigan Dept. Natural Resources caught and implanted 12 wild grass carp (700-1100 mm, 4-8 years old) from Lake Erie with acoustic tags and released them in Michigan and Ohio waters in western Lake Erie in 2014 and 2015. Several grass carp were located in Ohio waters near where they were tagged, while one individual was located near a coastal inlet in Michigan waters of Lake Erie. Future research plans include tagging up to 50 individual grass carp and installing acoustic receivers at tributary mouths and throughout the tributaries to monitor tributary use and determine how far upstream grass carp can disperse. Intra- and inter-lake movements of tagged grass carp will be monitored using the network of acoustic receivers deployed throughout Lake Erie and the other Great Lakes as part of the Great Lakes Acoustic Telemetry Observation System.

To predict what habitats are suitable for grass carp in the Great Lakes, scientists from University of Georgia and University Nevada Reno used a novel habitat suitability model called range bagging. This method uses bootstrap aggregation ("bagging") of niche boundaries (Drake 2015). The resulting measure, called "niche centrality", refers to the proportion of times an environment occurs within the environmental range of a species across the bootstrapped combinations of environmental variables (2 dimensions at a time are compared). Because niche centrality is proportional to the probability of occurrence, it predicts relative habitat suitability, and can be projected to each point on a map. The input data are species occurrence records—presences, and environmental data which describe climate related variables on a global scale. These input data were obtained from the'WorldClim' dataset and are comprised of 19 temperature and precipitation variables.

The habitat suitability model achieved high performance on test data (as assessed by the widely-used area under the receiver operating characteristic curve, a machine learning metric of classification performance: Fielding and Bell 1997; Berrar and Flach 2011). This indicates the model effectively estimates the relative probability of occurrence in the current range. The authors measured niche centrality separately for grass carp and *Hydrilla*, and then for grass carp individually given the predicted niche centrality of *Hydrilla*. *Hydrilla* niche centrality was "clipped" using a measure of the photic zone, and accumulated growing degree days based on benthic temperature observations. Niche centrality was calculated for grass carp for the comprehensive Great Lakes watershed region, and clipped using a submersed aquatic vegetation (SAV) and wetlands data layer, and finally by a combined SAV, wetlands and predicted *Hydrilla* niche.

High values of niche centrality for grass carp and *Hydrilla* indicate climate conditions in the Great Lakes basin fall generally within the predicted niche. Grass carp are typically restricted by food availability, which in the Great Lakes does not necessarily represent a great deal of lake surface area, but does represent some of the most sensitive areas of the nearshore region which are important for a number of ecological processes. Considering predicted *Hydrilla* habitat increased the amount of area for which grass carp may establish in the Great Lakes. *Hydrilla* has been found in watersheds adjacent to the Great Lakes and is considered a threat.

The habitat suitability model results for grass carp and *Hydrilla* have implications for habitat restoration. Millions of restoration dollars have been spent to rehabilitate or restore wetlands in the Great Lakes, which are habitats in which both *Hydrilla verticillata* and grass carp may establish – both of these species threaten valuable ecological resources in the Great Lakes basin.

Scientists at University of Toronto and Canada's Dept. Fisheries and Oceans used a hydraulic model and analyzed measures of stream flow and temperature to predict Asian carp spawning habitat suitability in the HEC. They found temperatures within the Great Lakes are suitable for triggering Asian carp maturation. Spikes in spring/summer water temperatures and flows in the HEC are suitable for triggering Asian carp spawning events, and there is adequate spawning habitat owing to turbulent flows suitable for spawning habitat. The hydraulic model permitted estimates of drift time and direction for spawned eggs, and indicated that if Asian carps spawned in the St. Clair River the eggs would likely end up settling in Lake St. Clair. Eggs spawned in Detroit River would likely end up in settling in western Lake Erie. Recent research suggests Asian carp eggs will still be viable and hatch after settlement.

Prior modeling of Sandusky River flow velocities and timing indicated that the river can provide suitable spawning habitat for grass carp. To establish evidence of natural reproduction by grass carp in Lake Erie tributaries, scientists from USGS-Great Lakes Science Center and Univ. Toledo sampled for eggs and larvae of grass carp weekly in main channel habitats in the Sandusky River OH in 2014 and 2015, and in the River Raisin MI in 2015. They also set light traps in off -channel river habitats and macrophyte beds and at tributary mouths. In 2015, eight Grass carp eggs were collected in the Sandusky River from June 15 – July 15, confirming evidence of natural reproduction. The scientists will expand sampling to other tributaries and model probability of Grass carp spawning from year to year. The scientists also will survey aquatic macrophyte composition and abundance that may provide habitat not only for Grass carp but other invasive species including tubenose goby, rusty crayfish and red swamp crayfish.

Actions needed to help assess risk and prevent spread of grass carp are relevant for other invasive species. Research is needed to quantify habitat suitability of grass carp in Great Lakes watersheds, track movements and spread, forecast reproductive success and effects on food webs, and model population response to control measures including fishing and selective biocides. Management agency use of eDNA, standardized sampling protocols, and citizen science are tools that can enhance surveillance for invasive species. Adoption of practices advocated by the aquatic nuisance species task force and National Habitattitude Campaign (http://www.glerl.noaa.gov/res/Programs/glansis/prevention.html) also can help prevent spread of invasive species.

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4.0 Panelists

Coordinating Conservation in the
St. Clair-Detroit River System

Wednesday, December 9th, 2015
EMU- Student Center

Panel Discussion: "What story do we want to be able to tell in five years?"
Regional approaches to advancing focused, measurable conservation implementation in the St. Clair-Detroit River System and Western Lake Erie.

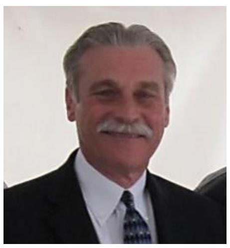
<u>Discussion Panel</u>

Dave Dempsey. Policy Advisor, International Joint Commission. Dave has served as environmental advisor to Michigan Governor James J. Blanchard, as executive director for the Michigan Environmental Council, as a Presidential appointee to the Great Lakes Fishery Commission and as Communications Director for Conservation Minnesota. He is the author or co-author of four books on subjects related to the Great Lakes and he has served as an adjunct instructor at MSU in environmental policy and law. Dave has a Bachelor of Arts degree from Western Michigan University and a Master's degree in resource development from Michigan State University.

Patrick Doran. Assistant State Director and Conservation Director, The Nature Conservancy. Patrick leads investigations of conservation priorities in Michigan and the Great Lakes. This includes the identification and prioritization of important conservation areas, as well as the development and implementation of conservation strategies and measures of success. Prior to work with the Conservancy, Patrick held positions as a habitat biologist with the Washington Department of Fish and Wildlife, and was a senior ecologist/GIS analyst with The Wildlands Project. Patrick earned his doctorate from Dartmouth College and received dual master's degrees in ecology and environmental science from Indiana University.

Sandra Kok. Senior Remedial Action Plan Program Engineer, Environment and Climate Change Canada; Great Lakes AOC Unit.

For the past 21 years, Sandra has worked on all facets of the Canadian Areas of Concern program, addressing local Remedial Action Plan coordination, science and monitoring, planning and restoration. Her current role is focused on restoring and delisting the Detroit River and St. Clair River Areas of Concern in partnership with municipal, provincial and federal stakeholders, First Nations, and non-government organization. Sandra has a Master's degree in Environmental Engineering from the University of Alberta and a Chemical Engineering degree from the University of Toronto.



Russ Kreis, US EPA Research and Development.

For the last 20 of Russ's 30 years with EPA, he has served as the Station Director and Branch Chief of the Large Lakes Research Station in Grosse Ile, MI. Russ has authored or co-authored over 75 publications and reports. He has been involved with numerous activities in the Detroit River and Lake Erie including: project manager and project officer for EPA programs in the Detroit River; the Detroit River Stage I RAP data and writing team; Stage II Sediment Workgroup; the Detroit River Canadian Cleanup Committee Monitoring and Research Workgroup; the 4-Party Agreement Monitoring Committee and Delisting Criteria Workgroup; the GLWQA Lake Erie Annex 4 Nutrient Task Team; numerous interactions with the Lake Erie LAMP committees; and is a Lake Erie Millennium Network Co-Director. Russ received both his BS and MS degrees from Eastern Michigan University. He received his Ph.D. from the University of Michigan.

Coordinating Conservation in the
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Wednesday, December 9th, 2015
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Heather Stirratt. Great Lakes Regional Lead (Acting), NOAA's Office for CoastalManagement.
Heather works to better integrate NOAA's Office for Coastal Management programs and enhance programmatic connections with Great Lakes partners. She is currently focused on Great Lakes place-based conservation, community resilience, and strategic partnership development. Heather serves on the Great Lakes Water Quality Agreement Annex 2 (LAMP) and Annex 9 (Climate Impacts) Subcommittees, Upper Midwest and Great Lakes Landscape Conservation Cooperative Executive Steering Committee, USGS Climate Science Center Advisory Board, Lake Superior LAMP Working Group, and NOAA's St. Louis River Habitat Blueprint Implementation Team (Chair). Previously Heather chaired NOAA's Great Lakes Climate Working Group and served for over eight years as the National Ocean Service's representative to NOAA's Great Lakes Regional Team. Heather holds a MS degree in Marine Affairs, with specialties in fisheries management as well as ocean and coastal law, from the University of Rhode Island and a B.A. in Marine Affairs from the University of Miami.

Panel Moderator: Katie Kahl, Michigan Conservation Policy & Practices Specialist, The Nature Conservancy.
Katie builds partnerships and designs conservation strategies Michigan and the Great Lakes to achieve regional conservation goals. Her current work focuses on guiding the Conservancy's Western Lake Erie Coastal Conservation strategy, engaging conservation, business and community interests along a 150-mile stretch of Lake Erie coast. The project team works with partners to implement a suite of local conservation efforts that will optimally meet multiple conservation goals benefitting people and nature. Previously, Katie worked on the Conservancy's Great Lakes Climate team. Prior to joining the Conservancy in 2011, Katie was the Director of Conservation and Policy Research at Heart of the Lakes Center for Land Conservation Policy. She has also managed a 7-county green infrastructure initiative in West Michigan. Katie earned her doctorate and master's degrees from Michigan State University, with an emphasis in quantitative and landscape ecology.

5.0 2015 State of the Strait
Poster Presentation Abstracts

Contemporary Assessment and Identification of Restoration Priorities to Inform Adaptive Management Decisions using a Viability Analysis in the St. Clair-Detroit River System

Robin L. DeBruyne, Edward F. Roseman, Jason E, Ross, Kurt Newman, Russell M. Strach

As large-scale restoration plans for degraded aquatic habitats evolve, it is essential that multi-organizational collaborations have a common vision to achieve consensus on restoration goals. Development of restoration targets and post-restoration monitoring strategies can be focused using a viability analysis framework that supports an adaptive management process. In the St. Clair-Detroit River System (SCDRS), we used a viability analysis framework to evaluate environmental parameters associated with fisheries and aquatic restoration efforts and to gauge the overall health of the aquatic environment. Steps to derive the viability analysis included: 1) establishing meaningful baseline metrics, 2) identifying information deficiencies, and 3) placing the context of current conditions into a usable format for managers and practitioners. Most segments were designated in overall fair conditions and the targets were designated as either good or fair condition. Many metrics were unable to be assessed or assigned condition status, which identified data gaps in monitoring. Metrics associated with Native Migratory Fishes, Lake St. Clair, and Islands are generally in better condition than metrics associated with the Coastal Terrestrial System, Aerial Migrants, and Coastal Wetlands. This was not unexpected given the highly urbanized landscape of the SCDRS. Future work will include periodic updates of indicator condition and closing of information gaps. Resource managers in the corridor will use these results to identify research and restoration priorities and to assess progress towards meeting restoration goals. Viability analysis is a robust and accommodating framework, adaptable to any restoration monitoring program and, through the determination of common desired endpoints, can aid consensus building and collaboration across jurisdictional boundaries.

Synopsis of Shoreline Restoration Projects in the St. Clair River

Jason Fischer, Edward Roseman, Dave Mifsud, Stacey Ireland, Kevin Keeler, Robert Hunter, Dustin Bowser, Dana Castle, Stacy Provo, Jenny Sutherland, Ryan Young, Carson Pritchard, Paige Wigren, Ethan Acromite, Nathan Williams, Emily Galassini, Ellen O'Neil, Jake Magier

Like many large rivers throughout the U.S., the St. Clair River has undergone significant anthropogenic modifications. Development along the shoreline has hardened and steepened the banks disrupting the aquatic-terrestrial transition zone and reducing the availability of shallow water habitat. Loss of fish and wildlife habitat is listed as a beneficial use impairment to the St. Clair River, and increasing riparian connectivity through softened shorelines is a main objective of the St. Clair-Detroit River System Initiative. To address this objective, select locations of the St. Clair River shoreline were softened and shallow water areas were re-established. To evaluate the effectiveness of these restoration projects, we conducted a multifaceted monitoring approach, allowing us to assess the use of these areas by multiple species and life history stages of those species. Sampling included egg collections to determine use by spawning fishes, light trapping to target larval fishes, and collections of adults and juvenile fishes and mudpuppies using minnow traps, backpack electrofishing, and micromesh gillnets. Few fish eggs and larvae were collected in the spring, although larvae of serial spawning fishes (e.g., Gobiidae and Cyprinidae) were readily collected in the summer months. Use of multiple gears also allowed a variety of species to be collected. Mudpuppies (*Necturus maculosus*) and hornyhead chubs (*Nocomis biguttatus*) were frequently observed in minnow traps, but rainbow darters (*Etheostoma caeruleum*) and mottled sculpins (*Cottus bairdii*) were best observed through electrofishing. This work provides a framework for assessment of shoreline restoration sites targeting multiple species and life stages.

Effects of Invasive Phragmites australis and Typha x glauca on Methane Emissions in a Southeastern Michigan Freshwater Wetland

Susannah Iott, Kristin Judd

Wetlands are responsible for emitting 20-39% of total global methane (CH4), an important greenhouse gas that traps 24 times more heat per molecule than does CO2. Variation in wetland plant species composition may affect methane emissions by influencing the composition and activity of microorganisms producing CH4 in wetlands and by acting as conduits, via their aerenchyma, for emission from sediments to the atmosphere. This research addresses the following questions: What is the relative importance of plants as pathways for evasion of methane to the atmosphere? How do two common invasive wetland plants differ in their impacts on the flux of methane from wetlands to the atmosphere? We sought to determine the relative importance of two common invasive wetland plants on methane emissions by measuring flux from *Phragmites australis* and *Typha x glauca*, in order to determine how these invasive species impact methane flux from wetlands. We used closed system chambers to sample CH4 and used gas chromatography, with a flame ionizing detector (FID), to compare concentrations to a known standard. Preliminary results show that *Typha x glauca* has greater methane emissions than *Phragmites australis*.

Mudpuppy (Necturus maculosus) Assessment and Habitat Restoration along the Huron-Erie Corridor: Conservation of the Obligate Host for the Endangered Salamander Mussel (Simpsonaias ambigua)

David Mifsud, Amanda Bryant, Megan English, Katherine Greenwald, Richard Kik IV, Dana Leigh, Maegan Stapleton, Amber Stedman, Sean Zera

Michigan's largest salamander, the Mudpuppy (*Necturus maculosus*) plays an important role in local ecosystems as an environmental indicator and obligate host to the State Endangered Salamander Mussel (*Simpsonaias ambigua*). Historically abundant throughout the Great Lakes region, this fully aquatic species has declined in recent years including mass die-offs in portions of the Detroit River, Lake St. Clair, and Lake Erie. Factors suspected to contribute to the reduced population levels include habitat degradation and loss, the alteration of aquatic communities by invasive species, and toxic algal blooms from excessive nutrient loading. Additionally, Mudpuppies are negatively affected by the application of lampricidechemicals which are known to cause large scale mortality among local populations. This project aims to assess the current status of Mudpuppies along the Huron - Erie Corridor (HEC). The multifaceted study includes baseline field assessments, health screening, tissue and opportunistic whole animal archiving for future work, DNA and populations analysis, spatial analysis, and habitat restoration. This work will provide critical data that is currently unknown along approximately 100 miles of Great Lakes habitat and significant connecting waters. Funds for this project are provided through the Great Lakes Fish and Wildlife Restoration Act.

Developing Urban Forest Stewards, Detroit, MI

Lisa Perez

Michigan Technological University, Michigan Alliance for Environmental & Outdoor Education, Belle Isle Park, USDA Forest Service and eight other partners conducted a 3-year program to develop and expand youth and community capacity to manage and steward the urban forests on Belle Isle - including conducting an invasive species inventory and control, monitoring biodiversity of plant and animal species, protecting habitat of rare species, and communicating the scenic, cultural, and ecosystem services of the Belle Isle forest preserve. This was accomplished by conducting a series of forestry-related workshops over three school years and summer teacher institutes that reached 60 teachers annually. Teachers each: (i) designed and conducted a service learning forest stewardship project on Belle Isle, (ii) created natural areas at their schools with native species, and (iii) conducted family forest open houses on Belle Isle to introduce parents to the stewardship work of the students. Students worked closely with foresters and natural resource professionals as part of their stewardship project and community workdays to introduce them to potential natural resource career paths.

Adaptive Reef Construction to Facilitate Fish Spawning Habitat Restoration in the St. Clair – Detroit River System

Ed Roseman, Jim Boase, Mary Bohling, Dustin owser, Justin Chiotti, Jaquelyn Craig, Robin BeBruyne, Rich Drouin, Jason Fischer, Rob Hunter, Stacey Ireland, Greg Kennedy, Jen Read, Mike Thomas, Lynn Vaccarro

The St. Clair-Detroit River System extends from southern Lake Huron to western Lake Erie. Habitat alteration and exploitation of fish stocks have significantly reduced spawning and recruitment of fish populations. To enhance and restore fish spawning habitat, spawning reefs were constructed at Belle Isle (2004) Fighting Island (2008, 2013), and Grassy Island (2015) in the Detroit River, the Middle Channel of the St. Clair River (2012), and main channel (2014). Natural rock and limestone large enough to inhibit nonnative sea lamprey reproduction were used. Response by several native species including lake whitefish, lake sturgeon, walleye, and suckers was positive and immediate. Two additional reefs will be constructed by 2017 in efforts to adequately remediate the Beneficial Use Impairment 14 in the Detroit River Area of Concern, and provide adequate amounts of suitable spawning substrate for fish in the central Great Lakes.

Lake Erie Coastal Marsh Aquatic Invertebrate Community Structure Across Habitats Dominated by Two Different Emergent Macrophytes

Bianca Sander, Steven Francoeur

The objective of this project was to determine if a difference in the diversity or abundance of aquatic invertebrate communities occurred between areas dominated by *Phragmites australis* versus *Typha* sp. in a freshwater coastal marsh. The hypothesis was that aquatic invertebrate community characteristics would be different across plant types with greater diversity, richness, and abundances in *Typha* sp. compared to *P. australis*. Sampling took place at Lake Erie Metropark in southeast Michigan during the summer of 2013. Invertebrates were collected using Hester-Dendy samplers and identified in the laboratory. Invertebrates were assessed using the Shannon-Wiener Index (H'), taxon richness (R), and abundance values which were all analyzed using t-tests and Mann-Whitney U-tests. Community structure was analyzed using principal component analysis (PCA) and a multivariate analysis of variance (MANOVA) was used to compare factor scores. Environmental variables of water temperature (C), pH, dissolved oxygen concentration (mg/L), and percent dissolved oxygen saturation were measured and analyzed using repeated measures analysis of variance and Spearman correlations. There was no significant difference in invertebrate richness or diversity ($p>0.05$), nor were there any significant differences in the abundance of individual invertebrate taxa between the two plant types ($p>0.05$), except for *Helobdella modesta*, which was statistically more abundant in *Typha* sp. ($p<0.05$). PCA and MANOVA results showed no invertebrate grouping patterns with respect to dominant plant species ($p>0.05$), but did indicate three groupings of invertebrate taxa which frequently co-occurred. Mean abundances of invertebrate functional feeding groups (FFG) were not statistically different based on plant type (p always >0.05), except for predators, which was greater in *Typha* sp. ($p<0.05$). PCA and MANOVA of FFG data found no grouping patterns with respect to plant species ($p>0.05$), suggesting FFG were not different based on plant type. In conclusion, these findings suggest that freshwater *Phragmites australis* and *Typha* sp. marshes were equally capable of supporting abundant and diverse aquatic invertebrate communities.

St. Clair-Detroit River System Initiative

Michelle Selzer (on behalf of the St. Clair-Detroit River System Initiative Partnership)

Following a successful 10-year collaboration of managers and researchers under the former Huron Erie Corridor Initiative, the St. Clair-Detroit River System (SCDRS) Initiative was formed in 2013 under a formal Partnership Agreement based on Collective Impact principles. Participants include natural resource and water quality managers, environmental scientists, aquatic ecologists, and community stakeholders. Implementation of the Partnership Agreement provides a foundation of continued collaboration to advance the 2014-2023 Strategic Vision. Elements of this blueprint include the adoption of a Common Agenda of integrated Strategic Priorities for the next decade; Guiding Principles to provide a consistent basis for achieving Desired Outcomes through defined strategies that are linked by Theme Areas of mutual interest to direct a Science Strategy; and, a Monitoring Plan that help to inform, evaluate, and coordinate decisions of the Partnership. In 2014, the Steering Committee established five management priorities to guide coordinated management, science, and monitoring efforts toward a Common Agenda. Actions include (non-ranked): 1. Address Beneficial Use Impairments to de-list the Detroit River Area of Concern and St. Clair River Area of Concern in both countries 2. Improve water quality through reductions in pollutants from SCDRS sources 3. Increase overall biodiversity through protection and improvements to a connected mosaic of habitats in the system 4. Increase production of indigenous fish stocks through protection and improvements to functional habitats in the system 5. Reduce impacts on habitats, biodiversity, and fisheries from Aquatic Invasive Species threats. To achieve the five management priorities between 2014-2023, nine priority objectives were identified: 1. Complete habitat improvement projects 2. Reduce loading of total phosphorus & dissolved reactive phosphorus 3. Identify contaminants of emerging concern 4. Increase riparian complexity & connectivity 5. Increase area of functional wetlands & their connectivity 6. Increase river spawning habitat 7. Identify & protect critical habitat areas for rare species 8. Develop surveillance monitoring for Aquatic Invasive Species 9. Implement information & education programs. How can you support the SCDRS Initiative? * Sign onto the Partnership Agreement * Join a SCDRS Initiative Subcommittee * Attend the Annual Meeting (see website for meeting details) * Sponsor the Annual Meeting * Sponsor the SCDRS.org website. For more information on the SCDRS Initiative, visit the website at http://scdrs.org/

6.0 Conference Program

Coordinating Conservation in the St. Clair-Detroit River System
Wednesday, December 9th, 2015
Eastern Michigan University – Student Center

Agenda and oral presentations

8:00-8:50	Registration, Continental breakfast buffet
8:50-9:00	Welcome (Steve Francoeur, US co-chair)
9:00-9:30	Blue Accounting Framework Steve Cole, Great Lakes Commission
9:30-9:50	Lake Erie's Biodiversity Conservation Strategy Luca Cargnelli, Environment and Climate Change Canada
9:50-10:10	The St Clair Detroit River System Initiative: The Collective Impact, the Common Agenda and a Thriving Ecosystem Rich Drouin, Ontario Ministry of Natural Resources and Forestry
10:10-10:30	Developing a Shared Vision for Coastal Conservation in Western Lake Erie Douglas Pearsall, The Nature Conservancy
10:30-10:50	Coffee Break
10:50-11:10	The Upper Midwest and Great Lakes Landscape Conservation Cooperative and Coastal Wetland Landscape Conservation Design Bradly Potter, Upper Midwest & Great Lakes LCC

11:10-11:30	GLNPO-sponsored Nutrient/Eutrophication Dynamics Research in Western Lake Erie Sandra Kosek-Sills, Ohio Lake Erie Commission
11:30-11:50	EPA National Coastal Condition Assessment Beth Hinchey-Malloy, Lake Erie LAMP
11:50-1:30	Lunch & poster session
1:30-1:50	Linking Biological Inventories to Wetland Management in the Straits Dennis Albert, Oregon State University
1:50-2:10	An Update on the American and Canadian Status of Beneficial Use Impairments in the Detroit and St. Clair River Areas of Concern Melanie Foose, Michigan Department of Environmental Quality
2:10-2:30	A Multi-chemical Hazard Metric Predicts Chironomid Abundance in the Detroit River Ken Drouillard, University of Windsor
2:30-2:50	Coffee Break
2:50-3:10	Fish Habitat Restoration Efforts in the St. Clair-Detroit River System, with Emphasis on Lake Sturgeon Justin Chiotti, USFWS
3:10-3:30	Habitat Suitability and Potential Threat of Grass Carp and Other Selected Invasives in the St. Clair-Detroit River Corridor Ed Rutherford, NOAA GLERL
3:30-4:50	Panel Discussion
4:50-5:00	Concluding remarks (Steve Francoeur, US co-chair)
5:00-6:00	Reception

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