2020

Checkup: Assessing Ecosystem Health of the Detroit River and Western Lake Erie

John Hartig
University of Windsor, jhhartig@uwindsor.ca

Steven Francoeur
Eastern Michigan University

Jan Ciborowski
University of Windsor

John Gannon
International Joint Commission

Claire Sanders
Essex Region Conservation Authority

See next page for additional authors

Authors
John Hartig, Steven Francoeur, Jan Ciborowski, John Gannon, Claire Sanders, Patricia Galvao-Ferreira, Collin Knauss, Gwen Gell, and Kevin Berk

CHECKUP

Assessing Ecosystem Health of the Detroit River and Western Lake Erie

STATE of the STRAIT

2020

Cover Photos: Upper left: western Lake Erie algal bloom by National Aeronautics and Space Administration; Middle right: Osprey (*Pandion haliaetus*) by Fred Drotar; Lower right: lake sturgeon (*Acipenser fulvescens*) collected off the Fighting Island reef by U.S. Fish and Wildlife Service; Lower left: restored habitat of Blue Heron Lagoon on Belle Isle by Friends of the Detroit River; Lower middle left: contaminated sediment remediation at Black Lagoon by Bob Burns, Friends of the Detroit River; Upper middle left: soft shoreline along Wayne County's Elizabeth Park by Emily Wilke.

Checkup: Assessing Ecosystem Health of the Detroit River and Western Lake Erie

John H. Hartig, University of Windsor
Steven N. Francoeur, Eastern Michigan University
Jan J.H. Ciborowski, University of Windsor
John E. Gannon, International Joint Commission
Claire E. Sanders, Essex Region Conservation Authority
Patricia Galvao-Ferreira, University of Windsor
Collin R. Knauss, University of Michigan
Gwen Gell, University of Michigan
Kevin Berk, University of Windsor

Based on the 2019 State of the Strait Conference held at the University of Windsor, Windsor, Ontario, Canada

2020

Suggested citation: Hartig, J.H., Francoeur, S.F., Ciborowski, J.J.H., Gannon, J.E., Sanders, C.E., Galvao-Ferreira, P., Knauss, C.R., Gell, G., Berk, K., 2020. Checkup: Assessing Ecosystem Health of the Detroit River and Western Lake Erie. Great Lakes Institute for Environmental Research Occasional Publication No. 11, University of Windsor, Ontario, Canada ISSN 1715-3980.

This page intentionally left blank

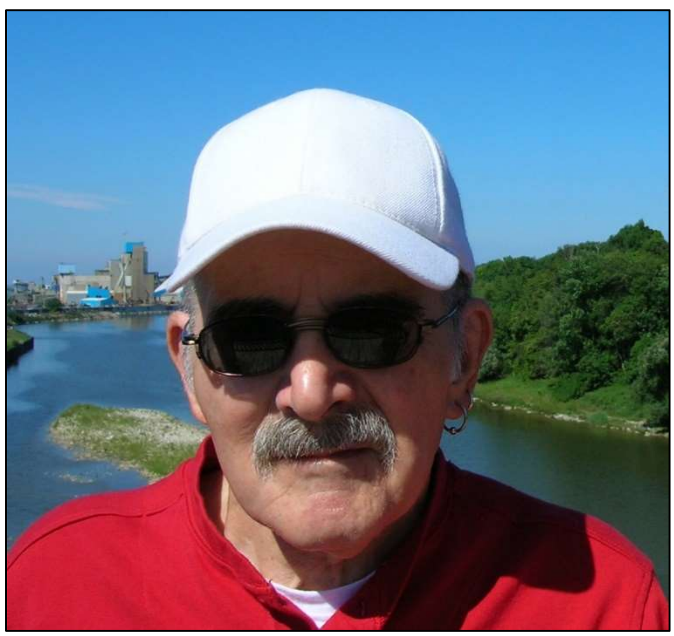
Table of Contents

Pressure Indicators

Dedicated
To

Ric Coronado
(1941 - 2019)

Ric Coronado was the founder of the Citizens Environment Alliance in Windsor and a tireless and effective citizen advocate for environmental and labor issues in Essex County and beyond. In the 1980s, Ric established and chaired the Environment Committee at Canadian Auto Workers (CAW) Local 444. In 1990, he was responsible for pushing for the first environmental contract language between Chrysler and the CAW that established a joint National Environment Committee. This became the model for joint workplace environment committees that were later established in all Canadian 'big three' automotive manufacturing facilities. Ric was also instrumental in the formation of the Windsor Environmental Advisory Committee and the formation of the Labor Caucus for the Canadian Environmental Network. Simultaneously, he spent years working on Detroit River issues through the Binational Public Advisory Council and was a strong supporter of Canada-U.S. State of the Strait Conferences. Ric was a spirited mentor to countless environmental activists in the Windsor area and beyond. His legacy lives on in all who advocate for clean air, clean water, and healthy natural habitats in the place we call home.



Preface

As The Queen's representative in Ontario, I take special pleasure in recognizing the tremendous effort that is the 2020 State of the Strait report.

Last year, I had the opportunity to take part in the 15th anniversary celebrations for this invaluable scientific and cultural endeavour. At the time, I noted that the dialogue it engenders is more important than ever.

In these early years of the 21st century, uncertainty abounds. Indeed, as the final draft of this report comes together, we are only beginning to understand the likely long-term impact of the COVID-19 pandemic on the world around us. Meanwhile, the climate crisis continues, accelerating effects on biodiversity and threatening to cause irreversible damage. The 50th anniversary of Earth Day this year put such issues into further relief and, fortunately, drew greater attention to all the unfinished business that remains.

Through all of this, local authorities and communities need access to sources of reliable information; they need help navigating silos of expertise, shifting currents, and echo chambers of disinformation. This is especially true when it comes to protecting the Great Lakes and its associated waterways, without which society as we know it would be unthinkable.

Indeed, as the Anishinaabe people have said, water is the lifeblood of Mother Earth. Not only that, water flows through our society and saturates our culture. It is our duty to be good stewards and to ensure the perpetuation of our most basic resource for the benefit of future generations.

We are fortunate that we that we have both formal and informal mechanisms for binational collaboration. The long-standing International Joint Commission has evolved from an organization handling boundary disputes to a trusted body responsible for the environmental integrity of the Great Lakes and beyond.

The State of the Strait conference is yet another initiative that makes a significant contribution. During key biennial conferences, both researchers and policymakers, as well as interested stakeholders and members of the public, have the rare opportunity to come together and learn from each other. Reports like this one are invaluable in presenting relevant indicators, measuring progress, and considering how to adjust collective efforts.

Of course, to develop strong evidence-based policy, it is essential to engage those who will be affected, and the better informed they are, the more committed they will be to find workable solutions. That is why I heartily commend everyone involved in the 2020 State of the Strait report, for both the depth and breadth of their collaboration, and for the care taken in making their findings accessible.

This report deserves to be disseminated widely. Environmental stewardship remains a key value of Ontarians and I have no doubt that all that follows in these pages will be of great interest and influence.

The Honourable Elizabeth Dowdeswell
Lieutenant Governor of Ontario

Acknowledgements

Windsor-Essex sits on the traditional territory of the Three Fires confederacy of First Nations, comprised of the Ojibway, the Odawa, and the Potawatomie. Metropolitan Detroit sits on the traditional territory of the Wyandot of Anderdon Nation. We acknowledge and respect the longstanding relationships herein with First Nations people.

This Detroit River-Western Lake Erie Indicator Project, the November 19, 2019 State of the Strait Conference, and this final report were made possible by financial and in-kind support from many organizations and agencies. We gratefully acknowledge:

- BASF Corporation
- CDM Smith
- Community Foundation for Southeast Michigan
- Cooperative Institute for Great Lakes Research (CIGLR)
- Detroit River Canadian Cleanup
- Detroit Zoological Society
- DTE Energy
- Eastern Michigan University
- Environmental Consulting & Technology, Inc. (ECT)
- Essex Region Conservation Authority
- Friends of Ojibway Prairie
- Friends of the Detroit River
- Friends of the Ojibway Prairie
- Government of Canada, Canadian Consulate General
- Great Lakes Integrated Sciences and Assessments Program (GLISA)
- Great Lakes Water Authority
- International Association for Great Lakes Research
- International Joint Commission
- International Wildlife Refuge Alliance
- Michigan Department of Environment, Great Lakes and Energy, Office of the Great Lakes

- Michigan Sea Grant
- Ontario Ministry of Natural Resources and Forestry
- SEMIWILD
- The Nature Conservancy
- The Nature Conservancy Canada
- University of Michigan, Rackham Graduate School
- University of Michigan-Dearborn, Environmental Interpretive Center
- University of Michigan-Dearborn, Office of Metropolitan Impact
- University of Windsor
- University of Windsor' Great Lakes Institute for Environmental Research
- University of Windsor's Faculty of Law
- U.S. Fish and Wildlife Service

The foundation of this project and report are the trend data and the 61 individual indicator reports (see Section 7.0) prepared by 40 partner organizations. Without access to their data, knowledge, and practical management experience, this project and report would not have been possible. We gratefully acknowledge the following organizations who shared data and prepared indicator reports:

- Alliance of Rouge Communities
- Audubon Great Lakes
- Bike Windsor Essex
- City of Windsor, Environmental Sustainability and Climate Change
- Cooperative Institute for Great Lakes Research (CIGLR)
- Defiance College
- Detroit Greenways Coalition
- Detroit Office of Sustainability
- Detroit Housing and Revitalization Department
- Detroit River Canadian Cleanup
- Detroit River Hawk Watch
- Detroit River-Western Lake Erie Cooperative Weed Management Area
- Detroit Zoo

- Detroiters Working for Environmental Justice
- Environment and Climate Change Canada
- Essex Region Conservation Authority
- Friends of the Detroit River
- Friends of the Rouge
- Great Lakes Integrated Sciences and Assessments Program (GLISA)
- Great Lakes Water Authority
- Heidelberg College, National Center for Water Quality Research
- Holiday Beach Migration Observatory
- Michigan Department of Environment, Great Lakes and Energy
- Michigan Department of Health and Human Services
- Michigan Department of Natural Resources
- National Audubon Society
- Ontario Ministry of Natural Resources and Forestry
- Ontario Ministry of the Environment, Conservation and Parks
- Parks Canada
- Parks Canada, Point Pelee National Park
- Southeast Michigan Council of Governments
- The Nature Conservancy
- University of Michigan – Department of Mechanical Engineering, School of Environment and Sustainability, Taubman College of Architecture and Urban Planning, and the Water Center
- University of Toledo
- University of Windsor – Department of Biological Sciences, Faculty of Law, and Great Lakes Institute for Environmental Research
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Wayne State University, Center for Urban Studies

- WindsorEssex Economic Development Corporation

Collin Knauss and Gwen Gell from the University of Michigan both received Rackham Fellowships to help prepare indicator reports. Kevin Berk of the University of Windsor's Faculty of Law received a fellowship to prepare indicator reports with funding from University of Windsor's Faculty of Law and Great Lakes Institute for Environmental Research, and the Cooperative Institute for Great Lakes Research. The Community Foundation for Southeast Michigan provided funding to the International Association for Great Lakes Research to help prepare this integrative and comprehensive assessment of ecosystem health. Other law students from University of Windsor's Faculty of Law who worked on indicators included Claudia Tsang, Antonia Hristova, and Muhammad Khan.

In addition, we thank all those who attended the conference, including local citizens, environmental and conservation organizations, researchers, students, and government and industry representatives, all of whom played an important role in the success of the conference.

We gratefully acknowledge Mary Lou Scratch of the Great Lakes Institute for Environmental Research and students from the University of Windsor for their assistance convening the conference on November 19, 2019 and Kyle Swiston and Sharon Lackie of the Great Lakes Institute for Environmental Research for their efforts in updating and maintaining the website. Finally, we would like to acknowledge and sincerely thank CDM Smith, especially Carl R. Johnson for securing the firm's support and Charlotte E. Nichols for doing the design and layout of this report. Without their contributions, this report would not have been possible.

This page intentionally left blank

1.0 Executive Summary

The Canada-U.S. State of the Strait Conference is a biennial forum that brings stakeholders together to assess ecosystem status and provide advice to improve research, monitoring, and management programs for the Detroit River and western Lake Erie. It now has a 22-year history of transboundary cooperation to better inform ecosystem-based management. The 2006 conference compiled long-term datasets on 50 indicators and performed a comprehensive assessment of ecosystem health. The 2019 conference performed an updated comprehensive assessment of ecosystem health based on 61 indicators.

Although there has been considerable improvement in the Detroit River ecosystem and a surprising and heartening recovery of biota since the 1960s, much additional cleanup and restoration needs to be undertaken to restore the region's physical, chemical, and biological integrity as called for in the Canada-U.S. Great Lakes Water Quality Agreement. Western Lake Erie is now at risk of crossing several potential tipping points caused by the interactions of a variety of drivers and stresses. This report identifies eight key environmental and natural resource challenges that are threatening ecosystem health and recommended next steps: climate change; eutrophication and algal blooms; toxic substance contamination; invasive species; habitat loss and degradation; nonpoint source pollution; human health and environmental justice; and population growth, transportation expansion, and land use changes.

Environmental and natural resource laws need to be protected and enforced, as they are the foundation of environmental protection efforts. Considerable voluntary, collaborative initiatives, that go beyond regulatory compliance, will also be needed. The Detroit River and western Lake Erie are microcosms of human use and abuse of the Great Lakes and should be viewed as a "proving ground" for restoring ecosystem health and advancing ecosystem-based management. This comprehensive ecosystem health assessment is a good example of a trans-national network working to strengthen science-policy-management linkages in support of remediation and restoration. Further investment in this transnational network is warranted.

Although the total number of indicators assessed and the percentage of indicators with quantitative targets have increased between the 2006-2007 assessment and the 2018-2019 assessment, the percentage of achievement of quantitative targets has decreased slightly. Continued priority must be placed on science-based, quantitative, target setting for ecosystem integrity. Long-term monitoring is essential in order to practice adaptive management that assesses state of the ecosystem, sets management priorities, and implements management actions in an iterative fashion for continuous improvement. Without a commitment to science-based quantitative target setting and long-term monitoring, management is flying blind.

Climate change is the most pressing environmental challenge of our time. Indeed, addressing any of the eight environmental and natural resource challenges identified above is demanding, but mitigating them all at once and in the face of the climate change crisis is daunting. Climate change will make the scientific understanding of many of the other environmental and natural resource challenges more difficult and will make solving them more complicated. Indeed, climate change has been called a “threat multiplier” where warmer, wetter, and wilder climatic conditions amplify other threats like harmful algal blooms, combined sewer overflow events, species changes, poor air quality effects on vulnerable residents, and more.

With increasing pressure placed on the Detroit River and western Lake Erie by growing human populations and increasing human activities, both scientists and resource managers need a better understanding of the relationships between cumulative stress from human activities and valued ecosystem services. Indeed, we will need a stronger scientific foundation that informs both policy makers and the broader society, strengthens ecosystem-based management, and creates a dynamism among the public, private, academic, philanthropic, and nongovernmental sectors to retreat from current potential tipping points and avoid further environmental, societal, and economic harm.

Science-informed policy and management should have a clear understanding of root causes of problems. However, that will not always be possible. All decisions about water should be made based on the precautionary principle that states that when human activities may lead to unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm. Indeed, the 2012 Great Lakes Water Quality Agreement calls for strengthened measures to anticipate and prevent ecological harm.

The major accomplishment of the public outcry over water pollution of the Detroit River, Lake Erie, and other degraded ecosystems in the 1960s was clearly the enactment of many important environmental laws and a binational agreement, including the Canada Water Act of 1970, the U.S. National Environmental Policy Act of 1970, the Canada-U.S. Great Lakes Water Quality Agreement of 1972, the U.S. Clean Water Act of 1972, the U.S. Endangered Species Act of 1973, and the U.S. Toxic Substances Control Act of 1976.

A major accomplishment of recent decades has been the establishment of a plethora of nongovernmental environmental and conservation organizations like Citizens Environmental Alliance, Friends of the Rouge, Friends of the Detroit River, Detroit River Canadian Cleanup, Detroiters Working for Environmental Justice, Essex County Field Naturalists’ Club, International Wildlife Refuge Alliance, Detroit Riverfront Conservancy, SEMI Wild, Belle Isle Conservancy, and more. These informed, engaged, and vocal nongovernmental organizations are building capacity for cleanup and restoration and helping create a sense of place in this watershed that bodes well for the future. Continued investment in nongovernmental organization capacity building is warranted.

Education is an important key to the way people understand and value the places they call home and the ecosystems within which they live. Solutions to problems arise out of cooperative learning. Cooperative learning is essential to address the current challenges facing southeast Michigan and southwest Ontario. Indeed, cooperative learning, reconnecting people to waterways via greenways and blueways, and place-making can help lead to development of a stewardship ethic. For over two decades, the State of the Strait Conference has practiced cooperative learning through public and student involvement, with no registration fees.

International events, economic changes, and impacts of climate change will test the Great Lakes basin in future decades. Our region's ability to effectively meet these challenges will require foresight, investment, and cooperation. Adequate investments are not currently being made in monitoring and evaluation, and our region's intellectual and environmental capital isn't being leveraged sufficiently, thereby limiting our region's ability to address economic and environmental challenges and compete with the rest of the world. The State of the Strait Conference has a more than 20-year history of cooperative binational efforts to strengthen science-policy-management linkages in support of ecosystem health. Governmental, business, and foundation sector investments in the State of the Strait Conference will be needed to sustain this important work.

As was noted at the Rio de Janeiro Earth Summit, humanity stands at a defining moment in history. One choice in life is to follow a path toward stewardship of our natural resources and sustainable development. Another choice is to continue to deplete natural capital, degrade environments, and impose limitations on the choices available to our children and grandchildren. As the Global Environment Facility has stated, the legacy is ours to shape.

2.0 Introduction

Situated at the heart of the Laurentian Great Lakes are the Detroit River and western Lake Erie (Figure 1). Approximately one-third of the population of the Great Lakes basin resides within the Lake Erie watershed. Of all the Great Lakes, Lake Erie is exposed to the greatest stress from urbanization, industrialization, and agriculture. Despite being the smallest of the Great Lakes by volume (483 km^3) and the shallowest (mean depth: 19 m), it is the most biologically productive. Lake Erie is naturally divided into the western, central, and eastern basins. The western basin is shallow (mean depth: 7 m), turbid because of high sediment loadings from the watershed, and mixes frequently as a result of winds.

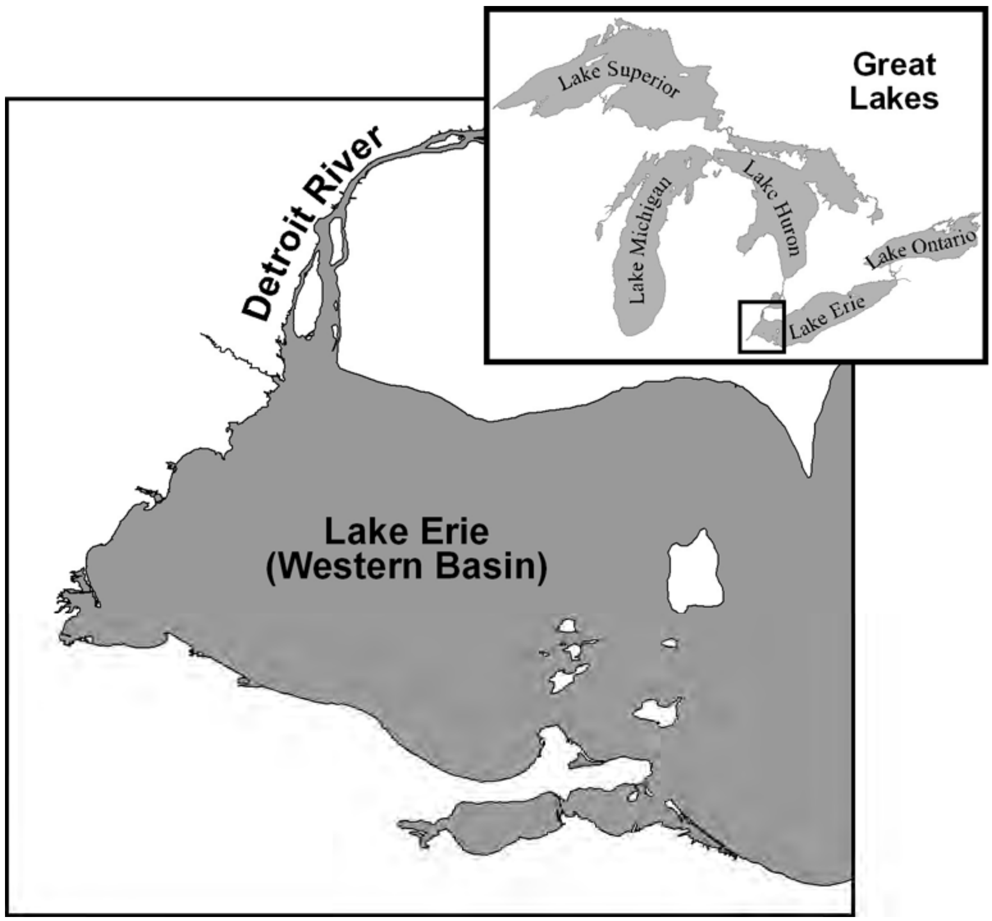


Figure 1. The Detroit River and western Lake Erie located in the heart of the Great Lakes basin ecosystem.

The Detroit River is not a river as most people understand it, but a 51-km connecting channel through which water from all of the upper Great Lakes watersheds (i.e., lakes Superior, Michigan, and Huron) flows to the lower Great Lakes (i.e., lakes Erie and Ontario). It provides 80% of the water inflow to Lake Erie (Bolsenga and Herdendorf, 1993).

Human use and abuse of the Detroit River and western Lake Erie have resulted in substantial water pollution and natural resource degradation. Table 1 presents selected examples of historical anthropogenic impacts within the watershed of the

Detroit River and western Lake Erie. Despite the substantial impacts from

Table 1. Selected examples of water pollution and natural resource degradation of waters within the watershed of the Detroit River and western Lake Erie.

Water Body	**Example of Water Pollution or Natural Resource Degradation**
Detroit River (MI)	In the 1960s, the Federal Water Pollution Control Administration (predecessor of U.S. Environmental Protection Agency) identified it as one of the most polluted rivers in the United States
Lake Erie	The 1960s massive algal blooms on Lake Erie led to media reports that "Lake Erie is Dead"
Western Lake Erie (MI)	In the 1960s, the beaches at Sterling State Park in Monroe County were closed because of bacterial pollution
Rouge River (MI)	In the 1960s, the U.S. Department of Health, Education, and Welfare reported that Ford Motor Company's Rouge Plant was discharging over 3,400 liters of oil per day
Detroit River (MI)	In 1960 and 1967, oil pollution caused the death of 12,000 and 5,400 waterfowl, respectively
Rouge River (MI)	In 1969, the river caught on fire as a result of oil pollution
St. Clair River, Lake St. Clair, Detroit River, and western Lake Erie (ON/MI)	In 1970, the fisheries were closed as the result of the Mercury Crisis
Detroit River (MI/ON)	On April 22, 1970, the first Earth Day, the United Auto Workers and the Canadian Auto Workers held a wake on the Detroit River, symbolizing its death
Detroit, Rouge, and Maumee rivers, and River Raisin (MI/OH/ON)	In 1985, the International Joint Commission designated these rivers as pollution hotspots or Great Lakes Areas of Concern

St. Clair River, Lake St. Clair, and Detroit River (ON/MI)	In 1985, a large dry-cleaning solvent spill (called "The Blob") occurred in the St. Clair River from chemical industries in Petrochemical Valley in Sarnia, ON, resulting in the temporary closure of all municipal water intakes from the St. Clair River down to the Detroit River
Lake St. Clair	In 1988, zebra mussels were discovered in the lake as a result of ballast water release from ships
Lake Erie	In 1989, quagga mussels were discovered in the lake as a result of ballast water release from ships
St. Clair River	In 1990, round gobies were discovered in the river as a result of ballast water release from ships
Water Body	Example of Water Pollution or Natural Resource Degradation
Western Lake Erie	Since 2008, significant harmful algal blooms have been reported in nine of 11 years
Huron River in Michigan	In 2017, per- and polyfluoroalkyl substances (PFAS) contamination resulted in a "Do Not Eat" advisory on all fish from the Huron River
Detroit River, Maumee River, and western Lake Erie (MI/OH)	Currently, these aquatic ecosystems are designated as "impaired waters" under the U.S. Clean Water Act

human and industrial development in these watersheds, these ecosystems paradoxically still exhibit exceptional biodiversity and natural resource attributes (Table 2), reflecting in part the successes of efforts to reverse some of the greatest historical impacts of our use of the region.

Table 2. Examples of exceptional natural resource attributes of the Detroit River (modified from Hartig and Bennion, 2017).

Natural Resource Attribute	**Description**
Birds	• Over 350 species of birds have been identified

Table 2. Examples of exceptional natural resource attributes of the Detroit River (modified from Hartig and Bennion, 2017).

Natural Resource Attribute	Description
	in the Detroit River watershed (MI) by Detroit Audubon Society and over 400 species of birds have been identified in Essex County (ON) by Essex Region Conservation Authority • Detroit River is situated at the intersection of the Atlantic and Mississippi Flyways • 30 species of waterfowl have been documented using the Detroit River; more than 300,000 diving ducks use the lower Detroit River as stopover habitat during spring and fall migration, and many overwinter on the river • The lower Detroit River is one of the three best places to watch raptor migrations in the U.S.; 23 species of raptors migrate through the lower Detroit River; birders have seen over 100,000 raptors migrating in a single fall day • Lower Detroit River (MI/ON), Lake Erie Metropark (MI), Pointe Mouillee State Game Area (MI), lower Maumee River (OH), Holiday Beach/Big Creek (ON), Pelee Island Archipelago (ON), Pelee Island Natural Areas (ON), Point Pelee National Park (ON), and western Lake Erie have all been identified as "Important Bird Areas" (i.e., sites that provide essential habitat for one or more species of birds) by the National Audubon Society and partners • In 2011, Ducks Unlimited identified Detroit as one of the top ten metropolitan areas for waterfowl hunting in the United States • Detroit River and western Lake Erie offer exceptional birding opportunities; a ByWays to FlyWays Bird Driving Tour Map features 27 unique birding sites in southwest Ontario and southeast Michigan
Fish	• 113 species of fish have been identified in the Detroit River • Detroit River wetlands provide spawning areas

Table 2. Examples of exceptional natural resource attributes of the Detroit River (modified from Hartig and Bennion, 2017).

Natural Resource Attribute	Description
	for 26% of the fish species in the Great Lakes • An estimated 10 million walleye ascend the Detroit River from Lake Erie each spring to spawn, creating an internationally renowned sport fishery • Detroit River and Lake Erie are considered the "Walleye Capital of the World;" major international fishing tournaments, sponsored by FLW Outdoors and other organizations, are held annually on the Detroit River and western Lake Erie offering prize money of $500,000 or more
Biodiversity and International Designations	• The Detroit River and western Lake Erie have been recognized for their biodiversity in the North American Waterfowl Management Plan (one of 34 waterfowl habitat areas of major concern in the U.S. and Canada), the United Nations Convention on Biological Diversity (i.e., Detroit River and western Lake have identified as areas to receive biodiversity protection and conservation), the Western Hemispheric Shorebird Reserve Network (i.e., marshes along the lower Detroit River and northeast Ohio have been identified a Regional Shorebird Reserve), and the Biodiversity Investment Area Program of Environment and Climate Change Canada and U.S. Environmental Protection Agency (i.e., the Detroit River-Lake St. Clair ecosystem has been identified as one of 20 Biodiversity Investment Areas in the Great Lakes) • Humbug Marsh on the lower Detroit River (MI) and Point Pelee National Park on western Lake Erie (ON) have both been designated as a "Wetlands of International Importance" (i.e., wetlands protected by national governments to fulfil obligations under the international Ramsar Convention)

Table 2. Examples of exceptional natural resource attributes of the Detroit River (modified from Hartig and Bennion, 2017).

Natural Resource Attribute	Description
	• The Detroit River and western Lake Erie are part of the Detroit River International Wildlife Refuge, the only international wildlife refuge in North America • The Detroit River is the first river in North America to receive both American Heritage River and Canadian Heritage River designations

The State of the Strait Conference is a Canada-U.S. forum held every two years that brings together governmental managers, researchers, students, members of environmental and conservation organizations, and concerned citizens to assess ecosystem status and provide advice to improve research, monitoring, and management programs for the Detroit River and western Lake Erie. It now has a 22-year history of transboundary cooperation to better inform ecosystem-based management of these shared waters (Table 3). The 2006 conference focused on compiling long-term datasets on 50 indicators and performing a comprehensive assessment of ecosystem health (Hartig et al., 2007; Hartig et al., 2009). The binational State of the Strait Steering Committee determined that it was again timely to revisit indicators and perform another comprehensive assessment of ecosystem health and initiated efforts to again compile long-term data sets on key indicators of ecosystem health (Appendix A, Section 6.0). For the purposes of this report, an indicator is a measurable feature or features that singly or in combination provide useful information about status, quality, or trends in the Detroit River and western Lake Erie.

Brief reports were prepared for 61 indicators of ecosystem health, including background information, status and trends, management next steps, and research and monitoring needs (available on-line at http://web2.uwindsor.ca/softs/keyindicators/current-indicator-reports.htm, also collected in Appendix B, Sections 7.1-7.61).

Table 3. Biennial State of the Strait Conferences and themes, 1998-2019.

Date	Conference Theme	Reference
1998	Rehabilitating and conserving Detroit River habitats	Tulen et al., 1998
1999	Best management practices for soft engineering of shorelines	Caulk et al., 2000; Hartig et al., 2001
2001	Status and trends of the Detroit River ecosystem	Read et al., 2001
2004	Monitoring for sound management	Eedy et al., 2005
2006	Status and trends of key indicators	Hartig et al., 2007; Hartig et

Table 3. Biennial State of the Strait Conferences and themes, 1998-2019.

Date	Conference Theme	Reference
		al., 2009
2009	Ecological benefits of habitat modification	Hartig et al., 2010; Hartig et al., 2014
2011	Use of remote sensing and GIS to better manage the Huron-Erie Corridor	Francoeur et al., 2012
2013	Setting ecological endpoints and restoration targets	No report
2015	Coordinating conservation in the St. Clair-Detroit River System	Francoeur et al., 2016
2017	Urban Bird Summit: Status, trends, and risks to species that call the corridor home	Francoeur et al., 2018
2019	Assessing ecosystem health of the Detroit River and western Lake Eire	Hartig et al., 2020

These indicator reports became the focus of the November 19, 2019 State of the Strait Conference convened at the University of Windsor. Over 200 people participated in reviewing the available indicator trend data, recommending management next steps and research needs, and laying the foundation for assessing ecosystem health of the Detroit River and western Lake Erie. Conference poster abstracts are presented in Appendix C, Section 8.0. This report presents a comprehensive and integrative assessment of the state of the Detroit River and western Lake Erie ecosystem based on these indicators and discussions at the State of the Strait Conference. This report is intended to promote cooperative learning among stakeholders, strengthen the science-policy linkage, and encourage further remedial and preventive actions in the spirit of adaptive management where ecosystem status is assessed, management priorities are set, and management actions are implemented in an iterative fashion for continuous improvement.

3.0 Comprehensive and integrative Assessment

The Detroit River-Western Lake Erie Indicator Project was conceived in 2005 and undertaken in 2006 and 2007 in order to compile long-term data sets on 50 key indicators and perform a comprehensive assessment of ecosystem health based on available data and information (Hartig et al., 2007; Hartig et al., 2009). Many of these data sets were not widely accessible nor being used to comprehensively assess ecosystem health. Collectively, the knowledge from these indicators helped strengthen science-policy-management linkages and contributed to considerable pollution prevention, remediation, and restoration actions.

This report provides an update of the 2006-2007 Detroit River-Western Lake Erie Indicator Project. It is based on indicator trend data compiled in 2018 and 2019, 12 years after the initial assessment. Like the earlier indicator project, this assessment is comprehensive in that it makes use of all available data and information. It is integrative in that it identifies emerging trends from suites of indicators that may not be evident from analyzing single indicators. By the same token, all recommendations are informed by this integrative assessment. If one were to look at only a small number of these indicators, one might get an incomplete and possibly inaccurate assessment or picture. For a comprehensive assessment of ecosystem health, all indicator databases are important.

Presented below is an updated comprehensive and integrative assessment based on 61 individual indicator reports (see Sections 7.1-7.61). Although there are data and knowledge gaps, this assessment provides an updated account of ecosystem health and lays the foundation for continuing improvement in the spirit of adaptive, ecosystem-based management.

3.1 State of the Detroit River and Lake Erie

The Detroit River has a long history of human use and abuse (see Table 1). In the 1960s, the Detroit River was considered one of the most polluted aquatic ecosystems in United States by the Federal Water Pollution Control Administration. Examples of water pollution and natural resource degradation from the 1960s include:

- oil spills and pollution were common, killing waterfowl in substantial numbers;
- the Rouge River caught on fire in 1969;
- discharges from industries and municipalities were not strictly regulated because environmental laws had yet to be enacted;
- wastewater treatment plants were only achieving primary treatment with disinfection;
- Detroit's regional combined storm and sanitary sewer system was discharging more than 117.3 billion liters of untreated wastewater per year from combined sewer overflows;
- the macrobenthic invertebrate community was highly degraded throughout large portions of the river;

- no bald eagles, peregrine falcons, or osprey were reproducing in the watershed; and
- lake sturgeon and lake whitefish were not spawning in the river.

Growing public awareness and concern over this degradation led to the enactment of many important environmental laws and a binational agreement, including:

- The Canada Water Act of 1970;
- The U.S. National Environmental Policy Act of 1970;
- The Canada-U.S. Great Lakes Water Quality Agreement of 1972;
- The U.S. Clean Water Act of 1972;
- The U.S. Endangered Species Act of 1973; and
- The U.S. Toxic Substances Control Act of 1976.

These laws and the Great Lakes Water Quality Agreement, and complementary state, provincial, and local programs like Remedial Action Plans initiated in 1985 to restore Great Lakes Areas of Concern, provided the framework and impetus for investing billions of dollars on pollution prevention and control over the last 50 years.

Monitoring programs have now documented substantial environmental improvements since the 1960s, including (Table 4):

- over a 97% reduction in oil releases;
- a substantial improvement in municipal wastewater treatment by upgrading all plants from primary treatment to secondary treatment with phosphorus removal;
- over a 90% decrease in municipal phosphorus discharges;
- an over 90% reduction in untreated waste from combined sewer overflow discharges (i.e., in sewerage systems that carry both sanitary sewage and stormwater runoff, the portion of the flow which goes untreated to receiving rivers or lakes because of wastewater treatment plant overloading during storms);
- a 4,600 tons/day decrease in chloride discharges;
- an 80% reduction in mercury in walleye;
- a 91% decline in PCBs (i.e., Aroclor 1260), a 92% decline in DDE, and a 94% decline in 2,3,7,8-tetrachlorordibenzo-p-dioxin in herring gull eggs from Fighting Island (de Solla and Hughes, this report: 7.19);
- the remediation of 288,000 m^3 of contaminated sediment along the U.S. shoreline of the Detroit River between 1993 and 2020;

- the remediation of 396,800 m^3 of contaminated sediment in the lower Rouge River between 1986 and 2020; and
- the completion of 53 soft shoreline restoration projects, nine sturgeon spawning reefs, and numerous other island and riparian habitat restoration projects over the last 20 years.

The combined effect of these environmental and habitat improvements over the last 50 years has been a surprising ecological recovery, including the return of bald eagles, peregrine falcons, osprey, lake sturgeon, lake whitefish, and a few beaver (Table 4). This ecological recovery is remarkable, but much remains to be done to meet long-term goals. Monitoring and surveillance programs have documented a number of environmental and natural resource challenges that will be covered in the next section of this report.

Western Lake Erie is a classic example of human-caused water pollution, evidence of recovery, and then a return of major problems again in recent years. For example, accelerated nutrient enrichment of Lake Eire in the 1950s led to severe algal blooms and oxygen depletion in the 1960s that were a catalyst for the Canada-United States Great Lakes Water Quality Agreement of 1972 that focused on reducing phosphorus inputs. Subsequent phosphorus control programs led to a remarkable and relatively quick recovery by the late 1980s and early 1990s.

Burrowing mayfly populations (*Hexagenia* spp.) had been extirpated from western Lake Erie in the 1940s and 1950s resulting from municipal and industrial pollution associated with urban growth (Schloesser, 2005). Mayflies reappeared in sediments of western Lake Erie in 1992-1993 after an absence of over 30 years aided by pollution-abatement programs, possibly combined with the invasion of exotic zebra mussels in 1986 that changed the trophic status of nearshore waters (Krieger et al., 1996). Between 1997 and 2004, mayflies gradually expanded their distribution, spreading eastward in nearshore sediments and, by 2004, they were present throughout the entire western basin of Lake Erie (Green et al., 2013). There is high year-to-year variation in mayfly nymph density, but data from 2004 show the population was in the “good” range (Kreiger et al., 2007).

Table 4. An overview of changes in the status of key ecosystem health indicators in the Detroit River and western Lake Erie between peak anthropogenic stress in the 1960s-1980s and current conditions. The complete collection of indicator reports is presented in Appendix B – 7.0.

Indicator	Status in 1960s-1980s	Current Status (2010-2020)	Reference
Oil discharges	In 1961, 596,410 liters of oil and petroleum products were discharged into the Detroit River	Today, oil discharges are substantially reduced, and spills are infrequent and relatively minor	Hartig (this report: 7.6)
Winter duck kills due to oil pollution	In 1960 and 1967, 12,000 and 5,400 waterfowl, respectively, were killed by oil pollution in the Detroit River	Today, winter duck kills due to oil pollution have been eliminated	Hartig and Stafford (2003)
Level of wastewater treatment in Detroit's wastewater treatment plant	In the 1960s, it was only achieving primary treatment (removal of material that would either float or settle out and disinfection)	Today, the Great Lakes Water Authority's Water Resource Recovery Facility achieves secondary treatment with phosphorus removal and is in full compliance with its permit	Khan et al. (this report: 7.54)
Combined sewer overflows in Detroit's service area	Between 1960 and the late 1980s, Detroit's regional combined storm and sanitary sewer system was discharging more than 117.3 billion liters of untreated wastewater per year from overflows	In 2015, with implementation of all core elements of Great Lakes Water Authority's Combined Sewer Overflow control program, approximately 5.9 billion liters of untreated wastewater were released through overflows	Coffey et al. (this report: 7.44)
Phosphorus from Detroit's wastewater treatment plant	In 1966, Detroit's effluent total phosphorus concentration was 17.6 mg/L; in 1966, Detroit's phosphorus loading to the Detroit River was 14,600 tonnes/year	In 2016, the Water Resource Recovery Facility effluent total phosphorus concentration was 0.36 mg/L; in 2016, Detroit's total phosphorus loading to the Detroit River was 360 tonnes/year	Khan et al. (this report: 7.54)
Phosphorus loads and concentrations from the Maumee River	In the early 1970s, total phosphorus loads exceeded targets established through the Great Lakes Water Quality Agreement	Annual flow weighted mean dissolved reactive phosphorus concentrations decreased by 57% between the early 1970s and early 1990s, and then increased 52% between 2000 and 2018; spring flow weighted mean dissolved reactive phosphorus concentrations showed a similar pattern; increasing concentrations and loads exceed both Great Lakes Water Quality Agreement and Ohio Domestic Action Plan targets	Manning and Johnson (this report: 7.7)

Table 4. An overview of changes in the status of key ecosystem health indicators in the Detroit River and western Lake Erie between peak anthropogenic stress in the 1960s-1980s and current conditions. The complete collection of indicator reports is presented in Appendix B – 7.0.

Indicator	Status in 1960s-1980s	Current Status (2010-2020)	Reference
Algal blooms in Lake Erie	Accelerated nutrient enrichment of Lake Eire in the 1950s led to severe algal blooms in the 1960s that were a catalyst for phosphorus control programs	Phosphorus control programs were implemented starting in the early 1970s that led to improvements in algal blooms by the late 1980s and early 1990s; these improvements, however, were short lived with the return of harmful algal blooms in the late 1990s and early 2000s; "significant" harmful algal blooms have occurred or been forecasted in seven of the last 10 years	Bridgeman (this report: 7.24)
Mercury in walleye	In 1970, mean mercury concentration in Lake St. Clair walleye was 2.3 mg/kg	In 2015, mean mercury concentration in Lake St. Clair walleye was 0.2 mg/kg (80% decline since 1970)	Ontario Ministry of the Environment, Conservation and Parks (this report: 7.32)
PCBs in Herring Gull eggs	Fighting Island (Detroit River): In 1978, mean PCB concentration was 56 mg/kg Middle Island (western Lake Erie): In 1974, mean PCB concentration was 34 mg/kg	In 2015, mean PCB concentration was 5 mg/kg In 2018, mean PCB concentration was 10 mg/kg	de Solla and Hughes (this report: 7.19)
DDE in Herring Gull eggs	Fighting Island (Detroit River): In 1979, mean DDE concentration was 9.4 mg/kg Middle Island (western Lake Erie): In 1974, mean DDE concentration was 5.5 mg/kg	In 2015, mean DDE concentration was 1.1 mg/kg In 2018, mean DDE concentration was 0.8 mg/kg	de Solla and Hughes (this report: 7.19)
Mercury in Herring Gull eggs	In the 1970s and early 1980s, mean mercury concentration in eggs from Fighting Island in the Detroit River and Middle Island in western Lake Erie was	Mercury exhibits relatively high year-to-year variability; mean mercury concentration in Fighting Island and Middle Island eggs decreased slightly to 0.17 mg/kg in 2015 and to 0.12 mg/ in 2018, respectively; mercury concentrations in Middle Island eggs increased between 2005 and 2010 by	de Solla and Hughes (this report: 7.19)

Table 4. An overview of changes in the status of key ecosystem health indicators in the Detroit River and western Lake Erie between peak anthropogenic stress in the 1960s-1980s and current conditions. The complete collection of indicator reports is presented in Appendix B – 7.0.

Indicator	Status in 1960s-1980s	Current Status (2010-2020)	Reference
	approximately 0.2 mg/kg	nearly three times, before declining to more typical levels	
Polychlorinated naphthalenes (PCNs) in Herring Gull eggs	Fighting Island (Detroit River): In 1980-1981, total PCN concentrations were 13.9 ng/g Middle Island (western Lake Erie): In 1980-1981, total PCN concentrations were 10 ng/g	In 2005, total PCN concentrations were 3.5 ng/g In 2013, total PCN concentrations were 3.1 ng/g	de Solla and Hughes (this report: 7.19)
Per- and polyfluoroalkyl substances (PFAS) contamination of fish	PFAS was used commercially starting in the 1950s as a product to repel water, protect surfaces, resist heat, and other properties; environmental and drinking water contamination was not discovered until 2017	The 2017, per- and polyfluoroalkyl substances (PFAS) contamination resulted in a "Do Not Eat" advisory on all fish from the Huron River; PFAS has been largely phased out of use in the U.S. under a 2006 voluntary agreement	Michigan Department of Environment, Great Lakes, and Energy
Mayflies	In the 1940s and 1950s, mayflies were extirpated from western Lake Erie because of water pollution; mayflies were absent from the mouth of the Detroit River in 1929-1930 due to water pollution	In 1992-1993, mayflies returned to western Lake Erie in response to improved water quality after a 40-year absence; river wide monitoring has documented an increase in mayfly nymph abundance from less than 10 nymphs per m^2 in 1968 to 20 or more nymphs per m^2 in 1999 and 2004 (the two most recent years sampled); areas of the river still impacted by pollution continue to show low mayfly larvae abundance (particularly downstream of the confluence of the Rouge River and the Trenton Channel)	Wright and Tidd (1933); Ciborowski (this report: 7.25)
Oligochaete abundance in Detroit River	In the 1960s, there were up to one million worms/m^2	Densities have since declined by 80-90%, but the numbers suggest some locations (e.g., Trenton Channel) still fall in the "heavily polluted" category	Ciborowski (this report: 7.33)

Table 4. An overview of changes in the status of key ecosystem health indicators in the Detroit River and western Lake Erie between peak anthropogenic stress in the 1960s-1980s and current conditions. The complete collection of indicator reports is presented in Appendix B – 7.0.

Indicator	Status in 1960s-1980s	Current Status (2010-2020)	Reference
Chironomid abundance	Western Lake Erie: Between 1930 and 1961 increasing eutrophication resulted in a fourfold increase in larval density Detroit River: In 1968, mean density was less than 50 larvae/m^2	The community slowly recovered between 1961 and the 1980s and early 1990s; mean density declined and species diversity increased In 2004, mean density was 1,500 larvae/m^2	Ciborowski (this report: 7.15)
Bald Eagles	From 1961 to 1969 no Bald Eagle fledglings were produced in southeast Michigan, primarily due to egg-shell thinning caused by pesticides like DDT	In 2013-2015 there were 29 active nests in southeast Michigan, fledging 28-34 young per year	Mensing et al. (this report: 7.12)
Osprey	In the early-1960s, the Osprey population in Michigan was rapidly declining; by 2002 there was only one active nest in southern Michigan	In 2015, 2016, and 2017, there were 38, 50, and 52 nesting pairs, respectively, in southeast Michigan (e.g., Wayne, Macomb, Oakland, Livingston, Washtenaw, Monroe, and St. Clair counties)	Hartig (this report: 7.34)
Peregrine Falcons	In the 1960s, reproductive failure was occurring because of pesticides and no breeding pairs were found in the watershed	In 2015, there were 15 nesting pairs in southeast Michigan that fledged 30 young	Becher and Hartig (this report: 7.35)
Lake sturgeon	From 1970s to 1999 no lake sturgeon spawning was reported in the Detroit River	Since 2001, lake sturgeon is once again spawning in the river; estimated population size is 4,422 individuals utilizing the Detroit River (95% confidence interval: 2,758-6,087)	Chiotti and Boase (this report: 7.28)
Lake whitefish	By the 1960s and 1970s, lake whitefish abundance was at an all-time low because of: overexploitation, predation by and competition with invasive species, degradation of water quality and habitat,	In 2006, lake whitefish spawning was documented in the Detroit River for the first time since 1916; estimates of larval lake whitefish exported from the Detroit River to western Lake Erie ranged from 29 million in 2010 to 83 million in 2011	Roseman and DeBruyne (this report: 7.29)

Table 4. An overview of changes in the status of key ecosystem health indicators in the Detroit River and western Lake Erie between peak anthropogenic stress in the 1960s-1980s and current conditions. The complete collection of indicator reports is presented in Appendix B – 7.0.

Indicator	Status in 1960s-1980s	Current Status (2010-2020)	Reference
	and the loss of *Diporeia*, a major nutrient-rich food source		
Walleye population in Lake Erie	In 1978, the population was estimated to be approximately 10 million age-2+ walleye	In 2018, the population was estimated to be approximately 40 million age-2+ walleye	Wills et al. (this report: 7.39)
Beaver	Beaver was extirpated from the Detroit River during the Fur Trade Era; it was last reported in the Detroit River in 1877	Beaver returned to the Detroit River in 2008 for the first time in 131 years; beaver have now been reported from at least six locations in the Detroit River watershed	Hartig (2019a)
River otter in western Lake Erie	River otter was extirpated from Lake Erie in the early 1900s because of over-harvesting during the Fur Trade Era and then loss of habitat and pollution from urbanization	In the 2000s, river otter returned to the southern shore of western Lake Erie after an 80-year absence; in 2019, river otter returned to the northern shore of western Lake Erie at Point Pelee National Park after an over 100-year absence	Hartig (2020)

In general, the decline of walleye in Lake Erie in the 1960s was attributed to a combination of high exploitation, pollution, and interaction with invasive species. International harvest quotas were introduced in 1976, and the Great Lakes Fishery Commission's Lake Erie Committee began coordinated stock assessment and management in 1978 to sustain the population. In the early and mid-1970s the walleye population was considered under stress and depressed. There is high year-to-year variability in the walleye population, but walleye numbers in 2018 were four times the size of the population in 1978.

The banning of certain pesticides and the strict regulation of other toxic substances led to declines in polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene (DDE), and polychlorinated naphthalenes (PCNs) concentrations observed in Herring Gull eggs from Middle Island in western Lake Erie (Table 4). Concentrations of legacy contaminants in fish have also generally declined, but health advisories remain in effect for certain fish species and size classes. In general, contaminants in sediments have also exhibited a decreasing trend, but are still present at levels of concern to wildlife and human health (Godwin, this report: 7.8; Marvin, 2007). Although these overall trends are encouraging, scientists remain concerned about the long-term effects of persistent toxic substances.

Contributing to the problems of western Lake Erie have been the introduction of invasive species (see Table 1). Invasive species, like zebra and quagga mussels and round gobies, have dramatically altered food web dynamics and increased the complexity and difficulty of ecosystem-based management.

General reductions in contaminants led to the return of nesting bald eagles, peregrine falcons, and osprey. Beaver and river otter have returned also to western Lake Erie. However, looking at individual indicators can be misleading. Western Lake Erie is now at risk of crossing two interrelated potential tipping points caused by cultural eutrophication and manifested in harmful algal blooms, and climate change.

Western Lake Erie's respite from the manifestations of eutrophication in the late 1980s and early 1990s was short lived, with the return of harmful algal blooms (HABs) in the late 1990s and early 2000s (Table 4). For example, a HAB of the cyanobacterium *Microcystis* in August of 2014 resulted in a two-day "Do Not Drink" advisory in the City of Toledo due to levels of the toxin microcystin in finished drinking water that exceeded guidelines for safety recommended by the World Health Organization.

Indeed, the HAB forecast conducted by the National Oceanic and Atmospheric Administration and its partners has shown that HABs were "significant" in seven of the last 10 years (Table 4). There is an urgent need now for a coordinated and strategic response to the nutrient management issues on Lake Erie. Through the Canada-U.S. Great Lakes Water Quality Agreement, the Canadian and United States governments have jointly agreed to reduce phosphorus loadings to the lake in order to control the severity and geographic extent of the HABs (Environment and Climate Change Canada and U.S. Environmental Protection Agency, 2019).

The costs of these HABs and other consequences of eutrophication are borne by citizens on both sides of the border. Smith et al. (2019) have quantified the costs of HABs in the Canadian portion of the Lake Erie basin. The findings of that study predict that HABs will result in annual costs of $272 million (Canadian) in 2015 prices over a 30-year period if we do nothing and continue with business as usual. Economists define market costs as the total costs of delivering goods and services to customers, and they define non-market costs as the costs people are willing to pay for goods and services not traded in the open market (e.g., clean water and air, healthy fish and wildlife populations, etc.). The Smith et al. (2019) study concluded that the largest market costs will be imposed on the tourism industry ($110 million Canadian in equivalent annual costs) and the largest non-market costs will be borne by recreational users and those who place inherent value on the lake's quality ($115 million Canadian in equivalent annual costs).

Lake Erie and the Detroit River have been particularly prone to the impacts of climate change. Record high water levels are causing flooding and shoreline erosion. Tourism, recreation, fish and wildlife, shoreline property, natural shoreline features, and shipping are all being impacted by the changing climate, and the situation is expected to only worsen in the decades to come. Western Lake Erie and the Detroit River are increasingly experiencing record-breaking weather extremes, powerful storms, record high water levels, increasing flooding and erosion, and more. Warmer lake waters and greater frequency and intensity of storms are increasing agricultural nonpoint source runoff that is contributing to HABs (Michalak et al., 2013). Further discussion of these pressing environmental and natural resource challenges is presented in the next section.

3.2 Key Environmental and Natural Resource Challenges and Recommended Next Steps

The ecological recovery of the Detroit River is a remarkable story, but much remains to be done to meet the long-term goal of restoring the physical, chemical, and biological integrity consistent with the Canada-U.S. Great Lakes Water Quality Agreement. Further, western Lake Erie is now at risk of crossing several potential tipping points caused by the interactions of a variety of drivers and stresses. Below is a discussion of eight key environmental and natural resource challenges that are currently threatening ecosystem health and recommended next steps.

3.2.1 Climate Change

The Earth's average surface temperature has risen about 0.9°C since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere. Most of the warming has occurred in the past 35 years, with the five warmest years on record taking place since 2015.

> **"Scientific evidence for warming of the climate system is unequivocal."**
>
> *Intergovernmental Panel on Climate Change*

Greenhouse gas emissions from human activities are the leading cause of the earth's rapidly changing climate. Greenhouse gases play an important role in keeping the planet warm enough to inhabit. However, the Intergovernmental Panel on Climate Change (2018) has reported that with an additional increase in global air temperature of 1.5°C there would be increased risks to "health, livelihoods, food security, water supply, human security, and economic growth." Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

High water levels are putting a face on climate change in our region. High water levels on Lake St. Clair, Detroit River, and western Lake Erie have caused property damage and increased shoreline erosion and flooding. Scientists worry that climate change is increasingly turning extraordinary into the ordinary. They predict that warmer, wetter, and wilder weather is coming (e.g., Zhang et al., 2020) and that this will be one of the greatest environmental challenges of the 21st century (Table 5). These warmer, wetter, and wilder climate conditions will likely give rise to impacts that drive large-scale changes in ecosystem function. Warmer lakes, tributaries, and terrestrial ecosystems, reduced ice cover, and increased runoff will alter the range and distribution of certain bird and fish species, increase the frequency and severity of harmful algal blooms in the western basin of Lake Erie, exacerbate wetland loss, create new threats from invasive species, diminish beach health, and in some cases, displace or extirpate native species (Pryor et al., 2014).

Mitigating climate change will take global cooperation and all must do their part. The City of Windsor is committed to be a leader of climate change adaptation and mitigation through its daily actions and services. This is shown through the development of the 2012 Climate Change Adaptation Plan (City of Windsor, 2012). Indeed, Windsor was one of the first municipalities in Ontario and Canada to undertake adaptation planning. In November 2019, the City of Windsor declared a climate change emergency, acknowledging the dramatic impacts already happening and worsening in the future if things aren't improved.

In addition to adapting to the changing climate, the City of Windsor is taking steps to help the global effort to reduce greenhouse gas emissions. In 2017, the City of Windsor developed a Community Energy Plan with ambitious targets to support the global effort to keep global temperature increases within 1.5° C (City of Windsor, 2017). Through the implementation of this plan, the Windsor community will reduce per capita energy use and per capita CO_2 emissions by 40% between 2014 and 2041 (Richters, this report: 7.43).

In Detroit, climate change is projected to increase the intensity and frequency of storms that will test and overwhelm the city's infrastructure and threaten the health of residents in other ways. Flooding will continue to affect Detroit homes and streets due to projected increases in intense precipitation. Detroit is also projected to see a significant increase in very hot days, with as many as 65 days above 32.2°C (90°F) by the end of this century, exacerbating the burden of heat and poor air quality on the city's most vulnerable residents (Heeres et al., this report: 7.49).

Table 5. Potential or known impacts of climate change in the Detroit River and western Lake Erie ecosystem.

Indicator	Potential or Known Impact	Reference
Atmospheric temperature in the Western Lake Erie Climate Division	The average annual atmospheric temperature has increased by approximately 1°C between 1951 and 2018	Maher and Channell (this report: 7.11)
Precipitation in the Western Lake Erie Climate Division	The average annual precipitation has increased by 5.6% between 1951 and 2018, with the fall season exhibiting an increase of 12.6% during the same time period	Maher and Channell (this report: 7.37)
Lake Erie water levels	Average decadal water levels have increased from a low of 173.7 m in the 1930s to 174.3 m in the 2010s	Maher and Channell (this report: 7.27)
Ice cover on Lake Erie	Annual average winter ice cover on Lake Erie has decreased from 27% in the 1970s to 20% in the 2010s; annual maximum winter ice cover has decreased from 94% in the 1970s to 78% in the 2010s	Maher and Channell (this report: 7.14)
Carbon emissions	Michigan carbon emissions have decreased from 194 million tonnes in 2000 to 151 million tonnes in 2016; Wayne County carbon emissions have decreased from 18.1 million tonnes in 2011 to 15.3 million tonnes in 2017	Sick and Gell (this report: 7.10)
Bird species at Point Pelee National Park	Potential bird species turnover for the park between the present and 2050 is 35% in summer and 29% in winter under the high-emissions pathway; the park is or may become home to 20 species that are highly sensitive to climate change across their range	Harpur and Wu (this report: 7.38)
Turkey Vulture	Detroit River Hawk Watch has shown a substantial increase in turkey vultures between 1991 and 2015 and Holiday Beach Conservation Area has shown a dramatic increase in turkey vultures between1979 to 2015, likely due to expanding their range due to climate change	Oleyar and Hartig (this report: 7.22 and 7.23)
Climate change impacts in Windsor	Average temperature in Windsor has increased by almost 1°C since 1940; by 2050, the average annual temperature in Ontario will increase by 2.5°C to 3.7°C from the 1961-1990 baseline average; number of "hot" days (over 30 °C/86 °F) could almost quadruple by 2071-2100; heat related illnesses place a strain on health care services; energy costs will likely rise to cool buildings in summer; this increase in temperature allows for survival of invasive species and the expansion or introduction of insect vectors that carry disease	Richters (this report: 7.43)

Table 5. Potential or known impacts of climate change in the Detroit River and western Lake Erie ecosystem.

Indicator	Potential or Known Impact	Reference
Climate change impacts in Detroit	Climate change is projected to increase the intensity and frequency of storms that will test and overwhelm the city's infrastructure and threaten the health of residents; flooding will continue to affect Detroit homes and streets due to projected increases in intense precipitation; Detroit is projected to see a significant increase in very hot days, with as many as 65 days above 32.2°C (90°F) by the end of this century, exacerbating the burden of heat and poor air quality on the city's most vulnerable residents	Heeres et al. (this report:7.49)

Greenhouse gas emissions are driving global climate change, and Detroit is committed to contributing its fair share to efforts led by cities around the world in mitigating the impacts of climate change. Despite the United States pulling out of the Paris Climate Accord in 2017, over 400 U.S. Mayors (including Detroit Mayor Mike Duggan), representing 70 million Americans, have signed on to fight climate change and lower greenhouse gas emissions. On July 24, 2019, Detroit City Council unanimously passed an ordinance to greatly and swiftly reduce greenhouse gas emissions from the city. The ordinance stipulates that greenhouse gas emissions from city sources will be reduced from baseline conditions by 35% by 2024, 75% by 2043, and 100% by 2050. It will also work towards reducing citywide emissions by 30% by 2025 (Heeres et al., this report: 7.49). These carbon emission reduction targets established in the ordinance are based on the standards of the Paris Climate Agreement, which looks to prevent global temperatures from rising more than 2°C by the end of the century.

Greater coordination is needed at a local level among municipal departments, as well as all levels of government. While challenges around climate action at higher levels of government exist, municipalities can and will continue to be leaders in both mitigation and adaptation.

The International Joint Commission's Great Lakes Water Quality Board (2017) has recommended that the United States and Canada negotiate and develop a coordinated binational approach to advance strategies that support climate change adaptation and increase ecological resilience in the Great Lakes ecosystem region, with a particular emphasis on safeguarding Great Lakes water quality. However, no concrete binational climate change plans have been put into place in the Great Lakes Basin (Galvao-Ferreira et al., this report: 7.58).

Clearly, there are trade-offs between achieving sustainability and justifying the cost of mitigation and adaptation. Quantifying the costs of implementing climate change adaptation and mitigation plans vs. the costs of "doing nothing" will be important to get political and public buy-in. Public Safety Canada estimates that for every dollar invested in climate change adaptation, $3-5 is saved in recovery costs. As noted in the precautionary principle, it is better to avoid or mitigate an action or policy that has the plausible potential, based on scientific analysis, to result in major or irreversible negative consequences to the environment or public even if the consequences of that activity are not conclusively known. Further, the burden of proof that an action or policy is not harmful falls on those proposing the action.

It is recommended that:

- **as a high priority, the City of Windsor's Climate Change Adaptation Plan and Community Energy Plan and the Detroit Sustainability Action Agenda and the Detroit Climate Action Plan be fully implemented;**
- **a multinational climate change plan be developed for the Great Lakes Basin, consistent with what has been called for by the International Joint Commission's Great Lakes Water Quality Board (2017);**
- **physicochemical and biological monitoring programs be sustained to support ecosystem-based management; and**
- **researchers, decision-makers, climate change experts, land managers, and other stakeholders be regularly brought together to report, understand, and inform implementation of climate adaptation and mitigation actions.**

3.2.2 Eutrophication and Algal Blooms

Accelerated nutrient enrichment of Lake Erie starting in the 1950s led to severe water quality problems in the 1960s that were a catalyst for the Canada-United States Great Lakes Water Quality Agreement of 1972, which focused on reducing point source phosphorus inputs. Subsequent phosphorus control programs led to a measurable recovery by the late 1980s and early 1990s. These improvements, however, were relatively short-lived, with the return of accelerated eutrophication and intensification of cyanobacterial harmful algal blooms (cyanoHABs) in the late 1990s and early 2000s (Table 6).

The frequency of cyanoHABs is increasing largely because of increased bioavailable phosphorus loadings, causing tangible economic (Smith et al., 2019) and environmental harm. There has been considerable public, scientific, and regulatory interest in improving the management of Lake Erie in order to control algal blooms, which has resulted in the creation and adoption of nutrient reduction plans in both Canada and the United States (Environment and Climate Change Canada and U.S. Environmental Protection Agency, 2019).

The Maumee River is the single largest source of phosphorus loading to Lake Erie, with most of the load coming from agriculture. Bioavailable phosphorus appears to be the nutrient of greatest concern, as loading of bioavailable phosphorus is most tightly coupled to algal bloom severity. Priority management actions include adoption of multiple Best Management Practices (BMPs) including soil testing to inform application rates; subsurface placement of fertilizers; minimizing the amount of water leaving a field through enhanced drainage water management and improved soil water holding capacity; improving regulation and management of liquid manures from concentrated animal operations; applying manure phosphorus based on agronomic need; and developing experimental watersheds for field-testing management practices (Ohio Lake Erie Commission and State of Ohio, 2020).

Table 6. A summary of eutrophication and algal bloom indicators for the Detroit River and western Lake Erie.

Indicator	Status	Reference
Algal blooms in western Lake Erie	The severity of blooms generally increased from the early 2000s to 2019; harmful algal blooms in seven of the last 10 years have been measured or forecasted as "significant"	Bridgeman (this report: 7.24)
Plankton communities in western Lake Erie	In 13 of 14 years between 2000-2013, plankton index of biotic integrity values were less than three, reflecting eutrophic conditions (goal: 3-4, indicating mesotrophy)	Kane (this report: 7.36)
Phosphorus concentration and load from the Maumee River	Annual flow weighted mean dissolved reactive phosphorus concentrations decreased by 57% between the early 1970s and early 1990s, and then increased 52% between 2000 and 2018; spring flow weighted mean dissolved reactive phosphorus concentrations showed a similar pattern; these loadings are troubling as they exceed both Great Lakes Water Quality Agreement and Ohio Domestic Action Plan targets	Manning and Johnson (this report: 7.7)
Detroit River phosphorus load	The Detroit River total phosphorus load declined from 3,956 MTA in 1998 to 2,502 MTA in 2016, a 37% decline over 18 years; a 40% reduction in loading from 2008 baseline loading estimate is required to meet the target load of 1,858 MTA; an additional reduction of 567 MTA is required from the St. Clair-Detroit River watershed to meet this target load	Scavia et al. (this report: 7.2)
Detroit Water Resource Recovery Facility phosphorus discharge	There has been over a 90% reduction in phosphorus concentration and loading the Great Lakes Water Authority's Water Resource Recovery Facility since 1966; current effluent total phosphorus concentrations are approximately 0.4 mg/L, below the phosphorus discharge limit of 0.6 mg/L	Khan et al. (this report: 7.54)
Combined sewer overflow (CSO) controls in southeast Michigan	The quantity of uncontrolled CSO discharges in southeast Michigan has been reduced by 95%, on average, with completion of all core elements of CSO Control Program; as the program moves into the final phases, the remaining control measures are focused on fully complying with the	Coffey et al. (this report: 7.44)

	Michigan Water Quality Standards	
Canadian laws and policies to address algal blooms	The Canada-Ontario Lake Erie Action Plan calls for a 40% reduction in phosphorus runoff to Lake Erie by 2025; use of the Ontario Drainage and Nutrient Management acts could achieve greater control of phosphorus runoff, including use of two-stage ditch systems and strategic restoration of wetlands	Tsang and Galvao Ferreira (this report: 7.42)

Although the relative contribution of point sources of phosphorus is now minor in comparison with agricultural nonpoint sources, municipalities can reduce bioavailable phosphorus by ensuring continuing improvement of wastewater treatment to counter human population growth in the watershed, improving the functioning of home septic systems and small-scale treatment systems, eliminating direct connections of rural home septic systems into agricultural drain tiles and ditches, and improving management of urban nonpoint source runoff.

The Detroit River provides approximately 80% of the water inflow to Lake Erie, yet phosphorus concentrations in the Detroit River are relatively low compared to those in the Maumee River. The Detroit River total phosphorus load declined from 3,956 MTA in 1998 to 2,502 MTA in 2016, a 37% decline over 18 years (Table 6). Through the Great Lakes Water Quality Agreement, the United States and Canada have established a target of a 40% reduction in total phosphorus loading from the 2008 baseline loading estimate. The phosphorus target load is 1,858 MTA. This will require an additional reduction of 567 MTA from the St. Clair-Detroit River watershed to meet this target load.

It is important to note that there has been over a 90% reduction in phosphorus concentration and loading from the Great Lakes Water Authority's Water Resource Recovery Facility since 1966 (Table 6). Current effluent total phosphorus concentrations from this facility are approximately 0.4 mg/L, well below the permitted phosphorus discharge limit of 0.6 mg/L. Phosphorus loadings from this facility are not contributing to the cyanoHAB problems in western Lake Erie.

In 2018, following several years of large algal blooms in the western basin, the State of Ohio declared the Ohio open waters of the western basin to be officially "impaired" for recreational use (Davis et al., 2019). In response to public concern for algal blooms and the designation of Ohio's waters of western Lake Erie as impaired under the U.S. Clean Water Act, Ohio Environmental Protection Agency (EPA) is developing a Total Maximum Daily Load (TMDL). A TMDL is a regulatory approach to restoring impaired waters that identifies the maximum amount of a pollutant that a body of water can receive, while still meeting water quality standards. Ohio EPA projects that it will take 2-3 years to complete the TMDL.

In 2019, the Ohio Lake Erie Commission and the State of Ohio released an updated draft of the Ohio Domestic Action Plan to reduce phosphorus entering Lake Erie under the binational Great Lakes Water Quality Agreement. New action items include:

- establishing science-based priorities for agricultural BMPs and state programs to support H2Ohio (i.e., an Ohio initiative for safe and clean water) efforts to encourage farmers to implement scientifically backed best practices;

- outlining Ohio's efforts to create, restore, and enhance wetlands for nutrient reduction (as part of H2Ohio);

- updating actions for communities, including H2Ohio support for home sewage treatment system remediation; and

- integrating the role of watershed planning at the local level for siting projects to reduce nutrients efficiently, including a distribution of the load reduction throughout the Maumee River watershed based on the Ohio EPA Nutrient Mass Balance method.

The commitment to develop a TMDL for Ohio waters of western Lake Erie is an important development. **It is recommended that a high priority be placed on completing this TMDL in a timely fashion and on ensuring sound and actionable science that is designed with stakeholders and decision-makers to better inform management programs.**

The causes of recent changes to Lake Erie's nutrient status and the specific factors driving toxigenicity of algal blooms are still inadequately understood. Eliminating HABs and adequately controlling cultural eutrophication will require a better understanding of how to mitigate contributing factors such as nutrient loadings (including nitrogen), invasive species, within-lake nutrient cycling, algal physiology, and climate change. Further, the large size and international nature of Lake Erie algal blooms will require binational scientific and regulatory cooperation, with common goals and shared benchmarks. **Therefore, it is recommended that adequate funding be sustained for necessary binational, cooperative monitoring, research, and modelling, with a priority on actionable science, and that this science be closely coupled with management programs to achieve long-term goals for the Maumee River and Lake Erie.**

3.2.3 Toxic Substances Contamination

The Detroit River and western Lake Erie region has long been a center of heavy industry and urbanization, resulting in substantial pollution by toxic substances which accumulate in sediments, impact the biological community, and biomagnify in fish and wildlife. Progress has been made in reducing pollution and remediating contaminated sites in the region, but continued efforts are needed.

In general, contaminant levels in fish and herring gull eggs have declined, but health advisories remain in effect on the consumption of certain species and size classes of fish. Examples of declines in tissue concentrations of contaminants in biota include: 80% less mercury in Lake St. Clair walleye since 1970 when inputs were eliminated to the St. Clair River (Ontario Ministry of Environment, Conservation and Parks, this report: 7.32); 90% and 72% less PCBs in herring gull eggs (since the late 1070s) from Fighting and Middle Sister islands, respectively; and 88% and 86% less DDE in herring gull eggs (since the late 1070s) from Fighting and Middle Sister islands, respectively (de Solla and Hughes, this report: 7.19). Mercury concentrations in herring gull eggs from Fighting and Middle Sister islands have declined only slightly since the 1970s and show large year-to-year variability (de Solla and Hughes, this report: 7.19).

The contaminant trends in herring gull eggs suggest that the Detroit River appears to be the ultimate source of polychlorinated naphthalenes (PCNs) in gulls for most colonies downstream as far as Kingston, Ontario (de Solla and Hughes, this report: 7.19). Concern has been raised over the potential effects of environmental endocrine disruptors on avian populations and humans. One other recent example from 2017 is the finding of widespread per- and polyfluoroalkyl substances (PFAS) in the Huron River in Michigan, resulting in a "Do Not Eat" advisory on all fishes.

Control of contaminants at their source remains the primary imperative for action. Experience has shown that pollution prevention is much more ecologically sound and cost-effective than environmental remediation. Clearly, the adage that "an ounce of prevention is worth a pound of cure" holds true. Examples of important programs to prevent toxic substance problems include: "cradle to cradle" design for a circular economy; Design for Environment; ISO 14000; Life Cycle Assessment and Management; and Full Cost Accounting. These initiatives proactively identify and prevent toxic substance problems before they become manifest in the environment. Clearly, a higher priority needs to be placed on preventing pollution by toxic substances that pose the greatest risk to human and ecosystem health. **It is recommended that high priority be placed on preventing toxic substance problems consistent with the Canada-U.S. Great Lakes Water Quality Agreement goals of "zero discharge" and virtual elimination of persistent toxic substances.**

> **"Prevention is the best antidote!"**
>
> *World Health Organization, United Nations Environment Programme, and the International Labour Organization*

Management experience has shown that once toxic substance problems have been identified, quantifying annual toxic substance loading estimates by source, making these loading data publicly accessible, and reaching agreement on toxic substance loading reduction targets are essential for measuring and sustaining progress and achieving the long-term goal of virtual elimination of persistent toxic substances. Remediation of contaminated sediment hot spots will be essential to fully restore impaired beneficial uses like fish consumption advisories. All contaminated sediment remediation projects identified for use restoration in the River Raisin RAP have been completed (Hartig, this report: 7.47) and all contaminated sediment remediation identified for use restoration in the Rouge River has been completed, except for the shipping channel (Ellison et al., this report: 7.48) (Table 7). All contaminated sediment remediation identified for beneficial use restoration on the Canadian side of the Detroit River has been completed (Table 7; Sanders et al., this report: 7.46). Between 1993 and 2020, 288,000 m^3 of contaminated sediment were remediated along the U.S. shoreline of the Detroit River. In addition to these areas where contaminated sediments were remediated, widespread monitoring of sediment contaminants shows that concentrations of heavy metals, pesticides, and other chemicals have decreased in 126 of 160 records (Godwin, this report: 7.8).

However, U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes, and Energy have identified an additional 5.1 million m^3 of contaminated sediment that require remediation to meet long-term goals for restoring beneficial uses (Table 7; Ellison et al., this report: 7.48). These contaminated sediment hot spots in the Detroit River also contribute to biomagnification of contaminants in fish and herring gull eggs (de Solla and Hughes, this report: 7.19) and to impairments in the benthic macroinvertebrate community (Ciborowski, this report: 7.15, 7.25, 7.33). **Therefore, it is recommended that high priority be placed on remediation of 5.1 million m^3 of contaminated sediment along the U.S. shoreline of the Detroit River and the shipping channel of the Rouge River through Great Lakes Legacy Act and Great Lakes Restoration Initiative partnerships with local sponsors.**

Table 7. Contaminated sediment remediation and management targets for the River Raisin and Rouge and Detroit rivers.

Water Body	Contaminated Sediment Remediation Completed	Status Relative to Management Targets	Reference
River Raisin	In 1997, Ford Motor Company removed 20,000 m^3 of PCB-contaminated sediment In 2012, the U.S. Army Corps of Engineers performed strategic navigational dredging that removed 52,750 m^3 of PCB-contaminated sediment In 2012-2013 and 2016 under the Great Lakes Legacy Act, in partnership with Ford Motor Company, 95,350 m^3 of PCB-contaminated sediment were removed	All contaminated sediment remedial actions identified for use restoration in the River Raisin RAP have been completed	Hartig (this report: 7.47)
Rouge River	Between 1986 and 2020 there has been 396,800 m^3 of contaminated sediment remediated in the lower Rouge River	The shipping channel of the Rouge River requires further sediment remediation. A cooperative agreement has been signed between U.S. Environmental Protection Agency and Michigan Department	Ellison et al. (this report: 7.48)

Table 7. Contaminated sediment remediation and management targets for the River Raisin and Rouge and Detroit rivers.

Water Body	Contaminated Sediment Remediation Completed	Status Relative to Management Targets	Reference
		of Environment, Great Lakes and Energy for necessary remedial investigation work.	
Detroit River - Canada	In 2008, 975 m^3 of sediments, contaminated with heavy metals and PCBs, were remediated in the Turkey Creek-Grand Marais drain	No further contaminated sediment remediation is planned. No exceedances of severe effect levels for contaminants in sediments have been found.	Sanders et al. (this report: 7.46)
Detroit River – U.S.	Between 1993 and 2020 there has been 287,570 m^3 of contaminated sediment remediated along the U.S. shoreline of the Detroit River	An estimated 5.1 million m^3 of contaminated sediment requires remediation to meet long-term goals for restoring beneficial uses.	Ellison et al. (this report: 7.48)

3.2.4 Invasive Species

Human population growth in the Great Lakes basin ecosystem has been accompanied by a variety of stresses to the ecosystem, including habitat destruction and modification, chemical contamination, and the unintentional introduction of various nonindigenous species (NIS). Over 180 non-native species have become established in the Great Lakes within the past two centuries (MacIsaac and DeRoy, this report: 7.26). At least 11 species have been introduced in the Huron-Erie corridor since 1988 (Table 8). NIS can cause profound ecological and economic damage and are a major stressor in the Huron-Erie corridor.

Table 8. Examples of NIS introduced into the Huron-Erie corridor since 1988.

NIS	Location and Year Introduced
Zebra Mussel *Dreissena polymorpha*	Lake St. Clair in 1988
Quagga Mussel *Dreissena rostriformis bugensis*	Lake Erie in 1989
Round Goby *Neogobius melanostomus*	St. Clair River in 1990
Tubenose Goby *Proterorhinus marmoratus*	St. Clair River in 1990
Non-native Common Reed *Phragmites australis*	Erie Marsh on western Lake Erie in late 1980s-early 1990s
Spiny Water Flea *Bythotrephes longimanus*	Detroit River in 1994
European Frog Bit *Hydrocharis morsus-ranae*	Lake St. Clair & Detroit River in 2000
Emerald Ash Borer *Agrilus planipennis*	southeast Michigan in 2002
Viral Hemorrhagic Septicemia Virus	Lake St. Clair in 2002 or 2003
New Zealand Mud Snail *Potamopyrgus antipodarum*	Lake Erie in 2007
Copepod *Thermocyclops crassus*	Lake Erie in 2014
Copepod *Mesocyclops pehpeiensis*	Lake Erie in 2018
Cladoceran *Diaphanosoma fluviatile*	Lake Erie in 2015
Rotifer *Brachionus leydigii*	Lake Erie in 2017

Numerous pathways are responsible for NIS release including commercial shipping, live species trade, and unauthorized introductions. Ballast water release from commercial shipping has been the primary pathway for species introductions since 1959, with about 40% of these species introduced via ballast water release, dumping of solid ballast, and hull fouling.

The number of new NIS was seemingly reduced following implementation of mandatory ballast water flushing regulations for foreign ships entering the Great Lakes (MacIsaac and DeRoy, this report: 7.26). Despite this, four new invertebrate NIS have been reported in Lake Erie since 2014 (Table 8). Alternative pathways (e.g., aquarium trade) also introduce species and, without proper management, are likely to dominate longer-term invasions in the Great Lakes as ballast water treatment becomes mandatory.

It is recommended that preventing the introduction of NIS be a primary imperative for action by the governments of the United States and Canada, the eight Great Lakes states, and the provinces of Ontario and Quebec. Every year of delay results in substantial ecological harm and economic impacts.

It is recommended that there be greater alignment of NIS regulations with management in the region. For example, intensive grass carp eradication is of utmost importance given its expanding range in the southern part of western Lake Erie, and the high risks associated with the species (MacIsaac and DeRoy, this report: 7.26).

The IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments will require all vessels to have on-board water treatment systems by 2024, and places limits on the permissible abundance of discharged organisms (MacIsaac and DeRoy, this report: 7.26). **It is recommended that:**

- **governments ensure that these regulations also apply to the domestic 'laker' fleet in order to reduce inter-lake dispersal of NIS;**
- **the efficacy of ballast treatment should be verified through comprehensive sampling on the Great Lakes;**
- **region-wide regulations be enacted to alternative pathways of NIS; and**
- **species-specific methods of control and impact mitigation be developed.**

Finally, it is recommended that coordinated and consistent long-term monitoring programs be instituted to help detect and eradicate invasive species, if introduced, and to assess impacts should NIS become established. Early detection of NIS at low densities is an essential component of feasible eradication strategies (MacIsaac and DeRoy, this report: 7.26).

3.2.5 Habitat Loss and Degradation

Habitat is broadly defined as the physical substrate that supports the species that live in a particular place. For land-based species, habitat is largely two-dimensional, but for organisms that live above ground at least part of the time, such as birds, bats, and many insects, their habitat has a three-dimensional component. The habitat of aquatic organisms is also three-dimensional. The easiest way to understand habitat is to view it as home. Communities of species that share similar places (homes) live in habitats that we broadly categorize as woodlands, grasslands, oak-openings prairies, wooded and marsh wetlands, lakes, ponds, streams, and rivers. The variety of life habitats and the genetic variety that they support are known as biodiversity. In general, the greater the biodiversity, the healthier the habitat is for all the species living there.

Native peoples first lived in the Detroit-St. Clair corridor and were attracted by the water supply, natural resources, and transportation opportunities that supported their communities. Early accounts spoke of a rich variety of terrestrial, wetland, and aquatic habitats that supported an abundance of fish and wildlife and were used for fishing, hunting, and gathering. Crops were grown in meadows among the oaks, often maintained by what is known today as prescribed burns (Edsall and Gannon, 1998). In some places along the Detroit River, wetlands, so important to biodiversity, extended 1.6 km inland from the shore.

The same features that attracted native peoples to the region also attracted European settlers who saw opportunities for economic growth and prosperity and enhancement of their quality of life. The major growth in European settlements occurred in the early 1800s and coincided with beginning of the Industrial Revolution in England and Western Europe. Water and air pollution and pell-mell destruction of natural habitats for timber harvesting and land clearing to support agricultural development became widespread. Wetlands were drained and filled, and river shorelines were armored with breakwaters and docks for industrial development and shipping. Well into the 1950s, pollution and habitat loss were generally viewed as a necessary and unavoidable cost of economic growth (Hartig, 2014).

Public outcry and concern about pollution and habitat loss led to the environmental awareness movement of the 1960s and 1970s, culminating with the enactment of legislation, including the Canada Water Act of 1970, the U.S. National Environmental Policy Act of 1970, the Canada-U.S. Great Lakes Water Quality Agreement of 1972, the U.S. Clean Water Act of 1972, and the Endangered Species Act of 1973. In 1985, under the auspices of the Great Lakes Water Quality Agreement, the International Joint Commission identified pollution hotspots or Great Lakes Areas of Concern and called for the development of Remedial Action Plans (RAPs) to restore any of 14 beneficial use impairments (BUIs). Six RAPs are underway in the Detroit-St. Clair Corridor and western Lake Erie (i.e., St. Clair, Clinton, Detroit, Rouge, and Maumee rivers and the River Raisin). Especially pertinent to this assessment is the BUI relating to loss of fish and wildlife habitat, which calls for creating and restoring habitat with physical, chemical and biological characteristics necessary to support fish and wildlife populations.

The protection and restoration of healthy habitats and biodiversity in the Detroit-St. Clair Corridor should be viewed not only as an environmental issue, but as a quality of life issue for the residents and visitors of the region. Progress to date on water pollution improvements and restoring habitats is creating new economic and recreational opportunities, including river walks on both sides of the Detroit River (Hartig, 2019a). In such an urban-built environment, the re-connection with nature afforded by habitat creation, protection, and restoration is being increasingly recognized as important for psychological and physical health for children and adults. Richard Louv (2005) in his book, *Last Child Left in the Woods: Saving Our Children from Nature Deficit Disorder*, investigated the possible negative consequences that accompany reduced outdoor activities (e.g., attention deficit disorders, obesity, and dampening of creativity) as children have increasingly moved indoors. He expanded observations of this disturbing phenomenon to include adults in his more recent book titled *Vitamin N: The Essential Guide to a Nature-rich Life* (Louv, 2016). Dr. Ming Kuo has led a research team that has provided evidence that nature is not just a nice amenity in urban settings. Access to nature in urban areas, even in neighborhoods with high poverty, leads to better psychological well-being and social functioning, including improved human health (Kuo, 2015), reduced healthcare costs (Becker et al., 2019), and improved academic achievement (Kuo et al., 2018). Consequently, habitat creation, protection, and restoration should not be considered a superfluous "luxury" in urban planning and development. Rather it is essential to human health and well-being in the Detroit-St. Clair region today and in the future.

Of course, in such an urban-built region, the remaining natural habitats are largely reduced in extent and often degraded, so the challenges of habitat creation, protection, and restoration can be considered daunting. However, skeptics should be encouraged by the habitat contributions in this conference report. Indicator reports summarized green infrastructure, coastal wetlands protection, controlling invasive species in wetlands, and soft-engineering of the land-water interface. In each case, the importance of setting targets was emphasized. Monitoring progress in achieving targets is an essential complement to setting targets. Where monitoring indicates lack of sufficient progress in meeting targets, new projects may need to be initiated in an adaptive management mode to maintain and accelerate progress in meeting habitat creation, protection, and rehabilitation goals.

RAP Habitat Projects

Considerable habitat rehabilitation and enhancement has occurred on both sides of the Detroit River under the Detroit River RAP. On the U.S. side, nine of 14 habitat projects identified for removing the habitat BUI have been completed and five are underway (Table 9). On the Canadian side, 23 habitat rehabilitation projects have been completed and 14 are under design and development (Table 9).

The Land-Water Interface

The Southeast Michigan Council of Governments (SEMCOG) is exploring the integration of lands and waters of the built and natural environments in the seven-county area, including much of the watersheds on the U.S. side of the Detroit-St. Clair Corridor. Land use was inventoried in the categories of impervious, tree canopy, open space, bare ground, and water. For example, 14% and 23% of the land area in southeast Michigan and the Rouge River watershed, respectively, are covered with impervious surface, with a target of less than 10% (Table 9). Currently, 33% of southeast Michigan is covered with tree canopy, with a target of 40%.

Another program with potential for integration of lands and waters is the transboundary initiative between the U.S. Fish and Wildlife Service (USFWS) and the Essex Region Conservation Authority (ERCA). The Detroit River International Fish and Wildlife Refuge on the U.S side, established 2001, and the Western Lake Erie Watersheds Priority Natural Area on the Canadian side, administered by

Table 9. Current status and management targets for key habitat indicators.

Indicator	Current Status	Target	Reference
U.S. habitat restoration under the Detroit River RAP	Nine of 14 habitat projects completed and five underway	Completion of all 14 projects will allow removal of "loss	Burns and Lovall (this report: 7.61)

Table 9. Current status and management targets for key habitat indicators.

Indicator	Current Status	Target	Reference
		of fish and habitat" BUI	
Canadian Habitat restoration under the Detroit River RAP	• 18 of 19 habitat restoration projects have been implemented • Habitat restoration has been completed at 5 of 18 additional priority sites	Under development	Serran and Sanders (this report: 7.41)
U.S. soft shoreline on the Detroit River	44% soft shoreline in 2015 (19.6 km)	70% to reach a "good" state	Hartig and Knauss (this report: 7.56)
Canadian soft shoreline on the Detroit River	61% soft shoreline in 2017 (31.1 km)	70% to reach a "good" state	Sanders (this report: 7.55)
Coastal wetlands on the Detroit River	Currently, 97% of the coastal wetlands have been lost to development and 3% remain (approximately 56 ha)	Coastal wetlands in the Detroit River will comprise at least 25% of their historical area by 2030 (a net gain of 452 ha over the next 10 years)	Pearsall et al., (this report: 7.20)
Green infrastructure	• Impervious surface in southeast Michigan – 14% • Impervious surface in the Rouge River watershed – 23% • Tree canopy in southeast Michigan – 33%	< 10% < 10% 40%	SEMCOG (this report: 7.51)
Level of cooperation on transboundary conservation	U.S. and Canadian partners have cooperated on more than 10 projects/activities that represent a Level IV	A Level V would be achieved when transboundary cooperative conservation initiatives are	Khan (this report: 7.59)

Table 9. Current status and management targets for key habitat indicators.

Indicator	Current Status	Target	Reference
	(coordination of planning)	fully integrated	
Land conservation through the Detroit River International Wildlife Refuge	As of 2019, U.S. and Canada have 7,600.8 ha (18,782 acres) of lands enrolled on registries of lands for purposes of conservation and outdoor recreation	10,117 ha (25,000 acres) by 2025	Hartig and Knauss (this report: 7.53)
Invasive Common Reed in Erie Marsh	Area of dense coverage of invasive *Phragmites* has decreased from 132 ha in 2003 to 60 ha in 2018	Under development	May (this report: 7.31)
Cooperative Weed Management Area	Since its establishment in 2011, over 800 ha of land have been treated for invasive *Phragmites*; between 2015 and 2019 over 14,160 ha have been surveyed for invasive plant species	Under development	Fletcher et al. (this report: 7.50)

ERCA and established 2013, have similar conservation goals, and the two groups have signed a Memorandum of Understanding for cooperative conservation and ecosystem-based management in the spirit of the 2001 Conservation Vision for the Lower Detroit River Ecosystem. Khan (this report: 7.59) evaluated the "Level of Cooperation" in transboundary conservation between these two initiatives, whereby Level I is the lowest (No cooperation) and Level V is the highest (Fully cooperating on joint planning and, whenever appropriate, joint management). The current status of cooperation was determined to be Level IV (Coordination of planning) which is meritorious (Table 9). Further, each entity maintains a registry of lands for purposes of conservation and outdoor recreation in support of transboundary conservation. As of 2019, a U.S. and Canadian total of 7,600.8 ha (18,782 acres) of lands are enrolled in these registries of lands, with a target of 10,117 ha (25,000 acres) enrolled by 2025 (Table 9).

Wetlands

Protection and restoration of wetlands are a particularly difficult challenges because the Detroit River has lost 97% of the area that was once wetlands by conversion to other uses (e.g., agriculture, industry, commerce, dwellings, etc.). Nonetheless, encouraging progress is being made. Through the Lake Erie Biodiversity Conservation Strategy, a restoration target has been established – restore 25% of the historical area by 2030 (a net gain of 452 ha) over the next 10 years (Pearsall et al., this report: 7.20; Table 9). Wetland functions and benefits have also been substantially impacted by invasive species. The good news is that the Detroit River-Western Lake Erie Cooperative Weed Management Area was established to control *Phragmites* and other invasive plants on the U.S. side. Since its establishment in 2011, this Cooperative Weed Management Areas has treated (i.e., combination of herbicide treatment, mowing, and water-level management) over 800 ha of land for invasive *Phragmites* and between 2015 and 2019 it has surveyed over 14,160 ha for invasive plant species (Fletcher et al., this report: 7.50; Table 9). Erie Marsh Preserve is the largest wetland in the cooperative weed management area. The combination of treatments and water-level management in Erie Marsh Preserve during 2003-2018 has reduced the areal extent of *Phragmites* by approximately one half (May, this report: 7.31; Table 9).

Soft Engineering

As the St. Clair-Detroit River Corridor became such an important international shipping route and major urban area over the last two centuries, the Detroit River shoreline has become hardened for navigation and industrial development with breakwaters, steel sheet piling, etc. Such engineered structures have benefited commercial interests at the expense of fish and wildlife habitat. Soft engineering is the practice of using ecological principles to "soften" land-water interface by enhancing habitat without sacrificing the engineered integrity of the shoreline. As of 2015, 44% of the U.S. shoreline of the Detroit River is in soft shoreline (19.6 km), with a target of 70% to reach a "good" state (Hartig and Knauss, this report: 7.56; Table 9). On the Canadian side, 61% of the shoreline (31.1 km) is considered "soft", with a target 70% to reach a "good" state (Sanders, this report: 7.55; Table 9).

Challenges, Opportunities, and Recommendations

Scientists and engineers need to know whether their work is achieving its predicted outcomes. Resource managers need to know whether targets have been achieved, and for example, whether the habitat loss BUI can be delisted as part of a RAP in specific AOCs. Politicians need to know that the funds they approved for the work have been well spent, and partners in the work can celebrate their success. Citizens can be informed of the success and be called upon to support more actions to improve the quality of the region by communicating with elected officials. **It is recommended that continued priority be placed on establishing quantitative targets for habitat creation, protection, and rehabilitation programs; such projects are very important.**

Pre- and post-restoration monitoring must be an essential component of all habitat projects and programs. How else will it be known whether targets are being achieved? This sounds so basic that it may go without saying. But too often, habitat project funds are awarded for the construction work, but not for follow-up monitoring. Or, in some cases, funds are allocated for just short-term monitoring that is of insufficient duration for the habitat benefits to take effect. Monitoring is also important element of adaptive management, where determinations can be made to modify the project, as necessary, to achieve better ends or adjust targets. Monitoring also provides the information for technology transfer, whereby lessons learned in one location can be adopted or adapted to other place-based habitat projects elsewhere. **Therefore, it is recommended that every effort be made to ensure long-term monitoring is a priority and essential component of all habitat projects and programs.** In the U.S., the Great Lakes Coastal Wetland Monitoring Program, funded by Great Lakes Restoration Initiative, is a long-term investment in coastal wetland monitoring. On the Canadian side, the Canadian Wildlife Service invests in coastal wetland monitoring through St. Clair-Detroit River System Initiative.

Climate change is making monitoring of habitat projects more important than ever before. Water-level changes and fluctuations may adversely affect the ecosystem services anticipated from habitat projects, requiring adaptive management. Coastal wetlands likely will be particularly affected by water-level changes, and monitoring will be important for understanding how ecosystem services of wetlands will be affected and what adaptive management adjustments may be needed. Changes in precipitation patterns and amounts caused by climate change will affect stormwater management on tributaries to the Detroit-St. Clair Corridor. Monitoring stormwater runoff and flows is critical for focusing on the highest priority nonpoint and point source management actions to improving downstream water quality. **It is recommended that all habitat monitoring efforts be integrated with climate change programs and monitoring initiatives to better understand cause-and-effect relationships, measure progress toward quantitative targets, and practice adaptive management.**

Transboundary cooperative conservation efforts for the Detroit River and western Lake Erie have been exemplary, as evidenced by the work through the Detroit River International Wildlife Refuge (Khan, this report: 7.59) and on the Lake Erie Biodiversity Management Plan (Pearsall et al., 2012). However, continued strengthening and improving are warranted. **It is recommended that transboundary cooperative conservation efforts be strengthened by either: re-energizing the Priority Natural Area under Essex Region Conservation Authority, designating either Parks Canada, Bird Studies Canada, or Environment and Climate Change Canada as the lead federal agency to work with the U.S. Fish and Wildlife Service on the international wildlife refuge, establish a National Wildlife Area to work closely with the U.S. Fish and Wildlife Service on the international wildlife refuge, or work with local interests to establish Ojibway Urban National Park that could work closely with the U.S. Fish and Wildlife Service to bring conservation to cities.**

A major deterrent to improving habitat for many decades in the Detroit River has been contaminated sediments from legacy industrial pollution. After all, habitat improvements in areas with contaminated sediments could provide an attractive nuisance for fish and wildlife and increase their exposure and bioaccumulation of contaminants. Therefore, it is prudent to remediate contaminated sediments before restoring habitats. The Great Lakes Legacy Act is providing funding for remediation of contaminated sediment "hot-spots" in the Detroit River that has paved the way for fish and wildlife habitat creation, protection, and improvement projects largely though the subsequent Great Lakes Restoration Initiative (Hartig, 2019b).

Continued monitoring of these projects is important for documenting how well fish and wildlife are responding to habitat management actions, making necessary adjustments, as necessary, in an adaptive management mode, and communicating successes to the public and politicians on ecological and economic benefits of removal of contaminants and habitat creation, protection, mitigation, and rehabilitation. **It is recommended that the Great Lakes Legacy Act and Great Lakes Restoration Initiative in the U.S., and the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health and the Great Lakes Protection Initiative in Canada, ensure that long-term monitoring is viewed as an essential component of all habitat rehabilitation and enhancement projects.**

There always seems to be a shortage of human and financial resources that are deemed necessary and sufficient for long-term habitat monitoring in the Detroit-St. Clair Corridor. This is where citizen science volunteers become so important in supplementing and augmenting what monitoring professional scientists and engineers can provide. Hundreds of citizen scientists for the Friends of the Rouge and the Clinton River Watershed Council monitor “bugs” (macroinvertebrates) as indicators of water quality. Citizen scientists also assist with fish monitoring on the Rouge River and participate marsh bird monitoring efforts. Citizen science volunteers also participate in habitat restoration activities, including invasive species control, in coastal wetlands with the Detroit River International Wildlife Refuge and other organizations. Not only do the management agencies and nongovernmental organizations benefit from citizen scientists, but the citizens themselves also benefit from teamwork involvement and an improved understanding of stewardship and support of fish and wildlife habitat. **It is recommended that, based on the success of current citizen science monitoring in the watershed, a strong partnership between nongovernmental organizations and natural resource agencies be established to better promote citizen science, integrate monitoring programs, ensure sound scientific methods so that data can be used for management, and create synergies for more effective ecosystem-based management.**

Although the disciplines of ecology and engineering have been extant for a long time, the fields of ecological engineering, restoration ecology, and biological conservation, which are directly applicable to fish and wildlife habitat, are relatively new. Lessons learned from these fields should be applied to the planning and implementation of habitat projects in the Detroit-St. Clair Corridor. New research applications are especially needed concerning hydrology and groundwater pertinent to the ecological health of coastal wetlands and tributary streams. Better understanding of how changes in water levels because of climate change affect hydrology and groundwater is warranted. Ecosystem services’ models under different climate scenarios are needed to better envision the future and set habitat priorities. More research also would be helpful in better understanding the land-water interface and opportunities for green infrastructure protection and enhancement in urban-built environments. Research and development of new technologies, such as drones and remote sensors, might help augment data collected by scientists and citizens. Social science research would be helpful in better understanding the challenges and opportunities of connecting people to habitats for improving their own wellbeing, in addition to benefitting fish and wildlife. **Therefore, it is recommended that the State of the Strait Conference consider hosting a future conference on new research applications in habitat rehabilitation and enhancement.**

In urban-built environments with so many competing demands for funding, it is important to have strategic plans in place, whereby habitat protection and restoration projects are "back pocket" and "shovel-ready" to implement when funding becomes available, often on short notice. Existing habitats are substantially fragmented in urban environments. Planning priorities should include opportunities to connect existing and constructed habitats as corridors for fish and wildlife. Similarly, green corridors perpendicular to the St. Clair-Detroit Corridor to improve access for people to the waterfront should be enhanced. Permitting processes should be reviewed and revised as necessary to remove obstacles to enhancing fish and wildlife habitat and implementing green infrastructure in urban development projects, including soft engineering. Fish and wildlife habitat projects should include an educational component to improve public understanding of the importance of habitat creation and restoration in the urban setting and to garner public support for funding habitat initiatives with politicians. **Therefore, it is recommended that strategic habitat planning be conducted that includes development of green wildlife and greenway corridors, opportunities for soft shoreline, and adequate public education.**

3.2.6 Nonpoint Source Pollution

As regulatory programs came online and achieved greater control of pollutants from point sources starting in the early 1970s, the relative contribution of pollutants from nonpoint sources increased. Nowhere in the Great Lakes was this more evident than in Lake Erie. Starting in the 1990s, harmful algal blooms returned to the western basin of Lake Erie and hypoxia returned to the central basin of Lake Erie as a result of increased soluble reactive phosphorus loadings and higher annual runoff. The Maumee River is the single largest source of phosphorus loading to Lake Erie, with the majority of the load coming from agriculture. Manning and Johnson (this report: 7.7) have shown that both spring total and dissolved reactive phosphorus loadings from the Maumee River have steadily increased in recent years, with levels peaking in 2015, coinciding with large harmful algal blooms recorded in Lake Erie. These spring phosphorus loads exceed the targets established in the Great Lakes Water Quality Agreement in most of the recent years. **It is recommended that high priority be placed on more effective control of agricultural nonpoint source phosphorus loadings through applying combinations of practices like cover crops, buffer strips, wetlands, applying fertilizer below the soil surface on the lands with the highest phosphorus losses, and regenerative agriculture.** Scavia et al. (this report: 7.2) have shown that reducing current phosphorus loadings sufficiently to meet Great Lakes Water Quality Agreement target loadings will be a daunting challenge. Additional agricultural nonpoint source controls will be needed in other tributary watersheds, including the Detroit River. **It is recommended that sufficient monitoring and research continue to be undertaken to measure progress toward phosphorus target loads established in the Great Lakes Water Quality Agreement.**

The Rouge River watershed in southeast Michigan is largely urbanized, spans approximately 1,210 km^2, is home to over 1.5 million people in 48 communities and three counties, and is a tributary to the Detroit River. As industrial point sources of pollution were being addressed during the 1960s and 1970s through both federal and state regulatory initiatives, it soon became clear that more would need to be done to address nonpoint sources of pollution. Since 1985, over $1 billion has been spent on controlling combined sewer overflows and urban stormwater runoff (Ridgway et al., 2018). Dissolved oxygen concentrations in all three branches of the Rouge River have improved, which are now achieving the water quality standard over 90% of the time (DeMaria and Mullett, this report: 7.21). The benthic macroinvertebrate community has also shown general improvement in all three branches, with most stations assessed "fair" according to Stream Quality Index values (Patrella et al., this report: 7.13). Today, the Rouge River is the first river system in the nation to have a watershed-based stormwater permit for all communities in the watershed. The Alliance of Rouge Communities has been particularly effective in facilitating cooperation among watershed stakeholders and in coordinating sub-watershed planning in order to implement stormwater plans mandated under the stormwater permit. This serves as a model for others and demonstrates that watershed-based efforts can be effective. **It is recommended that: more opportunities be provided for cooperative learning among the many watersheds in the southeast Michigan and southwest Ontario region; and high priority be placed on establishing quantitative targets for reducing nonpoint source pollutant loadings by watershed to meet long-term ecosystem goals.**

SEMCOG (this report: 7.51) has shown that southeast Michigan and the Rouge River watershed have 14% and 23% impervious surface, respectively. The target for a healthy ecosystem is less than 10%. As impervious surface increases through urban sprawl, more wetlands are lost to development and more nonpoint source pollution occurs. This can further increase runoff, compounding nonpoint source pollution. In addition, SEMCOG (this report: 7.51) has shown that southeast Michigan currently has 33% tree cover, with a target of 40%.

Urban and suburban development in southeast Michigan has been accompanied by more and more wetland loss. To date, 97% of the original coastal wetlands along the Detroit River have been lost to development. Loss of wetlands translates into a loss of natural filtering capacity and more urban nonpoint source runoff. **It is recommended that high priority be placed on Detroit River coastal wetland restoration to achieve a minimum of 25% of their historical area by 2030 (a net gain of 452 ha over the next 10 years) (Pearsall et al., this report: 7.20). It is further recommended that:**

- **ordinances be developed to protect beneficial land uses, including wetland preservation, stormwater controls, soil erosion controls, and waterfront setbacks;**
- **best management practices be implemented to control erosion and reduce nonpoint source pollutants; and**
- **conservation easements be used to permanently protect river corridors, floodplains, shorelines, and wetlands.**

The importance of atmospheric nonpoint source pollution must not be overlooked. Air pollution from highways or from a combination of highways and manufacturing facilities has been linked to health impacts such as asthma, difficulty in breathing, and more. It typically impacts the most vulnerable in our society, including children and elderly. However, while it is common knowledge that air pollution is bad for human and ecosystem health, it has been difficult to draw a meaningful connection between air pollutant sources and health outcomes due to the multiple types of exposure communities often face.

Southwest Detroit has long been recognized for poor air quality, particularly Detroit zip code 48217, which remains among the most polluted in the state (Williams, this report: 7.1). It has the highest asthma hospitalization rates in the State of Michigan. It is impacted by both industrial facilities and transportation nonpoint sources. This community is 82% Black and has a median household income of $24,000, which is 35% lower than the state of Michigan's average (Williams, this report: 7.1). Roughly 44% of the people in 48217 live below the poverty line, according to the latest U.S. Census data, compared to 14% for the state of Michigan. **It is recommended that air pollution prevention and control, particularly in urban areas like Detroit and Windsor, remain a high priority, including:**

- **committing to long-term monitoring that quantifies loadings from both nonpoint and point sources;**
- **establishing reduction targets to meet air quality standards and eliminate human health impacts;**
- **developing a screening tool that assesses environmental burden and vulnerability based on human population characteristics and health conditions;**
- **assessing cumulative exposure to pollutants; and**
- **implementing the Detroit Sustainability Action Agenda, the Windsor Environmental Master Plan, and the Detroit Climate Action Plan.**

Some nonpoint source pollution problems can be addressed through management strategies and/or technological practices. However, the problem is also rooted in basic aspects of North American society, including dominant patterns of low-density suburban development and intensive agricultural development. Therefore, political as well as technical solutions are required. Science can help propose solutions to both kinds of problems.

Managing nonpoint source pollution must be approached in a holistic and comprehensive manner. In addition, priority management actions to reduce nonpoint source pollution must be made visible and understandable to a broad range of stakeholders and partners. **It is recommended that an effective educational campaign be developed and implemented to build public awareness and understanding that will be essential to resolve nonpoint source pollution issues.**

3.2.7 Human Health and Environmental Justice

Despite improvement in the quality of the Detroit River, exposure to contaminants and pathogens continues to affect human health, and communities of color are disproportionately exposed. There is an urgent need for the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws and policies – environmental justice. Presented below are four examples of human health issues based on available indicator data and a call for environmental justice for all.

Lead is a highly toxic metal that has significant adverse health effects. Children under age six are especially vulnerable to lead poisoning (Thompson and Meloche, this report: 7.30). Any amount greater than 5 µg/dL is considered an elevated blood lead level (EBLL) by the Center for Disease Control and Prevention (CDC). Lead was ubiquitously used for centuries, but today exposure to deteriorated lead-based paint is one of the leading causes of lead poisoning in Detroit children.

The proportion of tested Detroit children with elevated BLLs has declined substantially from a high incidence rate of 64.6% in 1998 to less than 10% in recent years (Thompson and Meloche, this report: 7.30). Provisional data for 2017 show that 1,632 Detroit children were found to have an EBLL, equivalent to 7.4% of the children tested. This demonstrates that lead hazards still pose a significant danger to Detroit children. **It is recommended that concerted efforts be made by health, government, and nonprofit and community development organizations to prevent and respond to lead poisoning in the City of Detroit, and that continued research and monitoring be performed to track this key indicator of children's health.**

West Nile virus is a mosquito-transmitted disease that was first discovered in Uganda in 1937 and is now found in all 48 contiguous states. Human illness due to West Nile virus was first documented in Michigan in 2002 and known to occur in southeast Michigan (Michigan Department of Health and Human Services, this report: 7.40).

The Michigan Department of Health and Human Services considers West Nile virus to be an emerging disease issue and devotes considerable resources to surveillance, management, and public education. No human vaccine against West Nile virus is currently available. **Therefore, it is recommended that effective practices be adopted, including using registered insect repellants, wearing long sleeves and pants from dusk through dawn, installing or repairing screens on windows and doors, reducing the number of mosquitoes around homes by emptying standing water, and sustaining adequate surveillance and monitoring.**

Air pollution respects no boundaries and impacts those who live adjacent to or downwind of the emitting sources. Southwest Detroit has long been recognized for poor air quality, particularly Detroit zip code 48217, which remains among the most polluted in the state (Williams, this report: 7.1). It has the highest asthma hospitalization rates in the State of Michigan. Despite a decrease in particulate air pollution in Southwest Detroit over the last 40 years, residents of southwest Detroit continue to be exposed to air pollution, particularly during dangerous spikes in short-term particle pollution.

In 2017, the University of Michigan's School of Public Health and Detroiters Working for Environmental Justice, a nonprofit in Detroit, Michigan, partnered on a study of human health impacts on residents in southwest Detroit resulting from exposure to air pollution (Martenies et al., 2017). Based on current air pollution levels, Martenies et al. (2017) showed that exposures to fine particulate matter (PM2.5), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) were responsible for more than 10,000 disability-adjusted life years (DALYs) per year, causing an annual monetized health impact of $6.5 billion.

Continuous and vigorous citizen oversight and advocacy are needed to ensure environmental justice for all (Williams, this report: 7.1). **It is recommended that environmental justice become a priority and demonstrated through:**

- **developing an environmental justice screening tool that assesses environmental burden and vulnerability based on human population characteristics and health conditions;**
- **assessing cumulative exposure to pollutants;**
- **committing resources to a long-term community air monitoring program;**
- **fully adopting the precautionary principle that states that when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm;**
- **fully adopting the Canada-U.S. Great Lakes Water Quality Agreement goals of zero discharge and virtual elimination of persistent toxic substances;**
- **implementing the Detroit Climate Action Plan and the Detroit Sustainability Action Agenda; and**
- **fully recognizing and adopting of the Principles of Environmental Justice as defined by the First National People of Color Environmental Leadership Summit convened in 1991.**

The Detroit River-Western Lake Erie Indicator Project was undertaken on the Traditional territory of Three Fires Confederacy of First Nations, comprised of the Ojibway, Odawa, and the Potawatomie, and of the Wyandot. Ecosystem health profoundly impacts the health of Indigenous people. It is also recognized that environmental justice for Indigenous peoples is not only about ecosystem and human health, but also about the legacy of colonization and racism in Canada and the United States (McGregor, 2010). **It is recommended that all future ecosystem health initiatives must be multinational, including First Nations.** Goals for the region must be the result of partnership with Indigenous nations and must be consistent with the laws and customs of the Three Fires Confederacy (the Ojibwe, Odawa, and Potawatomi Nations) and the Wyandot with whom the treaties in this region were signed (Berk, this report: 7.60).

3.2.8 Population Growth, Transportation Expansion, and Land Use Changes

The City of Detroit's population increased more than six-fold during the first half of the 20th century, due largely to a massive influx of eastern European and southern migrants coming to the area for the burgeoning automobile industry. However, by 2018, Detroit's population had decreased to slightly under 650,000 residents, one-third the population the city boasted at its peak in the 1950s (Knauss, this report: 7.3).

In 1900, the total population of southeast Michigan, a region including Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties, was nearly 600,000. More than a century later, in 2018, southeast Michigan's population was just over 4.7 million (SEMCOG, 2018). This region experienced steady population growth between 1900 and 1970, followed by relatively stable population level between 1970 and 2018.

The Southeast Michigan Council of Governments produces a new growth forecast once every five years. In their most recent forecast, it is estimated that by 2027, southeast Michigan's population will exceed its 2001 peak of 4.849 million, and by 2045, the population will reach 5.1 million (Knauss, this report: 7.3).

Historical population growth trends in the Windsor Census Metropolitan Area (including Windsor, LaSalle, Amherstburg, Tecumseh, and Lakeshore) show nearly two decades of population growth starting in 1987, followed by a decline or stagnation between 2006 and 2016, and then a substantial increase in population between 2016 and 2018 (Stark and Berk, this report: 7.4). Population forecasts conducted by the WindsorEssex Economic Development Corporation project slow growth rates through 2020-2023.

As people seek the "good life" further and further out from the urban core, land, energy, natural resources, and open space disappear. The land use pattern that results is costly to service and, over time, results in a loss of the very qualities sought by those who moved there. As the transportation system expands into previously undeveloped or minimally developed areas, valuable farmland is lost, water and air pollution can increase, wildlife habitat can be fragmented or lost to development, the amount of impervious surface can increase causing greater nonpoint source pollution, and biodiversity can be depleted. This also results in increased distance and travel time to places of employment. **It is recommended that southeast Michigan and southwest Ontario better utilize growth management techniques that systematically guide the type, rate, location, timing, public cost, and quality of land development to support growth, while preserving ecosystem health and quality of life.**

Future land use planning must balance the need for environmental protection, economic progress, and human development. **It is recommended that high priority be placed on developing and implementing model ordinances for sustainable land use practices and on undertaking research on sustainable, best management practices for urban areas.** Transportation, land use, environmental, and natural resource planning have traditionally been treated as separate initiatives and not effectively integrated (SEMCOG, this report: 7.5). Furthermore, plans, regulations, and enforcement are limited by hierarchical political boundaries, whereas stresses to the ecosystem follow watersheds and other natural boundaries. The ability of different communities, organizations, and agencies to collaborate on integrated planning and management strategies has been limited due to narrowly focused and uncoordinated legislation and regulations, governmental fragmentation, and relatively short planning and budgeting horizons.

Transportation and land use planning must become better integrated to accommodate sustainable environmental and natural resource conditions on a watershed scale. The goal should be to streamline and better coordinate the process of making land use and transportation planning decisions. All phases – from plan development to plan approval – should consider issues on a watershed basis.

Historically, transportation planning has been skewed by the promises of short-term economic gain espoused by land developers and highway department personnel who have a narrow perspective, as well as federal and state policies and funding that encourage the construction of infrastructure as a means of economic stimulus. In a major way, land use and transportation planning must become better integrated to accommodate sustainable environmental and natural resource conditions on a watershed scale.

There are no simple solutions to the problem of urban sprawl and its concomitant transportation needs. Alternatives to existing transportation modes and practices are needed, as well as better planning to design improved transportation systems (SEMCOG, this report: 7.9). For example, alternatives to automobiles include a balanced intermodal mix of walking/biking, public transit, aviation, and trucks/freight. Other important solutions will use technological advances, transportation demand management, transportation supply management, good land use planning, legislation, and education. Considerable progress has been made in greenway development in both the Detroit and Windsor metropolitan areas (Scott and Gell, this report: 7.57: Gell et al., this report: 7.45: Newton, this report: 7.52). In 2024, Windsor's 64 km of trails that are connected to the 1,600-km Great Lakes Waterfront Trail will be connected to southeast Michigan's 1,600 km of greenway trails through a dedicated bicycle and pedestrian lane on the Gordie Howe Bridge (Gell et al., this report: 7.45). Ultimately, progress in developing more balanced and environmentally-friendly transportation systems – particularly ones that offer better public transit options – will require political will, driven by public demand.

It is recommended that priority be given to implementing Windsor's and Essex County's Official Plans, Windsor's Environmental Master Plan, Windsor's Climate Change Adaptation Plan, Windsor's Community Energy Plan, Detroit's Master Plan, Detroit Future City Strategic Framework, Detroit's Sustainability Action Agenda, SEMCOG's Green Infrastructure Vision, SEMCOG's Regional Transportation Plan, the Detroit Climate Action Plan, and other related plans, and that there are linkages and adequate coordination to move forward in a complementary and reinforcing fashion toward a common sustainability vision. Further, it is recommended that a major educational campaign be implemented around population and the need and benefits of growth management and sustainable land use and transportation planning.

4.0 Concluding Thoughts and Summary of Recommendations

Although there has been considerable improvement in the Detroit River ecosystem and a surprising and heartening recovery of biota since the 1960s, much additional cleanup and restoration needs to be undertaken to restore the region's physical, chemical, and biological integrity as called for in the Canada-U.S. Great Lakes Water Quality Agreement. Western Lake Erie is now at risk of crossing several potential tipping points caused by the interactions of a variety of drivers and stresses.

Environmental and natural resource laws need to be protected and enforced, as they are the foundation of environmental protection efforts. Further, considerable voluntary, collaborative initiatives, that go beyond regulatory compliance, will be needed to meet long-term goals. Table 10 presents a summary of recommendations for each of the eight environmental and natural resource challenges identified in this report.

The Detroit River and western Lake Erie are microcosms of human use and abuse of the Great Lakes. They should be viewed as a "proving ground" for restoring ecosystem health and advancing adaptive, ecosystem-based management. This comprehensive and integrative assessment of ecosystem health, undertaken through the State of the Strait Conference, is a good example of a transnational network working across political boundaries on ecosystem-based management. Indeed, it is a model for cooperative efforts between two countries to strengthen science-policy-management linkages and promote remediation and restoration of aquatic ecosystems. Further investment in this transnational network is warranted to integrate monitoring, research, and modelling in assessment of ecosystem health as part of adaptive, ecosystem-based management.

Although the total number of indicators assessed and the percentage of indicators with quantitative targets has increased between the 2006-2007 and the 2018-2019 assessments, the percentage of achievement of quantitative targets has decreased slightly (Table 11). Continued priority must be placed on science-based, quantitative, target setting for ecosystem integrity. Long-term monitoring is essential in order to practice adaptive management that assesses state of the ecosystem, sets management priorities, and implements management actions in an iterative fashion for continuous improvement. Without a commitment to science-based quantitative target setting and long-term monitoring, management is flying blind.

Climate change is the most pressing environmental challenge of our time. Indeed, addressing any of the eight environmental and natural resource challenges identified in Table 10 is demanding, but mitigating them all at once and in the face of the climate change crisis is daunting. Climate change will make the scientific understanding of many of the other environmental and natural resource challenges more difficult and will make solving these challenges more complicated. Indeed, climate change has been called a "threat multiplier" where warmer, wetter, and wilder climatic conditions amplify other threats like harmful algal blooms, combined sewer overflow events, species changes, poor air quality effects on vulnerable residents, and more.

With increasing pressure placed on the Detroit River and western Lake Erie by growing human populations and increasing human activities, both scientists and resource managers need a better understanding of the relationships between cumulative stress from human activities and valued ecosystem services (Allan et al., 2013). Indeed, we will need a stronger scientific foundation that informs both policy makers and the broader society, strengthens ecosystem-based management, and creates a dynamism among the public, private, academic, foundation, and nongovernmental sectors to retreat from current potential tipping points and to avoid further environmental, societal, and economic harm.

Table 10. A summary of recommendations from this comprehensive and integrative assessment of ecosystem health.

Climate Change It is recommended that: • as a high priority, the City of Windsor's Climate Change Adaptation Plan and Community Energy Plan and the Detroit Sustainability Action Agenda and the Detroit Climate Action Plan be fully implemented; • a multinational climate change plan be developed for the Great Lakes Basin, consistent with what has been called for by the International Joint Commission's Great Lakes Water Quality Board (2017); • physicochemical and biological monitoring programs be sustained to support ecosystem-based management; and • researchers, decision-makers, climate change experts, and land managers are regularly brought together to understand and inform implementation of climate adaptation and mitigation actions.
Eutrophication and Algal Blooms It is recommended that: • a high priority be placed on completing a TMDL for western Lake Erie in a timely fashion and on ensuring sound and actionable science that is designed with stakeholders and decision-makers to better inform management programs; and • adequate funding be sustained for necessary monitoring, research, and modelling, with a priority on actionable science, and that this science be closely coupled with management programs to achieve long-term goals for the Maumee River and Lake Erie.
Toxic Substances Contamination It is recommended that: • a high priority be placed on preventing toxic substance problems consistent with the Canada-U.S. Great Lakes Water Quality Agreement goals of "zero discharge" and virtual elimination of persistent toxic substances; and • a high priority be placed on remediation of 5.1 million m^3 of contaminated sediment along the U.S. shoreline of the Detroit River and the shipping channel of the Rouge River through Great Lakes Legacy Act and Great Lakes Restoration Initiative partnerships with local partners.
Invasive Species It is recommended that: • preventing the introduction of NIS be the primary imperative for action by the governments of the United States and Canada, the eight Great Lakes states, and the provinces of Ontario and Quebec; • greater alignment of NIS regulations and management be achieved in the region; • governments ensure that NIS regulations apply to the domestic 'laker' fleet to reduce inter-lake dispersal of NIS, the efficacy of ballast treatment be verified through comprehensive sampling on the Great Lakes, region-wide regulations be enacted to alternative pathways of NIS, and species-specific methods of control and impact mitigation be developed; and • consistent, long-term monitoring programs be instituted to help detect and eradicate invasive species, if introduced, and assess impacts, should NIS become established.
Habitat Loss and Degradation It is recommended that: • continued priority be placed on establishing quantitative targets for habitat creation,

Table 10. A summary of recommendations from this comprehensive and integrative assessment of ecosystem health.

protection, and rehabilitation programs and projects; • every effort be made to ensure long-term monitoring is an essential component of all habitat projects and programs; • all habitat monitoring efforts be integrated with climate change programs and monitoring initiatives to better understand cause-and-effect relationships, measure progress toward quantitative targets, and practice adaptive management; • transboundary cooperative conservation efforts be strengthened by either: re-energizing the Priority Natural Area under Essex Region Conservation Authority, designating either Parks Canada, Bird Studies Canada, or Environment and Climate Change Canada as the lead federal agency to work with the U.S. Fish and Wildlife Service on the international wildlife refuge, establish a National Wildlife Area to work closely with the U.S. Fish and Wildlife Service on the international wildlife refuge, or work with local interests to establish Ojibway Urban National Park that could work closely with the U.S. Fish and Wildlife Service to bring conservation to cities; • the Great Lakes Legacy Act and Great Lakes Restoration Initiative in the U.S., and the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health and the Great Lakes Protection Initiative in Canada, ensure that long-term monitoring is viewed as an essential component of all habitat rehabilitation and enhancement projects; • based on the success of current citizen science monitoring in the watershed, a strong partnership between nongovernmental organizations and natural resource agencies is needed to better promote citizen science, integrate monitoring programs, ensure sound scientific methods so that data can be used for management, and create synergies for more effective ecosystem-based management; • the State of the Strait Conference consider hosting a future conference on new research applications in habitat rehabilitation and enhancement; and • strategic habitat planning be conducted that includes development of green wildlife and greenway corridors, opportunities for soft shoreline, and adequate public education.
Nonpoint Source Pollution It is recommended that: • a high priority be placed on more effective control of agricultural nonpoint source phosphorus loadings through applying combinations of practices like cover crops, buffer strips, wetlands, applying fertilizer below the soil surface on the lands with the highest phosphorus losses, and regenerative agriculture; • sufficient monitoring and research be undertaken to measure progress toward phosphorus target loads established in the Great Lakes Water Quality Agreement; • more opportunities be provided for cooperative learning among the many watersheds in the southeast Michigan and southwest Ontario region; • a high priority be placed on establishing quantitative targets for reducing nonpoint source pollutant loadings by watershed to meet long-term ecosystem goals; • a high priority be placed on Detroit River coastal wetland restoration to achieve a minimum of 25% of their historical area by 2030 (a net gain of 452 ha over the next 10 years); • ordinances be developed to protect beneficial land uses, best management practices be implemented to control reduce nonpoint source pollution, and conservation easements be used to permanently protect river corridors; • air pollution prevention and control, particularly in urban areas like Detroit and

Table 10. A summary of recommendations from this comprehensive and integrative assessment of ecosystem health.

Windsor, remain a high priority, including committing to long-term monitoring and assessment of human health impacts; and • an effective educational campaign be developed and implemented to build public awareness and understanding that will be essential to resolve nonpoint source pollution issues.
Human Health and Environmental Justice It is recommended that: • concerted efforts be made by health, government, and nonprofit and community development organizations to prevent and respond to lead poisoning in the City of Detroit, and that continued research and monitoring be performed to track this key indicator of children's health; • effective mitigation practices be adopted for West Nile Virus, including using registered insect repellants, wearing long sleeves and pants from dusk through dawn, installing or repairing screens on windows and doors (if people don't have air conditioning), reducing the number of mosquitoes around homes by emptying standing water, and sustaining adequate surveillance and monitoring; • environmental justice become a priority and demonstrated through developing an environmental justice screening tool that assesses environmental burden and vulnerability based on human population characteristics and health conditions, assessing cumulative exposure to pollutants, committing resources to a long-term community air monitoring program, fully adopting the precautionary principle that states that when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm, fully adopting the Canada-U.S. Great Lakes Water Quality Agreement goals of zero discharge and virtual elimination of persistent toxic substances, implementing the Detroit Climate Action Plan and the Detroit Sustainability Action Agenda, and fully recognizing and adopting of the Principles of Environmental Justice as defined by the First National People of Color Environmental Leadership Summit convened in 1991; and • all future ecosystem health initiatives must be multinational, including First Nations.
Population Growth, Transportation Expansion, and Land Use Changes It is recommended that: • southeast Michigan and southwest Ontario better utilize growth management techniques that systematically guide the type, rate, location, timing, public cost, and quality of land development to support growth, while preserving ecosystem health and quality of life; • a high priority be placed on developing and implementing model ordinances for sustainable land use practices and on undertaking research on sustainable, best management practices for urban areas; • priority be given to implementing Windsor's and Essex County's Official Plans, Windsor's Environmental Master Plan, Windsor's Climate Change Adaptation Plan, Windsor's Community Energy Plan, Detroit's Master Plan, the Detroit Future City Strategic Framework, Detroit's Sustainability Action Agenda, SEMCOG's Green Infrastructure Vision, SEMCOG's Regional Transportation Plan, the Detroit Climate Action Plan, and other related plans, and that there are linkages and adequate coordination to move forward in a complementary and reinforcing fashion toward a common sustainability vision; and

Table 10. A summary of recommendations from this comprehensive and integrative assessment of ecosystem health.

- a major educational campaign be implemented around population and the need and benefits of growth management and sustainable land use and transportation planning.

Table 11. A comparison of indicators between the 2006-2007 and 2018-2019 assessments of ecosystem health of the Detroit River and western Lake Erie.

Indicators	2006-2007 Assessment	2018-2019 Assessment
Total number of indicators	50	61
Pressure indicators	8	10
State indicators	37	32
Response indicators	5	19
Percentage of indicators with quantitative targets	34% (17 of 50)	57% (35 of 61)
Percentage of achievement of quantitative targets	29% (5 of 17)	26% (9 of 35)

Science-informed policy and management should have a clear understanding of root causes of problems. However, that will not always be possible. All decisions about water should be made based on the precautionary principle that states that when human activities may lead to unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm. Indeed, the 2012 Great Lakes Water Quality Agreement calls for strengthened measures to anticipate and prevent ecological harm (Canada and the United States, 2012).

The major accomplishment of the public outcry over water pollution of the Detroit River, Lake Erie, and other degraded ecosystems in the 1960s was clearly the enactment of many important environmental laws and a binational agreement, including:

- The Canada Water Act of 1970;
- The U.S. National Environmental Policy Act of 1970;
- The Canada-U.S. Great Lakes Water Quality Agreement of 1972;
- The U.S. Clean Water Act of 1972;
- The U.S. Endangered Species Act of 1973; and
- The U.S. Toxic Substances Control Act of 1976.

A major accomplishment of more recent decades has been the establishment of a plethora of environmental and conservation nongovernmental organizations like Citizens Environmental Alliance, Friends of the Rouge, Friends of the Detroit River, Detroit River Canadian Cleanup, Detroiters Working for Environmental Justice, Essex County Field Naturalists' Club, International Wildlife Refuge Alliance, Detroit Riverfront Conservancy, SEMI Wild, Belle Isle Conservancy, and more. These informed, engaged, and vocal nongovernmental organizations are building capacity for further cleanup and restoration and helping create a sense of place in this watershed that bodes well for the future. Continued investment in capacity building for these nongovernmental organizations is warranted.

Education is a key to the long-term change in the way people understand and value the places they call home and the ecosystems within which they live. Solutions to problems arise out of cooperative learning. Cooperative learning can be described as common learning among stakeholders to accomplish a common goal. Such cooperative learning is essential to address the current challenges facing southeast Michigan and southwest Ontario. Indeed, cooperative learning, reconnecting people to waterways via greenways and blueways, and place-making can all help lead to development of a stewardship ethic. For over two decades, the State of the Strait Conference has prioritized cooperative learning through public participation and student involvement, with no registration fees.

International events, economic changes, and the impacts of climate change will test the Great Lakes–St. Lawrence River basin over the next five decades (Kalafatisa et al., 2015). The region's ability to effectively meet these challenges will require foresight, investment, and cooperation. Kalafatisa et al. (2015) have shown that adequate investments are not currently being made in monitoring and evaluation and that the region's intellectual and environmental capital isn't being leveraged, limiting the region's ability to address its economic and environmental challenges and compete with the rest of the world. The State of the Strait Conference has more than a 20-year history of cooperative efforts between two countries to strengthen science-policy-management linkages in support of restoring and sustaining ecosystem health. Governmental, business, and foundation sector investments in the State of the Strait Conference will be needed to sustain this important work.

As was noted at the Rio de Janeiro Earth Summit, humanity stands at a defining moment in history (United Nations, 1992). One choice in life is to follow a path toward stewardship of our natural resources and sustainable development (Global Environment Facility, 2002). Another choice is to continue to deplete natural capital, degrade environments, and impose limitations on the choices available to our children and grandchildren. As the Global Environment Facility (2002) has stated, the legacy is ours to shape.

5.0 Literature Cited

Allan, J.D., McIntyre, P.B., Smith, S.D.P., Halpern, B.S., Boyer, G.L., Buchsbaum, A., Burton, G.A., Campbell, L.M., Chadderton, W.L., Ciborowski, J.J.H., Doran, P.J., Eder, T., Infante, D.M., Johnson, L.B., Joseph, C.A., Marino, A.L., Prusevich, A., Read, J.G., Rose, J.B., Rutherford, E.S., Sowa, S.P., Steinman, A.D., 2013. Joint analysis of stressors and ecosystem services to enhance restoration effectiveness. Proceedings of the National Academy of Sciences of the United States of America. 110, 1, 372-377.

Becker, M., Browny, M., Kuo, M., S. Van Den Eeden, S., 2019. Is green land cover associated with less health care spending? Promising findings from county-level Medicare spending in the continental United States. Urban Forestry & Urban Greening. 41.10.1016/j.ufug. 2019.02.012.

Bolsenga, S.J., Herdendorf, C.E., 1993. *Lake Erie and Lake St. Clair Handbook*. Wayne State University Press, Detroit.

Canada and the United States, 2012. Great Lakes Water Quality Agreement. Ottawa, Ontario, Canada and Washington, D.C., USA.

Caulk, A.D., Gannon, J.E., Shaw, J.R., Hartig, J.H., 2000. Best management practices for soft engineering of shorelines. Greater Detroit American Heritage River Initiative, Detroit, Michigan, USA.

City of Windsor, 2012. Climate Change Adaptation Plan. Windsor, Ontario, Canada.

City of Windsor, 2017. Community Energy Plan. Windsor, Ontario, Canada.

Davis, T.W., Stumpf, R., Bullerjahn, G.S., McKay, R.M.L., Chaffin, J.D., Bridgeman, T.B., Winslow, C., 2019. Science meets policy: a framework for determining impairment designation criteria for large waterbodies affected by cyanobacterial harmful algal blooms. Harmful algae, 81, 59-64.

Edsall, T.A., Gannon, J.E., 1998. Lake St. Clair Profile. U.S. Geological Survey, Great Lakes Science Center, Ann Arbor, Michigan, USA.

Eedy, R., J. Hartig, C. Bristol, M. Coulter, T. Mabee, and J. Ciborowski (Eds.). 2005. State of the Strait: Monitoring for Sound Management. Great Lakes Institute for Environmental Research, Occasional Publication No. 4. University of Windsor, Ontario, Canada.

Environment and Climate Change Canada and U.S. Environmental Protection Agency, 2019. Lake Erie Binational Phosphorus Reduction Strategy. Prepared by the Great Lakes Water Quality Agreement Nutrients Annex Subcommittee. Toronto, Ontario, Canada and Chicago, Illinois, USA.

Francoeur, S., Cargnelli, L., Cook, A., Hartig, J., Gannon, J., Norwood, G., (Eds.). 2012. State of the Strait: Use of Remote Sensing and GIS to Better Manage the Huron-Erie Corridor. Great Lakes Institute for Environmental Research, Occasional Publication No. 7, University of Windsor, Ontario, Canada.

Francoeur, S., Ciborowski, J., Gannon, J., Kashian, D., Kahl, K., (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.

Francoeur, S., Ciborowski, J., Ives, J., Kashian, D., Gannon, J., 2018. Urban Bird Summit: Status, Trends, and Risks to Species that Call the Corridor Home. Great Lakes Institute for Environmental Research, Occasional Publication No. 10, University of Windsor, Ontario, Canada.

Global Environment Facility, 2002. The Sustainability Challenge: An Action Agenda for the Global Environment. Washington, D.C.

Green, E.L., Grgicak-Mannion, A., Ciborowski, J.J.H., Corkum, L.D., 2013. Spatial and temporal variation in the distribution of burrowing mayfly nymphs (Ephemeroptera: *Hexagenia limbata* and *H. rigida*) in western Lake Erie. Journal of Great Lakes Research 39:280-286.

Hartig, J.H., 2014. *Bringing Conservation to Cities: Lessons Learned from Building the Detroit River International Refuge*. Ecovision World Monographs Series, Aquatic Ecosystem Health and Management Society, Burlington, Ontario, Canada.

Hartig, J.H., 2019a. Waterfront Porch: Reclaiming Detroit's Industrial Waterfront as a Gathering Place for All. Michigan State University Press, East Lansing, Michigan.

Hartig, J.H., 2019b. From Cleanup of the Detroit River to Revitalization of the Waterfront, in: Hartig, J.H., Krantzberg, G., Austin, J.C., McIntyre, P., (Eds.). Great Lakes Revival: How Restoring Polluted Waters Leads to Rebirth of Great Lakes Communities. International Association for Great Lakes Research, Ann Arbor, Michigan, pp. 27-32.

Hartig, J.H., 2020. River otter return to western Lake Erie – Could Detroit River be next? Great Lake Now, Detroit Public Television, Detroit, Michigan, USA.

Hartig, J.H., Kerr, J.K., Breederland, M., 2001. Promoting soft engineering along Detroit River shorelines. Land and Water-The Magazine of Natural Resource Management and Restoration. 45, 6, 24-27.

Hartig, J.H., Stafford, T., 2003. The public outcry over oil pollution of the Detroit River, in: Hartig, J.H. (Ed.), *Honoring Our Detroit River: Caring for Our Home*, Cranbrook Institute of Science, Bloomfield Hills, pp. 69-78.

Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., Vincent, A., 2007. State of the Strait: Status and Trends of Key Indicators. Great Lake Institute for Environmental Research, Occasional Publication No. 5, University of Windsor, Ontario, Canada.

Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., Vincent, A., 2009. Long-term ecosystem monitoring and assessment of the Detroit River and Western Lake Erie. Environmental Monitoring and Assessment. 158. 87-104.

Hartig, J.H., Zarull, M.A., Corkum, L.D., Green, N., Ellison, R., Cook, A., Norwood, G., Green, E., (Eds.). 2010. State of the Strait: Ecological Benefits of Habitat Modification. Great Lakes Institute for Environmental Research, Occasional Publication No. 6, University of Windsor, Windsor, Ontario, Canada.

Hartig, J.H., Zarull, M.A., Corkum, L.D., Green, N., Ellison, R., Cook, A., Green, E., Norwood. G., 2014. Habitat management lessons learned from the environs of the Detroit River International Wildlife Refuge. Journal of Great Lakes Research. 40, Supplement 2, 31-36.

Hartig, J.H., Bennion, D., 2017. Historical loss and current rehabilitation of shoreline habitat along an urban-industrial river – Detroit River, Michigan, USA. Sustainability 9, 5, 828-848.

Hartig, J.H., Francoeur, S.F., Ciborowski, J.J.H., Gannon, J.E., Sanders, C., Galvao-Ferreira, P., Knauss, C.R., Gell, G., Berk, K., 2020. Checkup: Assessing Ecosystem Health of the Detroit River and Western Lake Erie. Great Lakes Institute for Environmental Research Occasional Publication No. 11, University of Windsor, Ontario, Canada.

Intergovernmental Panel on Climate Change, 2018. Global Warming of 1.5ºC. World Meteorological Organization, Geneva, Switzerland.

International Joint Commission's Great Lakes Water Quality Board (Emerging Issues Work Group), 2017. Climate change and adaptation in the Great Lakes. Windsor, Ontario, Canada.

Kalafatisa, S.E., Campbell, M., Fathers, F., Laurent, K.L., Friedman, K.B., Krantzberg, G., Scavia, D., Creed, I.F., 2015. Out of control: How we failed to adapt and suffered the consequences. Journal of Great Lakes Research. 41, Supplement 1, 20-29.

Krieger, K.A., Schloesser, D.W., Manny, B.A., Trisler, C.E., Heady, S.E., Ciborowski, J.H., Muth, K.N., 1996. Recovery of burrowing mayflies (Ephemeroptera: Ephemeridae: *Hexagenia*) in western Lake Erie. Journal of Great Lakes Research. 22, 254-263.

Krieger, K.A., Bur, M.T., Ciborowski, J.J.H., Barton, D.R., Schloesser, D.W., 2007. Distribution and abundance of burrowing mayflies (*Hexagenia* spp.) in Lake Erie, 1997–2005. Journal of Great Lakes Research. 33, (Supplement 1), 20-33.

Kuo, M., 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. Frontiers in Psychology. 6.1093.1033389/fpyg.2015.0i093.

Kuo, M., Browny, M., Sachdeva, S., Kangjae, L., Westphal, L., 2018. Might school performance grow on trees? Examining the link between "greenness" and academic achievement in urban, high-poverty schools. Frontiers in Psychology 9.10.3389/fpsyg.2018.01669.

Louv, R., 2005. Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Algonquin: Chapel Hill.

Louv, R., 2016. Vitamin N: The Essential Guide to a Nature-Rich Life. Algonquin: Chapel Hill.

Martenies, S.E., Milando, C.W., Williams, G.O., and Stuart A. Batterman, S.A., 2017. Disease and Health Inequalities Attributable to Air Pollutant Exposure in Detroit, Michigan. Int. J. Environ. Res. Public Health 2017, 14, 1243-1266.

Marvin, C., 2007. Contaminants in western Lake Erie sediments, In: Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., Vincent, A., State of the Strait: Status and Trends of Key Indicators. Great Lakes Institute for Environmental Research, Occasional Publication No. 5, University of Windsor, Ontario, Canada, pp. 121-125.

McGregor, D., 2010. Honouring Our Relations: An Anishinaabe Perspective on Environmental Justice. UBC Press, Vancouver, B.C.

Michalak, A. M., Anderson, E. J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloglu, I., DePinto, J.V., Evans, M.A., Fahnenstiel, G.L., He, L., Ho, J.C., Jenkins, L., Johengen, T.H., Kuo, K.C., Laporte, E., Liu, X., McWilliams, M.R., Moore, M.R., Posselt, D.J., Richards, R.P., Scavia, D., Steiner, A.L., Verhamme, E., Wright, D.M., Zagorski, M.A., 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. Proceedings of the National Academy of Sciences of the United States of America, 110, 6448–6452.

Ohio Lake Erie Commission and the State of Ohio, 2020. Ohio's domestic action plan 2020 to address nutrients. Columbus, Ohio, USA.

Pearsall, D., Carton de Grammont, P., Cavalieri, C., Chu, C., Doran, P., Elbing, L., Ewert, D., Hall, K., Herbert, M., Khoury, M., Kraus, D., Mysorekar, S., Paskus, J., Sasson, A., 2012. Returning to a Healthy Lake: Lake Erie Biodiversity Conservation Strategy. Technical Report. A joint publication of The Nature Conservancy, Nature Conservancy of Canada, and Michigan Natural Features Inventory. Lansing, Michigan, USA.

Pryor, S. C., Scavia, D., Downer, C., Gaden, M., Iverson, L., Nordstrom, R., Patz, J., Robertson, G.P., 2014. Midwest, in: Melillo, J.M., Richmond, T.C., Yohe, G.W., (Eds.), Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, pp. 418-440.

Read, J., Murray, P., Hartig, J.H., (Eds.). 2001. State of the Strait: Status and trends of the Detroit River Ecosystem. Great Lakes Institute for Environmental Research, Occasional Publication No. 3, University of Windsor, Windsor, Ontario, Canada.

Ridgway, J., Cave, K., DeMaria, A., O'Meara, J., Hartig, J.H., 2018. The Rouge River Area of Concern - A Multi-Year, Multi-Level Successful Approach to Restoration of Impaired Beneficial Uses. Aquatic Ecosystem Health & Management, 21, 4, 398-408.

Schloesser, D.W., Kreiger, K.A., 2007. Abundance of burrowing mayflies, In: Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., Vincent, A., State of the Strait: Status and Trends of Key Indicators. Great Lakes Institute for Environmental Research, Occasional Publication No. 5, University of Windsor, Ontario, Canada, pp. 189-192.

Smith, R.B., Bass, B., Sawyer, D., Depew, D., Watson, S.B., 2019. Estimating the economic costs of algal blooms in the Canadian Lake Erie Basin. Harmful Algae. 87. doi.org/10.1016/j.hal.2019.101624

Southeast Michigan Council of Governments (SEMCOG), 2018. Population and Household Estimates for Southeast Michigan. Detroit, Michigan, USA.

Tulen, L.A., Hartig, J.H., Dolan, D.M., Ciborowski, J.J.H., (Eds.). 1998. Rehabilitating and conserving Detroit River habitats. Great Lakes Institute for Environmental Research Occasional Publication No. 1. Windsor, Ontario, Canada.

United Nations. 1992. Sustainable Development – Agenda 21. Rio de Janerio, Brazil.

Wright, S., Tidd, W.M., 1933. Summary of limnological investigations in western Lake Erie in 1929 and 1930. Transactions of the American Fisheries Society. 63, 271-285.

Zhang, L., Zhao, Y., Hein, D., Janes, T. Tucker, S., Ciborowski, J.J.H., 2020. Climate change projections of temperature and precipitation for the Great Lakes basin using the PRECIS regional climate model. Journal of Great Lakes Research 46, 255-266.

This page intentionally left blank.

6.0 Appendix A - State of the Strait Conference Program – November 19, 2019

University of Windsor, Vanier Hall

8:00-8:30 AM	Registration
8:30-8:45 AM	University of Windsor Welcome by Dr. Michael Siu, Vice President of Research and Innovation; First Nation Welcome by Russell Nahdee, Turtle Island of the Walpole Island First Nation; and Remarks by Consul Daniel Tremblay of the Consulate General of Canada
8:45-8:50 AM	Remarks by University of Windsor President Robert Gordon
8:50-9:05 AM	Opening Remarks by Ontario Lieutenant Governor Elizabeth Dowdeswell
9:05-10:20 AM	Eutrophication and Algal Blooms Session – Overview talk by Steve Francoeur of Eastern Michigan University, followed by a panel discussion (Mike McKay and Catherine Febria, Great Lakes Institute for Environmental Research, University of Windsor; Majid Khan, Great Lakes Water Authority; Laura Johnson, Heidelberg University; Katie Stammler, Essex Region Conservation Authority) on key findings and next steps relative to research, monitoring, and management
10:20-10:40 AM	Coffee Break
10:40-11:55 AM	Climate Change Session – Overview talk by Claire Sanders of Essex Region Conservation Authority, followed by a panel discussion (Karina Richters, City of Windsor's Supervisor of Environmental Sustainability and Climate Change; Joel Howrani Heeres, Director of Detroit's Office of Sustainability; Nick Schroeck, University of Detroit-Mercy Law School; Patrícia Galvão Ferreira, University of Windsor's Faculty of Law) on key findings and next steps relative to research, monitoring, and management
11:55-1:15 PM	Lunch and Networking
1:15-2:30 PM	Biological Health Session – Overview talk by Jan Ciborowski of University of Calgary, followed by a panel discussion (Tammy Dobbie, Point Pelee National Park; Ed Roseman, U.S. Geological Survey; Ken Drouillard and Hugh MacIsaac, Great Lakes Institute for Environmental Research; Donna Kashian, Wayne State University) on key findings and next steps relative to research, monitoring, and management
2:30-2:50 PM	Coffee Break

2:50-4:05 PM	2:50-4:05 PM – Habitat Session – Overview talk by John Gannon, Scientist Emeritus with the International Joint Commission, followed by a panel discussion (Jacqueline Serran, Detroit River Canadian Cleanup; Annette DeMaria, Alliance of Rouge Communities; Doug Pearsall, The Nature Conservancy; Bob Burns, Friends of the Detroit River) on key findings and next steps relative to research, monitoring, and management
4:05-4:35 PM	Blue Accounting: Are we making progress towards ecological goals and a Blue Economy? – Doug Pearsall, The Nature Conservancy
4:35-5:00 PM	Concluding Remarks – John Hartig, Great Lakes Institute for Environmental Research
5:00-6:30 PM	**Reception** – Courtesy of University of Windsor's Vice President of Research and Innovation

7.0 Appendix B – 61 Indicator Reports Organized by the Pressure-State-Response Model

This page intentionally left blank.

7.1 Air Pollution and Environmental Justice in Southwest Detroit, Michigan

Guy O. Williams, President and CEO, Detroiters Working for Environmental Justice, guy@detroitenvironmentaljustice.org

Background

Air pollution respects no boundaries and impacts those who live adjacent to or downwind of the emitting sources. Since the industrial revolution, socially constructed laws and systems created urban environments where the most vulnerable in our society, those of low income and disenfranchised minorities, bear the costs of air pollution in our modern society. Detroit is no exception.

In Detroit, air pollution is a by-product of a city forged by the industrial revolution and the creation of the automobile. The concentration of manufacturing, refining, traffic, and waste management within the city limits contributes to contaminated air.

Air pollution has been linked to health impacts such as cancer, asthma, difficulty breathing, and more. It typically impacts the most vulnerable in our society, children and elderly. However, while it is common knowledge that air pollution is bad for human and environmental health, it has been difficult to draw a meaningful connection between air pollutant emitters and health outcomes due to the multiple types of exposure communities often face. For example, a neighborhood might be adjacent to both a manufacturing plant and a highway that are both contaminating the air. The residents in the surrounding neighborhood have developed asthma. It is difficult to parse out the responsibility for poor air quality. Is it the manufacturing plant? Or the highway? Or both? Often, these heavily polluted areas are communities of color.

Southwest Detroit has long been recognized for poor air quality, particularly Detroit zip code 48217, which remains among the most polluted in the state. It has the highest asthma hospitalization rates in the State of Michigan. More than two dozen major industrial facilities surround the neighborhoods in 48217. This community is 82% Black and has a median household income of $24,000, which is 35% lower than the state of Michigan's average. Roughly 44% of the people in 48217 live below the poverty line, according to the latest U.S. Census data, compared to 14% for the state of Michigan.

This indicator report presents a summary of selected air quality trends and issues in Southwest Detroit, which borders the Detroit River, highlights of next steps, and what Detroiters Working for Environmental Justice (DWEJ), a nonprofit in Detroit, Michigan, is doing to promote environmental justice for all.

Detroiters Working for Environmental Justice (DWEJ)

Communities of color are disproportionately exposed to polluted air, water, and soil. Many of these communities of color that encounter toxic work conditions, environmental hazards, or polluted neighborhoods are also poor. Environmental justice shines a spotlight on the role that race and economics play in pollution.

DWEJ is a voice for cleaner, safer, healthier neighborhoods. It is dedicated to providing all Detroit residents with the tools they need to address environmental concerns in their own neighborhoods. DWEJ isn't seeking to simply redistribute environmental harms, but to abolish them.

Established in 1994, DWEJ has grown from a grassroots volunteer organization to a major voice recognized locally, statewide, and nationally for its innovative programs and projects that create sustainable, livable communities. As the first environmental justice organization in Michigan, its work is woven into the fabric of every Detroit neighborhood.

Examples of DWEJ activities and leadership include:

- In 2017, after many years of working with representatives from nonprofit, educational, business, and governmental organizations, as well as people in all our neighborhoods, DWEJ wrote and published the city's first climate action plan.
- After years of advocacy by DWEJ and others, an Office of Sustainability was established within Detroit City government in 2017.
- DWEJ provided key leadership for, and participated in, the development of the Detroit Sustainability Action Agenda in 2019.
- To help demonstrate action, DWEJ has established Future Build Construction Group to help break the cycle of poverty by giving Detroit residents the skills to work in living-wage jobs with a focus on repairing and protecting the environment.
- For decades DWEJ has been promoting environmental justice through education, building relationships, and shaping policy.

Status and Trends

Air Pollution

Southwest Detroit has a long history of air pollution stemming from industry and transportation. According to the U.S. Environmental Protection Agency (2017), particulate matter is a complex mixture of extremely small particles and liquid droplets and particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. These small particles can accumulate in the lungs and impact heart and lung health. Exposure to particulate matter can trigger asthma attacks, result in abnormal births, impact lung function, result in negative heart health, cause cancer, and result in death. Children, teenagers, and the elderly are particularly vulnerable to high particulate matter exposure. Atmospheric particulate matter has been monitored in Southwest Detroit for over 40 years.

Figure 1 presents a more than a 40-year time series for particulate matter at the old Detroit Southwestern High School on West Fort Street. In 1971, the U.S. Environmental Protection Agency promulgated an annual and 24-hour particulate standard based on total suspended particulates (TSP). In 1987, the U.S. Environmental Protection Agency changed the standard to PM10. Health studies indicated that particles smaller than 10 microns affect respiration. In 1997, the U.S. Environmental Protection Agency added an additional National Ambient Air Quality Standard for a smaller particle fraction size, PM2.5, which can get deeper into the lungs and possibly into the blood stream. In 2006, the U.S. Environmental Protection Agency revoked the PM10 annual standard but kept the PM10 24-hour standard. The PM2.5, 24-hour standard was also reduced from 65 $\mu g/m^3$ to 35 $\mu g/m^3$. In 2012, the U.S. Environmental Protection Agency reduced the annual

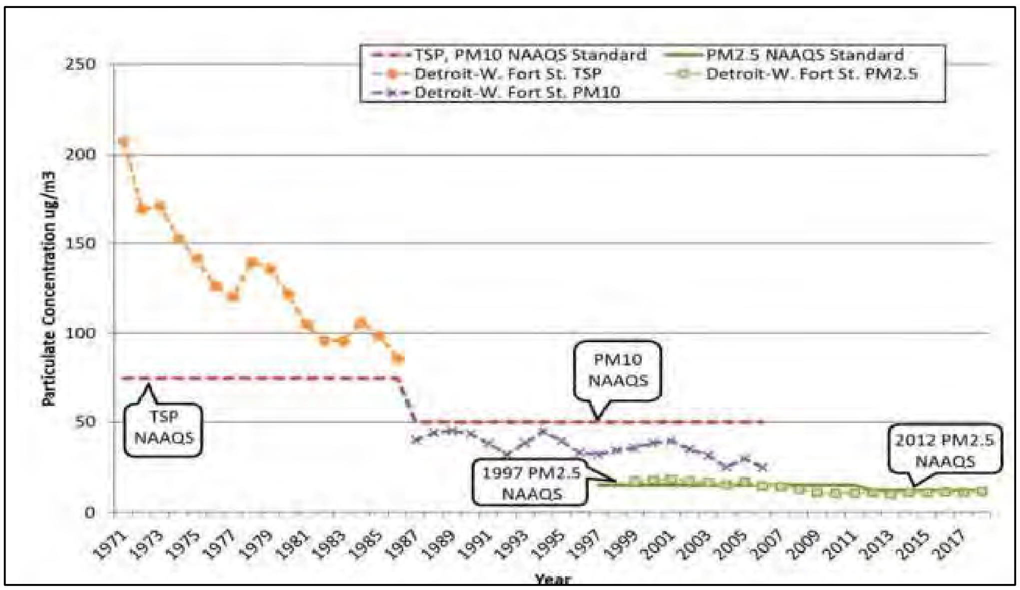


Figure 1. Particulate matter in air samples collected from the West Fort Street Station (near former Southwestern High School) in Detroit, 1971-2018 (Michigan Department of Environment, Great Lakes, and Energy, 2018).

standard from 15 $\mu g/m^3$ to 12 $\mu g/m^3$. In general, there has been a decrease in particulate air pollution over this time period; however, this Southwest Detroit monitoring station continues to have nonattainment issues for PM2.5 at certain times of the year.

The American Lung Association (2019) reported that despite improvements in air quality, the Metropolitan Detroit Region (i.e., Detroit-Warren-Ann Arbor) is still ranked the 12th most polluted city in the United States based on year-round particle pollution. The region also experienced more days with dangerous spikes in short-term particle pollution. Particulate air pollution is undoubtedly worse in Southwest Detroit.

Sulfur dioxide, or SO_2, is a colorless gas with a strong odor, similar to a just-struck match. It is formed when fuel containing sulfur, such as coal and oil, is burned, creating air pollution. SO_2 can harm the human respiratory system and make breathing difficult. People with asthma, particularly children, are extremely sensitive to these effects of SO_2.

Air quality monitoring for SO_2 has been performed at the West Fort Street Station for 45 years. Figure 2 shows the SO_2 trend for both the old annual standard (National Ambient Air Quality Standard) and the new 1-hour standard for West Fort Street in Detroit. In 2010, when the U.S. Environmental Protection Agency changed the standard from an annual average to a 1-hour standard, a portion of Wayne County (the county within which Detroit resides) was designated nonattainment. The trend data in Figure 2 show that air samples at the West Fort Street Station were not in compliance in 2010-2012, but were in compliance from 2013-2018.

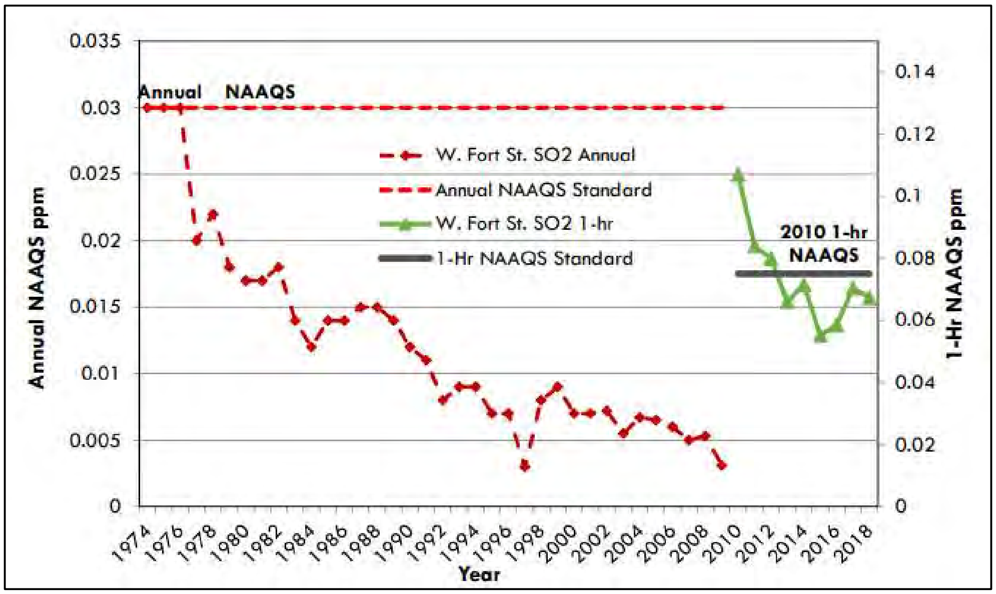


Figure 2. Historical annual and 1-hour SO_2 averages at West Fort Street Station (near former Southwestern High School) in Detroit, 1974-2018 (Michigan Department of Environment, Great Lakes, and Energy, 2018).

Ozone in the air we breathe can harm our health. People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers. In addition, people with certain genetic characteristics, and people with reduced intake of certain nutrients, such as vitamins C and E, are at greater risk from ozone exposure.

Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and airway inflammation. It also can reduce lung function and harm lung tissue. Ozone can worsen bronchitis, emphysema, and asthma, leading to increased medical care.

Long-term trend data for ozone were not available, but 48217 is known to be in noncompliance during certain times of the year.

Both SO_2 and ozone are associated with asthma and other respiratory and cardiac diseases, which are huge concerns in 48217. Indeed, residents suffer from high rates of asthma and other respiratory illnesses. American Lung Association (2019) reported that during 2015-2017, Wayne County had 18 high ozone days where the Air Quality Index values were 101-150, reflecting unhealthy conditions for sensitive groups. As a result, American Lung Association (2019) recommended that children, active adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.

A 2010 risk assessment of air toxics found nine pollutants and diesel particulates in the Detroit area exceeding the state's health-based cancer risk of one in one million (Department of Natural Resources and Environment, 2010a). Cancer risk reached as high as 10-100 in one million for benzene and formaldehyde during 2006 and 2007. Monitoring performed at a new community air monitoring station in 48217 confirmed exceedances of sulfur dioxide and also found naphthalene, arsenic and hexavalent chromium at levels of concern for cancer risk, though lower than previously measured in the 2000s (Michigan Department of Environmental Quality, 2018).

The above trend data, however, do not give the full picture. Federal and state regulations fail communities of color like 48217 because they weren't designed to account for multiple pollutant exposures. Simply put, the pollutant-by-pollutant regulatory approach does not adequately address the unique issues of having a cluster of major sources of pollution in a highly concentrated area like 48217. Neither the U.S. Environmental Protection Agency nor Michigan's Department of Environment, Great Lakes, and Energy require cumulative assessment of exposures. DWEJ has long advocated for this approach.

Human Health Impacts from Air Pollution in Detroit

In 2017, the University of Michigan's School of Public Health and Detroiters Working for Environmental Justice partnered on a study of human health impacts on residents in Southwest Detroit resulting from exposure to air pollution (Martenies et al., 2017). This study examined the diseases and health disparities attributable to air pollutants for the Detroit urban area.

Based on current levels, Martenies et al., (2017) showed that exposures to fine particulate matter (PM2.5), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) are responsible for more than 10,000 disability-adjusted life years (DALYs) per year, causing an annual monetized health impact of $6.5 billion. This burden is mainly driven by PM2.5 and O_3 exposures, which cause 660 premature deaths each year among the 945,000 individuals in the study area. NO_2 exposures, largely from traffic, are important for respiratory outcomes among older adults and children with asthma, e.g., 46% of air-pollution related asthma hospitalizations are due to NO_2 exposures. Based on quantitative inequality metrics, the greatest inequality of health burdens results from industrial and traffic emissions. These metrics also show disproportionate burdens among Hispanic/Latino populations due to industrial emissions, and among low income populations due to traffic emissions. Attributable health burdens are a function of exposures, susceptibility and vulnerability (e.g., baseline incidence rates), and population density.

Management Next Steps

Clearly, continuous and vigorous citizen oversight and advocacy are needed to ensure environmental justice for all. Key next steps include:

- Development of an environmental justice screening tool that assesses environmental burden and vulnerability based on human population characteristics and health conditions;
- Assessment of cumulative exposure to pollutants;
- Commitment to a long-term community air monitoring program;
- Full adoption of the precautionary principle that states that when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm;
- Full adoption of the Canada-U.S. Great Lakes Water Quality Agreement goals of zero discharge and virtual elimination of persistent toxic substances;
- Implementation of the Detroit Climate Action Plan;
- Implementation of the Detroit Sustainability Action Agenda; and
- Full recognition and adoption of the Principles of Environmental Justice as defined by the First National People of Color Environmental Leadership Summit convened in Washington, D.C. in 1991.

References

American Lung Association, 2019. State of the Air. Chicago, Illinois, USA.

City of Detroit, 2019. Detroit Sustainability Action Agenda. Detroit, Michigan, USA.

Department of Natural Resources and Environment, 2010. Detroit Air Toxics Initiative: Risk Assessment Update. Lansing, Michigan, USA.

Department of Natural Resources and Environment, 2018. 48217 community air monitoring project, September 2016-September 2017. Lansing, Michigan, USA.

Detroiters Working for Environmental Justice, 2017. Detroit Climate Action Plan. Detroit, Michigan, USA.

Martenies, S.E., Milando, C.W., Williams, G.O., and Stuart A. Batterman, S.A., 2017. Disease and Health Inequalities Attributable to Air Pollutant Exposure in Detroit, Michigan. Int. J. Environ. Res. Public Health 2017, 14, 1243-1266.

Michigan Department of Environment, Great Lakes, and Energy, 2018. Air Quality Annual Report. Lansing, Michigan, USA.

U.S. Environmental Protection Agency, 2017. What Is Particulate Matter? https://www3.epa.gov/region1/eco/uep/particulatematter.html (accessed 7 February 2020).

7.2 Detroit River Phosphorus Loads to Lake Erie

Donald Scavia, School for Environment and Sustainability, University of Michigan, scavia@umich.edu

Colleen M. Long, Water Center, University of Michigan

Lynn Vaccaro, Water Center, University of Michigan

Background

Among the Laurentian Great Lakes, Lake Erie is the warmest, shallowest, and most productive, contributing to its sensitivity to phosphorus loading. In the 1960s and 1970s, increasing phosphorus inputs led to severe algal blooms in the lake's western basin and periods of low oxygen (hypoxia) in the bottom waters of its central basin. Phosphorus abatement programs, initiated as part of the 1972 Great Lakes Water Quality Agreement (GLWQA), prompted wastewater treatment facilities to add secondary treatment, phosphorus was removed from most soaps and detergents, and soil conservation programs were enhanced. These changes reduced the amount of phosphorus released into the lake and led to clear improvements in water quality and fisheries. However, in the mid-1990s, water quality degraded as western basin harmful algal blooms and central basin hypoxia returned with conditions similar to the 1960s and 1970s, impacting fishing, swimming, tourism, and drinking water systems. Results from monitoring programs, lake models, and experimental studies showed that the increasing spring load of dissolved reactive phosphorus from the Maumee River watershed was the primary driver of the western basin algal blooms, and that the annual load of total phosphorus (TP) to the western and central basins was the primary driver of hypoxia.

In 2012, the United States and Canada signed a revised GLWQA that required new Lake Erie phosphorus loading targets and associated action plans. In response to this commitment, they adopted a target to reduce the annual load to the western and central basin by 40%. The Detroit River is a major contribution to that load.

The Detroit River

The Detroit River provides approximately 80% of the flow that enters Lake Erie. Nutrient concentrations in the Detroit River are relatively low compared to the Maumee River, the other primary source of phosphorus, but discharge is much greater. As such, it delivers a large annual TP load that contributes significantly to central basin algae production and sedimentation and, ultimately, to hypoxia extent. But because phosphorus concentrations are low, the flow tends to dilute nutrients in the western basin, and as a result it is not a significant driver of the western basin algal blooms, which are driven primarily by the Maumee River's spring load. The mixing zone between the Detroit River and western basin water is visible in satellite images where algae and sediment concentrations closer to the mouth of the Detroit River are lower (Figure 1), and the water tends to move quickly into the central basin.

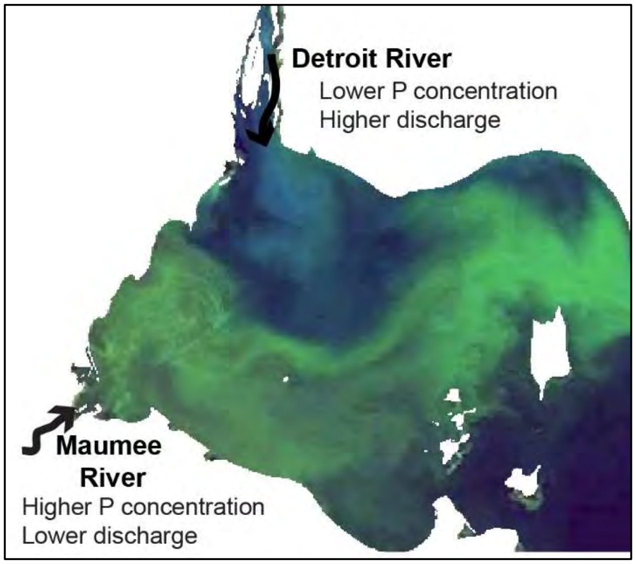


Figure 1. Image of the Western Lake Erie Basin in September 2015. The algal bloom originating from the mouth of the Maumee River is diluted and pushed away by the high volume of water with low phosphorus concentration entering from the Detroit River.

The watershed that feeds the Detroit River covers 19,000 km^2 between lakes Huron and Erie, with a large urban area in Michigan and extensive agriculture in Ontario (Figure 2). The Detroit River thus carries water and nutrients not only from its own direct watershed, but also from the Lake St. Clair and St. Clair River watersheds and Lake Huron. It is difficult to monitor what the Detroit River delivers to Lake Erie because the river is large and not well mixed, requiring extensive sampling across the river and over time. In addition, Lake Erie seiches occasionally cause flows to back up into the river, confounding estimates of river discharge.

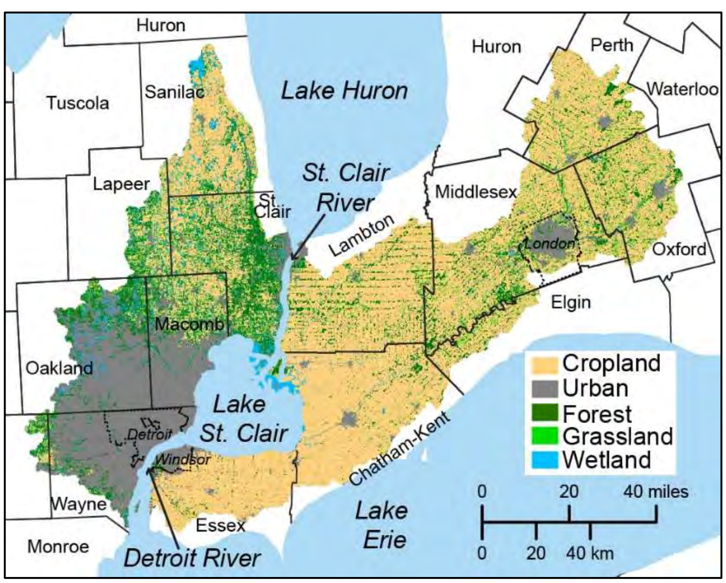


Figure 2. Land use (USDA-NASS, 2015; AAFC, 2015) in the St. Clair-Detroit river system watershed, all of which feeds the Detroit River.

The role of Lake St. Clair on Detroit River loads - To understand relative contributions of different subwatersheds and sources of phosphorus to the Detroit River's load to Lake Erie, it is necessary to consider the effect of Lake St. Clair on processing water and nutrients. On average between 2001 and 2015, Lake St. Clair retained 20% of its TP inputs annually (Scavia et al., 2019a), albeit with substantial inter-annual variability (Figure 3). Phosphorus sources upstream of Lake St. Clair thus contribute less to Lake Erie than they deliver to the St. Clair River or Lake St. Clair.

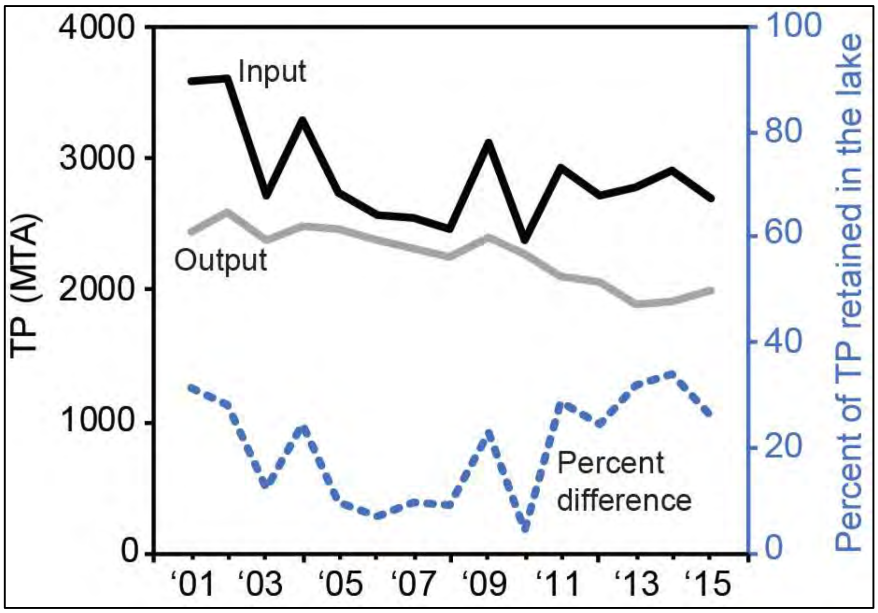


Figure 3. Input (solid black line), output (solid gray line), and percent of annual TP input that is retained in (dashed blue; right y-axis) Lake St. Clair.

Status and Trends

Sources of the Detroit River's phosphorus load to Lake Erie - Lake Huron's contribution to the Detroit River load is much larger than has been assumed in the past (Burniston et al., 2018, Scavia et al., 2019a) due to the identification of a previously "unmeasured load" that evades monitoring stations at the head of the St. Clair River (Scavia et al., 2019a). The most recent estimates demonstrate that Lake Huron contributes more than half of the Detroit River TP load to Lake Erie, even taking into account retention in Lake St. Clair (Figure 4). After Lake Huron, the largest sources of phosphorus are the Great Lakes Water Authority Water Resource Recovery Facility (GLWA WRRF) in Detroit, followed by the Thames River watershed, unmonitored loads from small drainage basins around Lake St. Clair, and the Sydenham and Clinton river watersheds (Figure 5). The remaining 10% of the system's load comes from unmonitored areas that drain to the Detroit and St. Clair rivers, and the Black, Rouge, Belle, and Pine river watersheds.

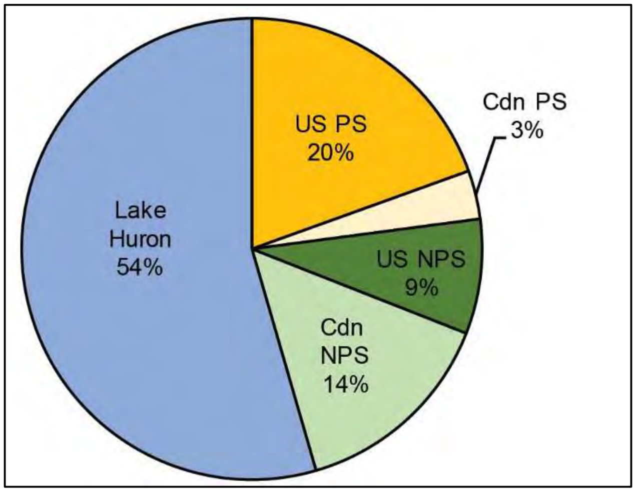


Figure 4. Proportions of the Detroit River's TP load to Lake Erie from Lake Huron and U.S. and Canadian point sources (PS) and nonpoint sources (NPS). This calculation takes into account retention in Lake St. Clair.

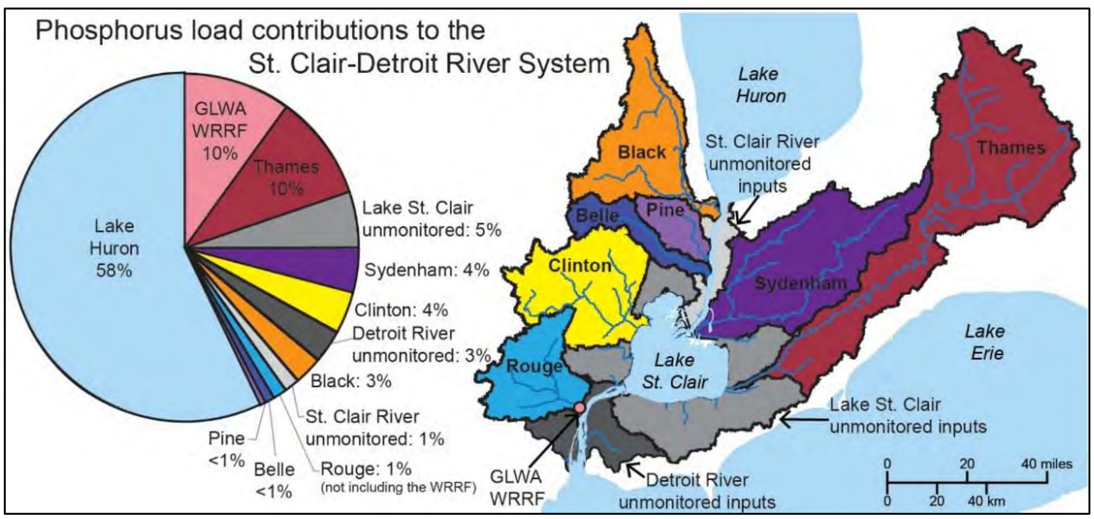


Figure 5. Proportions of the Detroit River's TP load to Lake Erie from all of the system's sources. Colors in the pie chart correspond to the map at right. Note that the GLWA WRRF is in the Rouge watershed, but it shown separately in the pie chart. These estimates do account for retention in Lake St. Clair.

Nonpoint sources provide 57% of the watershed TP load (i.e., the load not including the Lake Huron contribution), with 44% from agricultural nonpoint sources, reflecting both the intensity and extent of agriculture in this watershed. The watershed contains some of Canada's most productive farmland, including extensive row crops in the lower parts of the watershed and livestock operations in the upper part. Urban and suburban nonpoint sources (e.g., roadway runoff and runoff from other impervious surfaces, animal waste, turf fertilizer, leaf litter) account for 7% of the watershed TP load.

Point sources make up about 43% of the watershed TP load (502 MTA from the U.S. and 100 MTA from Canada). Wastewater treatment facilities are the largest point source, with industrial facilities such as food processing and metal finishing plants contributing smaller amounts. The GLWA WRRF is one of the largest wastewater treatment facilities in the world, treating sewage from 3 million residents across 77 communities. It also handles stormwater because much of the region has a combined sewer system. It contributes 23% of the watershed TP load, or 326 MTA, which is more than all other point sources combined, and more than any individual tributary.

Detroit River phosphorus loads have declined over the past 18 years - The Detroit River TP load declined from 3,956 MTA in 1998 to 2,502 MTA in 2016, a 37% decline over 18 years (Figure 6)(Scavia et al., 2019b). There are two primary reasons for the declines since 1998 (Scavia et al., 2019a): (1) The concentration of phosphorus in Lake Huron water declined after the 2000-2005 invasion of zebra and quagga mussels, which are voracious filter feeders that concentrate nutrients in their bodies and along the lake bottom; and (2) The Detroit Water and Sewerage Department made significant improvements to operations at its wastewater treatment facility (now called the GLWA WRRF) around 2010. Nonpoint source loads are influenced by precipitation patterns, land management, and land use; they did not show a statistically significant trend over this time period.

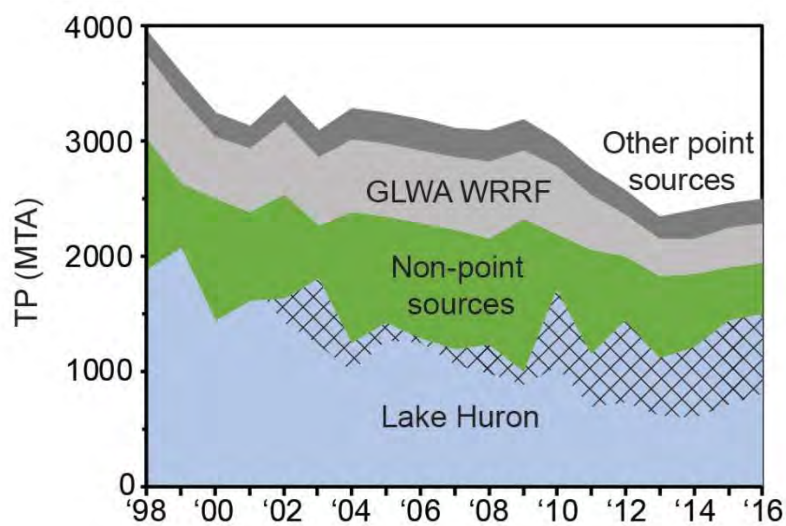


Figure 6. Time series of the total TP load to Lake Erie (which accounts for retention in Lake St. Clair). Hatched lines represent the unmeasured load from Lake Huron. Available data limited the estimate for the unmeasured load to 2001-2015; here, the value for 2016 is assumed to be the same as 2015.

Management Next Steps

Estimates of tributary loading for 2008 merit special attention because the GLWQA reduction targets use that year as a baseline. Scavia et al., (2019a, c) estimated that the 2008 Detroit River TP load was 3,096 MTA, which is roughly 50% higher than the value of Detroit River TP that was used by the U.S. and Canada when they determined load reduction targets (Maccoux et al., 2016) because that Detroit River TP load value was based on a considerably lower estimate of loading from Lake Huron.

A 40% load reduction from our 2008 estimate would result in a target load of 1,858 MTA. Because the 2013-2016 average Detroit River loads had already declined to 2,425 MTA, the remaining amount to reduce is 567 MTA (Figure 7). This is equivalent to 23% of the phosphorus load coming from all sources, including Lake Huron. This new understanding of the substantial contribution from Lake Huron is an important consideration for Canada and the U.S. as they refine efforts on the St. Clair-Detroit River System watershed sources. For example, if the U.S. and Canada seek to reduce the remaining 567 MTA from the St. Clair-Detroit River watershed load (i.e., sources not including Lake Huron), they will need to reduce those sources by 51% of the current load (2013-2016 average). Furthermore, because the GLWA WRRF has already reduced its load by over 40% since 2008, further improvements there are not currently part of the reduction strategy outlined in Michigan's action plans. So when removing Lake Huron and the WRRF from consideration, the remaining watershed point and nonpoint sources would need to be reduced by 72% from current levels to reach the target – a daunting challenge. Reducing the Lake Huron and GLWA WRRF loads each by 10-15% leaves 40-50% to be reduced from watershed sources.

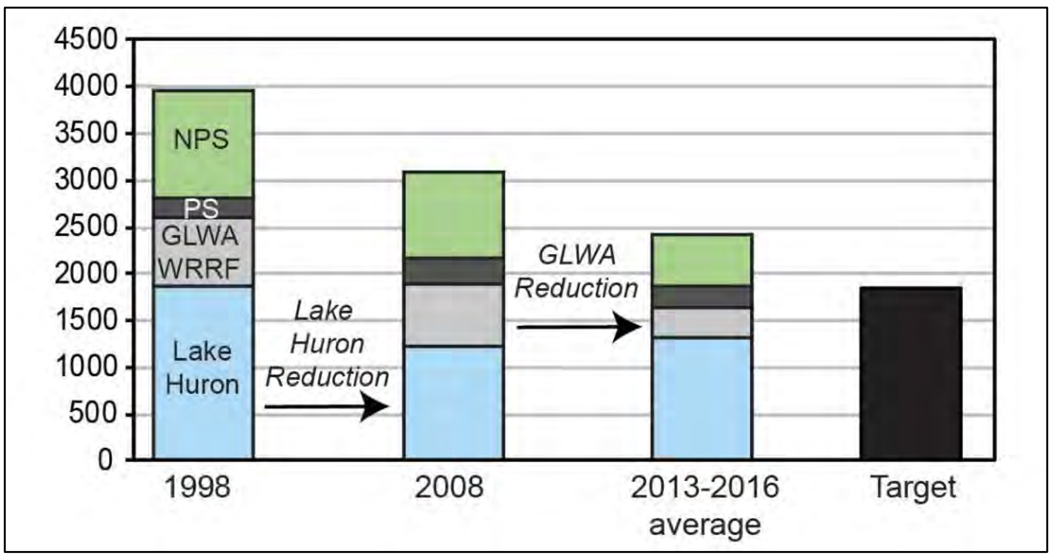


Figure 7. Contributions to the Detroit River TP load to Lake Erie for the water years 1998, 2008, and the 4-year average 2013-2016. The target represents a 40% reduction from the 2008 load as estimated in this report.

When considering sources of TP within the St. Clair and Detroit River System watershed, point and nonpoint sources are approximately equal contributors (Figure 5). While the WRRF in Detroit contributes over half of the point source load, substantial load reductions have already been made from this facility, and the high costs of further technological improvement may therefore be difficult to justify at this time. The other point source loads come from 150 other facilities, and while each is rather minor, accumulated reductions from all of them should help. Substantial reductions would also have to come from the agriculturally dominated nonpoint sources. Model analyses (e.g., Dagnew et al., 2019) suggest the most effective way to reduce those loads is to apply combinations of practices like cover crops, buffer strips, wetlands, and applying fertilizer below the soil surface on the lands with the highest phosphorus losses.

Research/Monitoring Needs

Lake Huron load - The previously unmeasured contribution to the Detroit River TP load appears to come from sediment resuspended along Lake Huron's southeast region, and any attempts to improve that estimate or to reduce that load will require additional analyses of its sources, phosphorus content, event frequency, and movement toward the outflow to the St. Clair River. It should be possible to enhance monitoring, thereby improving load estimates, by including continuous measurement of phosphorus surrogates, such as turbidity, that can be correlated with phosphorus concentrations (e.g., Robertson et al., 2018).

Watershed dynamics - To focus the most effective land management practices on the most appropriate lands requires a combination of higher resolution observations of properties such as soil P content and more accurate high-resolution models. The models commonly used have been calibrated to the mouths of the major tributaries, but to ensure their fidelity to watershed dynamics at a finer resolution requires nutrient monitoring efforts in the interiors of the sub-watersheds.

Detroit River load - Direct measurement of the Detroit River load is difficult because the river is not well mixed and seiches from Lake Erie complicate discharge estimates. There have been two basic approaches to estimate this load. One is to sum estimates of all of the loads to the Detroit River with (Scavia et al., 2019c) or without (Maccoux et al., 2016) accounting for load retention in Lake St. Clair. This approach avoids the measurement problems at the mouth of the river, but requires extensive monitoring upstream, including the historical difficulties with determining the load from Lake Huron. The second approach is to mount extensive field efforts, sampling frequently and across the profile of the river, sufficiently upstream of the effects of Lake Erie (e.g., Burniston et al., 2018, Totten and Duris, 2019). To ensure temporal and spatial consistency, and to connect load trends to potential actions upstream, both approaches are needed.

References

Agriculture and Agri-Foods Canada (AAFC). 2015. Annual Crop Inventory. Available at: https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed 1 July 2019).

Burniston, D., Dove, A., Backus, S., Thompson, A., 2018. Nutrient Concentrations and Loadings in the St. Clair River - Detroit River Great Lakes Interconnecting Channel. J. Great Lakes Res. 44, 398-411.

Dagnew, A., Scavia, D., Wang, Y.-C., Muenich, R., Kalcic, M., 2019. Modeling phosphorus reduction strategies from the international St. Clair-Detroit River system watershed. J. Great Lakes Res. 45, 4, 742-751.

Maccoux, M.J., Dove, A., Backus, S.M., Dolan, D.M., 2016. Total and soluble reactive phosphorus loadings to Lake Erie: A detailed accounting by year, basin, country, and tributary. J. Great Lakes Res. 42, 1151-1165.

Scavia, D., Bocaniov, S.A., Dagnew, A., Long, C., Wang, Y.-C., 2019a. St. Clair-Detroit River system: Phosphorus mass balance and implications for Lake Erie load reduction, monitoring, and climate change. J. Great Lakes Res. 45, 40-49.

Scavia, D., Bocaniov, S., Dagnew, A., Hu, Y., Kerkez, B., Long, C., Muenich, R., Read, J., Vaccaro, L., Wang, Y., 2019b. Watershed Assessment of Detroit River Phosphorus Loads to Lake Erie. Final project report produced by the University of Michigan Water Center. Available at: myumi.ch/detroit-river (accessed 1 July 2019).

Scavia, D., Bocaniov, S., Dagnew, A., Hu, Y., Kerkez, B., Long, C., Muenich, R., Read, J., Vaccaro, L., Wang, Y., 2019c. Detroit River Phosphorus Loads: Anatomy of a Binational Watershed. J. Great Lakes Res. 45, 1150-1161.

Totten, A.R., Duris, J.W., 2019. Spatial distribution of nutrients, chloride, and suspended sediment concentrations and loads determined by using different sampling methods in a cross section of the Trenton Channel of the Detroit River, Michigan, November 2014-November 2015: U.S. Geological Survey Scientific Investigations Report 2018–5141, 25 p., https://doi.org/10.3133/sir20185141 (accessed 1 July 2019).

U.S. Department of Agriculture- National Agricultural Statistics Survey (USDA-NASS). 2015. CropScape - Cropland Data Layer. Washington, D.C., USA.

7.3 Human Population Growth and Distribution in Southeast Michigan

C. Knauss, School for Environment and Sustainability, University of Michigan, crknauss@umich.edu

Background

During the 19th and first half of the 20th centuries, immigrants and farmers moved to big cities for the opportunity of higher income jobs in industry. By the middle of the 20th century, with greater accessibility offered by the automobile, big city residents were moving away from urban centers, seeking suburban areas with more space and within driving distances of their workplace. Suburbanization and the post-war baby boom generation filled in what are now the inner-ring suburbs. By the end of the 20th century, continued decentralization of traditional urban population centers affected the core cities in southeast Michigan (SEMCOG, 2002).

Southeast Michigan's population growth rate and pattern of expansion has followed a similar pattern experienced in many major metropolitan areas around the country (SEMCOG, 2001). All of the counties in southeast Michigan have experienced population increases, with the purchase of farmland for subdivisions and the clearing of woodlots for developments. People who moved farther away from the urban centers to enjoy the rural and suburban life are now finding that the city is moving to them; places that were once rural have been experiencing an outward push by urban areas.

Population growth and widespread distribution in southeast Michigan puts pressure on the ecosystem. Uncontrolled growth of urban areas poses serious threat to the natural environment, agricultural and energy resources, and human health and quality of life. Human population growth and expansion can:

- Increase impervious surface and lead to stormwater runoff problems;
- Decrease wildlife habitat;
- Increase water and air pollution;
- Increase herbicide and pesticide use; and/or
- Introduce non-native invasive species.

However, growth can be managed in ways that protect significant natural areas, conserve natural resources, protect essential ecological processes (e.g., groundwater recharge, stream flows), and prevent pollution (especially smog and hazardous wastes).

Status and Trends

The City of Detroit's population increased more than six-fold during the first half of the 20th century, due largely to a massive influx of eastern European and southern migrants coming to the area for the burgeoning automobile industry. However, by 2018, Detroit's population had decreased to slightly under 650,000 residents, one-third the population the city boasted at its peak in the 1950s (Figure 1). Detroit's population decline has been one of the largest in the United States.

In 1900, the total population of southeast Michigan, a region including Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties, was nearly 600,000. More than a century later, in 2018, southeast Michigan's population was just over 4.7 million (SEMCOG, 2018). This region experienced steady population growth between 1900 and 1970, followed by relatively stable population level between 1970 and 2018 (Figure 1).

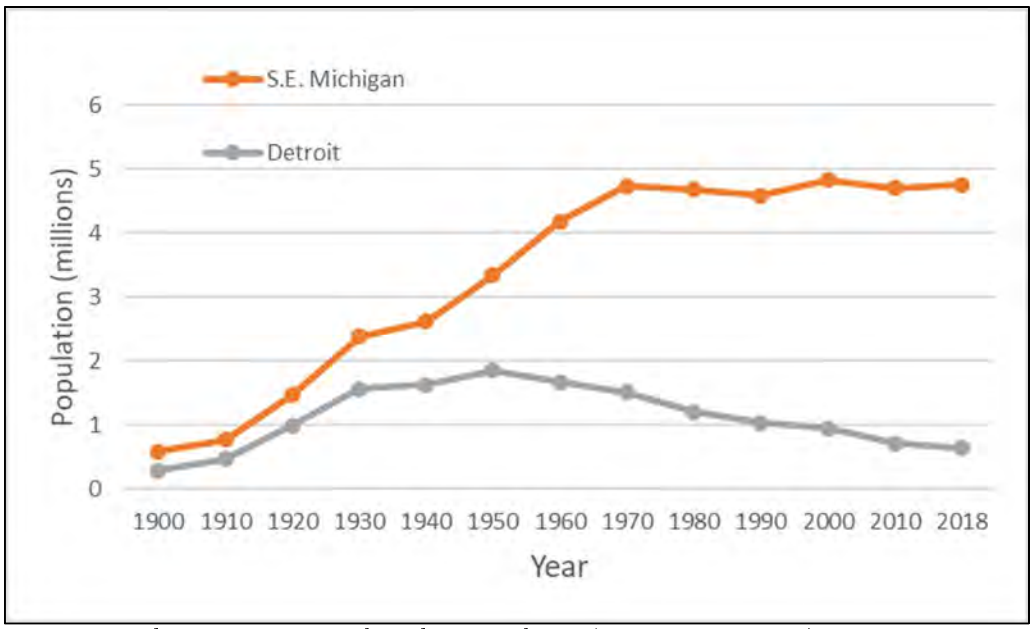


Figure 1. Population in Detroit and southeast Michigan from 1900 to 2018 (Data source: U.S. Census Bureau and Southeast Michigan Council of Governments).

Population distribution has changed substantially in southeastern Michigan between 1900 and 2018. Wayne County's dramatic population growth occurred between 1900 and 1950, followed by a 35% decline between 1970 and 2018. In contrast, Oakland, Macomb, and Washtenaw counties experienced steady growth from 1950 to 2018 (Figure 2). This pattern indicates people moving out of Detroit to surrounding areas. Oakland County has experienced the most growth, with the northern townships increasing 40% since 1990. As of 2018, the fastest growing areas in the region are in Macomb, Oakland, and Washtenaw counties, whereas Wayne County continued to exhibit substantial population decline (SEMCOG, 2018).

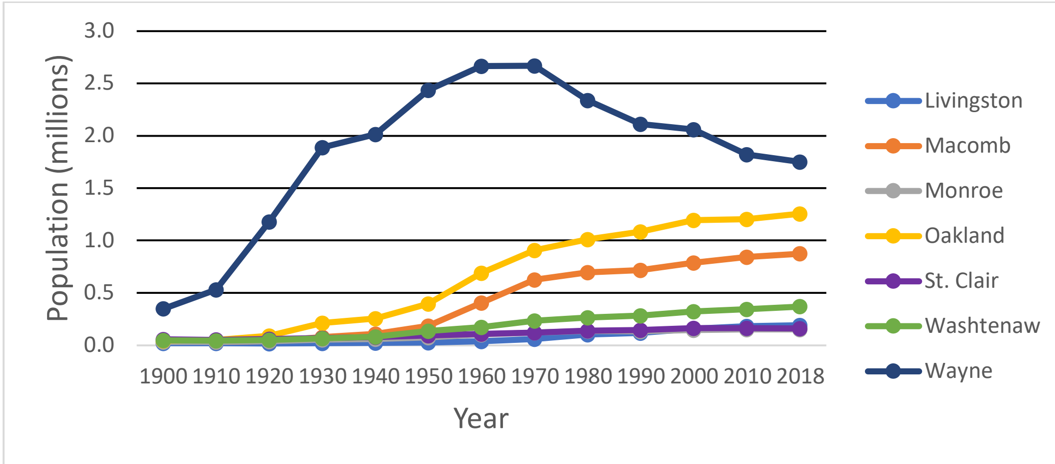


Figure 2. Population fluctuations in southeast Michigan by country, 1900-2018 (Data source: U.S. Census Bureau and Southeast Michigan Council of Governments).

The region added nearly 4.2 million people between 1900 and 2018. At the beginning of the 20th century, Wayne County was the only urbanized population center. By the beginning of the 21st century, Oakland and Macomb counties had joined Wayne County in becoming urbanized population centers (Figure 3). This reflects the overall shift from agrarian to urban living over the past 100 years (SEMCOG, 2002).

The Southeast Michigan Council of Governments produces a new growth forecast once every five years. In their most recent forecast through 2045 (Figure 4), it is estimated that by 2027, southeast Michigan's population will exceed its 2001 peak of 4.849 million, and by 2045, the population will reach 5.1 million (SEMCOG, 2017).

Management Next Steps

Population growth can dramatically change communities and landscapes. As new dwellings, businesses, and industries are built or expanded, land is converted from one use to another to accommodate that change. As development expands across suburbs and once rural landscapes, traffic congestion, commercial strips, and the destruction of a more pastoral landscape push people who seek open space further into the countryside. They are aided by a fast and efficient road network and relatively low land prices.

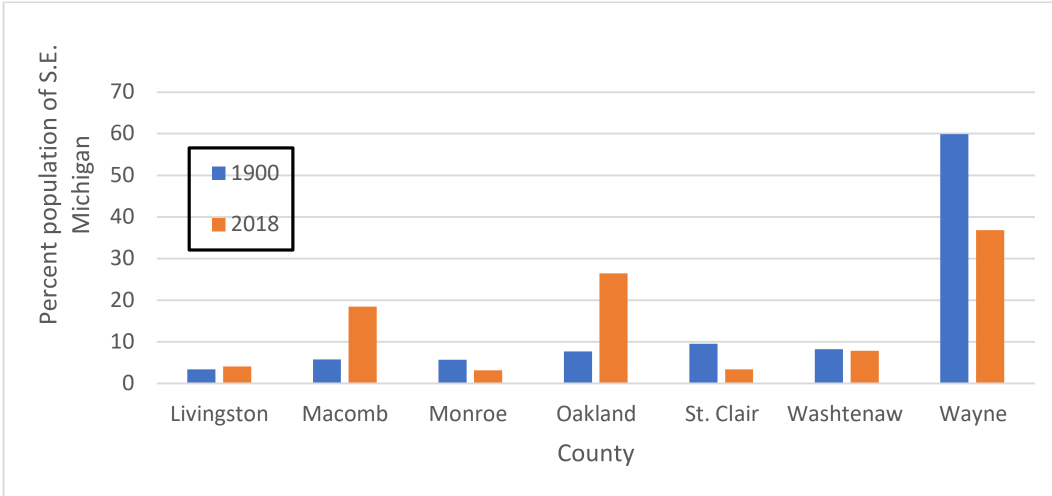


Figure 3. Percent of the Population of Southeast Michigan in Each County in 1900 and 2000 (Decennial Census, U.S. Census Bureau).

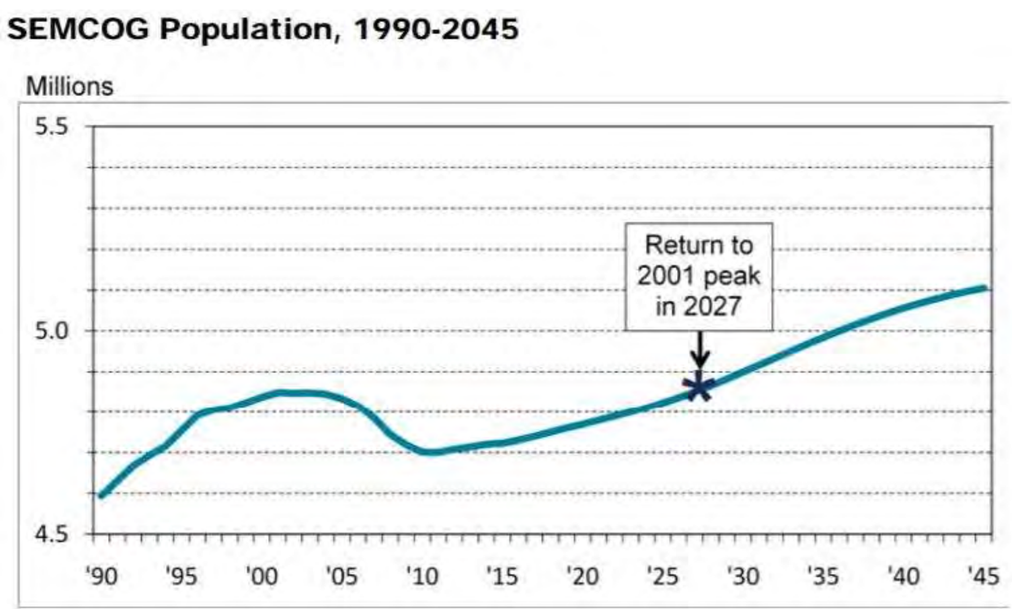


Figure 4. Population Forecast of Southeast Michigan from 1990-2045 (SEMCOG, 2017).

As people seek the "good life" further and further out from the urban core, land, energy, natural resources, and open space disappear. The land use pattern that results is costly to service and, over time, results in a loss of the very qualities sought by those who moved there. As the transportation system expands into previously undeveloped or minimally developed areas, water and air pollution can increase and wildlife habitat can be fragmented or lost.

The southeast Michigan region and its communities need to utilize growth management techniques that systematically guide the type, rate, location, timing, public cost, and quality of land development to support growth, while preserving quality of life. Promising techniques include:

- purchase of development rights;
- transfer of development rights;
- concurrency (pay as you go);
- urban and general services districts;
- development agreements;
- regional impact coordination; and
- interjurisdictional growth management.

Further, special efforts should be expended to integrate land use and transportation planning in southeast Michigan to better manage growth through the regional efforts. This could include:

- reaching agreement on a regional sustainability vision (i.e., economic, societal, and environmental) and signing a partnership agreement to generate cooperation amongst communities and businesses;
- empowering Southeast Michigan Council of Governments to expand its capability to map, inventory, and predict changes in population, land use, and transportation trends (e.g., 2045 Regional Development Forecast; SEMCOG, 2017);
- identifying constraint areas from an environmental and servicing perspective in order to indicate where development is and is not appropriate;
- developing regional sustainability policies to preserve key ecosystem features and quality of life (e.g., public transportation, minimizing nonpoint source pollution, stopping floodplain encroachment, limiting impervious surface area development, etc.); and
- proactively working with communities to implement policies and undertaking state of the environment/economy/society reporting every three to five years.

Continued priority should be given to educating the public about the environmental and natural resource consequences of population growth, population density, land use, and transportation practices. Developers along with land use and transportation planners need more education on sustainable design.

Research/Monitoring Needs

Southeast Michigan Council of Governments must continue to track population trends and predict future growth and distribution patterns. Also, more research is needed that integrates population trends with land use and transportation planning on a regional scale. Innovative best management practices must be identified that preserve quality of life and sustain our communities, economies, and environments. A combination of incentives and regulatory tools needs to be used to better manage growth and ensure sustainability.

References

SEMCOG, 2002. Historic Populations and Employment by Minor Civil Division, Southeast Michigan: Population, 1900-2000; Employment, 1970-2000. Detroit, Michigan, USA.

SEMCOG, 2017. Stabilizing and Sustaining: The Economic and Demographic Outlook for Southeast Michigan through 2045. Detroit, Michigan, USA.

SEMCOG, 2018. Population and Household Estimates for Southeast Michigan. Detroit, Michigan, USA.

Southeast Michigan Council of Governments (SEMCOG), 2001. 2030 Regional Development Forecast for Southeast Michigan: Population, Households, and Jobs, for Cities, Villages, and Townships 1990-2030. Detroit, Michigan, USA.

7.4 Human Population Growth and Distribution in the Windsor Census Metropolitan Area

Wendy Stark, WindsorEssex Economic Development Corporation, wstark@choosewindsoressex.com

Kevin Berk, Faculty of Law and Great Lakes Institute of Environmental Research, University of Windsor, berkk@uwindsor.ca

Background

Figure 1. Windsor Census Metropolitan Agglomeration (Source: Statistics Canada).

The Windsor Census Metropolitan Area (CMA; as identified by Statistics Canada to include Windsor, LaSalle, Amherstburg, Tecumseh, and Lakeshore; Figure 1) has experienced significant population growth in recent years. This trend is in line with many other urban areas in Ontario. According to Statistics Canada, the key contributor to this growth is the higher targets for permanent and temporary immigration set by the Canadian government (Statistics Canada, 2019a).

This trend is of great importance to the environmental status of the region as increases in human population can have profound impacts on ecosystems. Urbanization is the most impactful and irreversible form of anthropocentric land use. The widespread impacts of urbanization include changes in land-cover, hydrological systems, climate, biogeochemistry, and biodiversity. Urban expansion is a primary driver of habitat loss, loss of prime agricultural land, and encroachment on protected areas. The development of urban centers furthermore impacts travel demand and energy consumption (Seto et al., 2011).

As a result of this widespread impact it is essential to understand how urban populations are developing and to ensure that the development is conducted in environmentally responsible ways.

Status and Trends

The Windsor CMA experienced the third highest (tied with Ottawa-Gatineau) population growth in all of Canada from 2017 to 2018 (Figure 2). Windsor's CMA population growth of +2.5% over the year was above the Canadian average of +1.8% growth in large urban areas. Furthermore, the growth exhibited in Windsor was part of a greater trend across Canada as growth in large urban centers greatly outpaced growth in the rest of the country (+1.8% vs +0.6%). This trend also reflects greater growth occurring across Ontario as the five greatest centers for growth (Peterborough, Kitchener-Cambridge-Waterloo, Ottawa, Windsor, and London) are all Ontario CMAs (Statistics Canada, 2019b).

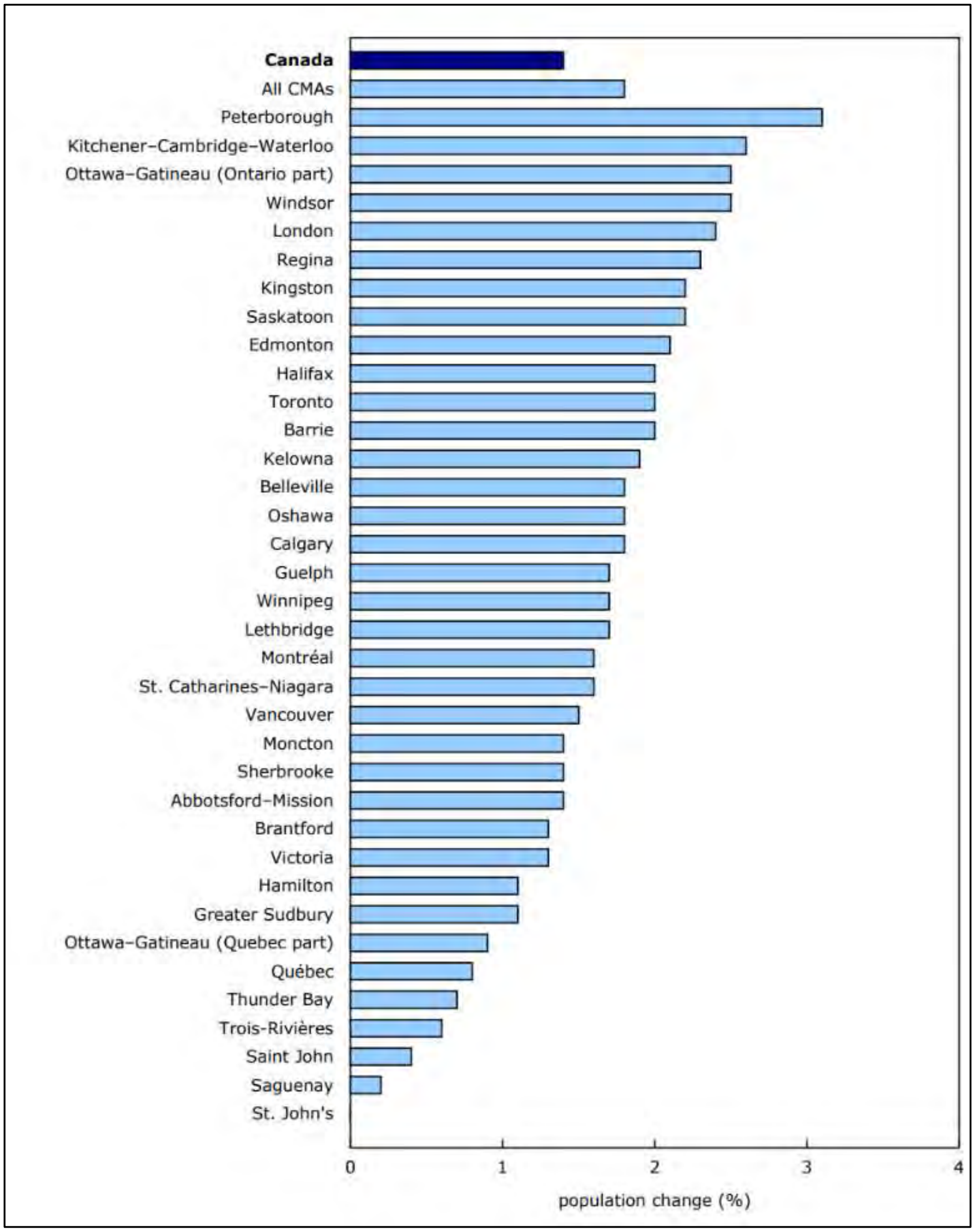


Figure 2. Population change percentage in each Canadian CMA from 2017 to 2018 (Source: Statistics Canada).

Historical population growth trends in the Windsor CMA show nearly two decades of population growth starting in 1987, followed by a decline or stagnation between 2006 and 2016, and then a substantial increase in population between 2016 and 2018 (Figure 3). This trend is consistent with Statistics Canada's hypothesis that the new growth in large urban areas is primarily driven by Canada's new immigration policies that have led to changes in the immigration system.

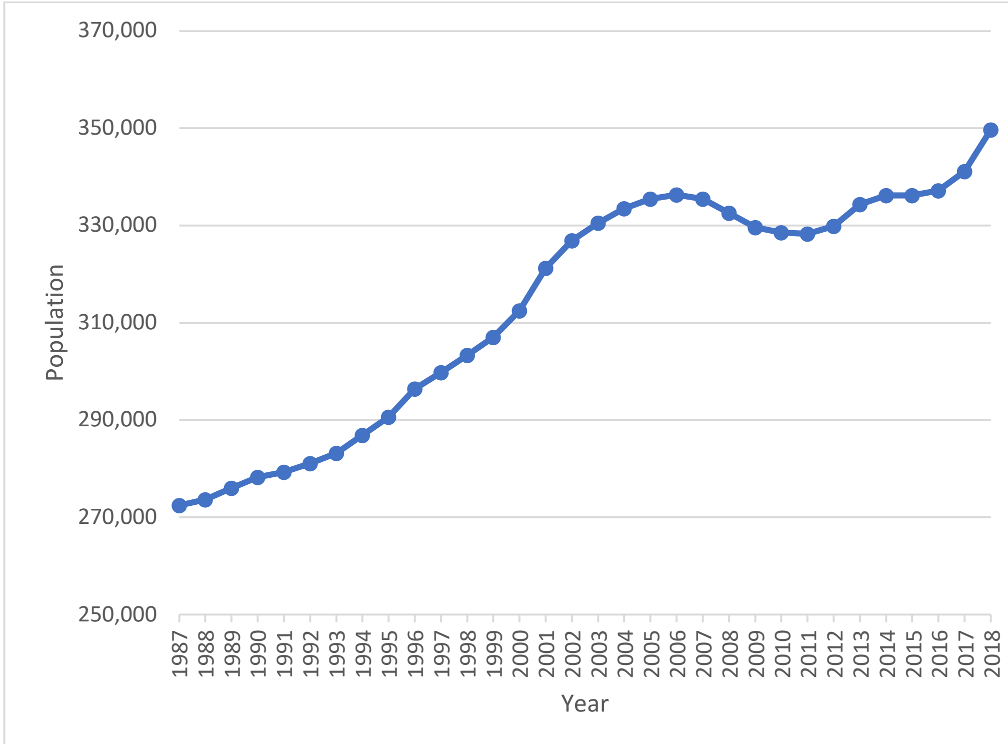


Figure 3. Windsor CMA historical population trend, 1987-2018 (Source – Statistics Canada).

Population forecasts conducted by the Windsor Essex Economic Development Corporation (Figure 4) project that the recent increase in population growth will continue through 2019 at a rate greater than the historical average, although not quite the rate of 2018, and further growth at lower rates through 2020-2023.

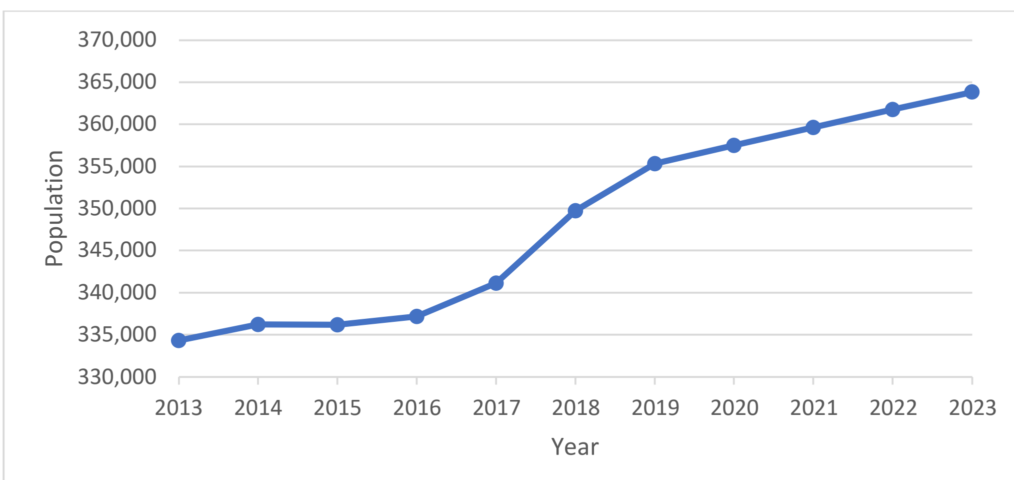


Figure 4. Windsor CMA's forecasted population trend (source: Conference Board of Canada).

Population projections released by the City of Windsor in 2018 (Figure 5; does not include the rest of the Windsor CMA) provide a similar short-term forecast with continued growth through 2026, but population stagnation to occur from 2026-2036 (City of Windsor, 2018).

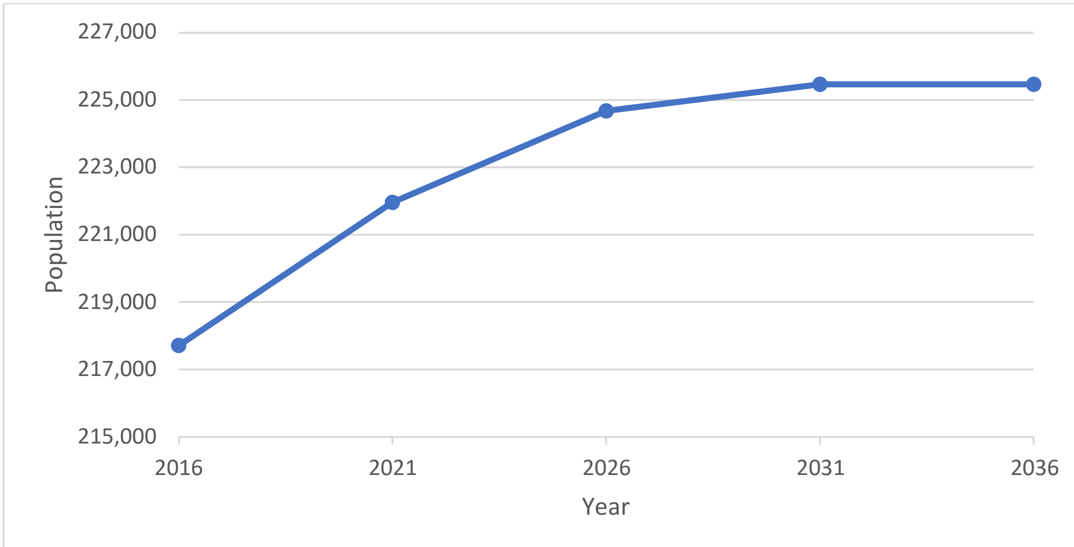


Figure 5. City of Windsor's forecasted populaton trend (Source: City of Windsor).

Management Next Steps

With the current and projected increases in population in the Windsor CMA, much work will need to be done to ensure that the pressure from further urbanization on the ecosystem is adequately managed and controlled. This work will include environmentally conscious expansion which prevents habitat loss, loss of prime agricultural land, and encroachment on protected areas.

Although urbanization poses threats to the environment in terms of land use, it can result in improved climate mitigation at the same time. This mitigation occurs when residential and employment spaces become more dense resulting in reduced energy consumption, less vehicle travel, and thus reduced carbon dioxide emissions. This is further reinforced by per capita emissions being lower in urban areas than national averages (Seto et. al, 2011).

The threats to the ecosystem and the potential mitigation benefits outlined above will require a coordinated effort to be managed and controlled. Environmentally responsible population growth requires climate mitigation and adaptation plans, coordination between businesses and governments, and strong land use laws. Multiple groups such as the city of Windsor, the governments of surrounding municipalities, provincial and federal governments, as well as the Essex Region Conservation Authority will be required to work together to ensure that the pressure on the ecosystem is being adequately controlled and addressed.

Research/Monitoring Needs

Due to the multifaceted impacts of population pressure on the ecosystem, and the corresponding requirement for a varied response to these pressures, individuals doing environmental work in the region will need to monitor the steps being taken to address the pressure. Specific attention will need to be paid to the ensuring that collaborative efforts are being made by various groups (including municipal governments, businesses, and conservation authorities) to adequately manage the pressure on the ecosystem, and potentially take advantage of prospective climate mitigation benefits of urbanization. Long-term monitoring is needed to measure ecosystem impacts of human population growth and expansion, and to adequately inform management consistent with adaptive management that assesses, sets priorities, and takes action in an iterative fashion for continuous improvement.

References

City of Windsor, 2018. Windsor Population Projections and Demand for Dwellings: 2016-2036. Windsor, Ontario, Canada.

Conference Board of Canada, 2019. Metropolitan Data. Ottawa, Ontario, Canada.

Seto K.C., Fragkias, M., Güneralp, B., Reilly, M.K., 2011. A Meta-Analysis of Global Urban Land Expansion. PLoS ONE 6, 8, e23777.

Statistics Canada, 2019a. Canada's Population Estimates: Subprovincial Areas, July 1, 2018. Ottawa, Ontario, Canada.

Statistics Canada, 2019b. Focus on Geography Series, 2016 Census. Ottawa, Ontario, Canada.

This page intentionally left blank.

7.5 Land Use Change in Southeast Michigan

Southeast Michigan Council of Governments

Background

The history of land use in southeast Michigan begins along the Detroit River. In the early 1700s, Antoine de la Mothe Cadillac established a military post along the waterway to advance French control of the fur trade. The land was seen as a secondary asset compared to the river that allowed easier transport of trade goods and military activities. The expansion of urban development began in earnest in the early 1800s when big changes occurred in transportation methods. At that time, the waterfront was becoming lined with many docks to support the steamboats and ships containing goods of all kinds as Detroit became a center of commerce. The 1860s marked a decrease in water transport as an extensive network of railways was built. Recognized as a geographic center for population and business, Detroit was linked to the electric interurban railway system in the late 19th and early 20th centuries. Since 1950, the region has experienced increases in urban area development and decreases in density due to the automobile.

Southeast Michigan is a major urban area with nearly five million people. Like many major urban areas throughout the United States, people in southeast Michigan began moving away from Detroit beginning in the 1950s seeking suburban areas with more space and within driving distance to their workplace. Personal automobiles and cheap fuel made this possible. In addition, federal tax subsidies for home mortgage interest and property taxes, as well as infrastructure financing policies, all supported new growth outside existing cities (SEMCOG, 2003).

Different beliefs in private property rights and the role of government have emerged due to the development outside the cities. Anti-sprawl or "Smart Growth" proponents are now advocating for denser, more walkable neighborhoods with a diversity of home designs and mass transit. Still others see regulations on growth as infringing on private property rights and a challenge to economic consumer demand. The 2001 Detroit Area Study found that 70% of respondents to a survey preferred the suburban auto-oriented neighborhood, instead of one that was more walkable and transit-oriented (SEMCOG, 2003). The effects of current sprawl are realized in increased housing prices, decreased water quality, need for additional infrastructure and transportation, loss of open space and natural habitat, and decreasing tax revenues in older communities.

The Southeast Michigan Council of Governments (SEMCOG) has identified four factors contributing to current land use trends:

- Population
- Households
- Employment

- Income

Southeast Michigan saw steady population growth through 1970, reaching a population of 4.736 million in that year. The region has since experienced two cycles of population decline and recovery, triggered by economic recessions, that left the region with fewer people in 2015 (4.722 million) than in 1970. The recent increase of 30,000 people since 2015 has pushed the region's population to 4.752 million as of 2018, which is still 80,000 below its year 2000 peak of 4.833 million (SEMCOG, 2018).

However, it is not only population growth that controls land development. More importantly, it is the increasing number and size of houses. This means that about the same number of people are occupying more houses that are each consuming more land. Fewer people on average are living in each house and this is primarily due to the decrease in the number of children being born. The number of people in each house decreased with an average of 2.66 people per house in 1990 decreasing to 2.47 in 2018 (SEMCOG, 2018).

Status and Trends

Very early land use changes started at the riverfront in the early 1800s as large docking structures for holding ferries and steamboats were constructed. By the late 1800s, docks lined 8 km (five miles) of riverfront (Kerr et al., 2003).

By the 1890s, Detroit's role changed from a commercial city with an even diversity of wholesale trading and retailing to one of heavy industrial manufacturing. At that time, convenient transportation was available with new electric horsecar lines, steam railroads, and steam-powered boats. This resulted in dense urban development that grew up around public transport.

A very significant change in land development occurred in the first half of the 20th century (Figure 1). A new transportation revolution began in 1920 as the number of people owning automobiles increased dramatically. There were 54,366 registered motor vehicles in 1913 and 989,010 in 1925 in the state of Michigan (U.S. Census Bureau, 1926). Development was no longer focused around rail lines as paved roads were built all over the region. The urbanized area increased from 1.5% in 1890 to 9% in 1950 (SEMCOG, 2001). Freeways and more affordable automobiles made transportation cheap and encouraged urban growth.

Agriculture in southeast Michigan peaked between 1880 and 1900 and has decreased since 1910 (USGS, 2003). More recent land use changes in southeast Michigan are evident in our rapid transformation of agricultural areas and open space to low density residential, commercial, and business developments (Norris et al., 2002). The rate of residential land development continues to increase because of a greater demand for new, lower density housing.

Each house is consuming more land. From 1990 to 2000, the amount of land used for homes increased by 19%, while the number of households only grew by 9% (SEMCOG, 2001 and 2003). Prior to 1990, there were 2.84 housing units per acre, but this has decreased to an average of 1.26 for housing built after 1990 (SEMCOG, 2003). This increase in the amount of land used for each house is significant because it accounts for 43% more land developed than would have been with the higher density construction before 1990.

The demand for housing development is not the only reason for the decrease in agricultural land. Some land previously farmed is no longer used since farming is generally less profitable, especially for small farms where operating costs are high compared with revenue. The overall decrease has been a loss of 15% or 117,358 ha (290,000 acres) of undeveloped land between 2000 and 2015.

Not only has the amount of land used for residential space increased in southeast Michigan, but also the pattern of development changed substantially, with significant out-migration from Detroit to the suburbs through the 2000s. Today, Detroit's population is less than half of what it boasted during its peak in the 1950s. In recent years, considerable infill housing development in Detroit has led to a stabilization in both population and out-migration. The city lost 23,000 persons a year during the 2000s, down to 11,000 per year from 2010 to 2015, with a further drop to a loss of only 4,000 per year since 2015 (SEMCOG, 2018).

Between 1996-2005, general nonresidential development showed a peak between the years 1998 and 2002. An average of 2.6 million m^2 (28 million square feet) of development occurred during those five years compared with an average of 1.6 million m^2 (17 million square feet) for 1996, 1997, and 2003-2005. From 2006 to 2017, the region has averaged 836,000 m^2 (nine million square feet) of nonresidential development.

In 1990, there were 379,000 ha (936,700 acres) of developed land and 809,000 ha (two million acres) of undeveloped land. In 2000, there were 445,000 ha (1.1 million acres) of developed land and 728,000 ha (1.8 million acres) of undeveloped land (SEMCOG, 2003). As of 2015, it was almost evenly divided, with 567,000 ha (1.4 million acres) developed, and 607,000 ha (1.5 million acres) undeveloped.

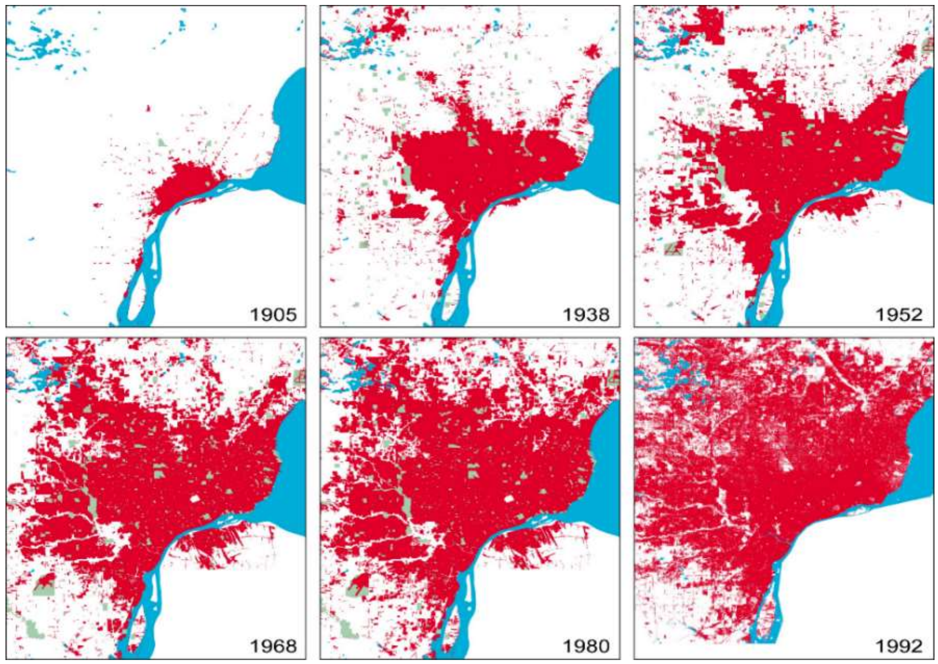


Figure 1. The History of developed land in southeast Michigan, 1905-1992 (USGS, 2003). This image shows the general rate of urban land growth in southeast Michigan through the twentieth century where red represents the area covered by "urban or built up land" according to Anderson et al. (1976).

Management Next Steps

Future land use planning must balance the need for environmental protection, economic progress, and human development. There is need for well-defined roles and responsibilities in land-use planning at all government levels under a common future vision (Norris et al., 2002). This can be done by establishing concrete regional goals, specific responsibilities for each level of government, and empowering local governments with the best available information (Michigan Land Use Leadership Council, 2003). To carry out their responsibilities, local land use decision-makers have a number of training resources available to them. The Planning and Zoning Center at Lansing, Michigan Association of Planning (MAP), and Michigan State University Extension offer training sessions for planning officials. The Michigan Municipal League (MML) and the Michigan Townships Association (MTA) provide advice to elected officials. In addition, the Michigan Land Use Leadership Council has constructed nine recommended actions that serve to guide future decisions in the state (Michigan Land Use Leadership Council, 2003). In summary, these recommendations include preserving farmland and open space by incorporating new incentives for landowners, encouraging partnerships with universities, foundations, and private and public entities, and clearly defining the allocation of funds in possible use of state bonds. More emphasis needs to be placed on developing model ordinances for sustainable land use practices. These model ordinances should be broadly disseminated through southeast Michigan.

Regional land use trends and programs need to be systematically evaluated and benefits assessed to help communities connect cost-efficiency and land use decisions directly (American Forests, 2006). The Urban Dynamics Research Program was created by the U.S. Geological Survey to aid community decision-makers in managing urban sprawl. Its focus is modeling land use change with respect to population growth. The National Science Foundation sponsors a Biocomplexity and Environment Program, one being Project SLUCE (Spatial Land Use Change and Ecological Effects). From 2001-2006 researchers based at the University of Michigan investigated land use change at the urban-rural fringe and the environmental interactions and impacts using models. Their research focused on southeast Michigan and, ultimately, want to be able to use their models to evaluate the potential for specific government interventions in creating better land use choices. An important first step for many communities is to implement a master or comprehensive plan.

Research/Monitoring Needs

Agricultural land and open space are currently changing most rapidly. The value of agricultural land in maintaining biodiversity across the landscape is well established. Therefore, research must focus on alternatives to the current rate of development because it is unsustainable. Land is being transformed from rural to urban faster than the population is growing and the negative impacts on the environment are real. Future research needs include inventorying land use models and assessing their accuracy at predicting what actually will occur on the land. Others include understanding ecosystem response to current development patterns. There is also a growing need to evaluate the ecosystem response and its impact on climate (U.S. Climate Change Science Program, 2003). Continued research is needed in sustainable, best management practices for urban areas. In addition, research in cover crops, those that improve soil quality and farming sustainability, will better equip farmers with tools for managing their farms for profit and sustainability. Finally, more research is needed on quantifying economic, environmental, and societal benefits of best management practices in land use planning and management. Such benefits assessment can be compelling rationale for sound land use decision-making.

References

American Forests, 2006. Urban Ecosystem Analysis Southeast Michigan and City of Detroit Michigan: Calculating the Value of Nature. Washington, D.C., USA.

Anderson, J.R., Hardy, E.E., Roach, J.T., Witmer, R.E., 1976. A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper 964. United States Government Printing Office. Washington, DC., USA.

Kerr, J.K., Olinek, W.S., Hartig, J.H., 2003. The Detroit River as an Artery of Trade and Commerce. In: Hartig, J.H., (Ed.), Honoring Our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 35-47.

Michigan Land Use Leadership Council, 2003. Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council. Lansing, Michigan, USA.

Norris, P.E., Soule, J., Weissert, C., Gage, S., Skole, D., 2002. Michigan's Opportunities and Challenges: MSU Faculty Perspectives. East Lansing, Michigan, USA.

Southeast Michigan Council of Governments (SEMCOG), 2001. 2030 Regional Development Forecast for Southeast Michigan: Population, Households, and Jobs, for Cities, Villages, and Townships 1990-2030. Detroit, Michigan, USA.

SEMCOG, 2003. Land Use Change in Southeast Michigan: Causes and Consequences. Detroit, Michigan, USA.

SEMCOG, 2004. Land Use in Southeast Michigan, Regional Summary, 1990-2000. Detroit, Michigan, USA.

SEMCOG, December 2006a. Population and Household Estimates for Southeast Michigan. Detroit, Michigan, USA.

SEMCOG, September 2006b. Nonresidential Development in Southeast Michigan, Summary 2005. Detroit, Michigan, USA.

SEMCOG, 2018. Population and Household Estimates for Southeast Michigan. Detroit, Michigan, USA.

United States Census Bureau, 1926. Statistical Abstract of the United States 1925. Forty Eighth Number. Government Printing Office. Washington, D.C., USA.

United States Climate Change Science Program, 2003. Strategic Plan for the Climate Change Science Program Final Report. Washington, D.C., USA.

United States Geological Survey (USGS), 2003. Detroit River Corridor Preliminary Assessment of Land Use Change. Urban Dynamics Research Program. Washington, D.C., USA.

7.6 Oil Pollution of the Detroit and Rouge Rivers

John Hartig, University of Windsor, Great Lakes Institute for Environmental Research, jhhartig@uwindsor.ca

Background

Industrial pollution of the Detroit and Rouge rivers dates back to the end of 19th century. However, the problem did not become a priority until the late 1940s when oil pollution resulted in massive winter duck kills (Hartig and Stafford, 2003). Historically, the lower half of the Detroit River froze from bank to bank during the winter. With the southward spread of industry, effluent along the western banks of the river caused the river to warm in pockets, leaving only patches of open water by the mid-1930s (Miller and Whitlock, 1948). The lower half of the river is distinct from the upper half in that it is divided and separated with shoals and islands, which provide an increased abundance of food for waterfowl (Hartig and Stafford, 2003). The combination of open water and food availability soon provided resting and feeding grounds for migrant waterfowl, which began to winter in these areas. Given their proximity to the industries, the open patches of water also contained high concentrations of oil. The result was waterfowl mortality, which occurred in varying degrees beginning in the mid-1930s. Oil spills continue to occur, including the largest oil spill in the Great Lakes in the last 18 years that occurred in 2002 (Figure 1).

Figure 1. Oil spill on the Rouge River in 2002 (photo credit: U.S. Coast Guard, Sector Detroit).

Waterfowl are affected by oil in many ways. External feather oiling causes loss of buoyancy which can result in drowning. Feather insulating properties are lost when feathers become matted (Figure 2a and b), which can result in death due to exposure of cold water (Hartig and Stafford, 2003). Reduced swimming or flying mobility may result in starvation. Ingestion of oil can result in internal pathological changes, causing sickness and/or mortality. If eggs are contaminated, the result is decreased hatchability and increased embryonic mortality (Hartig and Stafford, 2003).

Figure 2. Oil soaked Mallard Duck (A) and Ruddy Duck (B) from the 2002 Rouge River oil spill (photo credit: U.S. Fish and Wildlife Service).

In years of heavy ice cover, the impact of oil on waterfowl was magnified due to limited availability of open water (Hartig and Stafford, 2003). In 1948 the situation climaxed when approximately 11,000 ducks were killed due to oil pollution in the Detroit River (Table 1). Sportsmen were outraged and collected the oil-soaked waterfowl and threw them on the lawn of the State Capitol building in Lansing, in hopes that policymakers would address the overlooked issue (Cowles, 1975). This event marked the commencement of industrial pollution control programs in Michigan.

Table 1. Waterfowl mortality in the Detroit River due primarily to oil pollution (Hartig and Stifler, 1979; U.S. Department of Health, Education, and Welfare, 1962).

Year	Estimated Waterfowl Mortality
1948	11,000
1949	76
1950	871
1951	250
1952	1,000
1953	345
1954	238
1955	2,600
1956	191
1960	12,000
1967	5,400

Status and Trends

A series of relevant legislative events followed the massive 1948 winter duck kill. In 1949, the Michigan Legislature amended the water pollution control statute to establish the Michigan Water Resources Commission (Cowles, 1975). In addition, the definition of pollution was broadened, and state approval was required for all new uses of state waters. Still, oil slicks were reported on the Detroit River one-third of the time during the winter and spring between 1950 and 1955 by the U.S. Department of Health, Education, and Welfare (1962).

Other sources of oil pollution in the Detroit River, in addition to industry, were soon recognized. Some of these include municipal wastewater treatment plants, government installations, combined sewer overflows, and shipping (International Joint Commission, 1968). As these sources were identified, pollution control efforts became increasingly effective. According to the U.S. Department of Health, Education, and Welfare (1962), there was a 97.5% reduction in oil discharges to the Detroit River between the late 1940s and early 1960s (Figure 3). The Michigan Department of Natural Resources (1977) reported that there was an additional 80% decrease in point source discharges of oil between 1963 and 1976. As would be predicted, winter duck kills associated with oil pollution also decreased dramatically.

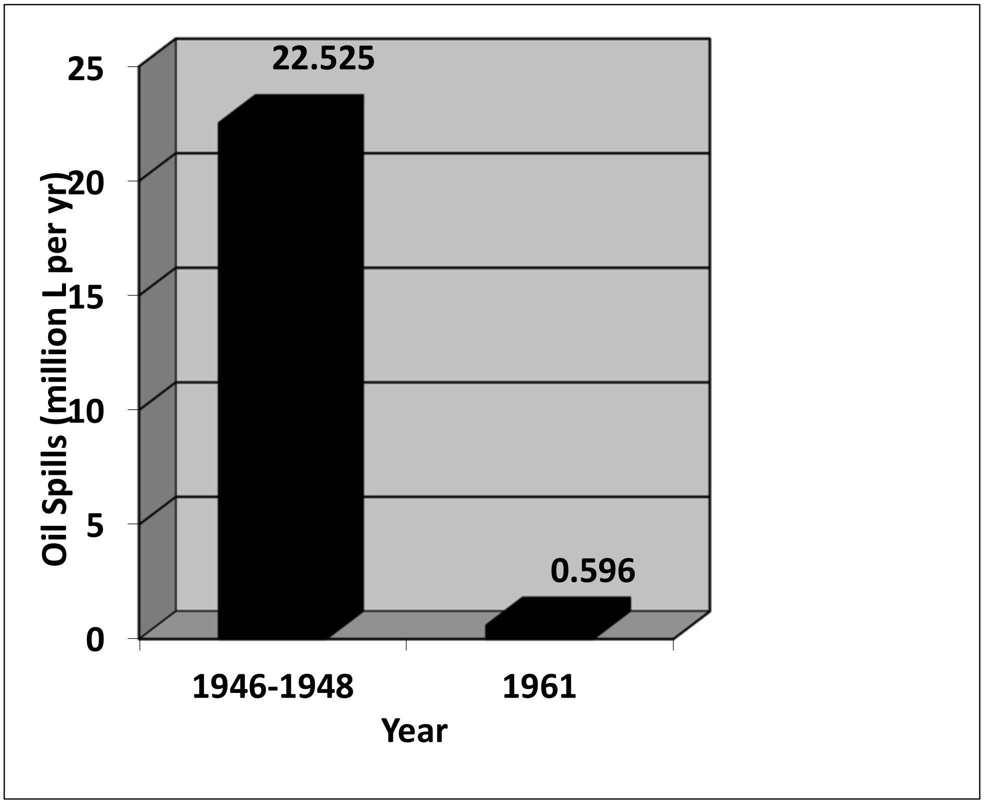


Figure 3. Total volume oil/other petroleum products spilled in Detroit River in gallons per year (1946-1948 and 1961).

Oil spill data collected by the U.S. Coast Guard National Response Center and the U.S. Environmental Protection Agency show a substantial reduction in the volume of oil spilled, however, there are still years in which total volume of oil and other petroleum products spilled in the Detroit and Rouge rivers approaches the estimated oil releases in 1961 (Table 2). In April 2002, a more than 380,000-liter oil spill occurred in the Rouge River. The U.S. Coast Guard and other governmental and industrial both partners and undertook a $7.5 million cleanup on 43 km of the lower Rouge River and both U.S. and Canadian sides of the Detroit River (Hartig and Stafford, 2003).

Ten ducks and geese died as a result of the oil pollution. While this number may seem insignificant to years past, it reminds us that oil pollution continues to be a threat to waterfowl.

Table 2. Total annual volume of oil/other petroleum products spilled into the Detroit River, 1995-2017. Data from 1995 to 2005 were collected by the U.S. Coast Guard National Response Center (2005). Data from 2017 were collected through emergency response activities of U.S. Environmental Protection Agency's On-Scene Coordinators.

Year	Volume of Oil/Other Petroleum Products Spilled into the Detroit River (liters)
1995	5,920
1996	7,129
1997	11,548
1998	3,903
1999	19,583
2000	15,983
2001	12,574
2002	383,222
2003	2,288
2004	83,763
2005	353
2006-2016	No Data
2017	11,476

It is important to note that the data presented in Table 2 represent reported incidents. There are undoubtedly unreported smaller spills and releases through combined sewer overflow events that are not accounted for. These figures are therefore conservative. Concern remains for oil pollution from both combined sewer overflow events and industrial releases.

Management Next Steps

Even with state and federal enforcement programs, there are still small oil spills. Greater emphasis must be placed on prevention. Key management recommendations include:

- Lower the allowable limits of oil and other contaminants from industrial contributors to Detroit and other municipal wastewater treatment plants;
- Identify high priority outfalls that empty into the Rouge and Detroit rivers and target them for implementing early warning systems;
- Heighten Michigan Department of Environmental, Great Lakes, and Energy and U.S. Environmental Protection Agency enforcement of industrial pretreatment programs;
- Educate the business community that it shares the responsibility of preventing the problem and becoming a part of the solution to oil pollution;

- Encourage industrial companies pursuing the voluntary ISO 14000 certification to identify oil as a "significant environmental aspect" in order to prevent accidental release of oil; and

- Increase public awareness of the need to prevent pollution, notice changes in water quality, and report problems immediately.

Research/Monitoring Needs

An early warning system is key to protecting the Detroit and Rouge rivers from oil pollution, and the wildlife that depends on these river ecosystems. It is recommended that governments pursue funding to expand implementation of early warning systems and sensors for water systems.

References

Cowles, G., 1975. Return of the River. Michigan Natural Resources Magazine. January-February Issue, Lansing, Michigan, USA.

Hartig, J.H., Stafford, T., 2003. The Public Outcry over Oil Pollution of the Detroit River, In: Hartig, J.H., (Ed.), Honoring Our Detroit River, Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 69-78.

Hartig, J.H., Stifler, M.E., 1979. Water Quality and Pollution Control in Michigan. Michigan Department of Natural Resources. Publication Number 4833-9803, Lansing, Michigan, USA.

International Joint Commission, 1968. Pollution of the Detroit, St. Clair, and St. Mary Rivers. Washington, D.C., USA and Ottawa, Ontario, Canada.

Michigan Department of Natural Resources, 1977. The Detroit River: 1966-1976: A Progress Report. Publication Number 4833-9438. Lansing, Michigan, USA.

Miller, H.J. and S.C. Whitlock. 1948. Detroit River ducks suffer heavy losses. Michigan Conservation. 17(4): 11, 15.

U.S. Coast Guard National Response Center, 2005. Emergency Response Notification System (Data collected from 1982-2005). Washington, D.C., USA.

U.S. Department of Health, Education, and Welfare. 1962. Pollution of the navigable water of the Detroit River, Lake Erie and Their Tributaries within the State of Michigan. Detroit, Michigan, USA.

This page intentionally left blank.

7.7 Phosphorus Loads and Concentrations from the Maumee River

Nate Manning, National Center for Water Quality Research, Heidelberg College, nmanning@heidelberg.edu

Laura Johnson, National Center for Water Quality Research, Heidelberg College, ljohnso1@heidelberg.edu

Background

Lake Erie (Figure 1) is a classic case of development, recovery from, and return to eutrophication, hypoxia, and HABs. Substantial increases in nutrient loading from agricultural, industrial, and urban sources in the mid-20th century led to severe water quality degradation in the 1960s (Rosa and Burns, 1987; Bertram, 1993; Makarewicz et al., 1989). These highly publicized problems ultimately led the governments of the United States and Canada to shape a Great Lakes Water Quality Agreement (GLWQA, 1978) with a focus on phosphorus (P) load reduction. The subsequent P abatement programs led to a relatively quick recovery (DePinto et al., 1986a) as indicated by decreases in total phosphorus (TP) loads (Dolan, 1993), water column TP concentrations (DePinto et al., 1986a; Ludsin et al., 2001), phytoplankton biomass (especially western basin cyanobacteria), and central basin bottom-water hypoxia (Makarewicz and Bertram, 1991; Bertram, 1993; Charlton et al., 1993), as well as by recovery of several ecologically and economically important fishes (Ludsin et al., 2001).

These improvements were relatively short lived, however, because hypoxia and HAB biomass began to increase during the 1990s (Scavia et al., 2014). There has been a return of extensive central basin hypoxia (Burns et al., 2005; Zhou et al., 2013; Rucinski et al., 2014) and increases in cyanobacteria blooms in the western basin (e.g., *Microcystis* spp. and *Lyngbya wollei*) (Bridgeman et al., 2012; Stumpf et al., 2012; Michalak et al., 2013), with record blooms set in 2011 (Michalak et al., 2013) and 2015, and a bloom in 2014 that led to a “do not drink” advisory for 400,000 people living in the Toledo, Ohio area.

This degradation in water quality prompted the U.S. and Canada to revise the GLWQA and set new P load reduction targets (GLWQA 2016). It was concluded that nonpoint source runoff from the Maumee River during the spring period of 1 March to 31 July each year was the best predictor of cyanobacteria bloom severity and so to achieve a bloom no greater than that observed in 2004 or 2012, 90% of the time, new Maumee River spring loading targets were set for total phosphorus (TP) (860 metric tons) and dissolved reactive phosphorus (DRP) (186 metric tons). This 860 metric ton target is approximately a 40% reduction from the 2008 spring load of 1,400 metric tons for TP and 310 metric tons of DRP. Furthermore, in order to reduce Central Basin hypoxia and achieve an August-September average hypolimnetic oxygen concentration of 2 mg/L or more, annual TP load to the western and central basins should not exceed 6,000 metric tons annually. This reduction corresponds to a 40% annual TP reduction relative to 2008 of all loads, which includes the Maumee River. The Ohio Domestic Action Plan to achieve these reductions has calculated the Maumee River target annual TP load as 2,287 metric tons.

Figure 1. Sediment loading from the Maumee River originating from agricultural nonpoint source inputs (Photo credit: NASA Landsat Program).

The Maumee River watershed consists of more than 16,835 square kilometers (6,500 square miles), located mostly in northwest Ohio, with smaller portions in eastern Indiana and southern Michigan. Water from the Maumee River enters Lake Erie's western basin at Toledo. The Maumee River is also the single largest source of phosphorus loading to Lake Erie, with the majority of the load coming from agriculture. More than 80% of the watershed is devoted to agricultural land uses. For more information about the Maumee River watershed can be found in Richards et al. (2002a).

The National Center for Water Quality Research (NCWQR) at Heidelberg University in Tiffin, Ohio has been monitoring water quality in the Maumee River since 1975. The sampling station is located at the Bowling Green drinking water intake, near the USGS gaging station at Waterville, Ohio. Three samples per day are collected by an automatic sampler. The samples are collected weekly and returned to the Center's Water Quality Laboratory for analysis. During periods of low flow, one sample per day is analyzed; at other times, all three samples are analyzed. This program produces about 425 samples per year and provides the most detailed data for nutrient load determination available anywhere in the Great Lakes (www.ncwqr.org). Previous studies of water quality trends in the Maumee River are included in Richards (2006), Stow et al. (2015), Jarvie et al. (2017), and Choquette et al. (2019).

Status and Trends

Total Phosphorus

Annual loads of TP from the Maumee River are shown in Figure 2. There is a gap in the graph because of a lack of funding during 1979-1981. Inter-annual variation in loads is high across the entire period of record, due to the influence of weather events. The slight downward trend in the data is not significant (p= 0.248). On average during this time, the Maumee River annual load to Lake Erie is about 19% of the estimated total annual load from all sources.

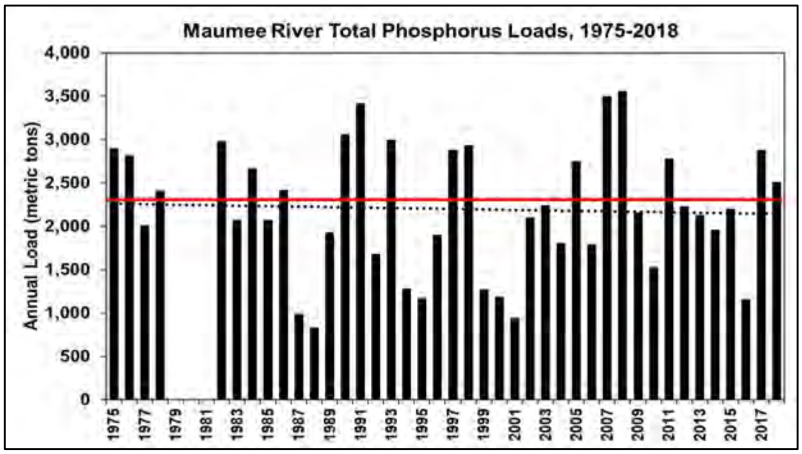


Figure 2. Total phosphorus loads in the Maumee River at Waterville, 1975-2018. The downward trend is not statistically significant. The red line is the Ohio Domestic Action Plan Target of 2287 metric tons annually.

As with the annual TP load, spring loads display a large amount of inter-annual variation, and while the long-term trend is negative, it is not statistically significant (p= 0.137) (Figure 3). When compared to the target spring TP load set by the GLWQA, the Maumee River has exceeded the target in 13 out of 18 years since 2000, with 2011, 2015 and 2017 attaining levels not seen since the early 1980s.

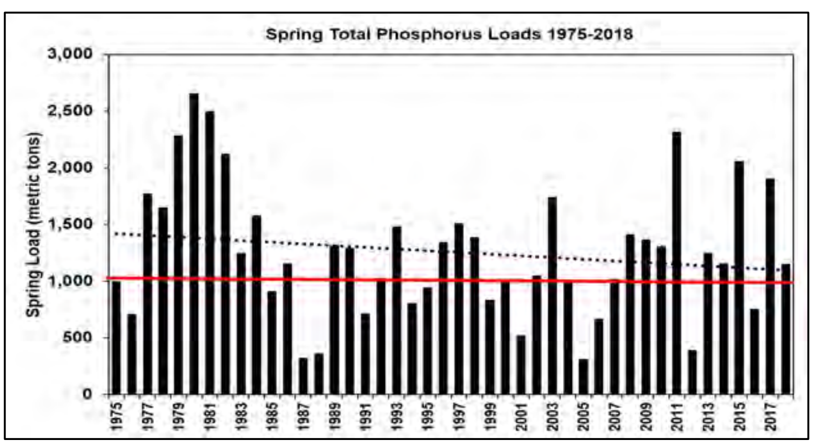


Figure 3. Spring (March 1 to July 31) total phosphorus loads from the Maumee River from 1975-2018 water years. The red line represents the GLWQA spring loading target for TP (860 metric tons).

Dissolved Reactive Phosphorus

Dissolved reactive phosphorus (DRP) is that portion of total phosphorus that is readily available for algal and other plant growth. Typically, about 10-30% of TP in the Maumee is DRP. DRP in the Maumee River decreased from the mid-1970s until the late 1980s and has since seen an increase of more than 200% (Figure 4). The increase in DRP loads to the western basin of Lake Erie from the Maumee River is significant (p=0.0002) and in multiple years has exceeded those recorded in the 1970s.

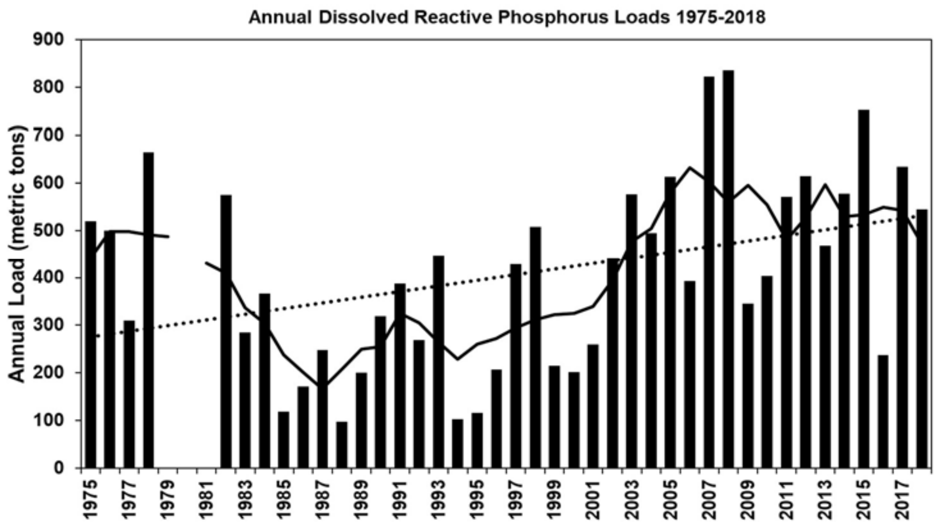


Figure 4. Annual dissolved reactive phosphorus loads in the Maumee River at Waterville, 1975-2018 water years. The positive trend is significant (p<0.001). The solid line is the five-year running average, showing the u-shaped pattern in the data.

The spring DRP loads from the Maumee River show a pattern similar to that of the annual loads, with decreasing loads through the 1980s, and then a steady increase, with levels peaking in 2015, coinciding with the largest harmful algal bloom recorded in Lake Erie (Figure 5). While the long-term (1975-2018) trend is not significant (p=0.313), since 1990, the trend is positive (+271%) and significant (p=0.0016). As with TP, DRP spring loads exceeded the Great Lakes Water Quality Agreement target for the Maumee in most years, particularly since 2000, with 2015 having the highest DRP loads since monitoring began.

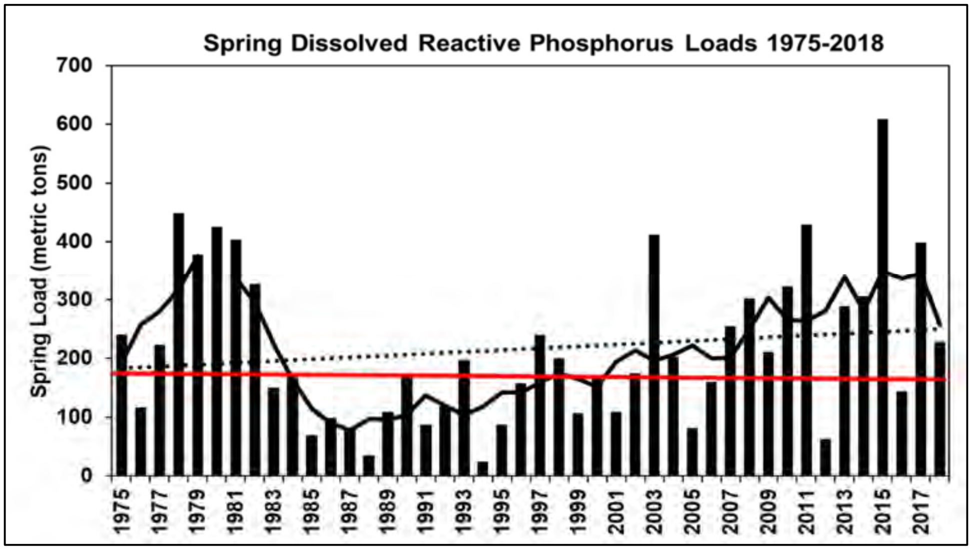


Figure 5. Spring dissolved reactive phosphorus loads from the Maumee River. The solid black line is the five-year running average, showing the u-shaped pattern in the data. The red line represents the Great Lakes Water Quality Agreement spring loading target for DRP (186 metric tons).

Flow-Weighted Mean Concentrations

Total Phosphorus

Although annual and spring phosphorus loads are the measure by which we evaluate success in managing inputs to Lake Erie, important information can also be obtained by examining trends in flow-weighted mean concentrations (FWMCs) of total phosphorus and of other forms of phosphorus. The FWMC is calculated as the load divided by the discharge. Interannual variation is much lower in FWMC because it is not as heavily influenced by changes in discharge, thus making it easier to assess long-term trends especially in very wet or dry periods.

Over the period of record, annual TP FWMCs decreased by 21% (Figure 6), which is a larger decrease than the annual TP loading (Figure 2), but this decrease is also not significant (p=0.161). The spring TP FWMC did significantly decrease (24%, p=0.0003) over the period of record (Figure 7), however, this relationship is driven by the decrease in loads prior to 1990. Since 1990, the relationship is flat, with no significant trend (p=0.271).

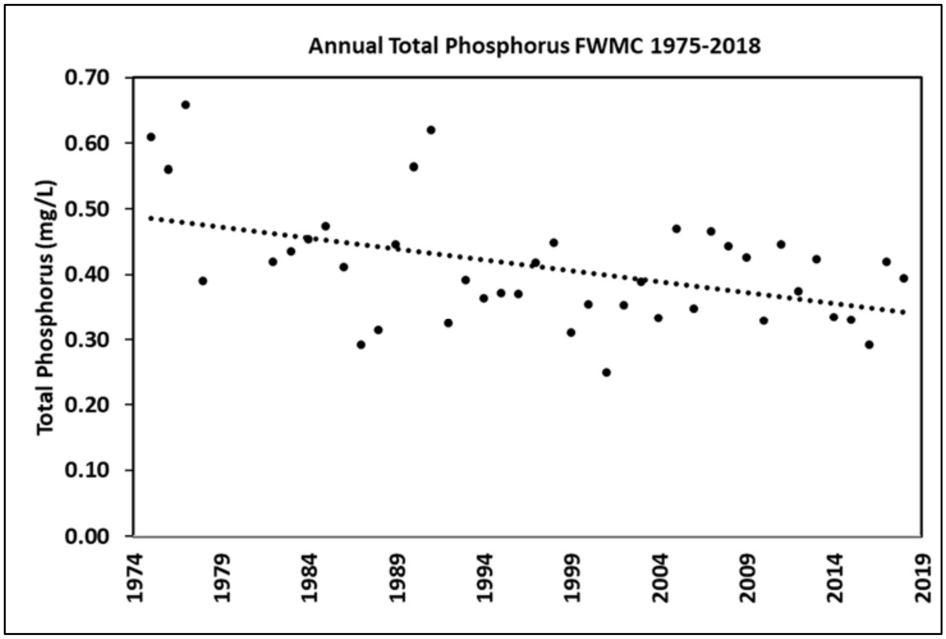


Figure 6. Total phosphorus annual flow-weighted mean concentrations for the Maumee River at Waterville, 1975-2017.

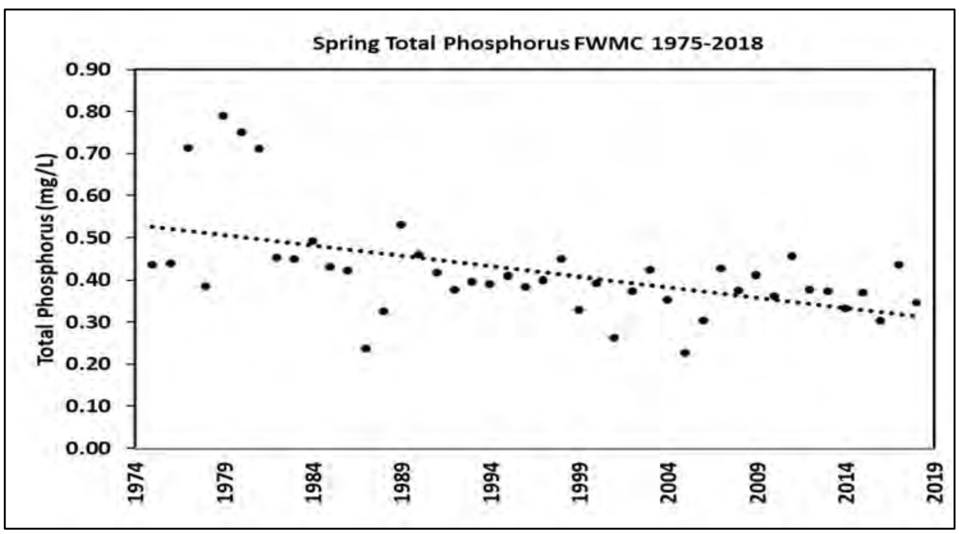


Figure 7. Total phosphorus spring flow-weighted mean concentrations for the Maumee River at Waterville, 1975-2017.

Dissolved Reactive Phosphorus

Annual DRP FWMCs (Figure 8) decreased by 57% between the early 1970s and early 1990s, and then increased 52% between 2000 and 2018. The spring DRP FWMC shows a similar pattern to the annual FWMC, with significant decreases from the 1970s into the mid-1990s, and then an increase to levels similar to the 1970s by the early 2010s (Figure 9). The percentage of TP that is DRP has increased over the last 20 years, with levels regularly exceeding 25%, well above what was seen in the 1970s through the 1990s (Figure 10).

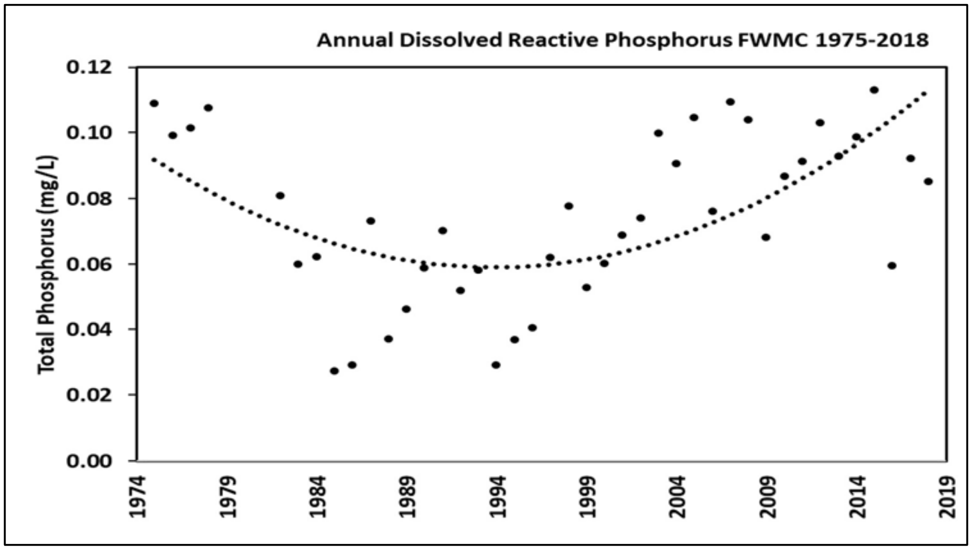


Figure 8. Dissolved reactive phosphorus annual flow weighted mean concentrations for the Maumee River at Waterville, 1975-2018 water years. The parabolic trend is significant (p=0.0021).

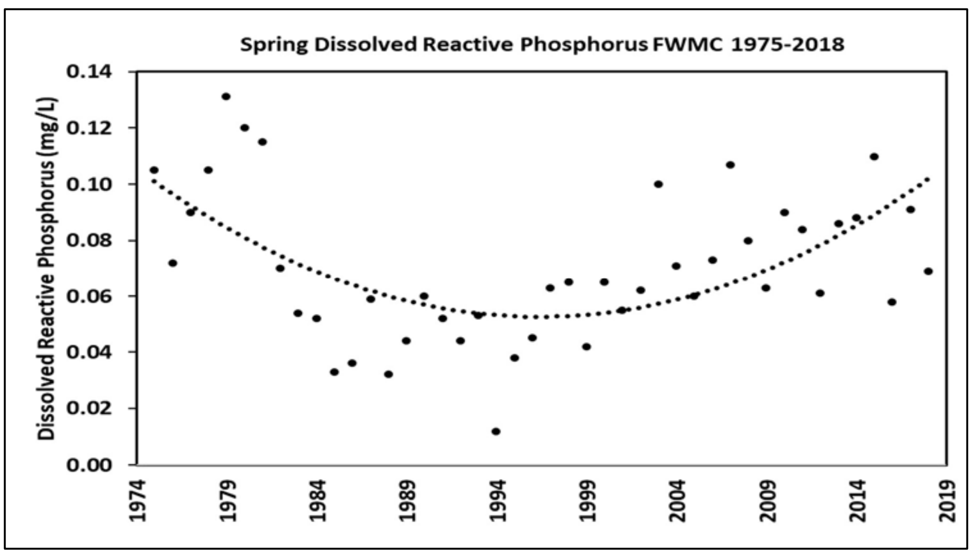


Figure 9. Dissolved reactive phosphorus spring flow weighted mean concentrations for the Maumee River at Waterville, 1975-2018 water years. The parabolic trend is significant (p=0.0117).

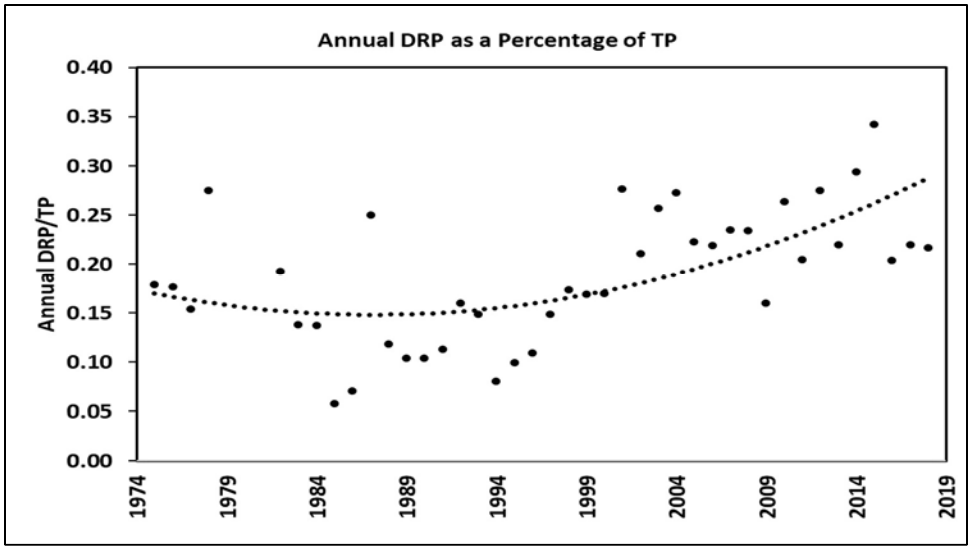


Figure 10. Dissolved reactive phosphorus as a percent of total phosphorus, annual values for the Maumee River at Waterville, 1975-2018. The parabolic trend is significant and represents a decrease of 35% followed by an increase from the minimum of 92%.

Trends in phosphorus loading from the Maumee River are troubling. While TP loads and FWMCs were flat, or decreasing slightly over the long term, they were still often well above the target levels set by the amendments to the Great Lakes Water Quality Agreement and the Ohio Domestic Action Plan. Dissolved reactive phosphorus is of particular concern, as its loads and FWMCs have increased in recent years, and the increases in DRP are linked to increased harmful algal blooms in the western basin and hypoxia in the central basin of Lake Erie. The increasing contribution of nonpoint sources, such as agriculture and urban runoff, are likely driving this increased DRP loading, but the mechanisms behind it are not yet well understood. The current loading targets may need to be amended in the future to account for the increasing bioavailability of phosphorus that enters Lake Erie.

Research/Monitoring Needs

Research is needed to determine the cause or causes of increased dissolved reactive phosphorus in the Lake Erie tributaries, however there are a number of challenges associated with reducing DRP exports from the Maumee watershed. These include (from Baker et al., 2019):

- The large loads of DRP moving from cropland through the Maumee River to the western basin represent the cumulative effects of many small DRP losses at the field scale. As such, these losses are of little economic concern for individual farmers.
- Subsurface drainage via tile systems is an essential component of crop production in much of the Maumee watershed. Recent research has confirmed that these tile systems represent major pathways for DRP export from cropland. Because of their economic benefits to farmers, intensification of these tile

- drainage systems is continuing, resulting in increased water yields from cropland, greater connectivity between cropland and stream systems, and increased DRP runoff.

- Utilization of no-till and reduced till cropping systems offer economic advantages to farmers, as well as erosion control benefits. These systems are often accompanied by increased runoff concentrations and loads of DRP because of a build-up of phosphorus soil test levels in the upper layers of the soil and development of soil macropores, which support preferential flow of water from the surface to tile systems. In part, increased DRP runoff is an unintended consequence of erosion control practices aimed at reducing particulate phosphorus loading.

- Winter cover crops, which are an integral part of the soil health movement and erosion control programs, can increase DRP runoff due to freeze-thaw breakdown of crop residues at the soil surface and related release of DRP.

- Past fertilizer application practices have increased the content of plant-available phosphorus in the soil such that current reserves, even when soil test levels are in the maintenance range, could sustain current crop yields for multiple years without addition of fertilizers. These legacy pools of phosphorus could sustain DRP runoff at current levels well into the future.

- Hydrology is a major driver of phosphorus runoff from cropland, as reflected in the large annual variability in DRP and TP export associated with stream discharge. Annual precipitation and spring discharge have significantly increased between 1966 and 2015. Climate change models predict that this region will see increased storm intensities and frequencies, such that DRP loading will increase, given current management practices.

<u>Future research needs (from Wilson et al., 2019)</u>

Identifying what and where BMPs are likely to be most effective requires a better understanding of:

- The combined influence of soil chemical and microbial activity on phosphorus dynamics. Specifically, how soil quality impacts water holding capacity, P loss, and water infiltration, as well as determining if reductions in P losses from breaking up soil P stratification by inversion tillage are outweighed by the damage to soil quality, specifically losses to water holding capacity, after tillage.

- The relationship between phosphorus stratification and preferential flow through tile drainage, the effectiveness of subsurface application of phosphorus, and how long subsurface application of phosphorus will take to be effective if applied in fields with existing phosphorus stratification.

- The impact of drainage water management on surface and tile flow of water and phosphorus.

- Nitrogen impacts on toxin production, and which practices might accomplish both nitrogen and dissolved phosphorus reductions.

- The spatial distribution and range of soil test phosphorus values, especially locations of fields with elevated phosphorus levels.

- The contribution of colloidal phosphorus to DRP measurements and whether colloidal phosphorus loss is controlled better by erosion mitigating BMPs or nutrient management.

- Clearer understanding of phosphorus cycling and dynamics at a variety of scales, including in-field, edge-of-field, and in-stream.

- The potential for in-stream processes to either contribute or reduce phosphorus (e.g., within the stream bed and from stream bank erosion) and if certain segments within rivers always contribute nutrients at the same rate or if that rate varies by time and/or stream condition (e.g., temperature, flood stage, etc.).

Management Next Steps

While significant efforts to manage the export of phosphorus from the Maumee River have been implemented in the last decade, the mechanisms driving the increasing trend in DRP are not well understood at this time. There is a growing body of evidence however that points to a number of management actions that could contribute to reductions in DRP. The largest reductions in DRP will likely be achieved through agricultural practices, such as:

- Soil test informed applications rates (i.e., following tri-state fertility guidelines and only applying phosphorus that is needed);

- Subsurface placement of fertilizers (e.g., banding, in-furrow with seed) to minimize enrichment of phosphorus in the surface layer of the soil, and especially in no-till agriculture, which reduces soil erosion by keeping crop and plant residues on the surface longer;

- Minimizing the amount of water leaving a field through a variety of practices such as drainage water management and improved soil water holding capacity;

- Improvements in the regulation and management of liquid manures from concentrated animal operations; and

- Application of manure P based on agronomic need using tri-state fertility recommendations.

Though other sources are a minor contribution relative to agricultural nonpoint sources, municipalities can reduce DRP by:

- Continued reductions in sewage treatment plant effluent concentrations to counter human population growth in the basin;

- Improvements in the functioning of home septic systems and small-scale treatment systems and elimination of direct connections of rural home septic systems into agricultural drain tiles and ditches; and

- Improved management of urban nonpoint runoff.

The causes of major changes in nutrient status that have occurred in Lake Erie in recent years are poorly understood, but it is clear that management programs, research, and monitoring must be sustained and closely coupled in order to achieve management goals for the Maumee River and Lake Erie. The collection and interpretation of water quality data, on which we base our current knowledge of phosphorus in the Maumee River and Lake Erie, is a program of the National Center for Water Quality Research and the U.S. Geological Survey (USGS). While this program has continued for many years, it is in constant jeopardy of being cut or eliminated. Without it, estimates of annual and spring phosphorus loads for Lake Erie, the basic yardstick by which we assess success in managing Lake Erie, will not be possible (Dave Dolan, Natural and Applied Sciences at University of Wisconsin-Green Bay, personal communication 2004). This critical program needs to be continued and should be funded on a permanent basis.

References

Bertram, P.E., 1993. Total phosphorus and dissolved oxygen trends in the central basin of Lake Erie, 1970–1991. Journal of Great Lakes Research. 19, 224–236.

Bridgeman, T.B., Chaffin, J.D., Kane, D.D., Conroy, J.D., Panek, S.E. Armenio, P.M., 2012. From River to Lake: Phosphorus partitioning and algal community compositional changes in Western Lake Erie. Journal of Great Lakes Research. 38, 1, 90-97.

Burns, N.M. Rockwell, D.C. Bertram, P.E. Dolan, D.M. Ciborowski, J.J.H., 2005. Trends in temperature, secchi depth, and dissolved oxygen depletion rates in the central basin of Lake Erie, 1983–2002. Journal of Great Lakes Research. 31, Supplement 2, 35–49.

Charlton, M.N. Milne, J.E. Booth, W.G. Chiocchio, F., 1993. Lake Erie offshore in 1990 — restoration and resilience in the central basin. Journal of Great Lakes Research. 19, 291–30.

Choquette, A.F., Hirsch, R.M., Murphy, J.C., Johnson, L.T. Confesor Jr, R.B., 2019. Tracking changes in nutrient delivery to western Lake Erie: Approaches to compensate for variability and trends in streamflow. Journal of Great Lakes Research. 45, 1, 21-39.

DePinto, J.V. Young, T.C.McIlroy, L.M., 1986. Impact of phosphorus control measures on water quality of the Great Lakes. Environmental Science and Technology. 20, 752–759.

Great Lakes Water Quality Agreement, 1978. International Joint Commission, IJC, Great Lakes Water Quality Agreement of 1978 Agreement with Annexes and Terms of Reference, Between the United States of America and Canada. International Joint Commission, Windsor, Ontario, Canada.

Great Lakes Water Quality Agreement, 2016. The United States and Canada adopt phosphorus load reduction targets to combat Lake Erie algal blooms. https://binational. net/2016/02/22/finalptargets-ciblesfinalesdep (accessed 25 Feb 2016).

Jarvie, H.P., Johnson, L.T., Sharpley, A.N., Smith, D.R., Baker, D.B., Bruulsema, T.W. Confesor, R., 2017. Increased soluble phosphorus loads to Lake Erie: Unintended consequences of conservation practices? Journal of Environmental Quality, 46, 1, 123-132.

Ludsin, S.A., Kershner, M.W., Blocksom, K.A., Knight, R.L., Stein, R.A., 2001. Life after death in Lake Erie: nutrient controls drive fish species richness, rehabilitation. Ecological Applications. 11, 731–746.

Makarewicz, J.C. Bertram, P., 1991. Evidence for the restoration of the Lake Erie ecosystem. Bioscience. 41, 216–223.

Michalak, A.M., Anderson, E.J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloğlu, I., DePinto, J.V., 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. Proceedings of the National Academy of Sciences. 110, 16, 6448-6452.

Richards, R.P., 2006. Section 10.10. Trends in sediment and nutrients in major Lake Erie tributaries, 1975-2004. In, Lake Erie Lakewide Management Plan Toronto, Ontario, Canada.

Richards, R.P., Calhoun, F.G., Matisoff, G., 2002a. The Lake Erie Agricultural Systems for Environmental Quality project: An introduction. Journal of Environmental Quality. 31, 6-16.

Richards, R.P., Baker, D.B., Eckert, D.J., 2002b. Trends in agriculture in the LEASEQ watersheds, 1975-1995. Journal of Environmental Quality. 31, 17-24.

Richards, R.P., Baker, D.B., 2002. Trends in water quality in LEASEQ rivers and streams, 1975-1995. Journal of Environmental Quality, 31, 90-96.

Rosa, F., Burns, N.M., 1987. Lake Erie central basin oxygen depletion changes from 1929–1980. Journal of Great Lakes Research. 13, 4, 684-696.

Rucinski, D., Scavia, D., DePinto, J., Beletsky, D., 2014. Lake Erie's hypoxia response to nutrient loads and meteorological variability. Journal of Great Lakes Research. 40, 3, 151-161.

Scavia, D., Allan, J.D., Arend, K.K., Bartell, S., Beletsky, D., Bosch, N.S., Brandt, S.B., Briland, R.D., Daloglu, I., DePinto, J.V., Dolan, D.M., Evans, M.A., Farmer, T.M., Goto, D., Han, H., Hook, T.O., Knight, R., Ludsin, S.A., Mason, D., Michalak, A.M., Richards, R.P., Roberts, J.J., Rucinski, D.K., Rutherford, E., Schab, D.J., Sesterhenn, T.M., Zhang, A., Zhou, Y., 2014. Assessing and addressing the re-eutrophication of Lake Erie: central basin hypoxia. Journal of Great Lakes Research. 40, 2, 226–246.

Stow, C.A., Cha, Y., Johnson, L.T., Confesor, R., Richards, R.P., 2015. Long-term and seasonal trend decomposition of Maumee River nutrient inputs to western Lake Erie. Environmental Science & Technology. 49, 6, 3392-3400.

Stumpf, R.P., Wynne, T.T., Baker, D.B., Fahnenstiel, G.L., 2012. Interannual variability of cyanobacterial blooms in Lake Erie. PLoS One. 7, 8, e42444.

Wilson, R.S., Beetstra, M.A., Reutter, J.M., Hesse, G., Fussell, K.M.D., Johnson, L.T., King, K.W., LaBarge, G.A., Martin, J.F. and Winslow, C., 2019. Commentary: Achieving phosphorus reduction targets for Lake Erie. Journal of Great Lakes Research. 45, 4-11.

Zhou, Y., Obenour, D.R., Scavia, D., Johengen, T.H., Michalak, A.M., 2013. Spatial and temporal trends in Lake Erie hypoxia, 1987–2007. Environmental Science and Technology. 47, 899–905.

This page intentionally left blank.

7.8 Trends in Sediment Contaminant Concentrations in the Huron-Erie Corridor

Casey M. Godwin, University of Michigan, Cooperative Institute for Great Lakes Research, cgodwin@umich.edu

Background

The legacy of anthropogenic pollution in the Laurentian Great Lakes manifests in impaired water quality, degraded habitat, and decreasing wildlife populations. While pollutants can take years or decades to move thorough the water and biota of the lakes (Hites, 2006; Carlson et al., 2010), they can persist even longer in the form of contaminated sediments. The primary classes of contaminants in Great Lakes sediments are organic chemicals produced through industrial activities or heavy metals from both industrial activities and combustion of fossil fuels. Organic contaminants of concern the Laurentian Great Lakes include long-known examples such as DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyl), but also emerging contaminants such as PFAS (poly- and perfluorinated compounds). Heavy metals of widespread concern in sediments include mercury, lead, and cadmium. Both heavy metals and organic contaminants in sediments can be incorporated into the food web, including fish and birds. In response to this legacy of pollution, both the United States and Canada instituted pollution control measures beginning in the 1970s.

Status and Trends

Assessing the effectiveness of pollution control measures for reducing contaminants in Great Lakes sediments is a difficult task: contaminants exhibit both strong spatial variation and slow rates of change. Extensive spatial surveys have been performed in each of the Laurentian Great Lakes and interconnecting channels (Marvin et al., 2002; Mitchell et al., 2018). These surveys are critical for understanding spatial distribution of contaminants, but do not necessarily tell us whether levels of contaminants are increasing or decreasing in response to management actions (see Forsythe et al., 2004; Szalinska et al., 2006; Forsythe and Marvin, 2009). As a result, we lack historical measurements of many contaminants found in surface sediments. In some cases, archived sediment material can be analyzed using modern techniques (Painter et al., 2001; Sverko et al., 2007), but this approach is limited by the availability of that material. A different approach is to examine the concentration of contaminants across the depth of a sediment core. By pairing measurements of contaminant concentration with radiometric estimates of the year in which the sediments were deposited, researchers can reconstruct the history of contaminant concentrations (Soonthornnonda et al., 2011; Yuan et al., 2014; Codling et al., 2018). This approach is technically difficult and has known drawbacks (Codling et al., 2018), but can be useful when archival samples are missing.

Despite reductions in the contaminant discharge and deposition to the basin (Painter et al., 2001; Mohapatra et al., 2007; Li et al., 2018), and local remediation of contaminated sediments (Richman et al., 2017), many contaminants remain elevated (Burniston et al., 2011). This report summarizes the trends in sediment contaminants over time in order to determine whether basin-wide management actions are achieving the desired outcomes. Data summarized herein come from seventeen peer-reviewed publications that measured sediment contaminants at the same locations during multiple years (either through repeated sampling or within a single core). Together, these data comprise 160 different available records of contaminant concentrations through time. The complete dataset is available from the author upon request.

Figure 1 summarizes the trends in contaminant concentrations over time, separated by waterbodies within the corridor. Overall, 126 out of 160 records (79%) showed a decrease in contaminant concentration between the first and final years of available data. Compared to the first year for each record, the concentration of contaminants decreased by a median of 45% by the time of the most recent measurement. The number of records varies dramatically throughout the corridor, but in each case the majority show a reduction in contaminant concentrations from past to present. Some of most dramatic improvements in contaminant concentrations come from the St. Clair River (Richman et al., 2017), where remediation of sediments in the Cole Drain and Dow waterfront areas decreased organic contaminants in suspended sediments by more than 99% between 1995 and 2008.

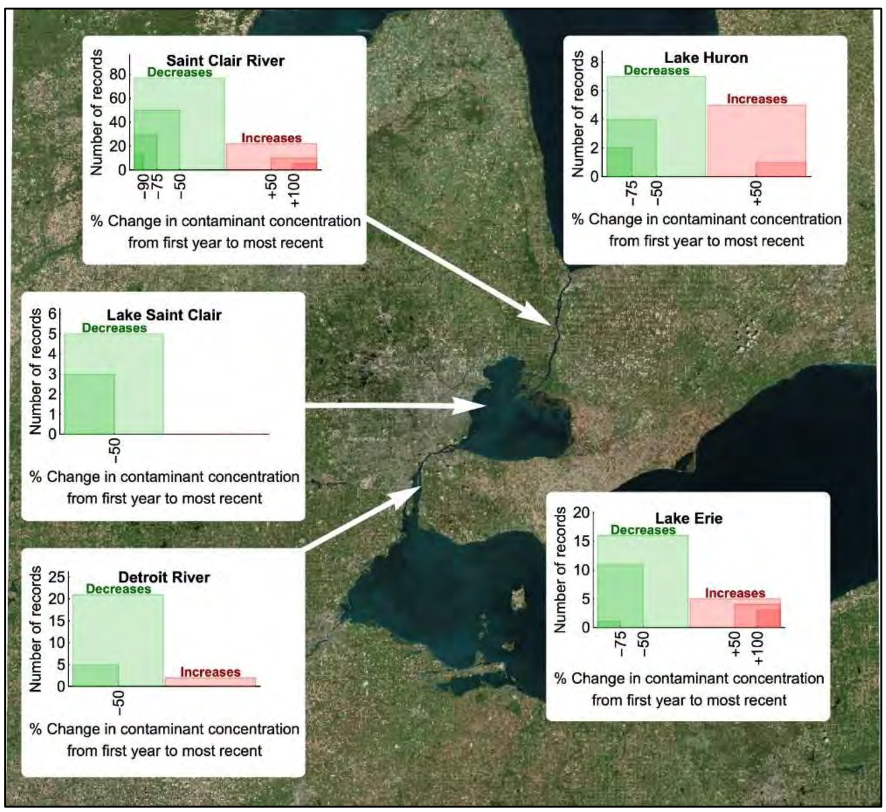


Figure 1. Summary of changes in contaminant concentrations over time within the Huron-Erie corridor. In each panel, the height of the bars represents the number of individual records showing a decrease (green) or increase (red) in contaminant concentration between the first and final years of the study. The darker inset bars depict the number of those records showing an increase or decrease of at least the magnitude displayed on the horizontal axis.

Although Figure 1 indicates that the problem of sediment contamination is improving, there are a substantial number of records where contaminant concentrations have actually increased over time, in some cases by 100% or more (Codling et al., 2018). One particularly concerning example is PFAS in Lake Erie, where concentrations have increased by more than 1000% since the 1970s. This dramatic change is due, in part, the absence of background PFAS prior to industrial production of the chemicals.

Both classes of contaminants (organics and heavy metals) investigated by these studies are more likely to exhibit decreases than increases over time (Figure 2). For heavy metals, these decreases are mostly attributable to reductions in loading (Drevnick et al., 2012; Yuan et al., 2018), resulting in deeper distribution of contaminants in sediments over time. For organic chemicals, the decreases in sediment contaminant concentrations over time are attributable to both decreased loading (Guo et al., 2018) and degradation and advection within the sediments and water (Codling et al., 2018).

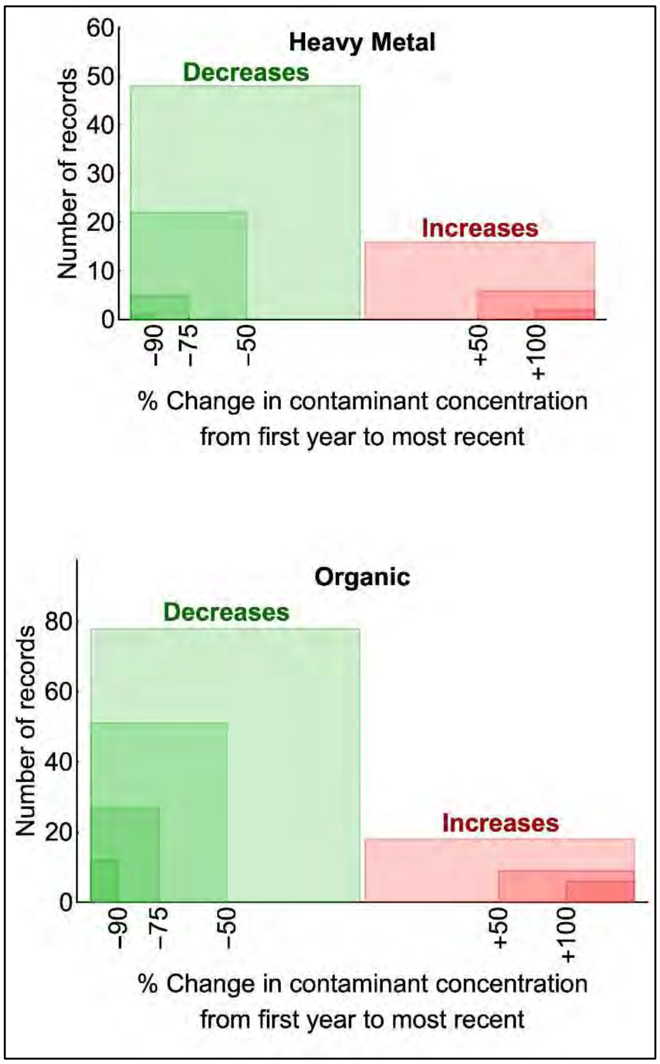


Figure 2. A summary of changes in heavy metal and organic contaminant concentrations over time within the Huron-Erie corridor.

While the overall trends are encouraging, there are two important cautions for interpreting the findings from this synthesis. The first is that trends in sediment concentrations are not always linear through time. Indeed, many records show dramatic intra- and interannual variation, particularly when analyzing the strata from a single core (Yuan et al., 2014; Codling et al., 2018). The implication of this caveat is that short-term records or those with few timepoints may show patterns that are not representative. The second caution for interpreting these trends is that some contaminants may show dramatic changes over time but remain at levels that are not considered hazardous to human or wildlife. Some of the studies summarized here directly compare their findings to contaminant standards and regulations (Painter et al., 2001), a necessary step to link these trends to management actions.

References (Including those in dataset)

Burniston, D., Klawunn, P., Backus, S., Hill, B., Dove, A., Waltho, J., Richardson, V., Struger, J., Bradley, L., McGoldrick, D., Marvin, C., 2011. Spatial distributions and temporal trends in pollutants in the Great Lakes 1968–2008. Water Quality Research Journal 46, 269-289.

Carlson, D.L., DeVault, D.S., Swackhamer, D.L., 2010. On the rate of decline of persistent organic contaminants in lake trout (*Salvelinus namaycush*) from the Great Lakes, 1970-2003. Environmental Science & Technology 44, 2004-2010.

Codling, G., Sturchio, N.C., Rockne, K.J., Li, A., Peng, H., Tse, T.J., Jones, P.D., Giesy, J.P., 2018. Spatial and temporal trends in poly- and per-fluorinated compounds in the Laurentian Great Lakes Erie, Ontario and St. Clair. Environ. Pollut. 237, 396-405.

Drevnick, P.E., Engstrom, D.R., Driscoll, C.T., Swain, E.B., Balogh, S.J., Kamman, N.C., Long, D.T., Muir, D.G., Parsons, M.J., Rolfhus, K.R., Rossmann, K. R., 2012. Spatial and temporal patterns of mercury accumulation in lacustrine sediments across the Laurentian Great Lakes region. Environ. Pollut. 161, 252-260.

Forsythe, K.W., Dennis, M., Marvin, C.H., 2004. Comparison of mercury and lead sediment concentrations in Lake Ontario (1968-1998) and Lake Erie (1971–1997/98) using a GIS-based Kriging Approach. Water Quality Research Journal 39, 190-206.

Forsythe, K.W., Marvin, C.H., 2009. Assessing historical versus contemporary mercury and lead contamination in Lake Huron sediments. Aquatic Ecosystem Health & Management 12, 101-109.

Forsythe, K., Marvin, C., Valancius, C., Watt, J., Aversa, J., Swales, S., Jakubek, D., Shaker, R., 2016. Geovisualization of mercury contamination in Lake St. Clair sediments. Journal of Marine Science and Engineering 4, 19-29.

Frank, R., Holdrinet, M., Braun, H., Thomas, R., Kemp, A., Jaquet, J.-M., 1977. Organochlorine insecticides and pcbs in sediments of Lake St. Clair (1970 and 1974) and Lake Erie (1971). Science of the Total Environment 8, 205-227.

Gewurtz, S. B., Helm, P. A., Waltho, J., Stern, G. A., Reiner, E. J., Painter, S., Marvin, C.H., 2007. Spatial distributions and temporal trends in sediment contamination in Lake St. Clair. Journal of Great Lakes Research 33, 3, 668-685.

Gewurtz, S. B., Shen, L., Helm, P. A., Waltho, J., Reiner, E. J., Painter, S., Brindle, I.D., Marvin, C.H., 2008. Spatial distributions of legacy contaminants in sediments of Lakes Huron and Superior. Journal of Great Lakes Research 34, 153-168.

Guo, J., Salamova, A., Venier, M., Dryfhout-Clark, H., Alexandrou, N., Backus, S., Bradley, L., Hung, H., Hites, R.A., 2018. Atmospheric flows of semi-volatile organic pollutants to the Great Lakes estimated by the United States' integrated atmospheric deposition and Canada's Great Lakes basin monitoring and surveillance networks. Journal of Great Lakes Research 44, 670-681.

Hites, R. A., 2006. Persistent organic pollutants in the Great Lakes: an overview. Handbook of Environmental Chemistry, Persistent Organic Pollutants in the Great Lakes 5, 1-12.

Jia, J., Thiessen, L., Schachtschneider, J., Waltho, J., Marvin, C., 2010. Contaminant trends in suspended sediments in the Detroit River-Lake St. Clair-St. Clair River corridor, 2000 to 2004. Water Quality Research Journal 45, 69-80.

Li, A., Guo, J., Li, Z., Lin, T., Zhou, S., He, H., Ranansinghe, P., Sturchio, N.C., Rockne, K.J., Giesy, J.P., 2018. Legacy polychlorinated organic pollutants in the sediment of the Great Lakes. Journal of Great Lakes Research 44, 682-692.

Marvin, C.H., Charlton, M.N., Reiner, E.J., Kolic, T., MacPherson, K., Stern, G.A., Braekevelt, E., Estenik, J., Thiessen, L., Painter, S., 2002. Surficial sediment contamination in Lakes Erie and Ontario: A comparative analysis. Journal of Great Lakes Research 28, 437-450.

Marvin, C.H., Sverko, E., Charlton, M.N., Thiessen, P.L., Painter, S., 2004. Contaminants associated with suspended sediments in Lakes Erie and Ontario, 1997-2000. Journal of Great Lakes Research 30, 277-286.

Marvin, C., Waltho, J., Jia, J., Burniston, D., 2013. Spatial distributions and temporal trends in polybrominated diphenyl ethers in Detroit River suspended sediments. Chemosphere 91, 778-783.

Mitchell, D.E., Forsythe, K.W., Marvin, C.H., Burniston, D.A., 2018. Assessing statistical and spatial validity of sediment survey design and sampling densities: examples from Lake Erie. Water Quality Research Journal 53, 118-132.

Mohapatra, S.P., Nikolova, I., Mitchell, A., 2007. Managing mercury in the Great Lakes: an analytical review of abatement policies. J. Environ. Manage. 83, 80-92.

Painter, S., Marvin, C., Rosa, F., Reynoldson, T.B., Charlton, M.N., Fox, M., Thiessen, P.L., Estenik, J.F., 2001. Sediment contamination in Lake Erie: A 25-year retrospective analysis. Journal of Great Lakes Research 27, 434-448.

Richman, L., Milani, D., Marvin, C., 2017. Trends in suspended sediment quality in the upper St. Clair River: Assessment of large-scale remediation of contaminated sediments in a dynamic riverine environment. Aquatic Ecosystem Health & Management 21, 93-106.

Richman, L., Milani, D., 2010. Temporal trends in near-shore sediment contaminant concentrations in the St. Clair river and potential long-term implications for fish tissue concentrations. Journal of Great Lakes Research 36, 722-735.

Soonthornnonda, P., Zou, Y., Christensen, E.R., Li. A., 2011. PCBs in Great Lakes sediments, determined by positive matrix factorization. Journal of Great Lakes Research 37, 54-63.

Sverko, E., Tomy, G.T., Marvin, C.H., Zaruk, D., Reiner, E., Helm, P.A., Hill, B., McCarry, B.E., 2007. Dechlorane plus levels in sediment of the lower Great Lakes. Environmental Science & Technology 42, 361-366.

Szalinska, E., Drouillard, K. G., Fryer, B., Haffner, G. D., 2006. Distribution of heavy metals in sediments of the Detroit River. Journal of Great Lakes Research 32, 442-454.

Yuan, F., Depew, R., Soltis-Muth, C., 2014. Ecosystem regime change inferred from the distribution of trace metals in Lake Erie sediments. Scientific Reports 4, 7265.

Yuan, F., Chaffin, J. D., Xue, B., Wattrus, N., Zhu, Y., Sun, Y., 2018. Contrasting sources and mobility of trace metals in recent sediments of western Lake Erie. Journal of Great Lakes Research 44, 1026-1034.

7.9 Transportation in Southeast Michigan

Background

Southeast Michigan's transportation system – with more than 40,000 km (25,000 miles) of roads – supports more than 160 million km (100 million miles) of travel each day and provides the foundation upon which communities and the economy depend. This complex system of highways, transit, rail, ports, trails, and airports knit the region together, connecting people to jobs, businesses, services, and amenities. The multimodal transportation network also distributes freight to stores and industry, expanding the region's economic reach to markets throughout the country and the world. Creating a transportation system with robust travel options gives residents with different needs access to jobs, education, health care, recreation and social opportunities, and other core services. A coordinated and efficient transportation system is a necessary element to a healthy and thriving Southeast Michigan region (SEMCOG, 2019).

Southeast Michigan's Transportation System: By the Numbers

- 160 million – Kilometers that people travel each day on Southeast Michigan roads
- 40,000 – Kilometers of public roads in Southeast Michigan
- 6,400 – Kilometers of all-season truck routes in the region
- 2,900+ – Bridges in the region
- 3,680+ – Kilometers of fixed-route bus service in Southeast Michigan
- 52+ million – Annual transit ridership in 2016
- 47% – Percentage of U.S.-Canada border trade that crosses through Southeast Michigan ports of entry
- $600 million – Value of goods crossing Southeast Michigan ports of entry per day
- $94 million – Value of freight moved in and out of Southeast Michigan annually via rail
- $18 billion – Value of goods shipped each year via air cargo in Southeast Michigan

- 163.3 million – Tonnes of freight moved in, out, and through Southeast Michigan annually
- 4,800+ – Kilometers of bikeways, walkways, and routes in Southeast Michigan
- 56,655 – Hectares of parkland in Southeast Michigan, 80% of which is in large regional parks greater than 80 ha
- 33% – Percentage of tree canopy in Southeast Michigan
- 137,600+ – Hectares of wetlands in Southeast Michigan, 30% of historical wetland coverage
- 17.9 million – Annual total vehicle hours delay for freeway congestion
- 74% – Percentage of Southeast Michigan resident who are dissatisfied with the condition of roads and bridges
- 34 million – Domestic and international travelers at Detroit Metropolitan Airport in 2017; 19th busiest in North America.
- 8 – International border crossings in the region
- 7 – Commercial marine ports in the region
- 6 – Rail/truck intermodal terminals in the region

Status and Trends

Existing Conditions and Challenges

Vital components of the transportation system, including bicycle and pedestrian travel, conditions of bridges and pavement, congestion, environmental considerations, freight, intercity transportation, safety and security, tourism, public transit, and travel demand management, all work together to create a comprehensive transportation system.

Bicycle and Pedestrian

Every trip likely begins or ends with walking or biking. Communities see bicycle and pedestrian facilities as quality-of-life enhancements for residents. In addition to recreational benefits, Southeast Michigan's bicycle and pedestrian network:

- Provides residents transportation choices,
- Enhances accessibility of the region's transit system,
- Decreases fossil fuel consumption,
- Contributes to the economic vitality of downtowns, and
- Empowers those who cannot operate private automobiles.

Much has been accomplished recently in Southeast Michigan. New pedestrian and bicycle facilities across the region fill in gaps in the trail network and provide safer travel experiences. Since 2013, 110 projects have been funded through the Transportation Alternative Program (TAP) for walking and biking facilities, streetscapes, and Safe Routes to School projects:

- 174 km of shared-lane markings
- 168 km of local bike routes
- 91 km of shared-use paths
- 75 km of conventional bike lanes
- 38 km of protected bike lanes

Increased bicycle and pedestrian travel helps foster and improve:

- Healthy and active communities
- Economic development and placemaking
- State and national recreational trails and bike routes
- The number and use of local facilities
- More options for short daily trips

Existing challenges related to biking and walking travel in Southeast Michigan include gaps in the system, maintenance and operation, and safety.

Bridges

An essential component of Southeast Michigan's transportation system, the more than 2,900 bridges in the region cross over rivers, streams, railroads, and other roadways. Bridges are longer lasting and more expensive per square foot than typical roadways.

Bridges pose specific challenges to the region's transportation system:

- Maintenance costs: Maintenance and rehabilitation are vitally important, as replacement costs are many times more costly. Regular capital preventative maintenance is important to keep past investments in good shape. Bridges must also be barricade-free for police, fire, EMS, and other public services. Safety and the economy can be impacted when bridges deteriorate to the point of requiring weight restrictions or permanent closure.

- Access: Bridges are essential for creating continuous networks for pedestrian and bicycle travel. A bridge with inadequate pedestrian, bicycle, or Americans with Disabilities features cannot be easily modified.

- Climate resiliency: Understanding and planning for the impacts of extreme weather events on bridges is important for current and future infrastructure projects.

- Economic development: Bridges with clearance or weight restrictions can significantly impact the movement of freight and goods. Information on a bridge's status (i.e., open, closed, detour routes, and travel times) should be readily available to ensure that freight and truck travel through the network with minimal impediments.

Congestion

Managing road congestion in Southeast Michigan can positively impact safety and security, efficient and reliable operations, quality of life, and economic development. Alleviating congestion allows users to travel with fewer delays and restrictions. It opens access for employers to a broader regional labor pool and enables just-in-time shipments to ensure goods can move into, though, and out of the region efficiently.

In order to reduce congestion, technology is increasingly important:

- Use of web and mobile applications to plan routes prior to making trips or to make adjustments in real-time.

- Use of sophisticated traffic signal and camera systems that enable signal timing to automatically adjust during peak periods to accommodate heavier traffic operations. Cameras can be centrally monitored, and signals adjusted to ease bottlenecks.

- Connected and automated vehicles will change traffic patterns and may lower congestion on Southeast Michigan roads in the future.

Challenges related to congestion:

- With more people working and moving around, use of the transportation system continues to increase, as does the number of congested locations along the freeway system.

- Incidents on freeways increase the amount of time freeways are congested.

- There is not enough funding to implement strategies to relieve congestion in Southeast Michigan.

Environment

Southeast Michigan's transportation system plays a significant role in the region's air quality, water, and natural resources. Air quality is primarily affected by passenger cars, large trucks, trains, and ships, plus point sources from local industry. Transportation can affect water and natural resources by generating stormwater runoff, changing wetland and woodland dynamics, disrupting the movement of water and wildlife, and impacting local habitat conditions. At the same time, weather events such as severe storms, freeze-thaw cycles, and extreme heat wreak havoc the region's aging infrastructure.

Improving air, water, and natural resources requires an integrated planning approach. Southeast Michigan's dense transportation network and the millions of people and vehicles that travel in the region every day have a sustained impact on its physical landscape.

Some important transportation trends and challenges related to the environment:

- Incorporating planning for the environment into transportation projects.
- Changing precipitation events and high amounts of impervious surfaces can result in degraded water resources, localized flooding, overtaxed infrastructure, and property damage.
- Recognizing that other infrastructure – underground drinking water, wastewater and stormwater systems, in addition to numerous private utilities – are found in right-of-way corridors. Developing water asset management programs that align with transportation asset management programs will achieve the greatest value for investment while protecting environmental and public health.
- Natural resources – wetlands, woodlands, riparian corridors, and agricultural land – help reduce stormwater runoff, flooding, and erosion; replenish groundwater; and stabilize streamflow.
- Promoting pedestrian and bicycle travel, ridesharing, telecommuting, and use of public transit reduces transportation-related emissions.

Freight Travel

The freight transportation system enables Southeast Michigan industry to resource raw materials, ship products to connections throughout the world, and distribute goods within the region. Each component of the freight system – trucks, water, air, rail – plays a crucial role in delivering goods on-time with minimal cost per unit. As Southeast Michigan's economy changes and new technologies impact how goods are shipped and delivered, the freight transportation system must also adapt to serve this new economic make-up, retain efficient access to national and world markets, reduce impacts on the environment, and minimize the cost of goods.

Challenges related to freight travel:

- Any disruptions in operating the region's international bridges and tunnels has significant implications for Southeast Michigan, the U.S., and Canada. Construction of the Gordie Howe International Bridge and modernization of the Blue Water Bridge U.S. customs plaza are major steps in addressing redundancy and reliability.
- Reducing congestion and increasing the reliability and speed of highways helps business increase competitiveness and decrease costs to consumers.
- Labor shortages could impact freight movement as truck drivers retire and fewer people choose driving trucks as a career. Trucking companies are investing in advanced technologies to expand automated capabilities of truck

driving and experimenting with truck platooning and other operations. These strategies will reduce the number of people needed to drive trucks in the future.

- Infrastructure condition impacts freight traveling via truck. Maintaining the quality of freeway pavement, while restoring the growing number of arterials and local roads that connect to freight destinations is an ongoing challenge that requires planning, coordination, and a sustained increase in resources devoted to road construction.

Intercity Transportation

Travel options between cities – usually on a fixed route and schedule via air, bus, and rail – offer passengers, businesses, and leisure travelers' alternative choices to driving.

Challenges continue to focus on access, reducing the gaps in the system, and a lack of dedicated funding. The lack of north/south rail service between Southeast Michigan and Toledo reduces rail-service options for east coast and southern state destinations. The lack of connection between Southeast Michigan and Canada also imposes international access issues and impacts opportunity for economic activity. While there have been recent improvements, such as public transportation to and from Detroit Metropolitan Airport, there are still challenges to connecting people to the places they need to go around the region.

Pavement

Pavement is a foundational element of Southeast Michigan's transportation system. All road users – car, bus, bicycle, and freight haulers – need quality pavement for a safe, predictable trip. Extending pavement life depends on consistent monitoring and fixes that are appropriate to the age and condition of the pavement.

SEMCOG collects pavement condition data using the Pavement Surface Evaluation and Rating (PASER) system on federal-aid-eligible roads. This results in an annual pavement condition rating of good, fair, or poor. These data are used to create asset management plans that match the condition of the roadway with appropriate fixes.

The percent of roads in Southeast Michigan that are rated poor is increasing. An additional $1.2 billion needs to be invested in the region for the next 25 years to bring roads back to 80 percent good or fair. It will take an additional $600 million per year over that time period to get roads to 90 percent good or fair.

As a cold-weather state, changing precipitation patterns, freeze/thaw cycles, and extreme heat contribute to the challenges of improving pavement condition across the region. Increased costs for winter road maintenance further impact funding.

Safety

Arriving safe is the most important result of any trip. Between 2002 and 2016, more than $220 million was invested in traffic safety improvement projects in Southeast Michigan. SEMCOG seeks to improve safety for all road users by applying a comprehensive and coordinated approach that follows the Four Es of Traffic Safety

– Engineering, Education, Enforcement, and Emergency Services.

Primary challenges related to safety:

- Biking and walking are increasingly popular travel modes for shorter trips. Pedestrians and bicyclists involved in traffic crashes are especially vulnerable to serious injury and death. New facilities need to provide safe walking and biking travel to people regardless of ability. Safe travel practices and increasing awareness of the rules of the road for all travelers should be addressed by law enforcement.

- Distractions while driving, biking, and walking are exacerbated by smart phones and other electronic devices. Traffic safety education should focus on reducing distractions.

- Lane departure crashes have increased fatality rates because they frequently result in high-speed and head-on collisions. Low-cost engineering countermeasures can be implemented on many roads to reduce lane departures.

Security

Transportation security planning focuses on preparing for those rare events that have acute, unpredictable, and disruptive effects, threatening nearby lives, property, and environmental quality. These events can range widely, from severe weather, to armed or explosive attacks, to infrastructure or utility failure, to a sports championship parade. These events can affect a small area or the entire region. As such, transportation systems are crucial, allowing people to move to safety, providing clear paths for emergency response, and enabling the affected area to receive the goods and equipment needed for recovery.

Security planning involves professionals from a wide range of fields working together. Emergency management staff organize preparation, response, and recovery activities. Intelligent Transportation System (ITS) planners prioritize investments in responsive traffic signals. Transportation engineers design resilient facilities. Transportation operations' staff communicate road and transit system conditions. Emergency response personnel stand ready to respond, while local planners include emergency response considerations in master plans and site design.

Examples of security approaches related to the transportation system:

- Preparedness – Updated emergency management and response plans help communities prepare for all aspects of low-frequency, high-risk events. Training for responders and operations coordinators is encouraged.

- Response – Fast communications between all entities responsible for traffic safety operations is crucial. Greater support is needed for efficient, coordinated responses through incident management task forces.

- Recovery – Being able to quickly return to normal transportation operating conditions helps all aspects of recovering from a major event. Greater use of technology is needed to help communities implement emergency response plans.

Tourism

Travel related to tourism and recreation is an important function of Southeast Michigan's transportation system. These attractions can generate travel demand, impact traffic congestion and air quality, and play a significant role in the region's economy. Coordinating efforts among tourism, recreation, and transportation planning agencies can help enhance access and mobility.

Tourism attractions in the region range from urban centers with theaters, sports arenas, and museums, to rural areas with wildlife preserves and U-pick farms and orchards. In addition, parks, beaches, commercially active downtowns and historic main streets attract tourists and residents.

Collaboration and cooperation between tourism and recreation venues is important to the success of tourist attractions, destinations, and the region. It is also important that multiple modes are available to access these destinations.

Transit

Transit provides transportation options needed for people to reach jobs, education, health care, and other essential services. A properly designed and implemented transit system will improve regional access and Southeast Michigan's ability to compete with other regions for business, industry, and tourism.

To achieve such a system, transit service must be frequent, reliable, and coordinated across providers. A vibrant transit system must also include rapid transit corridors crossing multiple service areas that are supported by integrated feeder bus service and demand responsive service to accommodate those with special needs, including the elderly. Given the current funding, transit agencies are challenged to provide sufficient core bus service.

Transit providers have made progress on increasing service hours, frequency, reliability, and quality. They have modernized equipment, expanded services, and have taken coordination to unprecedented levels. Despite this progress, funding limitations remain a significant challenge to improving transit. Support for transit in Southeast Michigan lags behind almost every other region of similar size and economy. Another major barrier to more frequent and reliable service is that large parts of the region are allowed to opt-out of funding transit. Southeast Michigan spent about $270 million in transit services in 2016, or $67 per capita. Figure 1 shows how Southeast Michigan's per capita transit expenditures compares with other regions.

Travel Demand Management Next Steps

Travel Demand Management (TDM)

TDM seeks to increase efficiency in the transportation system by reducing the need for high-cost capacity projects through these strategies (SEMCOG, 2019):

- Carpooling and vanpooling – reducing the number of single-occupant vehicle trips

- Encouraging transit use – reducing the number of single-occupant vehicle trips
- Variable work hours – reducing the need to travel during peak hours when roads are congested
- Telecommuting – reducing the need to travel to work

These strategies increase awareness of alternative commute travel options and provide incentives and information to encourage and help individuals modify their travel behavior. A comprehensive set of TDM strategies can reduce congestion and improve air quality.

Changing from a solo commute, even for just one day a week, has these additional benefits:

- Saving money
- Reducing stress
- Cutting carbon emissions
- Staying healthy by walking, biking, or taking transit
- Regaining valuable time by letting someone else drive either in a car/vanpool or on a bus

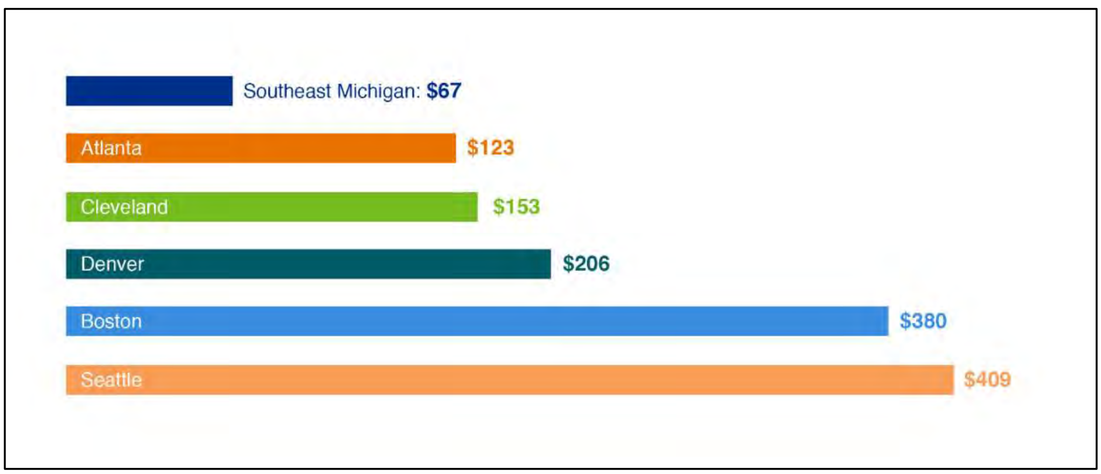


Figure 1. A comparison of per capita expenditures on transit services in southeast Michigan with selected other urban areas in the United States.

Additional information can be found at SEMCOG.org/RTP.

References

Southeast Michigan Council of Governments (SEMCOG), 2019. 2045 Regional Transportation Plan for Southeast Michigan. Detroit, Michigan, USA.

This page intentionally left blank.

7.10 Wayne County's Carbon Emissions

Professor Volker Sick, Global CO2 Initiative, University of Michigan, Mechanical Engineering, vsick@umich.edu

Gwen Gell, University of Michigan, Urban and Regional Planning, ggell@umich.edu

Background

Water vapor, carbon dioxide, and other gases in the Earth's atmosphere trap some of the sun's heat close to the surface, creating a natural "greenhouse" that permits life to flourish. Without these gases the Earth would be too cold for life to survive. In the last 60 years, however, human activities have increased the concentration of these greenhouse gases in the atmosphere, trapping more of the sun's heat close to the Earth's surface. The heat-trapping properties of carbon dioxide, methane, nitrous oxide, water vapor, and other greenhouse gases in the Earth's atmosphere is undeniable, but uncertainty remains as to precisely how the Earth's climate will respond to increased levels of greenhouse gases (GHG) from human activities. These activities include the burning of fossil fuels to run cars and trucks, heat homes and businesses, power factories, and to run equipment for agriculture, logging, and mining.

Evidence continues to build that accelerated warming of the Earth's surface temperature has occurred and that this shift is attributed to human activities that have increased the levels of greenhouse gases. Since pre-industrial times, atmospheric concentrations of carbon dioxide have increased by 43%, while atmospheric levels of other greenhouse gases such as methane have nearly doubled, and atmospheric levels of nitrous oxide have increased by 18% (U.S. Environmental Protection Agency, 2017). These increases in levels of GHGs have enhanced the heat-trapping capability of the Earth's atmosphere.

Since the recent shift in national climate change policy, specifically federal leadership backing out of the Paris Climate Accord and undermining long-standing environmental legislation, smaller government agencies have independently promised to stay the course to reduce GHG emissions. The State of Michigan is continuing to make strides towards its goal, set in 2009, to reduce carbon emissions 20% below 2005 levels by 2020 and 80% below 2005 by 2050 (Center for Climate and Energy Solutions, 2019). The City of Detroit, under the leadership of Mayor Mike Duggan, has committed to continue city-wide efforts towards reaching climate change goals established at the Paris Climate Accord (City of Detroit, 2019).

Status and Trends

Human activities over the last century (primarily the burning of fossil fuels) have changed the composition of the atmosphere in ways that threaten to dramatically alter the climate in years to come. As of 2016, the United States has slightly curbed emissions. Had the country continued to emit carbon at the 2005 rate (6 billion tonnes CO_2) it is estimated there would be an 18% increase in today's carbon emission levels. In fact, the U.S. is currently emitting 5.2 billion tonnes CO_2, about 14% less than in 2005 (Carbon Brief, 2019). There are many reasons for this slight reduction in trends including:

- Shifting the type of energy production from coal to gas
- Shifts to renewable energy production
- Reduced fuel consumption
- Changes in transportation trends (fewer miles per capita, more efficient vehicles, less air travel emissions)
- The 2008 financial crisis with associated reduction in manufacturing, etc.

Despite the decline in CO_2, the U.S. is the world second largest contributor of carbon dioxide emissions – the primary greenhouse gas (Oakridge National Laboratory, 2015). Figure 1 presents greenhouse gas emissions by sector in the United States in 2014. Overall, the United States' greenhouse gas emissions are largely the result of energy production (World Resources Institute, 2018).

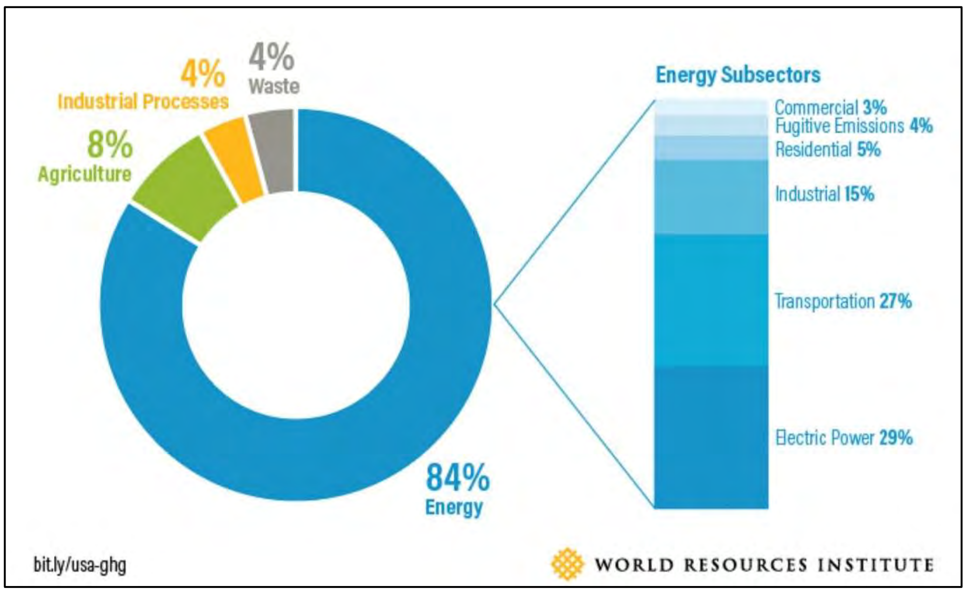


Figure 1. Greenhouse gas emissions by sector in the United States, 2014 (World Resources Institute, 2018).

Michigan is one of the top 10 CO_2 emitting states in the United States at 2.86% of total U.S. emissions, with nearly two-thirds of all Michigan emissions the result of electric power and transportation (World Resources Institute, 2018).

The United States has used a variety of agencies to collect carbon emission data. In 2000, the U.S. Energy Administration began to examine carbon emissions from energy use by state. The agency published data through 2016. Overall, Michigan's carbon emissions have declined by over 40 million tonnes since 2000 (Figure 2). This decrease reflects the shifts in types of energy conversion processes, energy usage, and energy efficiency (U.S. Energy Information Administration, 2019). However, in

2013 there was a spike in emissions, a trend which is confirmed in data collected by the U.S. Environmental Protection Agency for Wayne County (U.S. Energy Information Administration, 2019).

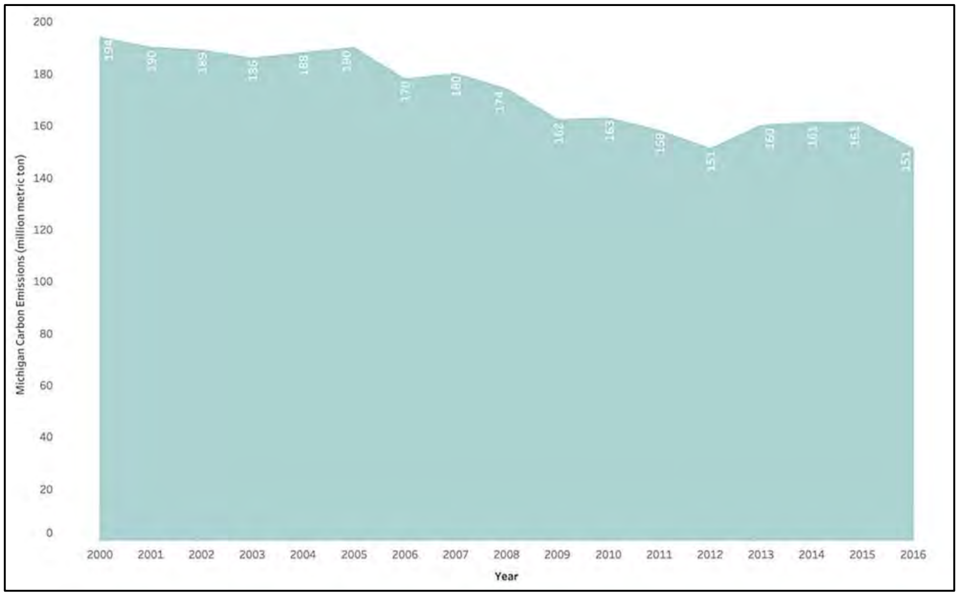


Figure 2. Michigan's carbon emissions, 2000-2016 (U.S. Energy Information Administration, 2019).

In 2009, the U.S. Environmental Protection Agency implemented a regulation requiring the reporting of greenhouse gas emissions from sources which emit 25,000 tonnes of carbon dioxide or more per year in the United States. As a result, data have been compiled from these self-reporting facilities. While this reporting captures specific sources of fossil fuel emissions, it does not capture all large sources of carbon dioxide emissions, such as transportation. Because each facility is geographically pinpointed, it is possible to break down emissions by county.

Wayne County Carbon Dioxide Emission Trends

Since 2011, direct emissions of carbon dioxide, excluding the transportation sector, have been reported to the U.S. Environmental Protection Agency. Figure 3 presents these trends showing that Wayne County carbon dioxide emissions have declined from 18 million tonnes or more in 2011-2013 to slightly more than 15 million tonnes in 2017, representing an over three million tonne reduction over this time period (U.S. Environmental Protection Agency, 2019).

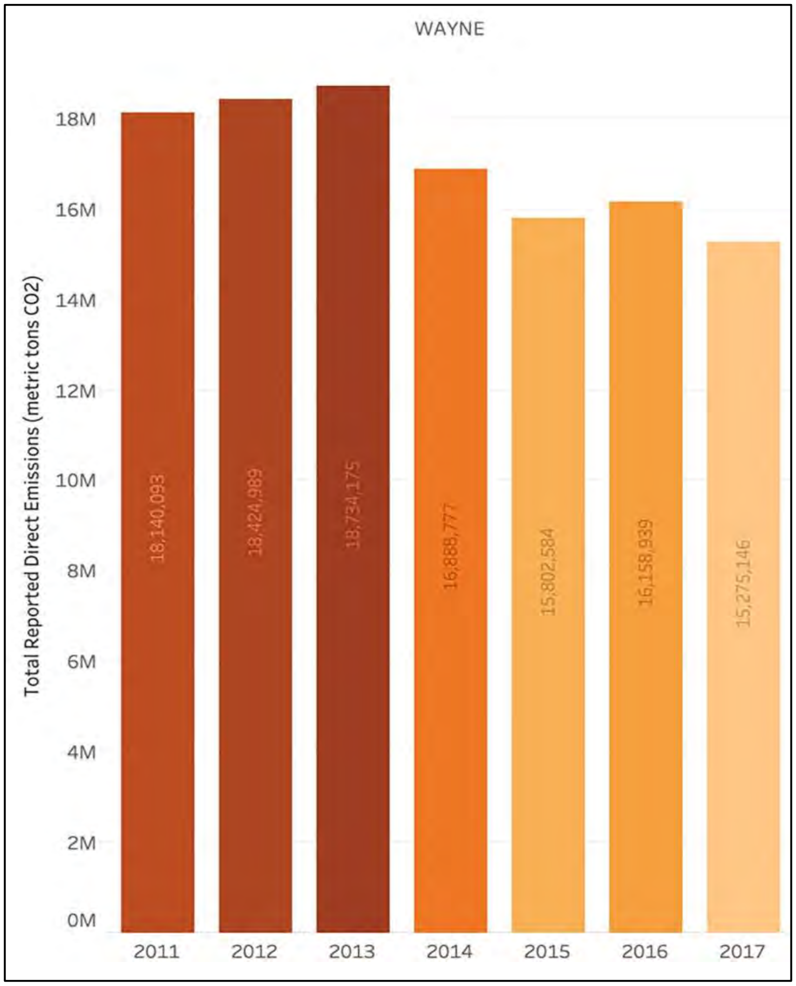


Figure 3. Wayne County carbon dioxide emissions reported to U.S. Environmental Protection Agency (2019), 2011-2017.

Figure 4 presents the proportion of carbon dioxide emissions by sector over the 2011-2017 time period. Power plants contributed most of the carbon dioxide emissions in Wayne County, followed by the metal refining sector (U.S. Environmental Protection Agency, 2019). Power plants have shown a steady reduction in carbon emissions since 2012, while metal industries have shown a slight decline, and the chemical sector has shown a general increase in carbon emissions over this time period (U.S. Environmental Protection Agency, 2019). High-emitting facilities are generally located along the Detroit and Rouge rivers, as seen in Figure 5. This is primarily due to the fact that most power and steel plants are located along these rivers to take advantage of water transportation of coal and other raw materials.

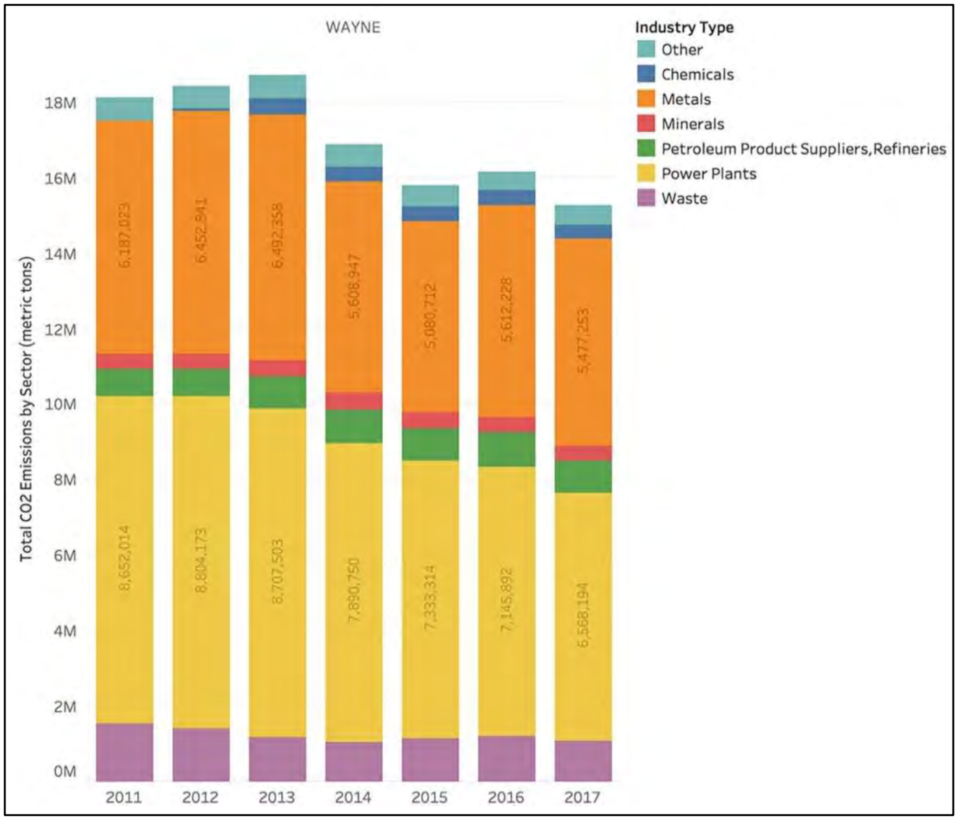


Figure 4. Relative contribution of carbon dioxide emissions in Wayne County by source category, 2011-2017 (U.S. Environmental Protection Agency, 2019).

Figure 5. Map of Wayne County sources of carbon dioxide emissions showing relative contribution (U.S. Environmental Protection Agency, 2019).

Management Next Steps

Carbon dioxide emissions have been reduced in the last 17 years. Evidence suggests that this reduction in carbon dioxide emissions is a result of a shift from coal to natural gas. The burning of natural gas still emits carbon dioxide and other greenhouse gases which will need to be addressed over the long term.

Ongoing data collection of carbon dioxide sources and emissions will need to continue in order to make informed decisions in the future regarding a shift to cleaner habits and energy production. Key policy questions include:

- How will the fragmentation of leadership on climate change and the United States pulling out of the Paris Agreement affect carbon and other greenhouse gas emissions in the future?
- What new approaches and innovative technologies can high-emitting industries adopt to further reduce their emissions to meet targets of the Paris Agreement?
- What can individuals, families, businesses, and the nongovernmental sector do to reduce their carbon emissions and show leadership?
- How can best policies and best management practices by shared to encourage cleaner habits and energy production?

References

Carbon Brief, 2019. Analysis: Why U.S. Carbon Emissions Have Fallen 14% since 2005. Retrieved from: https://www.carbonbrief.org/analysis-why-us-carbon-emissions-have-fallen-14-since-2005 (accessed: 29 June 2020).

Center for Climate and Energy Solutions, 2019. U.S. State Greenhouse Gas Emissions Targets. Retrieved from: https://www.c2es.org/document/greenhouse-gas-emissions-targets/ (accessed: 29 June 2020).

City of Detroit, 2019. Detroit City Council Formal Session. Retrieved from: https://detroitmi.gov/sites/detroitmi.localhost/files/events/2019-07/New%20Business%207-9-19.pdf (accessed: 29 June 2020).

Oakridge National Laboratory, 2015. Carbon Dioxide Information Analysis Center (CDIAC). Ranking of the world's countries by 2014 total CO2 emissions. Oakridge, Tennessee, USA. Retrieved from: https://cdiac.ess-dive.lbl.gov/trends/emis/top2014.tot (accessed: 29 June 2020).

Stanton, R., 2019. Ann Arbor declares climate emergency, sets 2030 carbon-neutral goal. (November 5). Retrieved from: https://www.mlive.com/news/ann-arbor/2019/11/ann-arbor-declares-climate-emergency-sets-2030-carbon-neutral-goal.html (accessed 29 June 2020).

United Nations Framework Convention on Climate Change (UNFCC), 2018. The Paris Agreement. (October 22). Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed: 29 June 2020).

U.S. Energy Information Administration, 2019. February State energy-related carbon dioxide emissions by year. Retrieved from: https://www.eia.gov/environment/emissions/state/analysis/pdf/table1.pdf (accessed: 29 June 2020).

U.S. Environmental Protection Agency, 2017. Climate Change Indicators: Atmospheric Concentrations of Greenhouse Gases. Washington, D.C., USA. Retrieved from: https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases (accessed: 29 June 2020).

U.S. Environmental Protection Agency, 2019. Greenhouse Gas Reporting Program Data Sets. (February 20). Washington D.C., USA. Retrieved from: https://www.epa.gov/ghgreporting/ghg-reporting-program-data-sets (accessed: 29 June 2020).

We Are Still In, 2019. Who's In. Washington D.C. Retrieved from: https://www.wearestillin.com/signatories?title=&field_sector_target_id=10&field_public_value=All&field_address_administrative_area=MI&field_location_proximity=25&field_location_proximity-lat=&field_location_proximity-lng=&geolocation_geocoder_google_geocoding_api=&geolocation_geocoder_google_geocoding_api_state=1 (accessed: 29 June 2020).

World Resources Institute, 2018. Six charts to understand U.S. greenhouse gas emissions. (September 26). Washington, D.C., USA. Retrieved from: https://www.wri.org/blog/2017/08/6-charts-understand-us-state-greenhouse-gas-emissions (accessed: 29 June 2020).

This page intentionally left blank.

7.11 Atmospheric Temperature Changes in the Western Lake Erie Climate Division

Erin Maher, Great Lakes Integrated Sciences + Assessments, University of Michigan, eemaher@umich.edu

Kimberly Channell, Great Lakes Integrated Sciences + Assessments, University of Michigan, kimchann@umich.edu

Background

Globally, temperatures are increasing as an effect of climate change. According to ongoing analysis at NASA's Goddard Institute for Space Studies, Earth's average global temperatures have increased by approximately 0.8° Celsius, with two thirds of the warming occurring after 1975 (GISS, 2019; Lenssen et al., 2019). While this information applies on a global scale, the trend can also be observed on a local scale.

The western Lake Erie climate division also exhibits a warming trend. Using combined data from three National Oceanic and Atmospheric Administration (NOAA) U.S. climate divisions in the western Lake Erie area (displayed below in Figure 1), these trends are examined in the following section (Vose et al., 2014). The use of data sourced from NOAA allows for high confidence in the analyses of these data.

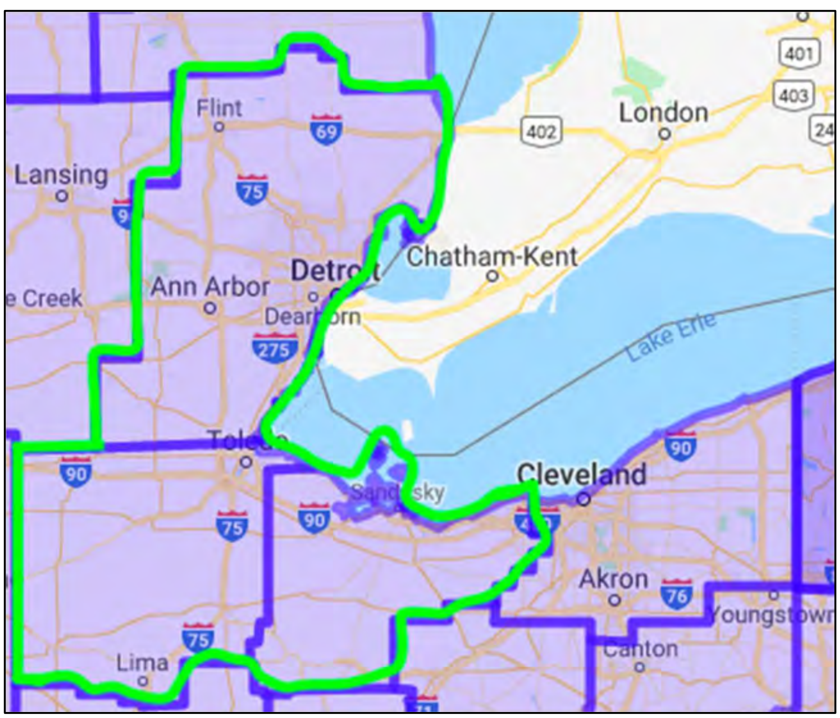


Figure 1. The green outline shows the area of the three NOAA Climate Divisions used for analysis of temperature trends in the western Lake Erie area.

The trend of increasing temperatures has had and will continue to have various impacts on the region. These impacts include changes in local ecosystems and amplified extremes in regional temperature, amongst others (Wuebbles et al., 2019). Because of this, it is important to consider and monitor the changes in atmospheric temperatures.

Status and Trends

An overall increase in annual average atmospheric temperature has been observed in the western Lake Erie climate division since 1951. This trend is demonstrated below in Figure 2 showing annual average temperature data from 1951 to 2018. The time series of the annual average atmospheric temperatures in the region trends upwards, as shown by the linear trendline, while also exhibiting inter-annual variability.

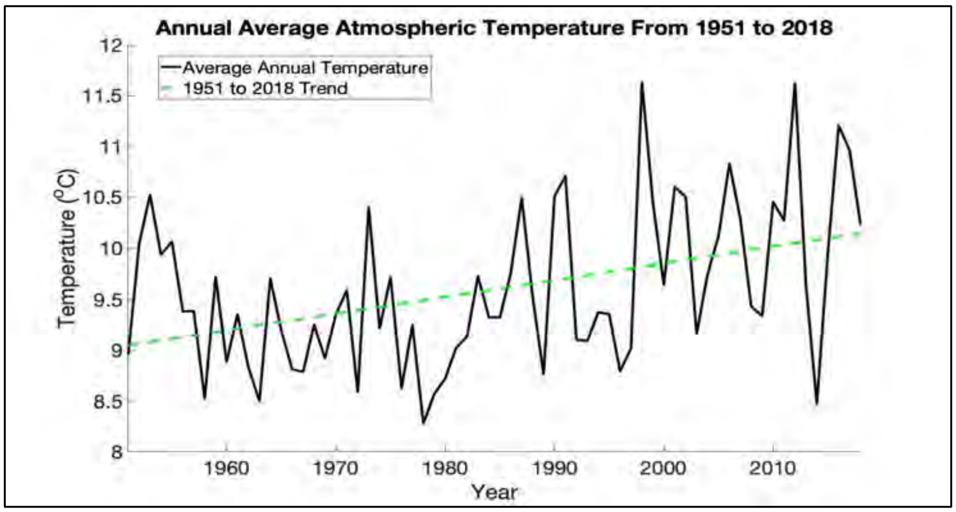


Figure 2. Annual average atmospheric temperature (black solid) in the western Lake Erie climate division from 1951 to 2018, shown here with the trendline (green dashed) for the same time period.

Looking solely at the annual increase in average atmospheric temperature does not tell the whole story, making it important to examine seasonal trends. The annual trend is broken down seasonally in the following figure. Each season exhibits an increase in temperature since 1951 with winter showing the greatest increase and summer showing the smallest increase (Figure 3). It is interesting to note that the increase in average winter temperature is well above the annual average, while the increase in summer temperature is well below the annual average.

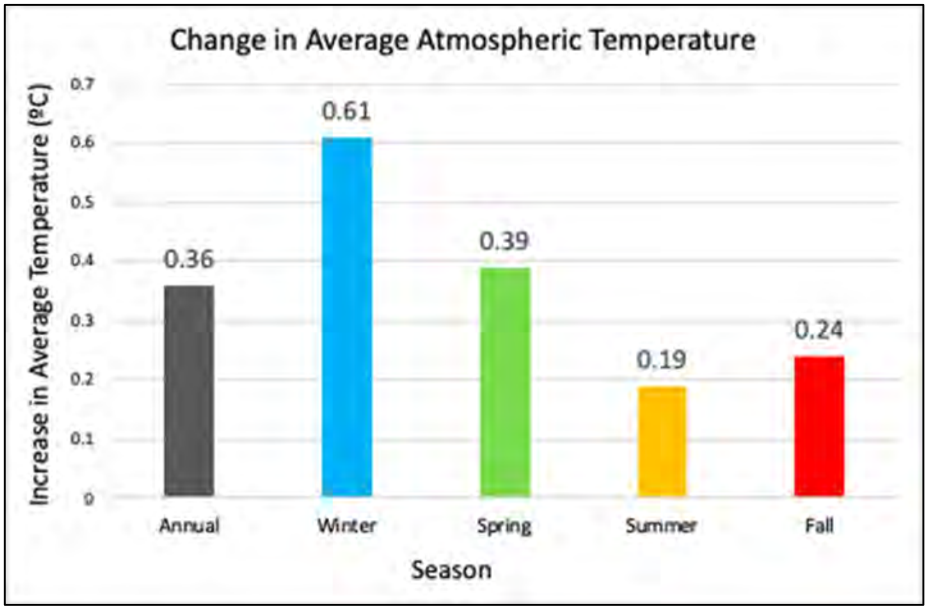


Figure 3. Change in annual average and seasonal atmospheric temperature in °C in the western Lake Erie climate division. Calculated as the difference between the 1951-1980 averages and the 1951-2017 averages.

It is important to recognize that these values are for annual average temperatures. While the overall trend is upward, it is still possible to have extreme cold or hot days or periods that appear to be outside of this trend. Figure 4 shows the ten-year running average of annual average temperatures from 1951 to 2018, with the individual annual averages represented with black circles.

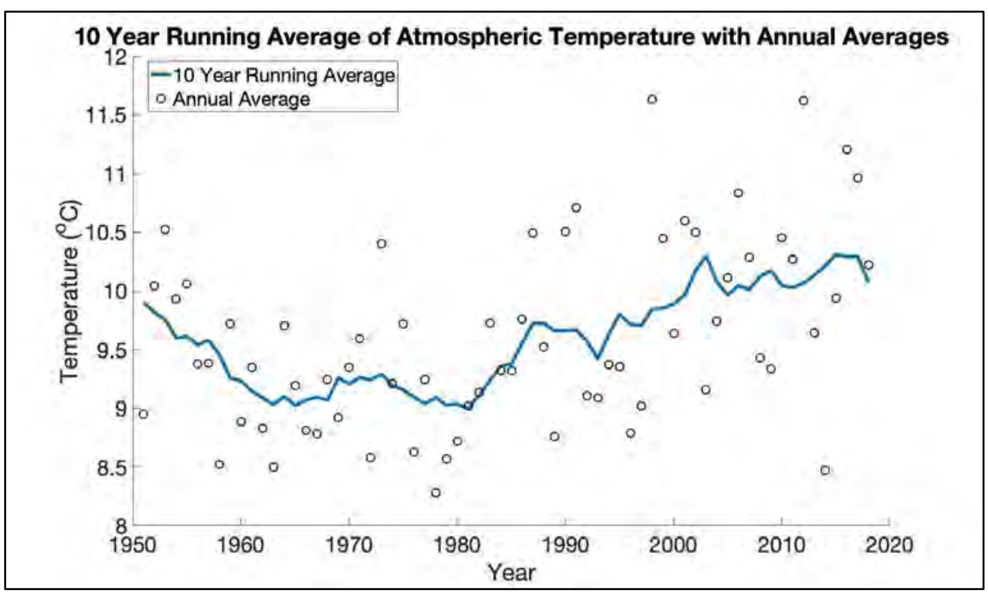


Figure 4. Comparison of ten-year running average (blue solid) with annual averages (black circles) to demonstrate variability of temperature.

There is a period of a few years after 1950 that is anomalously warm, which can be attributed to natural variability. Consequently, the ten-year running average temperature during this period appears similar to ten-year running average temperatures of recent years. However, it is important to note that extremes in recent years are much higher than in any past period.

To analyze trends in days with high heat in the western Lake Erie climate division, days per year above two temperature thresholds (32°C and 35°C) are shown in Figure 5 below. These thresholds were chosen because at these temperatures, regardless of relative humidity, the NOAA advises extreme caution with regard to heat related disorders (National Weather Service Heat Index). Extreme heat is generally observed more at a local, rather than regional scale, so Toledo, OH was chosen to represent a local look at historical extreme heat.

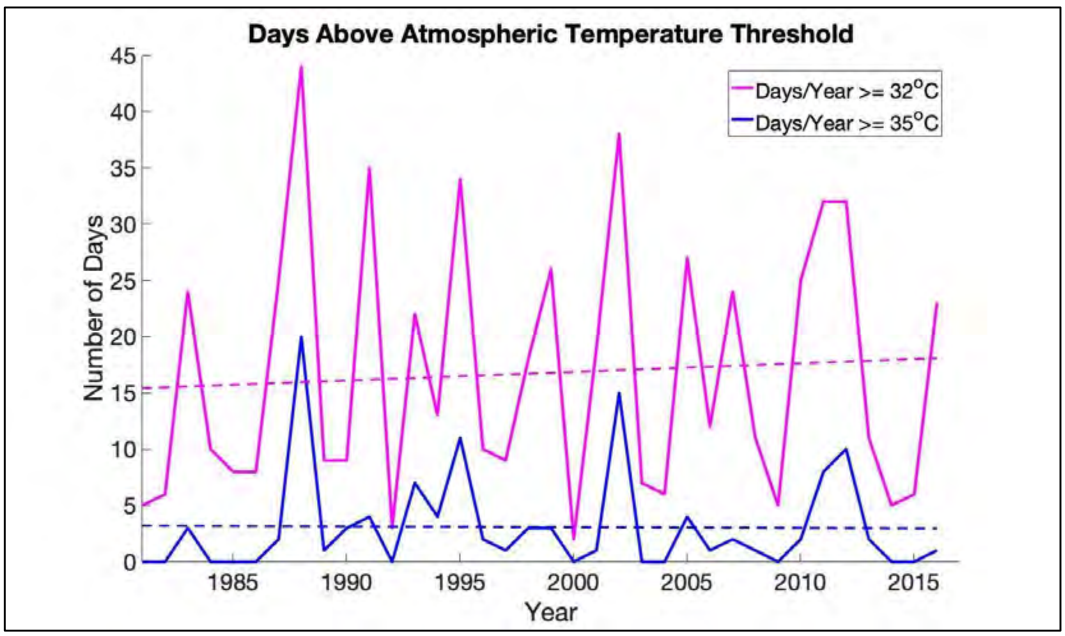


Figure 5. Days above 32°C (pink) and 35°C (blue) over time between 1981 and 2016 in Toledo, OH. The solid lines represent the number of days per year at or above the given thresholds while the dashed lines represent linear trendlines.

The figure above does not show any significant trend for either heat threshold between 1981 and 2016. Despite this lack of trend, it is important to note that there are multiple instances of high numbers of high heat days in a year. These days can be health hazards and the possibility of several high heat days needs to be considered.

Management Next Steps and Future Research Needs

In the future, atmospheric temperature changes in the western Lake Erie climate division should continue to be monitored. This will allow for continued analysis of regional trends and planning for future impacts. Monitoring both annual and seasonal trends in atmospheric temperature, along with extreme heat days, will allow for better understanding of regional changes, and more informed decision making and planning.

Increases in atmospheric temperature impact a range of sectors in the western Lake Erie climate division. As temperatures rise, competing species will migrate into the region potentially causing wildlife populations better adapted to cold temperatures to decline (Jump et al., 2009). Increases in evaporation rates will also result from higher atmospheric temperatures, which contributes to lower lake levels (Deacu et al., 2012). The combined effects of increased atmospheric temperatures, lake water temperatures, and precipitation can also exacerbate harmful algal bloom (HAB) formation (Reutter et al., 2011; Mackey, 2012; Ficke et al., 2007). More runoff from storms leads to higher nutrient loadings to Lake Erie (Michalak et al., 2012). Warmer surface water temperatures, that are influenced by warmer atmospheric temperatures, can lead to higher stratification (less vertical mixing) in the lake, which allows these nutrients to stay in the warm surface waters and contribute to the formation of algal blooms (Shuter et al., 2009; Magnuson et al., 1997). All of these impacts are important considerations for the management of the western Lake Erie climate division.

References

Deacu, D., Klyszejko, E., Spence, C., Blanken, P., 2012. Predicting the Net Basin Supply to the Great Lakes with a Hydrometeorological Model. Bull Amer Met Soc, pp. 1739-1759, doi: 10.1175/JHM-D-11-0151.1.

Ficke, A.D., Myric., C.A., Hansen, L.J., 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries. 17, 4, 581-613.

GIS Surface Temperature Analysis (GISTEMP) Team. 2019. version 4. NASA Goddard Institute for Space Studies. https://data.giss.nasa.gov/gistemp/ (accessed: 1 May 2020).

Hayhoe K., Wake, C.P., Huntington, T.G., Luo, L., Schwartz, M.D., Sheffield, J., Wood, E., Anderson, B., Bradbury, J., DeGaetano, A., Troy, T.J., Wolfe, D., 2007. Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics 28, 381–407.

Jump, A.S., Matayas, C., Penuelas, J., 2009. The altitude-for-latitude disparity in the range restrictions of woody species. Trends in Ecology and Evolution. 24, 694-701.

Karl, T.R., Melillo, J.M., Peterson, T.C., 2009. Global Climate Change Impacts in the United States. U.S. Global Climate Change Research Program. Cambridge University Press, Cambridge, Massachusetts, USA.

Lenssen, N., Schmidt, G., Hansen, J., Menne, M., Persin, A., Ruedy, R., Zyss, D., 2019. Improvements in the GISTEMP uncertainty model. J. Geophys. Res. Atmos. 124, 12, 6307-6326, doi:10.1029/2018JD029522.

Mackey, S. D., 2012. Great Lakes Nearshore and Coastal Systems, In: Winkler, J., Andresen, J., Hatfield, J., Bidwell, D., Brown, D., (Coordinators), U.S. National Climate Assessment Midwest Technical Input Report. Available from the Great Lakes Integrated Sciences and Assessments (GLISA) Center, Ann Arbor, Michigan, USA.

Magnuson J.J., Webster, K.E., Assel, R.A., Bowser, C.J., Dillon, P.J., Eaton, J.G., Evans, H.E., Fee, E.J., Hall, R.I., Mortsch, L.R., Schindler, D.W., Quinn, F.H., 1997. Potential effects of climate change on aquatic systems: Laurentian Great Lakes and Precambrian Shield Region. Hydrological Processes.11, 825-871.

Michalak, A.M., Anderson, E.J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloglu, I., Depinto, J.V., Evans, M.A., Fahnenstiel, G.L, He, L., Ho, J.C., Jenkins, L., Johengen, T.H., Kuo, K.C., Laporte, E., Liu, X., McWilliams, M.R., Moore, M.R., Posselt, D.J., Richards, R.P., Scavia, D., Steiner, A.L., Verhamme, E., Wright, D.M., Zagorski, M.A., 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. Proceedings of the National Academy of Sciences. 110, 16, 6448-52.

National Weather Service Heat Index. National Oceanic and Atmospheric Administration. https://www.weather.gov/safety/heat-index (accessed 1 May 2020).

Reutter, J.M., Ciborowski, J., DePinto, J., Bade, D., Baker, D., Bridgeman, T.B., Culver, D.A., Davis, S., Dayton, E., Kane, D., Mullen, R.W., Pennuto, C.M., 2011. Lake Erie Nutrient Loading and Harmful Algal Blooms: Research Findings and Management Implications. Final Report of the Lake Erie Millennium Network Synthesis Team. Ohio Sea Grant College Program, The Ohio State University. Lake Erie Millennium Network, Windsor, Ontario, Canada.

Shuter, B.J., Trumpickas, J., Minns, C.K., 2009. Forecasting impacts of climate change on Great Lakes surface water temperatures. Journal of Great Lakes Research. 35, 454-463.

Vose, R.S., Applequist, S., Squires, M., Durre, I., Menne, M.J., Williams, Jr, C.N., Fenimore, C., Gleason, K., Arndt, D., 2014. NOAA's Gridded Climate Divisional Dataset (CLIMDIV). MID10, OHD01, OHD01. NOAA National Climatic Data Center. doi:10.7289/V5M32STR. Asheville, North Carolina, USA.

Wuebbles D., Kling, G., 2006. Executive Summary Updated 2005. Confronting Climate Change in the Great Lakes Region. Union of Concerned Scientists, Washington, D.C., USA.

Wuebbles, D., Cardinale, B., Cherkauer, K., Davidson-Arnott, R., Hellmann, J., Infante, D., Johnson, L., de Loe, R., Lofgren, B., Packman, A., Seglenieks, F., Sharma, A., Sohngen, B., Tiboris, M., Wilson, R., Kunkel, K., Ballinger, A., 2019. An Assessment of the Impacts of Climate Change on the Great Lakes. Environmental Law & Policy Center, Chicago, Illinois, USA.

7.12 Bald Eagle Reproductive Success

Chris Mensing, U.S. Fish and Wildlife Service, East Lansing Field Office, chris_mensing@fws.gov

Nicole LaFleur, Detroit River International Wildlife Refuge, nicole_lafleur@fws.gov

John Hartig, University of Windsor, Great Lakes Institute for Environmental Research, jhhartig@uwindsor.ca

Background

Bald eagles (*Haliaeetus leucocephalus*) are large fish-eating raptors, averaging 4.5-6.4 kg (10-14 lbs) for females and 3.6-4.1 kg (8-9 lbs) for males, with an approximate 2.1 m (seven-foot) wingspan (Figure 1). The bald eagle has been selected as an indicator of aquatic ecosystem health by the Lake Erie Lakewide Management Plan and by the State of the Lakes Ecosystem Conference (SOLEC) (Environment Canada and the U.S. Environmental Protection Agency, 2003).

Figure 1. Mature Bald Eagle (Photo credit: U.S. Fish and Wildlife Service)

Bald eagles were documented in the early-1900s as being "evenly distributed" throughout Michigan (Michigan DNR, 2005). The population then declined through the mid-1900s due to loss of nesting habitat and persecution by humans (shooting, poisoning, trapping, and electrocution). In the 1950s the decline of eagles in Michigan accelerated until they were on the brink of extinction in the 1970s. This trend was similar throughout the lower 48 states and southern Canada. This decrease was a result of several factors, most influential being the increased use of organochlorine compounds such as DDT and PCBs following World War II (Colborn, 1991; Bowerman et al., 1995; Bowerman et al., 1998; Bowerman et al., 2003). Exposure to these contaminants in avian species causes reproductive failure, sterility, life-threatening deformities such as crossed bills and egg-shell thinning, altered behavior such as impaired foraging abilities, increased susceptibility to disease through immune system dysfunction, and in cases of acute poisoning, death.

These reproductive impairments reached a peak in the mid-1970s, resulting in only 38% of Michigan's bald eagle populations successfully fledging young. In 1980, bald eagles nesting along the Lake Erie shoreline experienced complete reproductive failure. Bald eagle recovery efforts in the U.S. and throughout North America were initiated in 1972 with the banning of DDT in the United States by the U.S. Environmental Protection Agency and in 1973 with the passage of the Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS). As a result, from 1981 through 2005 the Michigan bald eagle population has continually increased and continues to do so (Figure 2; Michigan DNR, 2005).

Geographic Area of Coverage

For the purpose of this indicator report, the geographic area of coverage is southeast Michigan, including Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties. The results of long-term reproductive monitoring are summarized below for all bald eagles nesting within the seven-county region.

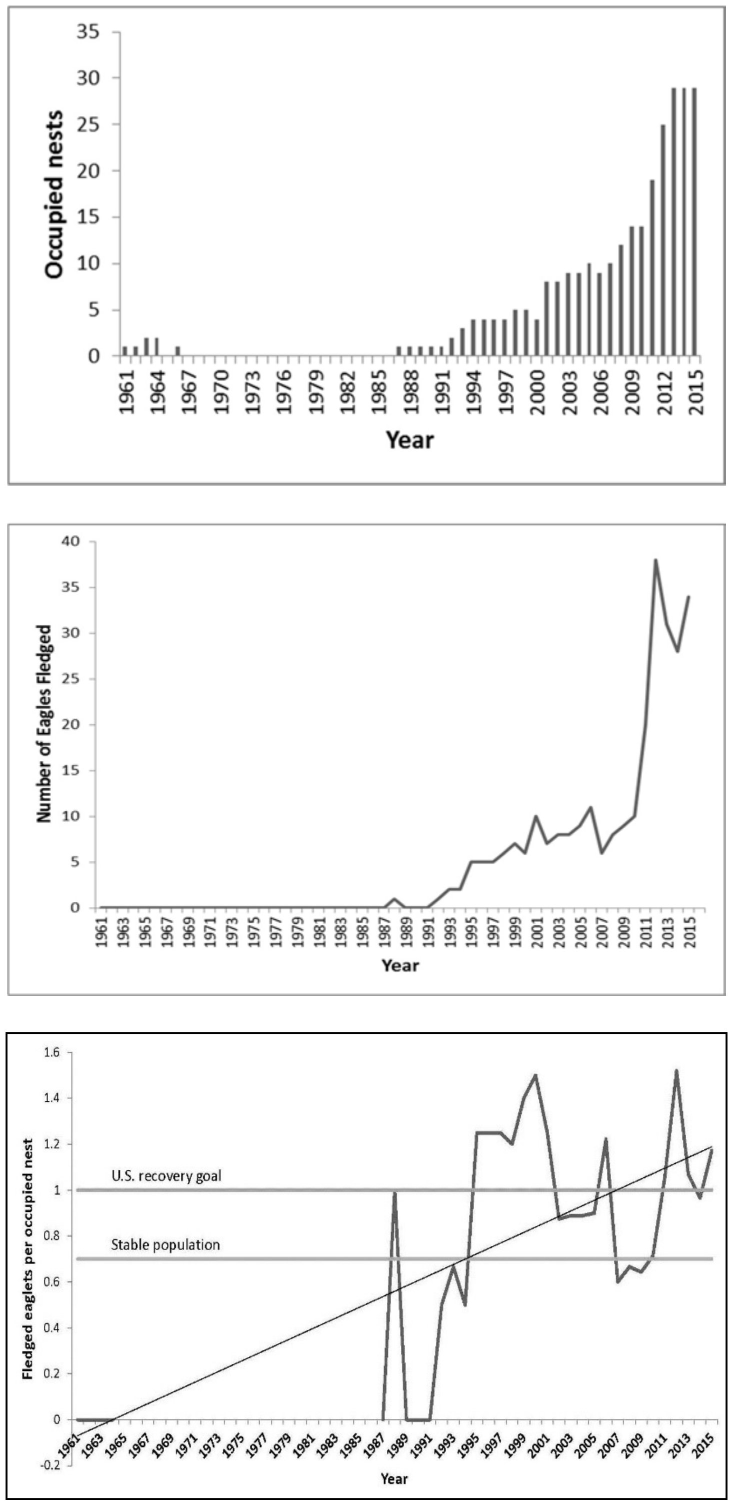
Use as a Biological Indicator

Biological indicators are important tools for estimating ecosystem health. Bald eagles are ideal as biological indicators because they are a vulnerable species with low tolerance to environmental contaminants (Golden and Ratner, 2003). The increasing population of bald eagles suggests that contaminants in the ecosystem are less prevalent. However, not all population shifts are due to environmental toxins. In Michigan, anthropogenic factors such as collisions with vehicles are the main cause of female eagle mortality and should be considered when planning for management action (Simon, 2016).

Status and Trends

In Michigan, the Michigan Department of Environment, Great Lakes, and Energy and the USFWS coordinate a monitoring program aimed at assessing the health of bald eagles. For this indicator report, bald eagle data have been compiled from a combination of fixed-wing aircraft and helicopter surveys and citizen reports.

From 1961 to 1987 there were no bald eagles produced in Metropolitan Detroit due primarily to organochlorine contamination (Figure 2). Since 1991, there has been a steady increase in the number of occupied bald eagle nests per year in metropolitan Detroit. From 2012-2015, at least 25 active nests have been documented each year, resulting in the fledgling of 28 or more young per year. An average of 1.06 eaglets were fledged per occupied nest in southeast Michigan from 1995-2015, which is indicative of a stable or increasing population and meeting the U.S. recovery goal. In 2007, the USFWS removed the bald eagle from the endangered species list because their populations recovered sufficiently across the United States.



A.

B.

C.

Figure 2 A: Number of occupied bald eagle nests in southeast Michigan, 1961-2015; B: Number of eaglets fledged in southeast Michigan, 1961-2015; and C: Number of eaglets fledged per occupied nest in southeast Michigan, 1961-2015, including trend line (data source: USFWS).

Management Next Steps

The bald eagle remains federally protected in the U.S. under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act and is classified as a "species of special concern" in Ontario.

Efforts should be undertaken to protect existing nesting and foraging habitats (Watts, 2015). Management should continue to place a priority on control of contaminants at the source and on the remediation of contaminated sediment "hot spots", to ultimately ensure that contaminant levels in fish and other aquatic prey do not result in reproductive impairment of bald eagles. Reproductive outcomes and contaminant exposures should continue to be monitored. This species will also benefit from increased public outreach and awareness of the threats to the health of the species and the ecosystem.

Research/Monitoring Needs

Yearly monitoring of the bald eagle population should continue throughout the Detroit River and western Lake Erie watersheds. Eaglets should continue to be banded and have representative samples taken to monitor levels of contaminants, so as to determine health status of individual eagles and the ecosystems in which they reside. Contaminants of concern include organochlorine compounds and heavy metals, as well as emerging new generation compounds. Furthermore, additional laboratory and field studies may be necessary to further clarify the role of environmental endocrine disruptors on reproduction in avian populations (Bowerman et al., 2000).

References

Best, D. A., Elliot, K. H., Bowerman, W. W., Shieldcastle, M., Postupalsky, S., Kubiak, T., J., Tillitt, D. E., Elliot, J. E., 2010. Productivity, embryo and eggshell characteristics, and contaminants in bald eagles from the Great Lakes, USA, 1986 to 2000. Environ. Toxicol. Chem. 29, 7, 1581-1592.

Bowerman, W.W., Giesy, J.P., Best, D.A., Kramer, V.J., 1995. A review of factors affecting productivity of bald eagles in the Great Lakes region: Implications for recovery. Environmental Health Perspectives. 103, Suppl. 4, 51-59.

Bowerman, W.W., Best, D.A., Grubb, T.G., Zimmerman, G.M., Giesy, J.P., 1998. Trends of contaminants and effects in bald eagles of the Great Lakes Basin. Environmental Monitoring and Assessment. 53, 197-212.

Bowerman, W.W., Best, D.A., Grubb, T.G., Sikarskie, J.G., Giesy, J.P., 2000. Assessment of Environmental Endocrine Disruptors in Bald Eagles of the Great Lakes. Chemosphere. 41, 1569-1574.

Bowerman, W.W., Roe, A.S., Gilbertson, M.J., Best, D.A., Sikarskie, J.G., Mitchell, R.S., Summer, C.L., 2003. Using bald eagles to indicate the health of the Great Lakes' environment. Lakes & Reservoirs: Res. and Manage. 7, 183-187.

Colborn, T., 1991. Epidemiology of Great Lakes Bald Eagles. J. Toxicol. and Environ. Health. 33, 395-453.

Environment Canada and the U.S. Environmental Protection Agency, 2003. State of the Lakes 2003. Environment Canada and the U.S. Environmental Protection Agency, En40-11/35-2003E, Chicago, Illinois, USA and Toronto, Ontario, Canada.

Golden, N.H., Rattner, B.A., 2003. Ranking Terrestrial Vertebrate Species for Utility in Biomonitoring and Vulnerability to Environmental Contaminants. Reviews of Environmental Contamination and Toxicology. 176, 67-136.

Michigan Department of Natural Resources, 2005. Bald Eagle (*Haliaeetus leucocephalus*). Lansing, Michigan, USA.

Simon, K.L., Bowerman, W.W., Rattner, B.A., Yonkos, L.T., Murrow, J.L., Angel, C.R., 2016. Bald Eagles (*Haliaeetus leucocephalus*) as Indicators of Great Lakes Ecosystem Health. Dissertation submitted to the University of Maryland. College Park, Maryland, USA.

Watts, B.D., 2015. Estimating the residual value of alternate bald eagle nests: Implications for nest protection standards. The Journal of Wildlife Management. 79, 5, 776-784.

This page intentionally left blank.

7.13 Benthic Macroinvertebrates in the Rouge River

Sally Petrella, Watershed Monitoring Manager, Friends of the Rouge,
spetrella@therouge.org

Timothy J. Maguire, Postdoctoral Researcher, Great Lakes Institute for Environmental Research, University of Windsor, maguiret@uwindsor.ca

Susan Thompson, Environmental Specialist, Wayne County Department of Public Services, Environmental Services Division, sthompso@waynecounty.com

Background

At 1,210 km^2 (467 square miles), the Rouge River watershed has 200 km (125 miles) of river in its four major branches and includes numerous tributaries, lakes, and impoundments. Located in densely-populated southeast Michigan, it is the state's most urbanized watershed: home to 1.35 million people in 48 communities and three counties and is more than 50% urbanized. The watershed has long suffered from industrial pollution, stream alteration, sewer overflows, illegal discharges, stormwater pollution, and more. Urbanization combined with the area's lakeplain geology and clay soils produce flashy stream flows that rise and fall rapidly following rain and snowmelt. Bank erosion and sedimentation are ubiquitous, posing problems for aquatic life.

Benthic macroinvertebrates, which are bottom-dwelling small aquatic animals without a backbone, are widely used as indicators of the biological health of a stream. Spending all or a portion of their lives in streams, they cannot escape pollution and vary in their ability to tolerate it. Benthic macroinvertebrates can be categorized by their level of sensitivity, making it easy to develop metrics to rate stream sites based on the number and type of organisms found. Sites with a healthy community of benthic macroinvertebrates include sensitive families like mayflies, caddisflies, and stoneflies, which are lost as sites become degraded.

Status and Trends

Surveys for benthic macroinvertebrates were conducted on the Rouge River by the Michigan Department of Natural Resources (MDNR) from 1973-1994 (Beam and Braunscheidel, 1998). Most of the early studies found "very poor" to "poor" benthic communities in the downstream portions of all of the major branches (Main, Upper, Middle and Lower), as well as the Evans Branch on the Main, Bell Creek on the Upper, and all of the Lower branch. "Fair" communities with sensitive families like mayflies and caddisflies were found in the upstream sections of the Main, Upper and Middle branches and in Tonquish Creek, a Middle branch tributary. The only "good" rating in the watershed was for Johnson Creek, a coldwater tributary to the Middle branch and the Middle branch downstream of the confluence with Johnson Creek downstream all the way to Newburgh Lake.

A bioassessment was conducted by the Michigan Department of Environmental Quality (2009) in the summer of 2005 to assess the conditions and attainment of Michigan Water Quality Standards, evaluate impacts from permitted point sources, and identify potential nonpoint sources of impairment. Fifty-one sites were sampled for benthic macroinvertebrates. The majority of the sites were considered acceptable though most were dominated by crustaceans, worms, netspinner caddisflies, and chironomids (midge larvae), reflective of urbanization including habitat loss, siltation, and altered hydrology. Johnson Creek was the only highlight with the three stations there rated higher than the rest of the Middle 1 subwatershed.

In 2001, Friends of the Rouge (FOTR) began collecting benthic macroinvertebrates every spring and fall using a protocol developed by the state of Michigan Department of Environmental Quality and updated by the Michigan Clean Water Corps. Stream Quality Index (SQI) scores are calculated that categorize sites from "poor" to "excellent" that roughly correlate with the state scores discussed above (Latimore, 2006). Wayne County partnered with Friends of the Rouge to use the same protocol to sample downstream sites. Between 2001 and 2019, data were collected from 108 sites. Sites were sampled each season for three years, then put on a rotation to be sampled every other year.

In comparison to the 1973-1994 MDNR data, the FOTR data showed an overall improvement in benthic macroinvertebrate communities in the downstream sections of all of the major branches (Figure 1) with most sites "fair." Exceptions to that included continued "poor" communities in Evans Creek and the Middle Rouge downstream of the confluence with Tonquish Creek, as well as one site on Tonquish Creek. The Main branch near Eight Mile had several sites with "good' communities, including sensitive species like dobsonflies.

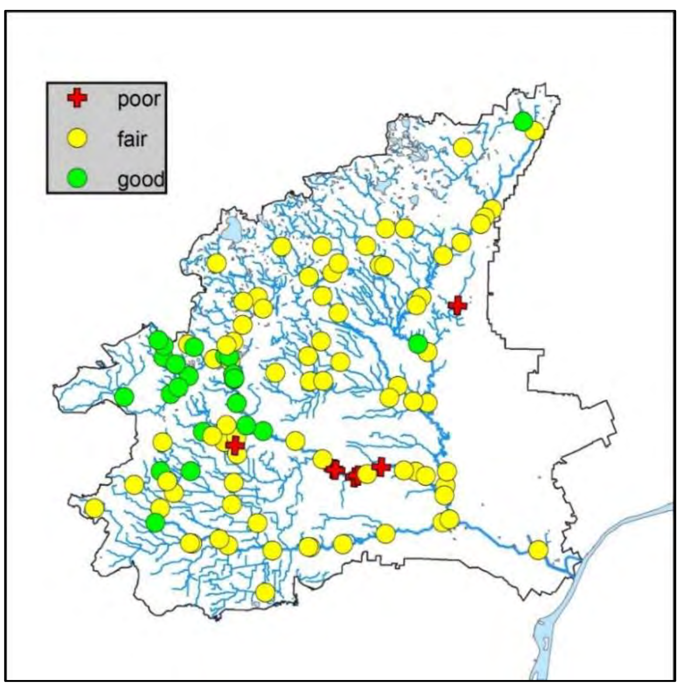


Figure 1. Average SQI scores for benthic macroinvertebrates in the Rouge River watershed, 2001-2019.

To track trends over time, SQI scores were plotted over time for all sites and then analyzed by subwatershed (Figure 2), with the coldwater tributary Johnson Creek analyzed separately and then checked for statistically significant trends (Table 1). The Main, Lower, and Upper subwatersheds have declining scores, but only the Upper subwatershed has a significant declining trend. Johnson Creek as well as the Middle 1 and Middle 3 demonstrate significantly improving trends in scores.

These data were further analyzed for trends by combining data for the branches with subareas (Main 1/2 combined with Main 3/4, Lower 1 with Lower 2, and Middle 1 and Middle 3, respectively). Table 2 contains a summary of this analysis. In this case, all trends were significant, most likely due to the increased number of data points. The Middle branch was the only branch with a positive trend; the Main, Upper and Lower branches all show significant declining trends in scores. The Johnson Creek, a Middle Rouge tributary, continues its positive trend.

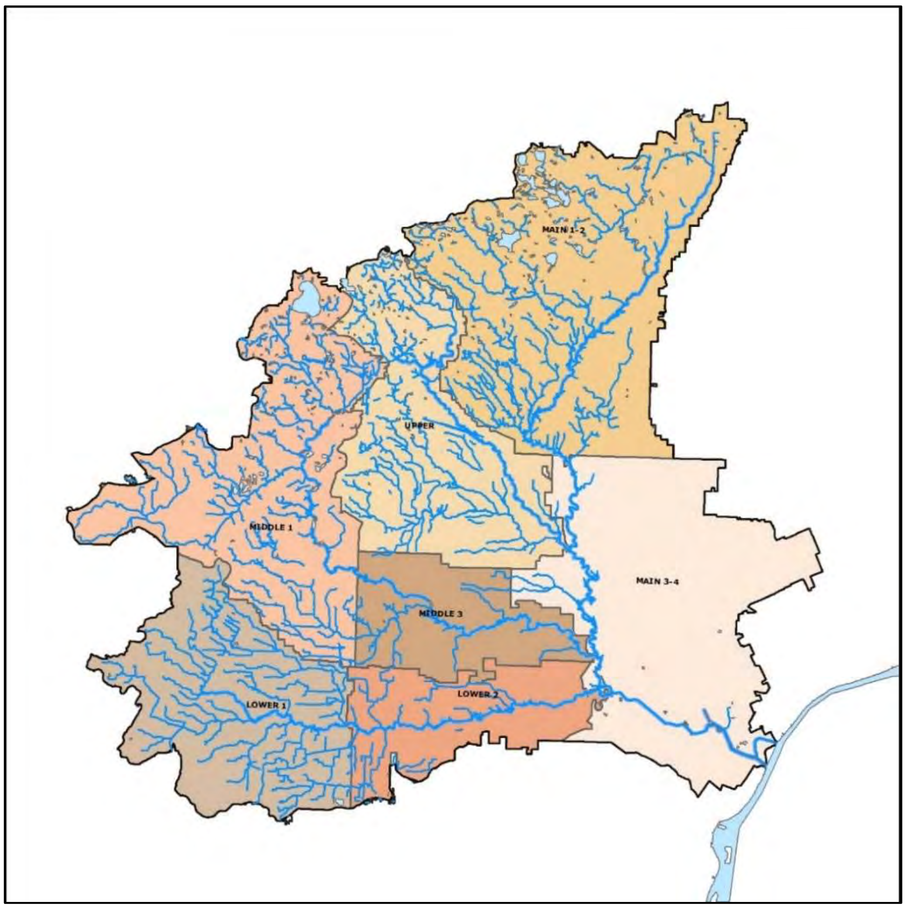


Figure 2. Subwatersheds of the Rouge River used for analyzing benthic macroinvertebrate data.

Table 1. FOTR and Wayne County spring and fall bug hunt data summary by subwatershed of the Rouge River, 2001-2019.

Branch	**slope**	**p-value**	**True trend**	**Average SQI Score**	**Water Quality Rating**
Main 1-2	-0.1620	0.1109	no trend	28	Fair
Main3-4	-0.4335	0.1716	no trend	26	Fair
Upper	-0.2651	0.0016	yes, negative	24	Fair
Johnson Creek	0.3870	0.0031	yes, positive	37	Good
Middle 1	0.3310	0.01110	yes, positive	31	Fair
Middle 3	0.5000	0.0002	yes, positive	21	Fair
Lower 1	-0.1874	0.0869	no trend	29	Fair
Lower 2	-0.2100	0.1296	no trend	26	Fair

Table 2. FOTR and Wayne County spring and fall bug hunt data summary for all and individual branches of the Rouge River, 2001-2019.

Branch	**slope**	**p-value**	**True trend**	**Average SQI Score**	**Water Quality Rating**
All branches	0.0408	0.4170	no trend	28	Fair
Main All	-0.1883	0.0456	yes, negative	28	Fair
Upper	-0.2651	0.0016	yes, negative	24	Fair
Johnson Creek	0.3870	0.0031	yes, positive	37	Good
Middle All	0.4862	0.00002	yes, positive	28	Fair
Lower All	-0.2288	0.0092	yes, negative	28	Fair

Management Next Steps

The Rouge River benthic macroinvertebrate community is considered “fair” or “acceptable” at most locations but continues to be dominated by tolerant organisms and is missing sensitive species like mayflies, stoneflies, and caddisflies at many sites. Average SQI scores are declining in all but the Middle branch and Johnson Creek.

In most cases, urbanization and stormwater runoff is impacting the Rouge River benthic macroinvertebrate communities. Projects to reduce stormwater impact and improve habitat are needed to mitigate the effects of urbanization. Increasing urbanization is continuing to challenge the Rouge River watershed.

At this time, the headwaters of the Middle and Lower branches that contain the healthiest community of benthic macroinvertebrates are undergoing rapid development. Recent modeling of land use change over time found these areas to be the most rapidly changing from forest to urban (Figure 3; red areas are the most rapidly urbanizing, while green areas are reforesting).

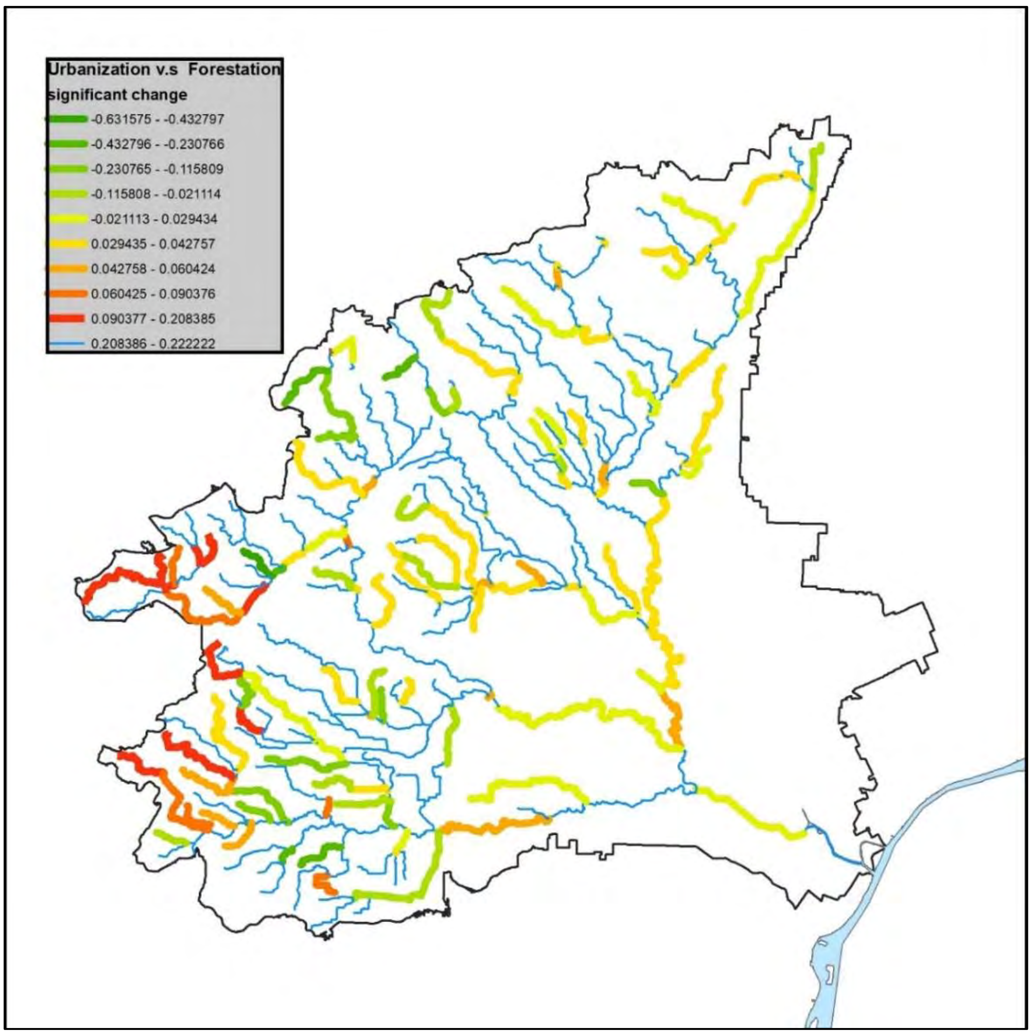


Figure 3. Urban and forest land use changes in the Rouge River watershed.

While changes in development within the Middle and Lower branches, relative to the levels of urbanization in the downstream portions of the watershed, may seem small, the impact on Middle and Lower branches healthy benthic communities may be disproportionately large. These Middle and Lower branch communities are vitally important to provide the invertebrate seed populations which could expand with future improved conditions downstream.

The two sections of the river with continuing “poor” communities are Evans Creek and the downstream sections of Tonquish Creek. Evans Creek is highly modified with a partially enclosed, straightened, and armored channel with many large stormwater inputs. The downstream end of Tonquish Creek and the Middle Rouge downstream of the confluence with Tonquish Creek continue to have a “poor” macroinvertebrate community. These sections of the river that continue to have a “poor” macroinvertebrate community need to be examined more closely and addressed with remediation projects.

Research/Monitoring Needs

Long-term monitoring is critical for evaluating trends in benthic macroinvertebrate communities and effectiveness of cleanup efforts. In recent years, the Friends of the Rouge has struggled to identify long-term funding for monitoring efforts as federal, state, and local priorities change. Consistent long-term monitoring and targeted monitoring to pinpoint causes of decline are needed to gauge changes in water quality and habitat over time.

References

Beam, J.J. and Braunscheidel, J.J., 1998. Rouge River Assessment. State of Michigan Department of Natural Resources Fisheries Division Special Report Number 22. Lansing, Michigan, USA.

Evans, E. and Nuhfer, A., 1987. Rouge River Quality 1973-1986. Michigan Department of Natural Resources, Surface Water Quality Division, 87/043, Lansing, Michigan, USA.

Latimore. J., 2006. MiCorps Volunteer Stream Monitoring Procedures. Michigan Clean Water Corps. Ann Arbor, Michigan, USA.

Michigan Department of Environmental Quality Water Bureau, 2009. Biological Assessment of the Rouge River Watershed Wayne, Washtenaw and Oakland Counties, Michigan. June-August 2005, and September 2006. Staff Report. Lansing, Michigan, USA.

Nuhfer, A. J., 1989. An Assessment of River Rouge Quality Using the Index of Biotic Integrity. Fisheries Research Report No. 1962, October 18, 1989. Michigan Department of Natural Resources Fisheries Division. Hunt Creek Fisheries Station.

7.14 Changes in Ice Cover in Lake Erie

Erin Maher, Great Lakes Integrated Sciences + Assessments, University of Michigan, eemaher@umich.edu

Kimberly Channell, Great Lakes Integrated Sciences + Assessments, University of Michigan, kimchann@umich.edu

Background

During the winter months, the Great Lakes, including Lake Erie, experience various amounts of ice coverage. In most years, Lake Erie freezes earlier than the other lakes and experiences the highest surface ice coverage, due to its comparatively shallow depth and warmer temperatures. The maximum ice concentration in Lake Erie, defined as the maximum amount of lake surface area that is covered with ice represented as a percentage, often reaches 90% and above.

When considering annual maximum or average ice cover in the Great Lakes, it is common to treat each "ice year" as the period between December (of the previous year) and May (of the current year), as this is when freezing events occur in the region. Figure 1 demonstrates this, showing peak ice cover between February and March and zero ice cover in the beginning of December and after May. The analyses presented in the "Trends" section below use this time period (December to May) when discussing ice coverage in Lake Erie.

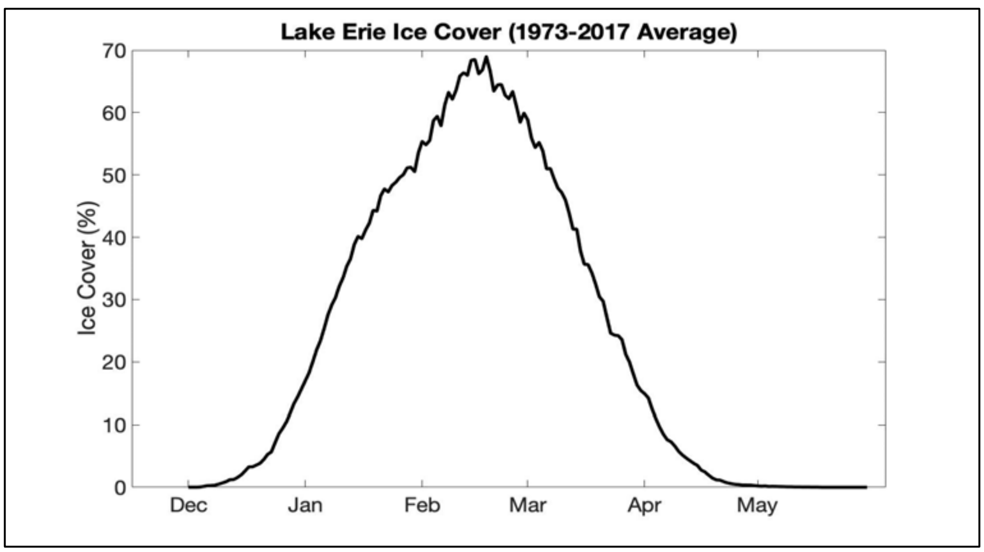


Figure 1. Average ice cover of Lake Erie from 1973 to 2017 presented as percentage of area covered by ice (ice concentration).

It is important to consider and monitor changes in ice cover in Lake Erie. Changes in percent ice coverage can lead to many different impacts, including changes in evaporation rates, which have implications for lake levels and precipitation amounts. Ice cover also affects shipping and navigation, as well as seasonal recreational activities on the lakes.

In the following section, historical ice cover on Lake Erie is visualized using data from the Great Lakes Environmental Research Laboratory (GLERL), which compiles the data from the Canadian Ice Service and U.S. National Ice Center (Assel et al., 2002, 2005, 2013; Wang et al., 2012a, 2018a, 2018b). The use of data sourced from GLERL allows for high confidence in the analyses of these data.

Status and Trends

While there is annual variability in Lake Erie ice coverage, there has been, on average, less ice cover in the decades since the 1990s than in the decades prior to the 1990s. This trend is observed in both average and maximum annual ice coverage on the lake. Figures 2 and 3 demonstrate this trend, with Figure 2 showing decadal averages for annual average ice cover and Figure 3 showing decadal averages for annual maximum ice coverage.

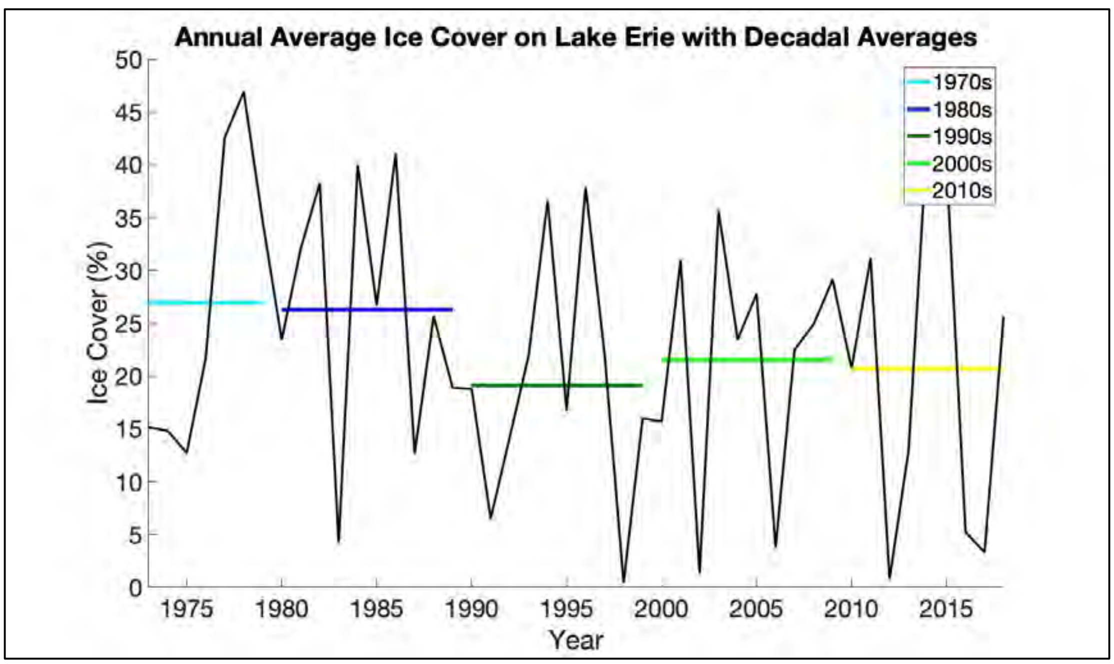


Figure 2. Annual average ice cover on Lake Erie (black) with decadal averages (1970s (cyan), 1980s (blue), 1990s (dark green), 2000s (green), 2010s (yellow)).

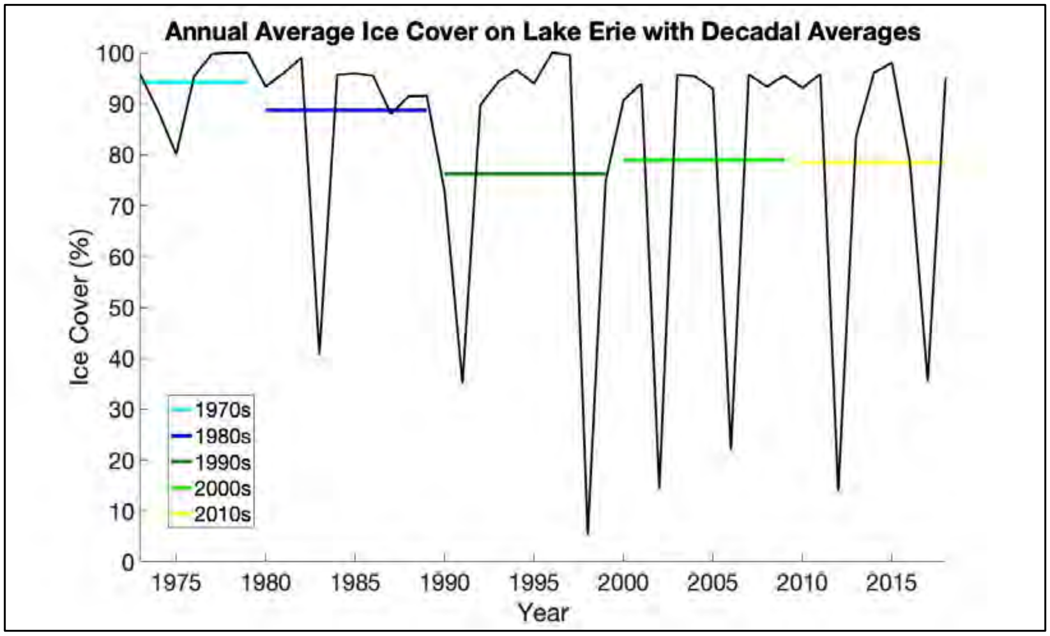


Figure 3. Annual maximum ice cover on Lake Erie (black) with decadal averages (1970s (cyan), 1980s (blue), 1990s (dark green), 2000s (green), 2010s (yellow)).

While a downward trend in ice coverage since the 1990s is observed, it is important to note that there is still substantial inter-annual variability in ice cover on Lake Erie (Mason et al., 2016). Because of this, both high and low ice years are still possible, despite the downward trend.

Figure 3 also displays specific years where the maximum ice cover on Lake Erie was much lower than usual. These low ice years have occurred more frequently since 1998 than in previous years, with the time period between events decreasing from about 7-8 years to 3-4 years. Events such as these can be related to modes of natural climate variability, including El Niño Southern Oscillations (ENSO), the Arctic Oscillation (AO), and/or the North Atlantic Oscillation (NAO) (Wang et al,. 2012b; Bai et al., 2012). For example, 1998 was a particularly strong El Niño year that contributed to higher than average winter temperatures and subsequently low ice coverage for Lake Erie. Future changes in these global-scale phenomena could have impacts on ice cover in Lake Erie.

Management Next Steps and Future Research Needs

In the future, ice cover changes in the Lake Erie should continue to be monitored. This will allow for continued analysis of regional trends and planning for future impacts. Monitoring both annual average and maximum trends in ice coverage will allow for better understanding of regional changes, and more informed decision making and planning.

Ice coverage can have various impacts on Lake Erie and its surrounding areas. Changes in the amount of ice cover affect evaporation rates in Lake Erie, with higher ice cover leading to less or no evaporation, and subsequently higher lake levels (Mishra et al., 2016). Lower ice coverage results in increased lake effect precipitation and increased evaporation rates, which contribute to lower lake levels.

Lower lake levels can present problems for shipping, as ships are forced to take on less cargo to account for decreased lake depth, causing economic losses (U.S. Department of Commerce et al., 2019; Sousounis and Bisanz, 2000). However, decreases in ice coverage can make navigation of the lake possible for cargo vessels longer into the winter season, whereas higher ice years can create navigational challenges (Millerd, 2011). Fluctuations in ice coverage has implications for the hydropower and fishing industries as well, as they depend upon access to the lakes (Lofgren et al., 2002; Yapa et al., 1984). All these impacts are important considerations for the management of the western Lake Erie climate division.

References

Assel, R.A., Norton, D.C., Cronk, K.C., 2002. A Great Lakes Ice Cover Digital Data Set For Winters 1973-2000. NOAA Technical Memorandum GLERL-121. Ann Arbor, Michigan, USA.

Assel, R.A., 2005. Great Lakes Ice Cover Climatology Update: Winters 2003, 2004, and 2005. NOAA Technical Memorandum GLERL-135. Ann Arbor, Michigan, USA.

Assel, R.A., Wang, J., Clites, A.H., Bai, X., 2013. Analysis of Great Lakes Ice Cover Climatology: Winters 2006-2011. NOAA Technical Memorandum GLERL-157. Ann Arbor, Michigan, USA.

Bai, X., Wang, J., Sellinger, C., Clites, A., Assel, R., 2012. Interannual variability of Great Lakes ice cover and its relationship to NAO and ENSO. Journal of Geophysical Research. 117, C03002.

Lofgren, B.M., Quinn, F.H., Clites, A.H., Assel, R.A., Eberhardt, A.J., Luukkonen, C.L., 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. Journal of Great Lakes Research. 28, 537-554.

Mason, L.A., Riseng, C.M., Gronewold, A.D., Rutherford, E.S., Wang, J., Clites, A., Smith, S.D.P., McIntyre, P.B., 2016. Fine-scale spatial variations in ice cover and surface temperature trends across the surface of the Laurentian Great Lakes. Climatic Change. 138, 71-83.

Millerd, F., 2011. The potential impact of climate change on Great Lakes international shipping. Climatic Change.104, 629–652.

Mishra, V., Cherkauer, K.A., Bowling, L.C., 2011. Changing thermal dynamics of lakes in the Great Lakes region: Role of ice cover feedbacks. Global and Planetary Change. 75, 155-172.

Sousounis, P., Bisanz, J.M., 2000. Preparing for a Changing Climate. The Potential Consequences of Climate Variability and Change: Great Lakes. University of Michigan, Atmospheric, Oceanic and Space Sciences Department, Ann Arbor, Michigan, USA.

Wang, J., Assel, R.A., Walterscheid, S., Clites, A.H., Bai, X., 2012a. Great Lakes Ice Climatology Update: Winter 2006 – 2011 Description of the Digital Ice Cover Dataset. NOAA Technical Memorandum GLERL-155, Ann Arbor, Michigan, USA.

Wang, J., Bai, X., Hu, H., Clites, A., Colton, M., Lofgren, B., 2012b. Temporal and Spatial Variability of Great Lakes Ice Cover, 1973–2010. Journal of Climate. 25, 1319-1329.

Wang, J., Kessler, J., Hang, F., Hu, H., Clites, A.H., Chu, P., 2018a. Great Lakes Ice Climatology Update of Winters 2012-2017: Seasonal Cycle, Interannual Variability, Decadal Variability, and Trend for the period 1973-2017. NOAA Technical Memorandum GLERL-170, Ann Arbor, Michigan, USA.

Wang, J., Kessler, J., Hang, F., Hu, H., Clites, A.H., Chu, P., 2018b. Analysis of Great Lakes Ice Cover Climatology: Winters 2012-2017. NOAA Technical Memorandum GLERL-171, Ann Arbor, Michigan, USA.

Yapa, P.D., Shen, H.T., 1984. Effect of ice cover on hydropower production. Journal of Energy. 110, 231-234.

This page intentionally left blank.

7.15 Chironomid Abundance and Deformities

Jan Ciborowski, University of Windsor, cibor@uwindsor.ca

Background

Chironomids, commonly known as midges, are mosquito-like insects whose larvae live in the sediments of all types of aquatic habitats. They are abundant throughout the Great Lakes, including Lake Erie and the Detroit River. Swarms of adult midges emerge in the spring and summer. They are often seen flying around lights on warm summer nights. After mating, females deposit their eggs on the water surface where they sink to the bottom and then hatch to become larvae. There are over a thousand species of chironomids in Canada. Some species can complete their life cycle in just a few weeks. The larvae of other species of chironomids can spend up to a year feeding on organic matter in the sediments. Chironomids are an important food source for fish and waterfowl (Ciborowski and Corkum, 2003). The adults provide food for amphibians, bats, and insect-feeding birds such as purple martins and swallows (Smits et al., 2004; Beck et al., 2013).

Chironomids can be an important freshwater quality indicator. The larvae of some species are sensitive to specific forms of pollution whereas others are quite tolerant. Because the larvae often feed on the debris in aquatic sediments, they are exposed to contaminants contained in the organic matter. The fact that chironomids live in such a wide variety of habitats makes them especially useful indicators. Large numbers of pollution-tolerant chironomids are often indicative of poor water quality conditions. These species have a substance similar to haemoglobin in their blood, which allows them to survive in places where the oxygen has become depleted. Excellent water quality conditions (characterized by high dissolved oxygen and low nutrient concentrations) are often characterized by relatively low densities and high species diversity (50% or more of the species being chironomids). Chironomid species diversity and their sensitivity to eutrophic conditions have been used to create trophic status classifications of lakes (oligotrophic, mesotrophic and eutrophic; e.g., Saether, 1975; Winnell and White, 1985; Langton et al., 2006).

The value of chironomids as an indicator pertains to more than just their abundance. Correlations have been found between larval mouthpart and antennae abnormalities and exposure to heavy metals and pesticides such as DDT, DDE, dieldrin, and hexacholorobenzene (Warwick, 1985; Dermott, 1989; Hudson and Ciborowski, 1996a; Doherty et al., 1999; Zhang, 2008). Deformities in chironomids are relatively rare (although much more common than in other types of organisms), so detecting an increase above the baseline level of deformities may require looking at over 100 larvae per site (Hudson and Ciborowski, 1996a; Burt et al., 2003). Midge larvae can metabolize organic contaminants such as PAHs (Harkey et al., 1994), but the breakdown products may also be responsible for morphological abnormalities. Research has also shown that sediments contaminated with trace metals and other pollutants harbor chironomids whose chromosomal activity levels are reduced, which could reflect lowered metabolic activity and inhibited RNA synthesis (Hudson and Ciborowski 1996b). The important role that chironomids play in the food web is also significant for representing the possible transfer of some contaminants (Ciborowski and Corkum, 2003; Smits et al., 2005).

Status and Trends

Abundance

In western Lake Erie, between 1930 and 1961 increasing eutrophication was evidenced by a fourfold increase in chironomid density (Carr and Hiltunen, 1965). In 1961, the three most abundant and widely distributed groups of organisms were chironomid larvae, oligochaetes, and fingernail clams. Chironomids made up 5% (355 larvae/m^2) of the total zoobenthic abundance and were evenly distributed at all sites across western Lake Erie (Carr and Hiltunen, 1965). There was no correlation with the number of oligochaete worms found, so chironomid larvae represent an independent indicator of environmental condition. Water conditions improved in Lake Erie through the 1980s and into the early 1990s. The benthic community slowly recovered as the western basin of Lake Erie returned from a eutrophic state to mesotrophic status. Doherty et al. (1999) examined the chironomid larvae in samples collected from western Lake Erie by the U.S. Geological Survey in 1982 and 1993. Between those periods of time, mean density declined whereas diversity (number of genera) rose (Figure 1).

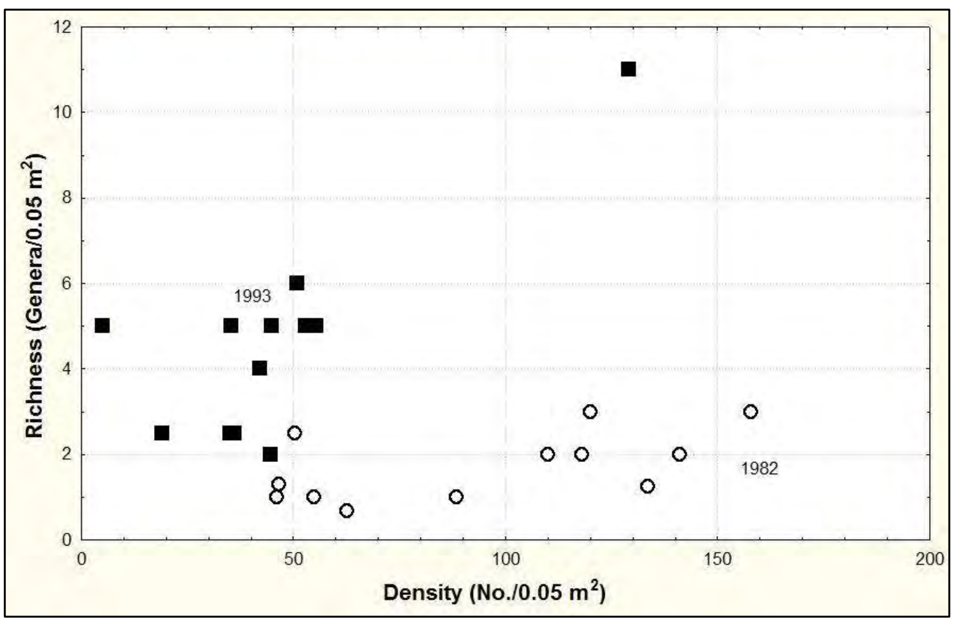


Figure 1. Comparison of number of genera and density of chironomid larvae collected from western Lake Erie locations in 1982 (open circles) and 1993 (filled squares). Data of Doherty et al. (1998) analyzed from samples provided by D.W. Schloesser, Great Lakes Science Center, USGS.

In the Detroit River, the overall abundance of chironomids has increased steadily from 1968–2004 (Figure 2). No comprehensive, reliable zoobenthic surveys have been conducted since that time.

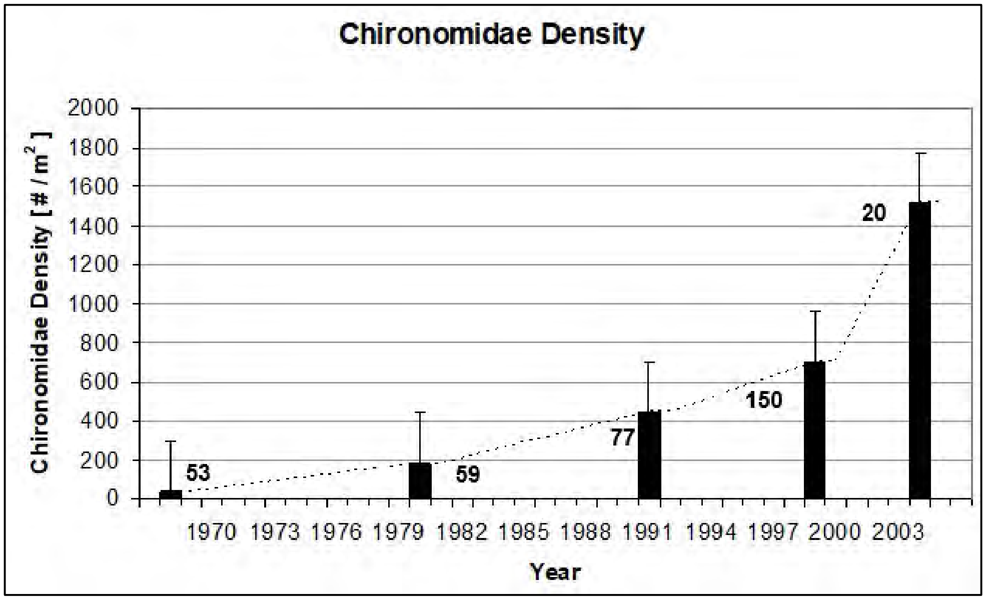


Figure 2. Mean ±SE density of larvae of Chironomidae in the Detroit River between 1968 and 2004. The number of sites sampled each year is indicated. Data compiled from Thornley and Hamdy (1984), Farara and Burt (1993), Wood (2004), and Zhang (2008).

Deformities:

The overall incidence of mouthpart deformities in two genera (*Procladius* and *Coelotanypus*) decreased from the 1980s to the 1990s (Doherty et al., 1999; Figure 3). Hudson and Ciborowski (1996a) studied the frequency of deformities in chironomids collected from five locations in the Huron-Erie Corridor in 1992 and 1993. Deformities were most commonly found at the head of the Detroit River near Peche Island. They were surprisingly rare at a location in the Trenton Channel, possibly because the larvae that could survive in Trenton Channel sediments were especially resistant to pollutants. Midge larvae reared in Trenton Channel sediments in the laboratory were much more prone to deformities than those reared in reference sediments (Hudson and Ciborowski, 1996b). The incidence of deformities in chironomids collected in the Detroit River in 2004 (Zhang, 2008) was lower than that observed in 1992/1993 (Hudson and Ciborowski, 1996a).

Figure 3. Incidence of mouthpart deformities in larvae of Procladius midges in western Lake Erie in 1982 (left) and 1993 (right). Colored areas enclose sampling sites (points) from which 75 or more larvae could be examined for deformities. Red areas - >6.0%; yellow areas – 1.6-6.0%; green areas <1.6%. Across the entire Great Lakes, approximately 2.3% of Procladius larvae have deformed mouthparts (Burt et al. 2003). Data analyzed by Doherty et al. (1998) from samples provided by D.W. Schloesser, Great Lakes Science Center, USGS.

Management Next Steps

The relative abundance, community composition, and morphological condition of chironomids larvae are all useful indicators of the condition of water and sediments in the Detroit River and western Lake Erie. Time trends suggest that concentrations of deformity-inducing contaminants in Detroit River sediments declined meaningfully between the 1980s and the early 1990s and remained relatively low through the mid-2000s. This reflects the concerted cleanup efforts that were undertaken at that time. We do not have current data to determine whether the continuing efforts to remediate sediment contamination in the Detroit River have resulted in further reduction in the incidence of deformities. Increases in midge larval biodiversity (number of genera) also suggest improving water quality in western Lake Erie between the 1980s and 1990s. The trend of increasing mean density of larvae in the Detroit River up to 2004 could imply either improving water quality conditions (improved survival) or declining sediment quality (enriched sediments, which sustain more larvae). This uncertainty could be resolved by examining community composition using a genus index of pollution (e.g., Winnell and White's (1985) or by examining temporal trends in sediment contamination and its risk to chironomids as assessed by a newly developed Hazard Score Metric (McPhedran et al., 2017).

Research/Monitoring Needs

Chironomids are a dominant part of the benthic community of the Detroit River and western Lake Erie. Because they can be found year-round and live in all types of aquatic habitats, the timing of benthic sampling is not as critical for these organisms as it is for other zoobenthic indicators such as *Hexagenia* mayflies and caddisflies. However, assessment of deformities requires that adequate numbers of larvae be collected at each location. Consequently, multiple replicate samples should be collected during surveys to assure the availability of enough specimens. Community composition assessment can be a valuable tool, permitting use of richness or pollution indices to assess changes in water quality or local conditions. Genus level identification requires that larvae be mounted on microscope slides and examined by an expert. However, samples that are properly preserved and stored can be examined and identified many years after they have been collected.

References

Beck, M.L., Hopkins, W.A., Jackson, B.P., 2013. Spatial and temporal variation in the diet of tree swallows: implications for trace-element exposure after habitat remediation. Archives of Environmental Contamination and Toxicology. 65, 575-587.

Burt, J., Ciborowski, J.J.H., Reynoldson, T.B., 2003. Baseline incidence of mouthpart deformities in Chironomidae (Diptera) from the Laurentian Great Lakes, Canada. Journal of Great Lakes Research. 29, 172-180.

Carr, J., Hiltunen, J., 1965. Changes in the bottom fauna of Western Lake Erie from 1930 to 1961. Limnology and Oceanography. 10, 551-569.

Ciborowski, J.J.H., 2003. Lessons from sentinel invertebrates: mayflies and other species, in: Hartig, J.H. (Ed.), Honoring Our Detroit River: Caring for Our Home, Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 107-120.

Ciborowski, J.J.H., Corkum, L.D., 2003. Appendix 9: Sediment-zoobenthos interactions, in: Heidtke, T.M., Hartig, J.H., Yu, B. (Eds.), Evaluating Ecosystem Results of PCB Control Measures within the Detroit River–Western Lake Erie Basin, Wayne State University, Detroit, Michigan, pp. 78-82.

Dermott, R.M., 1991. Deformities in larval *Procladius* spp. and dominant Chironomini from the St. Clair River. Hydrobiologia. 219, 171-185.

Doherty, M.S.E., Hudson, P.L., Ciborowski, J.J.H., Schloesser, D.W., 1999. Morphological Deformities in Larval Chironomidae (Diptera) from the Western Basin of Lake Erie: A Historical Comparison. In: Van Collie, R., Chasse, R., Hare, L., Julien, C., Mattel, L., Thellan, C., Niimi, A.J., Proceedings of the 25th Annual Aquatic Toxicity Workshop: October 18-21, 1998, Quebec City, Canadian Technical Report of Fisheries and Aquatic Sciences, No. 2269, 134.

Farara, D.G., Burt A.G., 1993. Environmental assessment of Detroit River sediments and benthic macroinvertebrate communities – 1991. Report prepared for the Ontario Ministry of Environment and Energy by Beak Consultants Limited, Brampton, Ontario, Canada.

Harkey, G.A., Landrum, P.F., Klaine, S.J., 1994. Comparison of whole-sediment elutriate and pore-water exposures for use in assessing sediment-associated organic contaminants in bioassays. Environmental Toxicology and Chemistry. 13, 1315-29.

Hudson, L.A., Ciborowski, J.J.H., 1996a. Spatial and taxonomic variation in incidence of mouthpart deformities in midge larvae (Diptera: Chironomidae: Chironomini). Canadian. Journal of Fisheries and Aquatic Sciences. 53, 297-304.

Hudson, L.A, Ciborowski, J.J.H., 1996b. Teratogenic and genotoxic responses of larval *Chironomus salinarius* group (Diptera: Chironomidae) to contaminated sediment. Environmental Toxicology and Chemistry. 15, 1375-1381.

Langdon, P.G., Ruiz, Z., Broderson, K.P., Foster, I.D.L., 2006. Assessing lake eutrophication using chironomids: Understanding the nature of community response in different lake types. Freshwater Biology. 51, 562-577.

McPhedran, K.N., Grgicak-Mannion, A., Paterson, G., Briggs, T., Ciborowski, J.J.H., Haffner, G.D., Drouillard, K.G., 2017. Assessment of hazard metrics for predicting field benthic invertebrate toxicity in the Detroit River, Ontario, Canada. Integrated Environmental Assessment and Management. 13, 410-422.

Saether, O., 1975. Chironomid communities as water quality indicators. Holarctic Ecology, 2, 65-74.

Smits, J.E., Bortolotti, G.R., Sebastian, M., Ciborowski, J.J.H., 2005. Spatial, temporal, and dietary determinants of organic contaminants in nestling tree swallows in Point Pelee National Park, Ontario, Canada. Environmental Toxicology & Chemistry. 24, 3159-3165.

Surber, E.W., 1957. Biological criteria for the determination of lake pollution, in: Tarzwell, C.M. (Ed.), Biological Problems in Water Pollution, U.S. Public Health Service, pp. 164-174.

Thornley, S., Hamdy, Y.H., 1984. An assessment of the bottom fauna and sediments of the Detroit River. Ontario Ministry of the Environment, Southwestern Region and Water Resources Branch, Toronto, Ontario, Canada.

Warwick, W. F., 1985. Morphological abnormalities in Chironomidae (Diptera) larvae as measures of toxic stress in freshwater ecosystems: Indexing antennal deformities in Chironomus Meigen. Canadian Journal of Fisheries and Aquatic Sciences. 42, 1881–1914.

Winnell, M.H., White, D.S., 1985. Trophic status of southeastern Michigan based on the Chironomidae (Diptera). Journal of Great Lakes Research. 11, 540-548.

Wood, S., 2004. The use of benthic macroinvertebrate community composition as a measure of contaminant induced stress in the sediments of the Detroit River. M.Sc. Thesis, University of Windsor, Windsor, Ontario, Canada.

Zhang, J., 2008. Zoobenthic indicators of environmental conditions in the L. Huron-L. Erie corridor. M.Sc. Thesis, University of Windsor, Windsor, Ontario, Canada.

This page intentionally left blank.

7.16 Common Tern Breeding Colonies in Southeast Michigan

Tom Schneider, Detroit Zoological Society, tschneider@dzs.org

Background

Common terns (*Sterna hirundo*) are a migratory species that winter in South America and breed in the northern United States. In the Great Lakes, they nest primarily in Michigan and New York (Figure 1). The nesting population has declined 19.1% in the last three decades (Morris et al., 2010) and they are listed as "Threatened" in Michigan. There have been 16 active colony sites recorded in Michigan since 2011 (Michigan Wildlife Action Plan, 2015), including several in the Detroit River and Lake St. Clair where they utilize artificial sites such as navigational piers, dredge piles, break walls (Cuthbert et al., 2003), and even a decommissioned lighthouse.

Figure 1. Common Tern – a "Threatened" species in Michigan (photo credit: U.S. Fish and Wildlife Service).

Status and Trends

Human activity and the associated man-made structures in the Detroit River created ample nesting habitat for common terns in the 1960s. At that time, more than 4,000 pairs of common terns were recorded nesting at five sites in the river (Norwood, 2011). However, many of these sites were lost as breeding habitat due to vegetation succession, erosion, gull competition, and predator pressures. By 2012 common terns were restricted to four navigational piers in the Trenton Channel at Grosse Ile, where the number fluctuated between 135 and 316 nesting pairs

(Norwood, 2011). Since then, high water has made the two sites at the county bridge uninhabitable, but birds still utilize the piers at the toll bridge piers. Detailed censusing has not occurred since 2011.

In 2010, a U.S.-Canada roundtable was held at the Detroit Zoo with common tern managers and researchers to develop a quantitative target for the number of breeding pairs and their productivity that considers the population ecology of the species (Norwood et al., 2011). Resource managers and researchers agreed that there should be expansion into new colony sites, including Belle Isle and other river island sites. The previous five-year mean for the number of breeding pairs was 361 across the region, with a goal of 780 pairs by 2020 (Norwood et al., 2001). Since that time, the number of birds has continued to decline, with birds nesting only at the toll bridge and at the South Channel lighthouse in 2019. Continued monitoring, management, and restoration will be required to achieve the common tern restoration target.

There have been several efforts to restore nesting habitat in the Detroit River. An historical site located on Belle Isle, an island park located near the head of the Detroit River, was the most productive breeding site in southeast Michigan, with over 1,200 nesting pairs and more than 2,000 chicks banded in 1959 and 1960, respectively (Nickell, 1959-60). The site is located on an artificial peninsula at the northern end of the island at the City of Detroit municipal water intake, now managed by the Great Lakes Water Authority. Terns abandoned the site in the mid-1960s due to human disturbance and in 2009 the Detroit Zoological Society, the Detroit Water and Sewerage Department, and the Detroit River International Wildlife Refuge removed vegetation, added gravel substrate, and social attraction methods consisting of tern calls and deployed decoys. In 2011, terns began nesting at the site in small numbers; less than 20 pairs nested and produced a limited number of chicks. However, predation pressure from raccoons, snakes, and birds limited reproductive success, and management efforts at this site stopped in 2018.

More recently, Friends of the Detroit River received a Great Lakes Restoration Initiative (GLRI) grant from National Oceanic and Atmospheric Administration to build dikes to protect coastal wetlands on Stony Island (2017) and Celeron Islands (2019) in the Detroit River (Figure 2).

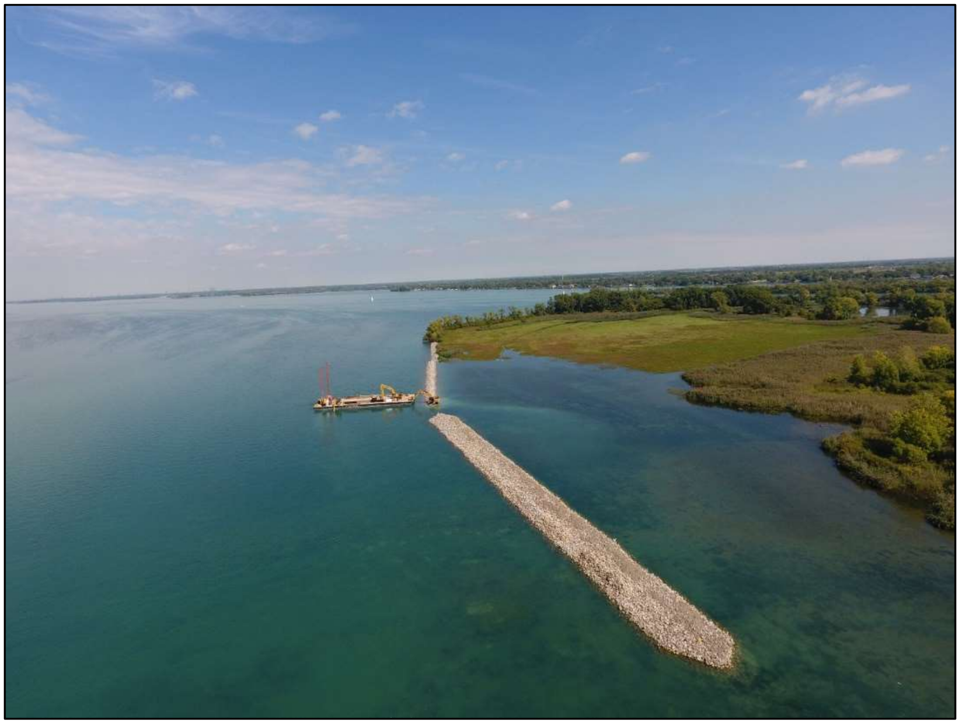


Figure 2. Tern nesting habitat at Stony Island (photo credit: Detroit Zoo).

These dikes were designed to both protect coastal wetlands and to create common tern nesting habitat with gravel placed on the top. The Detroit Zoological Society has been monitoring these sites, and in 2018 and 2019 tern decoys were placed in the hopes of attracting nesting terns. However, common terns have not nested at either site, although many birds have been observed using the sites for perching. In 2020, decoys and a sound system will be deployed on Celeron Island with the goal of attracting nesting terns.

Common tern numbers have increased in Lake St. Clair. Sometime after 2000, common terns colonized a lighthouse site in the St. Clair Flats when Save Our South Channel Lights restored the two decommissioned lighthouses (Figure 3). The restoration work included constructing cribbing around both houses and the first report of terns nesting occurred in 2012. The Detroit Zoological Society began monitoring the site and managing vegetation in 2013, and the colony has grown from 65 nesting pairs in 2013 to 180 nesting pairs in 2019. In 2018, Detroit Zoological Society received U.S. Fish and Wildlife Service Coastal grant funding to improve the nesting substrate, remove hazards, and lower the grading; with the goal of improving nesting success. Detroit Zoological Society and Save Our South Channel Lights will continue to manage this site for tern nesting, and it appears to be one of the most secure sites for common terns in southeast Michigan.

Figure 3. Lighthouse with improved tern nesting habitat (photo credit: Detroit Zoo).

References

Cuthbert, F.J., Wires, L.R., Timmerman, K., 2003. Status assessment and conservation recommendations for the common tern (*Sterna hirundo*) in the Great Lakes region. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.

Michigan Wildlife Action Plan, 2015. Open dunes and sand-soft cobble shores. Michigan Department of Natural Resources, Lansing, Michigan, USA.

Morris, R.D., Weseloh, D.V., Cuthbert, F.J., Pekarik, C., Wires, L.R., Harper, L., 2010. Distribution and abundance of nesting common and Caspian terns on the North American Great Lakes, 1976 to 1999. Journal of Great Lakes Research. 36, 44-56.

Nickell, W.P., 1959-1960. Great Lakes survey of gulls and terns in colonies (unpublished raw data). Cranbrook Institute of Science, Bloomfield Hills, Michigan, USA.

Norwood, G., Schneider, T., Jozwiak, J., Cook, A., Hartig, J.H., 2011. Establishing targets and endpoints for common tern recovery at Detroit River and western Lake Erie. Final report to Environmental Protection Agency. Detroit River International Wildlife Refuge, Grosse Ile, Michigan, USA.

Norwood, G.J., 2011. Nest-site selection, nocturnal nest desertion, and productivity in a common tern (*Sterna hirundo*) colony at Detroit River, Michigan. Master Thesis. Eastern Michigan University, Ypsilanti, Michigan, USA.

7.17 Conservation of Black Terns – A Michigan Species of Special Concern

Erin Rowan, Audubon Great Lakes, erin.rowan@audubon.org

Background

Black Tern (*Chlidonias niger*) is a Michigan "Species of Special Concern" that requires mats of floating vegetation in marsh wetlands for nesting. Since 2013, Detroit Audubon and Audubon Great Lakes have studied Black Terns at St. Clair Flats, Michigan with the primary goals of estimating colony size, breeding success, and productivity of this Michigan "Species of Special Concern." St. Clair Flats has been and remains Michigan's largest colony for this important species. The data collected are being used to determine land management and conservation strategies needed to abate threats to breeding success and remove limiting factors to colony occupancy. A species of conservation concern in most Great Lakes states, the Black Tern is receiving increasing attention by federal and state agencies, including the Upper Mississippi River/Great Lakes Joint Venture.

Status and Trends

Black Tern populations have experienced a decline of 48-71% between 1991 and 2006 in Michigan, and range-wide losses of 61% between 1966 and 1996 (Scharf, 2011). This constitutes a three percent annual reduction in numbers. New research (Wyman and Cuthbert, 2017) shows that colony abandonment has occurred at a faster rate than the population decline, and suggests that large colonies, like those at St. Clair Flats, hold the highest conservation value. Both the proximate and ultimate causes of the population decline are unclear. Preliminary demographic data from studies in breeding colonies in Wisconsin (Shealer, 2007) suggest adult survivorship may be too low in some areas to support population maintenance.

Basic demographic information for most colonies is lacking. Any effort to measure population demographics involves a long-term dataset and annual focused effort, and this project is no exception. Models from Wisconsin (Shealer, 2007) and Maine (F. Servello, pers. comm.) required trapping of over 1,000 adult Black Terns over a decade or more in order to properly estimate adult survivorship. The study conducted by Shealer (2007) estimated adult survivorship in those populations at approximately 62-65%, which is found to be too low to viably maintain a population. In order to better evaluate survivorship at a regional scale, long-term mark-recapture surveys need to be replicated in additional colonies. These replicative studies will confirm adult and natal site fidelity (best achieved with satellite transmitters), juvenile survivorship to breeding age (2 years), colony exchange rates (transmitters), and all relevant demographic information (Putnam, 2016). These concerns led to the expansion of the productivity survey to include trapping and banding of adult and young Black Terns in 2013. This dataset will inform land managers how best to remove limiting factors to Black Tern population growth.

Colony Locations

Black Terns changed nesting locations between and within seasons, in response to changing distributions of floating dead bulrush stem mats and water levels. 2013 was a record low water level year in the Great Lakes and 2019 was a record high water level year. The distribution of Black Tern subcolonies on St. Clair Flats has reduced over time, with some notable between-year changes, particularly 2018-2019. Perhaps most notably, Muscamoot Bay was the epicenter of breeding activity from 2016 onward, while Strawberry subcolony and others west of Harsen's Island dropped precipitously. Mackie subcolony increased significantly, and was then abandoned, as were Doty and Fisher subcolonies, while other colonies stayed roughly the same. Many areas which were fairly deep in 2015 and 2016, such as Strawberry and Mackie, were too deep for nesting and monitoring in subsequent years.

Deep water has many potential adverse effects to Black Tern nesting success. It is suspected that in high water years, vegetation mats trapped within ice sheets have more easily been lost in early spring storms, as ice ventures out to the middle of Lake St. Clair. A decline in available nesting mats has been observed as water levels have increased over time. In addition to a loss of vegetation mats, increased wave action during storm events causes more frequent nest failures. Higher water levels are also allowing larger motorboats to travel through historically narrow channels throughout the flats. Larger boats create more of a wake than small mud boats, which can also cause nearby nests to fail. One potential silver lining to the increase in water depth is that it makes the colonies increasingly difficult for land-based predators to reach.

While Black Terns are clearly adept at adjusting to micro-habitat conditions between years and within years (during re-nest attempts), they are losing nesting substrate as water levels continue to rise, and remaining subcolonies are more subject to nest failure during storm events in high water level years. Nesting subcolonies are being pushed east, inland towards Harsens Island, and fewer adults are breeding at St. Clair Flats than ever before.

Black Tern Nesting at St. Clair Flats

The minimum tally of pairs found nesting at St. Clair Flats over the years confirms that roughly 300 adults are present at St. Clair Flats annually. This suggests at least 150 single nesting attempts (Table 1). Given the high number of nest failures and subsequent re-nesting attempts, the overall number of nests found may not be a suitable surrogate for estimating the actual number of adults. Population estimates could potentially include some double counting of adults that switched colonies during the brief periods when we conducted peak counts. From 2016 onward, most of these counts were made during June 9-22 during concentrated flush counts.

Table 1. The total estimated minimum number of nests and adult Black Terns at St. Clair Flats during 2013-2019. These estimates are inherently subjective (see text), and these numbers represent what we believe are reliable minimum estimates, and very likely undercounts.

Year	2013	2014	2015	2016	2017	2018	2019
Adults	600	340	300	300	300	220	180
Nests	50	68	81	100	201	123	154

More nests have been found each year at St. Clair Flats (Table 1). This very likely is not representative of an increase in the number of nests, but rather an increase in the technicians' skill at finding them. Given that an estimated 300 adults are present each year, likely more (see above), these findings suggest that technicians are missing a lot of nests. Missing nests is unavoidable, as not all areas can be searched effectively each week. Colonies that fail early are often missed entirely, because surveyors are unable to access a colony prior to a storm failure or predation event. A more complete survey would require more technicians, boats, and person-hours. Ultimately, this would require more funding and multiple technicians, or perhaps daily visits of one technician.

Hatching and Fledging Success

Ideally, hatching and fledging success would be measured by following the ultimate fate of each egg, but with current technology, this is not yet possible. Instead, as previously mentioned, hatching success is used as a surrogate for fledging success and is based on the estimated number of eggs hatched versus the estimated number of eggs failed. Many nests still have unknown fates each year, and below hatching success ranges account for these unknowns (Table 2). Hatching success has declined over time as water levels rise. Effort in the field between 2017 and 2019 was consistent compared to past years.

In an effort to better measure fledging success, Audubon Great Lakes and partners at Indiana University deployed NanoTags, a type of radio transmitter, on 15 pre-fledged chicks in 2019. Using the Motus Wildlife Tracking System (motus.org), signals from tagged fledged chicks should be picked up by Motus towers along the migratory route south. Data review from Motus towers is still pending.

Table 2. The hatching success (%) of Black Tern nests found on St. Clair Flats during 2013-2019.

Year	2013	2014	2015	2016	2017	2018	2019
Hatching Success	47-95%	55-84%	50-81%	26-99%	35-89%	29-68%	19-73%

Banding of Adults

The number of banded adults has steadily increased over the years due to technicians fine-tuning capture methods over time (Table 3). In 2016, there was a slight drop in capture rates due to reduced effort in the field and a focus on training a new technician. In 2017, an increase in capture rates and effort resulted in 63 newly banded adults.

In 2019, the focus shifted from banding adults to monitoring nests and chicks so chicks could be captured and NanoTags could be deployed prior to fledging.

Banding of Chicks

Chick banding totals are presented in Table 3. While 432 flightless chicks have been banded, the actual number present was certainly much higher. Prior to 2019, adult capture had been the primary focus, so chick capture rates were lower with the exception of 2017, when multiple partners were in the field at peak hatching time, allowing for many more chicks to be captured and banded.

Table 3. Summary of annual adult and chick Black Terns banded at St. Clair Flats since 2013. Totals represent only newly banded adults (omits recaptures).

Year	New Adults	Recaptured Adults	Chicks
2013	9	0	32
2014	12	0	67
2015	37	0	76
2016	31	2	66
2017	63	9	132
2018	37	11	14
2019	12	14	45
Project Total	**201**	**39**	**432**

Recaptures

Thirty-nine individuals have been recaptured to date, including four natal recruits. More recaptures are expected to happen as adult and chick banding continues. The most exciting recapture to date (band #2451-31818) was banded as a chick in Mackie colony on June 30, 2014 and recaptured in Muscamoot on June 20, 2016. This bird was not captured in 2015 and represented the first ever natal recruit for St. Clair Flats.

Storms

Strong thunderstorms continue to be the primary threat to tern nests on St. Clair Flats. Six camera traps were set-up in 2018 in an effort to assist in identifying nest failures with certainty; however, these cameras only covered 10 nests. These results are based on a combination of nest cameras and nest monitoring efforts that observed nest failures following storm events each year. In particular, Fisher Highway appeared to experience significant nest loss, and subsequent abandonment by nesting adults following the May 28 and June 4-5, 2016 storms (E. Rowan, unpub. data) and has not been recolonized since. Increased water depth during 2016-2019 may have exacerbated storm damage, as wave action could have been more intense.

Predation Issues

Mammalian and avian predation generally are minimal at the flats, with weather a more important source of nest and chick loss (Putnam, 2016). Only a few cases of nest depredation events have been observed since monitoring began. In 2016, eggs were found destroyed by what appeared to be piercing, possibly by a bird of some kind. However, no diurnal heron activity in the colonies was noted (other than a flyover by a Great Blue Heron at Fisher Highway on July 7). Michigan Department of Natural Resources (MDNR) biologists reported single Black-crowned Night-Herons (unpub. data) in 2016 on Harsen's Island, though none have been observed on the flats.

Chick predation was extremely difficult to document, given that chicks are frequently on the move and impossible to locate after a short time following hatching. That said, a single chick was found with laceration wounds on its belly and back, injuries that were most consistent with a smallmouth bass attack (John Darling, Erin Rowan pers. comm.). Pike or muskellunge would have produced puncture wounds, and a Snapping Turtle (*Chelydra serpentina*) would have killed the chick. This chick recovered in the care of a licensed rehabilitator and was released. It is also possible that fish predation may be exacerbated by deeper water, as pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), or muskellunge (*Esox masquinongy*) may be better able to access the nesting areas. This merits further study.

A single raccoon was observed in May of 2016 swimming across Doty channel toward Doty East, though no Black Terns were yet nesting. This is a potential predation source to be aware of in the future. Each year technicians witnessed northern water snakes (*Nerodia sipedon*), especially near Mackie and Doty East, and also in Muscamoot. Eggs were found in Little and Big Muscamoot with pairs of puncture wounds surrounding intact nests that were empty in 2018 and 2019. Northern water snakes are probable egg predators, though more study is needed. Muskrats and mink continue to be present in the Black Tern colonies at St. Clair Flats, but do not seem to exert undue predation pressure.

New Technology

Motus Wildlife Tracking System uses coordinated automated radio telemetry arrays to track the movements of wildlife internationally. Digitally encoded radio transmitters, or NanoTags, are affixed to individuals and broadcast signals to Motus towers, which have been erected across the globe. Fourteen of these NanoTags were attached to banded Black Tern adults in 2017, and a Motus tower was erected on Harsens Island thanks to partners at Canadian Wildlife Service. Fifteen NanoTags were attached to banded Black Tern chicks in 2019 as well, and two additional Motus towers are being erected along western Lake St. Clair in 2020. Motus data will help determine migration routes and wintering grounds of the Black Terns at St. Clair Flats, and shed light on fledging success.

Nine geolocators were also deployed on adults in 2017, and six have since been recovered, three in 2018 and three in 2019. Two camera traps were utilized in 2017, and six were utilized in 2018, thanks to partners at the Detroit Zoo and Common Coast Research. Camera traps were installed in 2019 as well, but due to technical difficulties, were unable to record footage. The continued use of camera traps will hopefully elucidate causes of nest failure and potential nest and hatchling predation at St. Clair Flats.

Surveys of Additional Black Tern Colonies

As previously mentioned, to better understand Black Tern survivorship at a regional scale, long-term mark-recapture surveys need to be replicated in additional colonies. Outside of St. Clair Flats, Audubon Great Lakes and partners surveyed Black Terns at Ogontz Bay (Delta Co., Michigan) beginning in 2016. This site was abandoned in 2017. The colony reappeared at Ogontz Bay in 2018, but was inactive again in 2019. Baseline surveys of a Black Tern colony were conducted at Wigwam Bay State Wildlife Area (Arenac Co., Michigan) in 2017. In 2018 and 2019, this colony was regularly monitored, and adults and chicks banded. This research aims to measure the impact of wetland management on Black Tern nesting activity. Vegetation management, that creates openings in dense emergent marsh monocultures, is being used to recreate habitat that should be preferred by nesting Black Terns.

Management Next Steps

In 2019, Audubon Great Lakes obtained a MDNR Wildlife Habitat Grant to enhance wetlands within the diked units of the St. Clair Flats State Wildlife Area. This project will have similar goals as the project at Wigwam Bay. The diked wetlands at St. Clair Flats have greater protection from storm events and human disturbance compared to undiked wetlands, and managers can manipulate water levels. Each year, adult Black Terns are observed feeding in diked wetland units, but only one pair attempted to nest there in 2017. Unfortunately, this nest failed, due to a storm that caused the nesting substrate to break apart. In the fall of 2020, openings will be created within dense stands of cattail and *Phragmites* within the marsh, and the cut vegetation will be left behind. This will help to create hemi-marsh conditions by increasing the amount of open space, while combatting the spread of *Phragmites* (stems will be flooded). Further, cut plant debris will be left in place in the hopes that Black Terns utilize it for nesting. This habitat work will also benefit breeding and migratory waterfowl, and breeding marsh birds.

Partners at Detroit Audubon received funding from National Audubon to build and install Black Tern nesting platforms throughout St. Clair Flats in 2020. These platforms have been successfully used by Black Terns at Ogontz Bay and will hopefully help reduce nest failures at St. Clair Flats.

To best inform management at a statewide level, Audubon Great Lakes is working with multiple partners as part of the Great Lakes Black Tern Conservation Initiative to expand Black Tern colony monitoring across Michigan and other areas in the Great Lakes. A proposed larger-scale monitoring project will incorporate efforts to identify threats related to predation and invasive species and will directly inform where restoration efforts should be prioritized and whether conservation actions should focus on providing platforms or invasive species management.

References

Al-Saffar, M.A., 2015. Identifying important coastal wetlands in Michigan using the black tern (*Chlidonias niger surinamensis*). Final Report to the U.S. Fish & Wildlife Service, The Upper Midwest & Great Lakes Landscape Conservation Cooperative (UMGL LCC), Coastal Conservation Working Group (CCWG), East Lansing, Michigan, USA.

Kaplan, J., Putnam, C., 2016. Monitoring black tern productivity at Ogontz Bay, Michigan. Report to Audubon Great Lakes. Chicago, Illinois, USA.

Putnam, C., 2014. A first-year study of breeding success of marsh terns on St. Clair Flats, Michigan. Report to Detroit Audubon. Detroit, Michigan, USA.

Putnam, C., 2015. A second-year study of black terns nesting at St. Clair Flats, Michigan. Report to Detroit Audubon. Detroit, Michigan, USA.

Putnam, C., 2016. A third-year study of black terns nesting at St. Clair Flats, Michigan. A Report to Detroit Audubon. Detroit, Michigan, USA.

Scharf, W.C., 2011. Black tern (*Chlidonias niger*), in: Chartier, A.T., Baldy, J.J., Brenneman, J.M., (eds.), The Second Michigan Breeding Bird Atlas. Kalamazoo Nature Center. Kalamazoo, Michigan, USA.

Shealer, D., 2006. Effect of floating nest platforms on the breeding performance of black terns. J. Field Ornithol. 77, 184-194.

Shealer, D., 2007. Population dynamics of black terns breeding in southeast Wisconsin, 1999-2007. The Passenger Pigeon 69, 471-479.

Wyman, K.E., Cuthbert F.J., 2016. Validation of landscape suitability indices for black terns (*Chlidonias niger*) in the U.S. Great Lakes region. Condor. 118, 613-623.

Wyman, K.E., Cuthbert F.J., 2017. Black tern (*Chlidonias niger*) breeding site abandonment in U.S. Great Lakes coastal wetlands is predicted by historical abundance and patterns of emergent vegetation. Wetl. Ecol. Manag. 25, 583-596.

This page intentionally left blank

7.18 Conservation of Common Five-Lined Skink in Point Pelee National Park

Tammy Dobbie, Point Pelee National Park, tammy.dobbie@canada.ca

Stephen Hecnar, Lakehead University, shecnar@lakeheadu.ca

Background

Point Pelee National Park is located in southwestern Ontario at the southernmost point of the Canadian mainland. It was established as a national park in 1918 to protect significant natural resources and ecological processes. The park consists of 420 hectares (1,039 acres) of Carolinian forest and 1070 hectares (2,644 acres) of freshwater marsh. It has been identified a "Wetland of International Importance" under the Ramsar Convention of UNESCO. Although it is one of Canada's smallest national parks, it is well known for its biodiversity, with a unique and rare assemblage of plants and animals. The park is also world renowned for the viewing of migratory birds in the spring and Monarch butterflies in the fall.

The Common Five-lined Skink (*Plestiodon fasciatus*) is a species of lizard in the family Scincidae (Figure 1). The species is endemic to eastern North America. The Carolinian population of the five-lined skink, currently listed as Endangered under the Species at Risk Act, is found primarily within the coastal Lake Erie Sand Spit Savannah (LESSS) habitat at Point Pelee. It is currently monitored mainly along the west beach of the park as an indicator of the health of the coastal ecosystem. The preferred habitat for this species has been improved over the past few decades through resource management programs to supplement woody debris and to restore LESSS habitat.

Figure 1. Common Five-lined Skink (Plestiodon fasciatus)(credit: Point Pelee National Park).

Status and Trends

Monitoring of the Common Five-lined Skink was undertaken at Point Pelee National Park as part of long-term conservation efforts. Using the census data collected during 16 skink surveys from 1990-2012, 17 permanent quadrats, each 1 km in length, were established along the park beaches, on both the east and west sides (Figure 2). The quadrats were stratified, into high, medium and low, based on

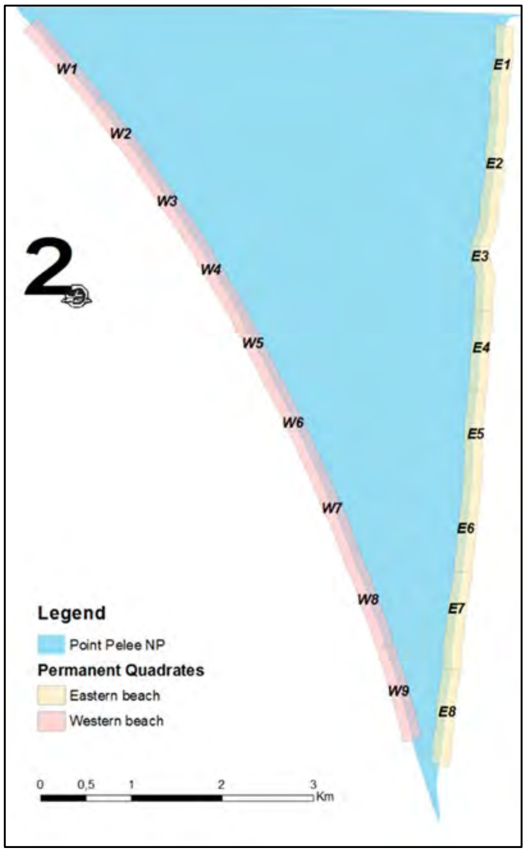


Figure 2. Map of skink monitoring quadrats.

the density of skinks observed during these surveys. Three of the quadrats were removed from the sampling design due to time and access constraints, however, these quadrats contained such a low percentage of the population (1.6%) that their exclusion was not expected to significantly impact population estimates. Starting in 2015, all of the high-density quadrats are sampled every year, along with two medium and two low quadrats (n=10), so that all quadrats are sampled every two years.

Quadrats were surveyed during the same time each year (late June-early July) during the peak of skink abundance and nesting activity. Quadrats were sampled by walking along the beach through the stabilized dune and cedar savannah habitats, checking under all woody debris and counting the total number of skinks and nests observed. Age class, sex, decay class of the woody debris, and number of eggs in each nest were also recorded.

The condition of the skink population was determined by estimating the average park abundance of skinks during the current monitoring period (2013-2017). The trend was assessed by comparing the 80% confidence intervals between the current and the previous period (2008-2012), where non-overlapping confidence intervals would indicate a significant change in abundance. See Parks Canada (2015) for more details of sampling design and statistical analyses.

The "Good-Fair" threshold for the skink population condition measure (107 skinks) was determined using one population standard deviation (±48.5) under the mean number of skinks observed in the 14 quadrats from 1990-2012 (155.3). The "Fair-Poor" threshold was determined using a population viability analysis based on the census data collected from 1990-2012. The risk of extinction for the most current Point Pelee population (2008-2012) rises sharply at < 50 individuals over multiple time scenarios, therefore, this was determined to be the Poor condition threshold (Parks Canada, 2015).

The condition of the skink population at Point Pelee National Park is well above the Good-Fair threshold (2013-2017: 197 ± 67.9 skinks) and has remained stable since the 2008-2012 monitoring period (80% CIs overlapping; Figure 3).

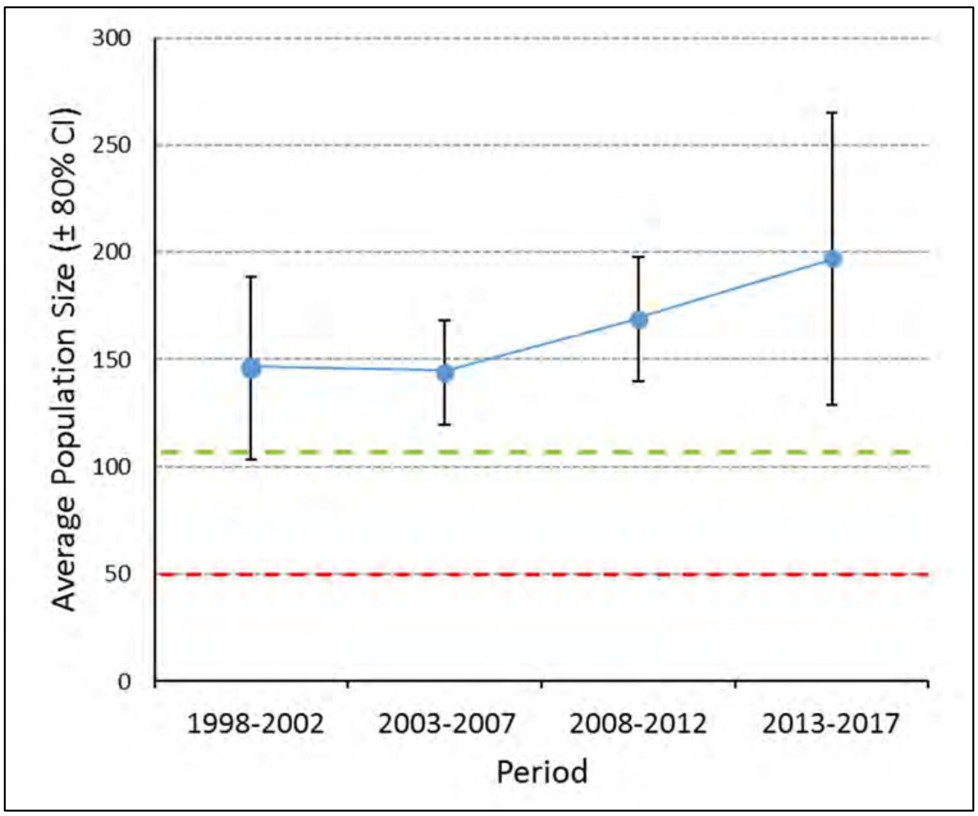


Figure 3. Average skink population size during each of the four 5-year monitoring periods. All periods show a total population census (i.e., all quadrats sampled), with the exception of 2013-2017, where 2015-2017 were population estimates (i.e., a subset of quadrats were sampled). Black error bars indicate the 80% confidence intervals. Dashed green line and red line show the "Good-Fair" threshold and "Fair-Poor" threshold, respectively.

Management Next Steps / Research/Monitoring Needs

The population of Common Five-lined Skinks at Point Pelee National Park has remained in good condition over the time period of 1998-2017 presented in Figure 3. Skinks at Point Pelee were experiencing a downward trend in the early 1990s attributed largely to disturbance and removal of woody debris by humans and illegal collection (Hecnar and Hecnar, 2013), however, the population saw improvement when the park began a project to increase the quality of habitat by adding more woody debris to stabilized dune areas in 1995. Woody debris provides essential shelter cover for this species.

Restoration of the LESSS habitat, which began in 2011, has also improved habitat for the population, especially in inland sites where natural succession had drastically reduced the amount of savannah habitat. Restoration efforts have converted dogwood thickets back to open savannah habitats through management actions such as cutting and prescribed fires. Skink monitoring has historically only taken place along park beaches, where the vast majority of the population was found. Future surveys will be expanded to newly restored interior LESSS sites in order to detect range shifts due to climate change or environmental stochasticity (e.g., large fluctuation in water levels).

More recently (2018-2019), monitoring has shown that the abundance of Common Five-lined Skink has declined at Point Pelee National Park and this is strongly correlated with high Lake Erie water levels. A similar trend has been found at Rondeau Provincial Park. Despite gains made in stabilizing skink populations through habitat and restoration projects, there remain serious concerns for this species' continued persistence at these sites due to predicted negative impacts of climate change on shoreline habitats (i.e., decreases in protective winter ice is projected to increase vulnerability to coastal erosion)(BaMasoud, 2013; BaMasoud and Byrne, 2011; 2012). Continued research, assessment, and conservation of Common Five-lined Skink are warranted to ensure protection of this endangered species.

References

BaMasoud, A., 2013. Shoreline Changes in Point Pelee, Canada: An Airphoto-based Analysis. Ph.D. dissertation, Wilfrid Laurier University, Waterloo, Ontario, Canada.

BaMasoud, A. Byrne, M.L., 2011. Analysis of Shoreline Changes (1959-2004) in Point Pelee National Park, Canada. Journal of Coastal Research, 27, 5, 839-846. doi:10.2112/jcoastres-d-10-00160.1.

BaMasoud, A. Byrne, M.L., 2012. The impact of low ice cover on shoreline recession: A case study from western Point Pelee, Canada. Geomorphology, 173, 141-148. doi:10.1016/j.geomorph.2012.06.004.

Hecnar, S.J., Hecnar, D.R., 2013. Five-lined skink research at Point Pelee National Park, 2012. Final Report. Leamington, Ontario, Canada.

Parks Canada, 2015. Operational Review of the Ecological Integrity Monitoring Program of Pointe-Pelee National Park. Monitoring and Ecological Information Division. Natural Resource Conservation. Parks Canada Agency. Gatineau, Quebec, Canada.

This page intentionally left blank

7.19 Contaminants in Colonial Waterbird Eggs – Detroit River

Shane de Solla, Environment and Climate Change Canada,
shane.desolla@canada.ca

Kimberley Hughes, Broadwing Biological Consulting, kimberleyhughes@rogers.com

Background

The herring gull (*Larus argentatus*) (Figure 1) is an opportunistic piscivore with a high breeding colony fidelity that lives year-round in the Great Lakes. Herring gulls feed heavily upon fish and aquatic invertebrates, but will also feed from terrestrial sources. Double-crested cormorants (*Phalacrocorax auritus*) (Figure 2) are large colonial waterbirds that feed virtually exclusively on fish, but like herring gulls, they are widespread in North America with breeding colonies throughout the Great Lakes. For both species, their eggs have a relatively high lipid content and may accumulate high levels of hydrophobic organic contaminants.

Herring gull eggs have been collected annually from 1974 onward from all five lakes and connecting channels in the Laurentian Great Lakes, as part of the Great Lakes Herring Gull Contaminant Monitoring Program of Environment and Climate Change Canada. In the last five years, cormorant eggs have also been collected from a subset of the same colonies as herring gulls.

Figure 1. Herring gull (Larus argentatus) and eggs (photo credit: Shane de Solla, Environment and Climate Change Canada).

Figure 2. Double-crested cormorant (Phalacrocorax auritus) and eggs (photo credit: Shane de Solla, Environment and Climate Change Canada).

Status and Trends

Herring Gulls

Up to 13 fresh herring gull eggs were collected from each of Fighting Island in the Detroit River and Middle Island in western Lake Erie during early incubation, late April-early May, most years, since 1974. However, herring gull eggs have been found only once since 2010 at Fighting Island. From 2015, cormorant eggs have been collected annually from Fighting Island. Eggs were analyzed individually from 1974 to 1986 but have been analyzed as a single pool of eggs at each site since 1987.

PCBs

Since 1974 (Middle Island) and 1978 (Fighting Island), PCB concentrations have greatly declined in herring gull eggs (Figure 3). In 2015, PCB concentrations were only 10% of the initial concentration in eggs from Fighting Island and 28% of the initial concentration in eggs from Middle Island in 2018. Generally, PCBs declined as a first order decay rate; however, PCB levels at Middle Island have been unchanging for the last decade. PCBs in eggs from Middle Island had the lowest rate of decline of any colony monitored within the five Great Lakes (de Solla et al., 2016). Since the early 1990s, concentrations in gull eggs were similar between the two colonies, but there were a couple of years with elevated PCBs in eggs in the late 2000s at the Middle Island colony.

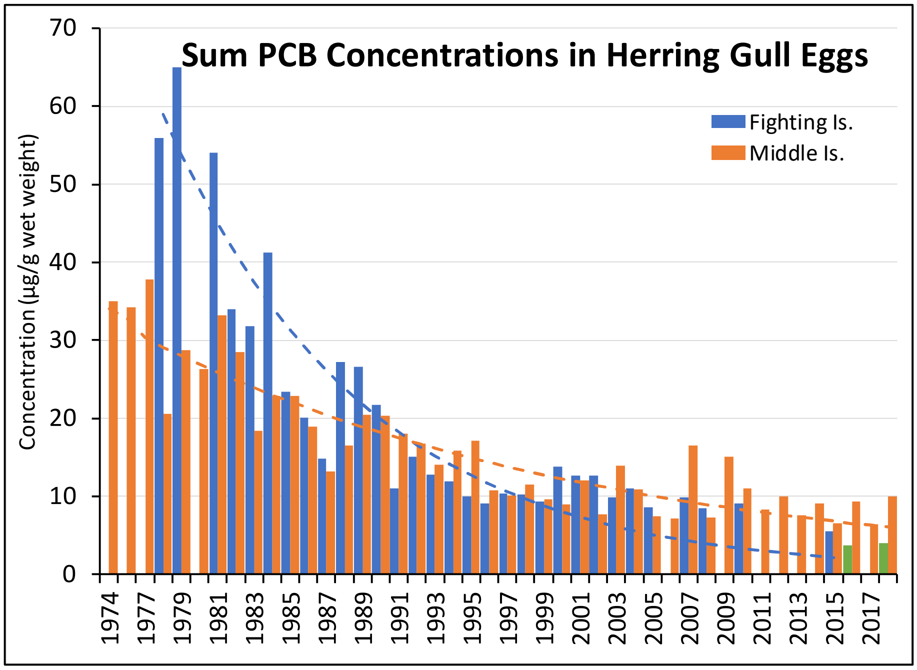


Figure 3. Sum PCBs in herring gull eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 1974-2018. The green bars indicate PCB concentrations in cormorant eggs from Fighting Island in 2016 and 2018 since no data are available for herring gulls.

DDE and other pesticides

Organochlorine pesticides such as DDE, a metabolite of DDT, were monitored annually. Similar to PCBs, DDE concentrations have greatly declined (Figure 4). In 2015, DDE concentrations were only 12% of the initial concentration in eggs from Fighting Island and 14% of the initial concentration in eggs from Middle Island in 2018. DDE declined as a first order decay rate but have been unchanging for the last decade. Concentrations were generally similar between Middle Island and Fighting Island, but there were a couple of years with elevated DDE concentrations in eggs in the late 2000s at the Middle Island colony. Other organochlorine pesticides, such as chlordane, hexachlorobenzene, and dieldrin show similar patterns, albeit at lower concentrations than DDE.

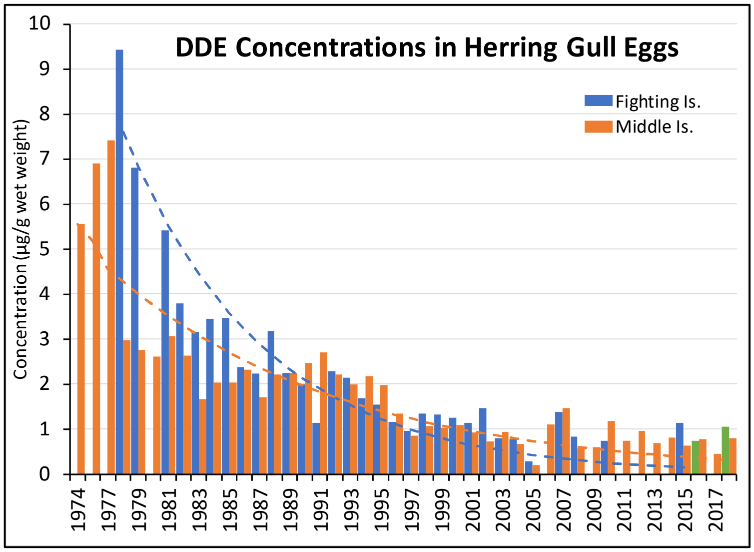


Figure 4. DDE in herring gull eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 1974-2018. The green bars indicate PCB concentrations in cormorant eggs from Fighting Island in 2016 and 2018 since no data are available for herring gulls.

Mercury (Hg)

Unlike organic contaminants, Hg concentrations have declined only slightly in gull eggs since the 1970s (Figure 5). Of note, concentrations increased in eggs from Middle Island between 2005 and 2010 by nearly three times, before declining to more typical levels. The increase in Hg in the late 2000s was even more pronounced in fish (Blukacz-Richards et al., 2017). No such increase was found in eggs from Fighting Island during this period.

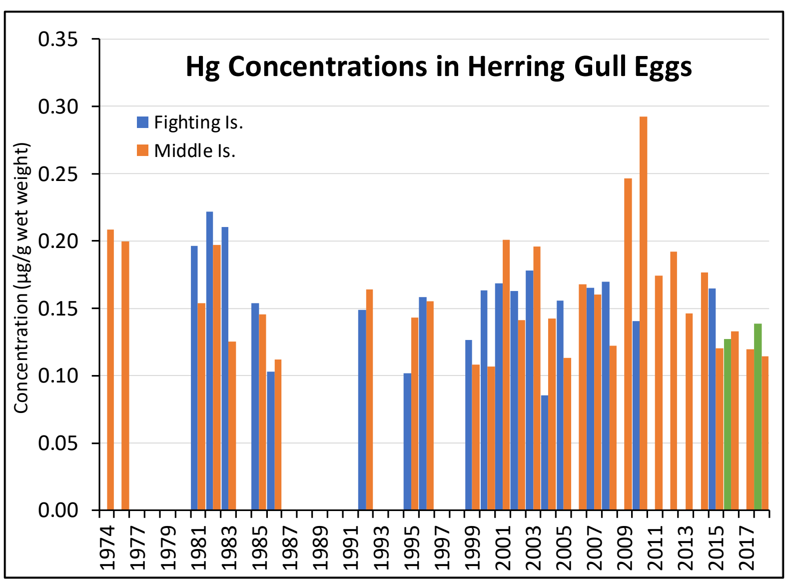


Figure 5. Mercury in herring gull eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 1974-2018. The green bars indicate PCB concentrations in cormorant eggs from Fighting Island in 2016 and 2018 since no data are available for herring gulls.

Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) were retrospectively measured in herring gull eggs from Fighting Island and Middle Island, roughly every five years from 1980 to 2013. We include data from whole body walleye (*Sander vitreus*) for comparative purposes (from McGoldrick et al., 2018). Like PCBs, concentrations initially declined from 1980 to 1995; however, from 1995 to the early 2000s, PCNs increased both in gulls but especially walleye, before subsequently declining (Figure 6). Concentrations were initially higher in gull eggs from Fighting Island, but from 1995 and onwards, concentrations were more similar between the two colonies. The Detroit River appears to be the ultimate source of PCNs in gulls for most colonies downstream as far as Kingston (Figure 7).

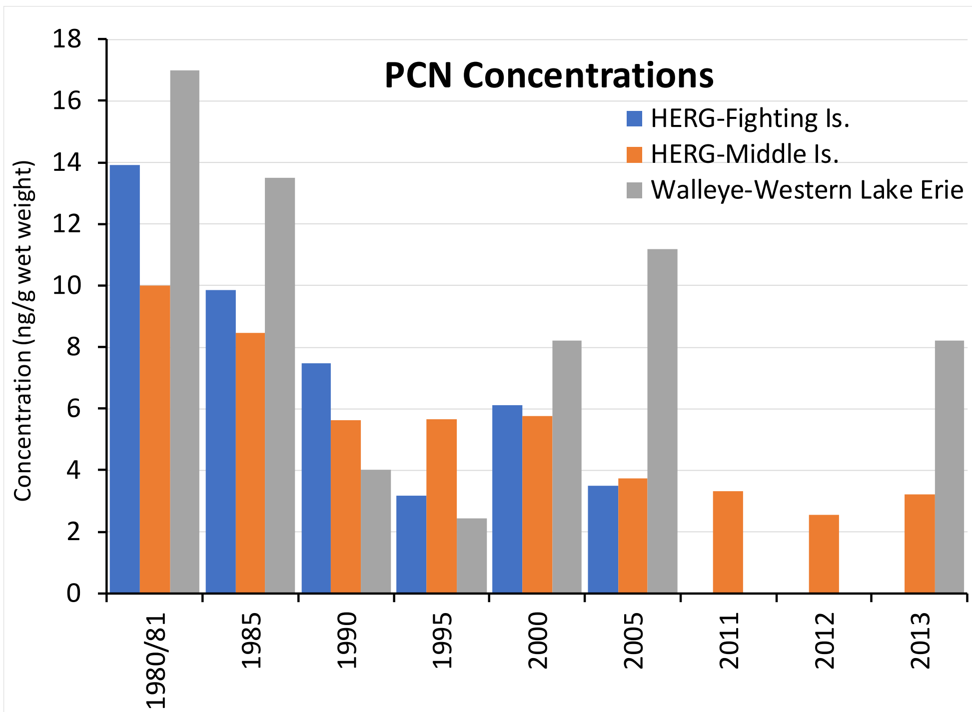


Figure 6. Sum PCNs in herring gull eggs and walleye from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 1980-2013.

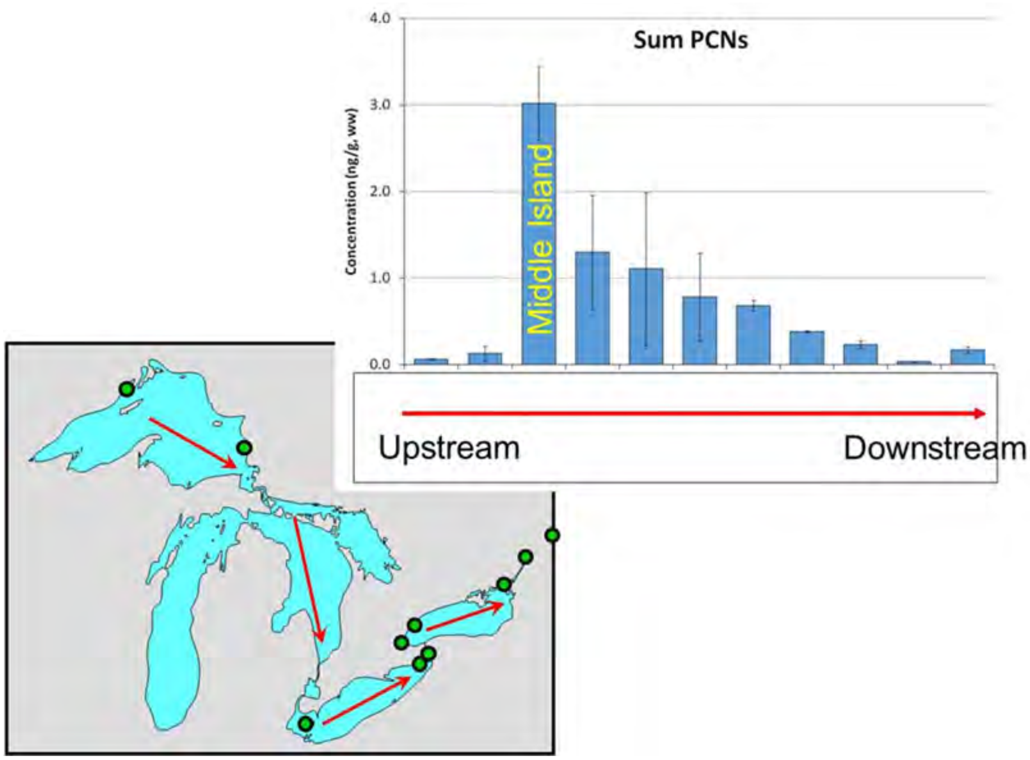


Figure 7. Sum PCNs in herring gull eggs from the Great Lakes in the order from upstream to downstream colonies, in 2011-2013.

Double-Crested Cormorants

PCBs

PCB concentrations were higher in double-crested cormorant eggs from Fighting Island than those from Middle Island from 2015 to 2018 (Figure 8). There is no evidence of declines in PCB concentrations at the two colonies over the short time period from 2015 to 2018. It is possible that PCBs may be increasing at Middle Island, but more years of sampling are required to determine any such trend. PCB concentrations in cormorants were on average one-third of those in gulls based on comparisons in eggs collected from Middle Island from 2015 to 2018.

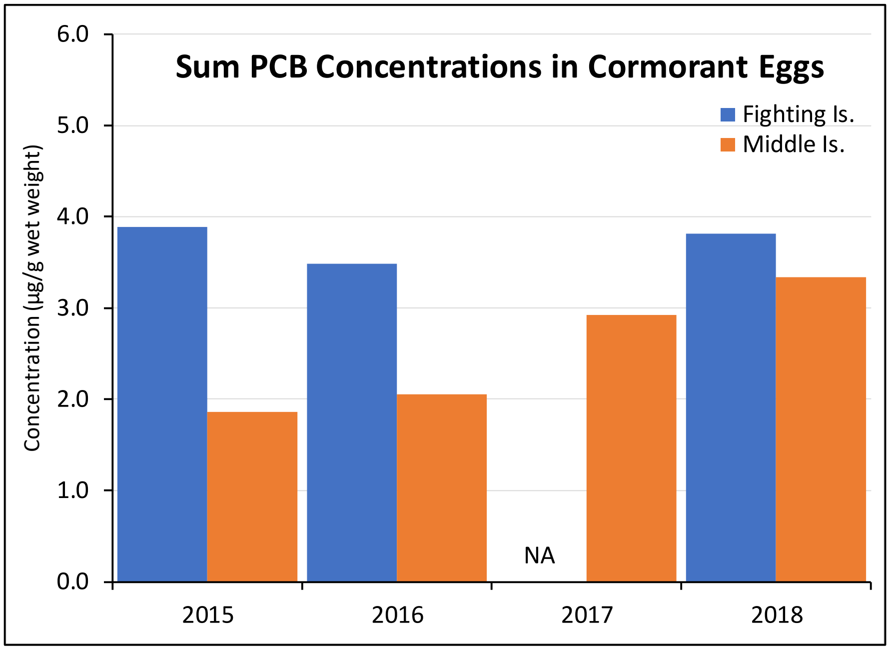


Figure 8. Sum PCB in double-crested cormorant eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 2015-2018. NA indicates that no data are available.

DDE and other pesticides

Like PCBs, concentrations of DDE were higher in cormorant eggs from Fighting Island than those from Middle Island (Figure 9). Trends in other organochlorine pesticides were similar to DDE, although at lower concentrations overall. DDE levels in cormorant eggs were similar to those in herring gull eggs.

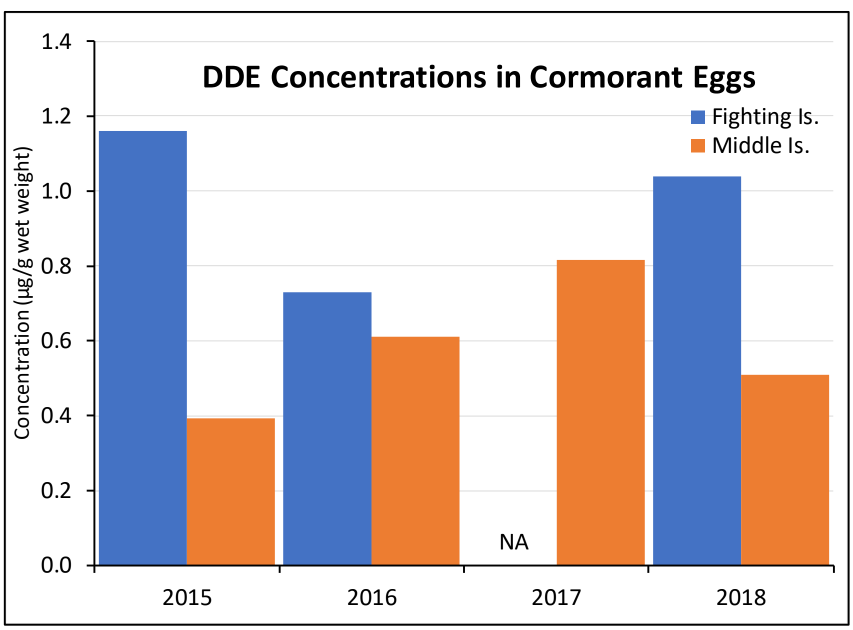


Figure 9. DDE in double-crested cormorant eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 2015-2018. NA indicates that no data are available.

Mercury (Hg)

Concentrations of Hg were higher in cormorant eggs from Fighting Island than those from Middle Island (Figure 10). Hg concentrations in cormorant eggs were similar to those in herring gull eggs.

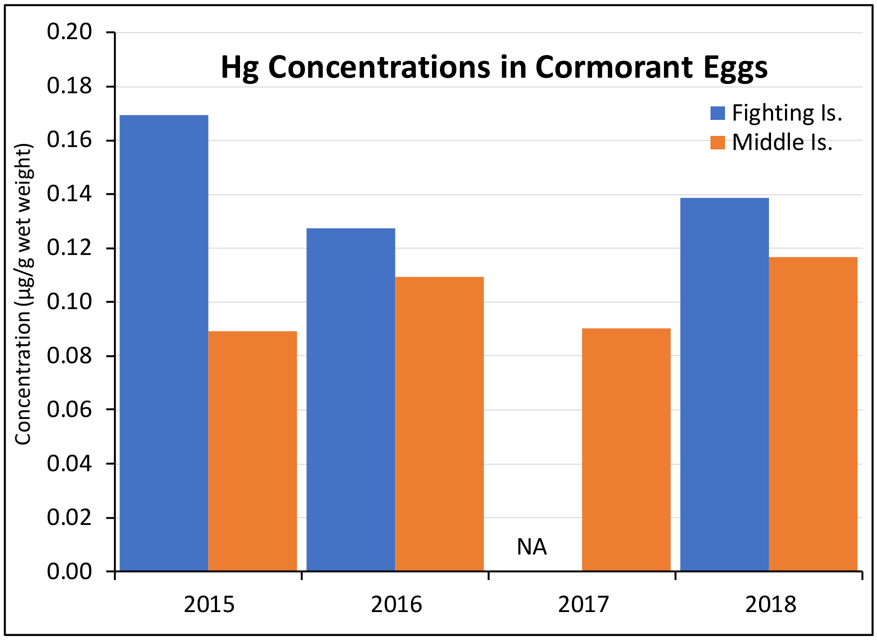


Figure 10. Mercury in double-crested cormorant eggs from Detroit River (Fighting Island) and western Lake Erie (Middle Island) from 2015-2018. NA indicates that no data are available.

Emerging Compounds

Although not analyzed on an annual basis, contaminants of emerging concern are also analyzed in gull eggs on a regular (monitoring) or irregular (surveillance) basis. Substituted diphenylamine antioxidants (SDPAs) and benzotriazole UV stabilizers (Lu *et al.*, 2018), organophosphate triester flame retardants (Su *et al.*, 2015), perfluorinated sulfonates and perfluorinated carboxylic acids (Letcher *et al.*, 2015) have been analyzed in eggs, including those from Middle Island. Unlike most legacy contaminants such as PCBs and organochlorine pesticides, some of these contaminants were either stable or increasing, reflecting their current or recent use.

Management Next Steps

The apparent increase of PCNs concentrations in both gulls and fish (McGoldrick et al., 2018) observed in Lake Erie after 1995 combined with the high levels of PCNs in suspended sediments in the Detroit River are almost certainly linked. Further, PCB concentrations in gull eggs from the colony immediately downstream of the Detroit River (Middle Island, western Lake Erie) have the lowest rate of decline of all colonies in the Great Lakes (de Solla et al., 2016). In 1993, large scale remediation of contaminated sediments was initiated within the Detroit River Area of Concern, and nearly 1,000,000 m^3 of contaminated sediments were removed from the Detroit River watershed (Zarull and Hartig, 2007). These data suggest that gulls and fish collected downstream of the Detroit River had increased body burdens following resuspension of contaminated sediments from remediation projects in the Detroit River conducted from the mid-1990s to mid-2000s (McGoldrick et al., 2018). Similarly, elevated Hg concentrations found in gull eggs from the Middle Island colony in some years and in fish (Blukacz-Richards et al., 2017) in the late 2000s may have also been have been associated with these events. These findings support the use of fish and wildlife indicator species as important tools for monitoring environmental conditions following such activities.

Interpretation of body burdens

Measurements of body burdens in colonial waterbirds integrate the net effect of factors such as bioavailability of contaminants, food web dynamics, and chemical partitioning behavior in the environment. One of the advantages of using colonial waterbirds as indicators is that their rates of elimination of body burdens for persistent organic pollutants (POPs) are generally much faster than the rates of environmental degradation; hence changes in body burdens reflect changes in the bioavailability of POPs. Degradation half-lives in sediment of the PCB congeners typically found in herring gull eggs range between 10 to 19 years in sediment (Sinkkonen and Paasivirta, 2000). Conversely, the half-life of p,p'-DDE in herring gulls was estimated to be 264 days (Norstrom et al., 1986), with half-lives for PCBs likely to be similar. Hence, colonial waterbirds respond faster to inputs of POPs through their diet than the degradation rate of POPs in the general environment. The half-lives of contaminants in gull eggs in the Great Lakes (de Solla et al., 2016) reflect rates consistent to losses in the environment, rather than metabolic loss.

References

Blukacz-Richards, E.A., Visha A., Graham M.L., McGoldrick D.L., de Solla S.R., Moore D.J., Arhonditsis G.B., 2017. Mercury levels in herring gulls and fish: 43 years of spatio-temporal trends in the Great Lakes. Chemosphere 172, 476-487.

de Solla S.R., Weseloh D.V.C., Hughes K.D., Moore D.J., 2016. Forty- year decline of organic contaminants in eggs of herring gulls (Larus argentatus) from the great lakes, 1974 to 2013. Waterbirds 39, 171-180.

Letcher, R.J., Su, G., Moore, J.N., Williams, L.L., Martin, P.A., de Solla, S.R., Bowerman, W.W., 2015. Perfluorinated sulfonate and carboxylate compounds and their precursors in recent eggs of herring gulls from across the Laurentian Great Lakes of North America: distribution and exposure implications. Sci Total Environ. 538, 468-477.

Lu, Z., De Silva, A.O., McGoldrick, D.J., Peart, T.E., Cook, C., Tetreault, G.R., Martin, P.A., de Solla, S.R., 2018. Substituted diphenylamine antioxidants and benzotriazole UV stabilizers in aquatic organisms in the Great Lakes of North America: terrestrial exposure and biodilution. Environ. Sci. Tech. 52, 1280-1289.

McGoldrick, D.J., Pelletier, M., de Solla, S.R., Martin, P.A., 2018. Legacy of legacies: Chlorinated naphthalenes in lake trout, walleye, herring gull eggs and sediments from the Laurentian Great Lakes indicate possible resuspension during contaminated sediment remediation. Sci. Total Environ. 634, 1424-1434.

Norstrom, R.J., Clark, T.P., Jeffrey, D.A., Won, H.T., Gilman, A.P., 1986. Dynamics of organochlorine compounds in Herring Gulls (Larus argentatus): I. Distribution and clearance of [14C]DDE in free-living herring gulls (Larus argentatus). Environ. Toxicol. Chem. 5, 41-48.

Sinkkonen S., Paasivirta J., 2000. Degradation half-life times of PCDDs, PCDFs and PCBs for environmental fate modeling. Chemosphere 40, 943-949.

Su, G., Letcher, R.J., Moore, J.N., Williams, L.L., Martin, P.A., de Solla, S.R., Bowerman, W.W., 2015. Spatial and temporal comparisons of legacy and emerging flame retardants in herring gull eggs from colonies spanning the Laurentian Great Lakes of Canada and United States. Environ. Res. 142, 720-730.

Zarull, M.A., Hartig, J.H., 2007. Contaminated sediment remediation, In: Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., (Eds). State of the Strait: Status and Trends of Key Indicators. Univ. of Windsor, Great Lakes Institute for Environmental Research Occasional Publication No. 5. pp. 305–308.

7.20 Detroit River Coastal Wetlands

Doug R. Pearsall, The Nature Conservancy, Lansing, Michigan, USA, dpearsall@tnc.org

John H. Hartig, Great Lakes Institute for Environmental Research, University of Windsor, Windsor, Ontario, Canada, jhhartig@uwindsor.ca

Anna Urso, The Nature Conservancy, Lansing, Michigan, USA, annaurso@tnc.org

Background

Wetlands form and exist where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Often called "nurseries of life," wetlands provide habitat for thousands of species of plants and animals (Figure 1).

Figure 1. Monguagon delta in Humbug Marsh Unit of the Detroit River International Wildlife Refuge, Wayne County, Michigan (credit: Jake Bonello).

Coastal wetlands are commonly formed where there is relatively flat land, shallow water, and a barrier to wave and wind action. Wetlands are valuable resources ecologically, recreationally, and aesthetically. Wetland functions and values, often dependent upon wetland type and location, include the following:

- they provide essential breeding, nesting, resting, feeding, and nursery grounds for many fish and wildlife, including endangered and threatened species;
- they stabilize and maintain the water table by retaining water during dry periods and storing excess water during storm and flood conditions;
- they minimize bank and shoreline erosion along rivers and lakes;
- they serve as living filters by removing nutrients and sediments from upland runoff waters that could otherwise pollute lakes and rivers;

- some function as sites for groundwater recharge, replenishing and purifying the water in aquifers that supply local wells; and
- others provide recreational opportunities, such as hunting, fishing, birding, and hiking.

Despite all the benefits provided by wetlands, over half of them in Michigan have been drained, filled, and developed, particularly coastal wetlands along the Detroit River.

Status and Trends

Coastal wetlands were extensive along the Detroit River 200 years ago (Manny et al., 1988; Manny, 2003). First explorers like Father Hennepin and Antoine Cadillac described the Detroit River as a pristine "paradise" with abundant edible fruits, lush meadows, forests, fish, and wildlife (Manny, 2003). In 1815, the river shoreline consisted of contiguous, coastal wetlands up to 1.6 km wide along both sides of the river (Figure 2). Vegetation types included submersed marsh, emergent marsh, wet meadow and shrub swamp, swamp forest, and lakeplain prairie. Since 1815, the Detroit River ecosystem has undergone dramatic changes. Habitats for fish and wildlife in the river are now degraded by contaminants, largely destroyed by shoreline and channel modifications, and greatly reduced in abundance and quality from historic levels. The largest habitat change has been encroachment into the river and hardening of the shoreline by the addition of steel sheet piling, concrete breakwaters, and fill material. A preliminary analysis of Figure 2 revealed 2,768 ha (10.7 mi^2) of coastal wetlands were present along the Michigan shore of the Detroit River in 1815 (Manny, 2003).

Later, more detailed analyses of the 1796 historical map, General Land Office (GLO) survey data, National Wetlands Inventory data, and recent georeferenced imagery show that the U.S. shoreline of the Detroit River has lost approximately 97% of its coastal wetlands to human development (Figure 3). This re-analysis of the 1796 map produced a total of 1,968 ha of coastal wetlands, and the GLO source indicated 2,048 ha. National Wetlands Inventory data show only 56 ha of connected wetlands remain (Hartig and Bennion, 2017).

Other losses of habitat included removal of limestone spawning grounds for lake whitefish and lake sturgeon to create navigation channels, clearing of wooded areas for agriculture, introduction of invasive species, and contamination of the water by waste effluents. In the process, people lost benefits provided by wetlands along the river, such as flood control, protection from shoreline erosion, and removal of nutrients and sediment.

The Lake Erie Biodiversity Conservation Strategy (LEBCS) is a binational initiative designed to support the efforts of the Lake Erie Lakewide Action and Management Plan by identifying specific strategies and actions to protect and conserve the native biodiversity of Lake Erie (Pearsall et al., 2012). The scope of LEBCS includes the lake itself, the Connecting Channels, including the Detroit River, and the adjacent watersheds to the extent that they affect the biodiversity of the lake. The LEBCS developed target values based on a review of existing Great Lakes conservation strategies, scientific assessments of Lake Erie, and input from the project core team,

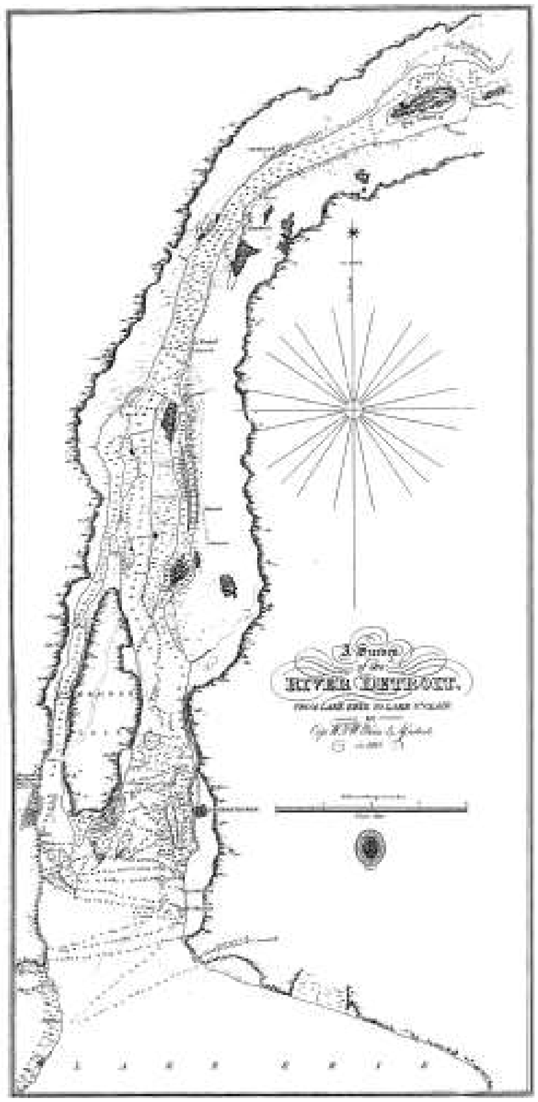


Figure 2. An 1815 map of the Detroit River showing coastal wetlands up to a mile wide along both sides of the river for most of its length, prior to shoreline development (Map Credit: Association of Canadian Map Libraries, Facsimile Number 20).

conservation organizations, and other stakeholders. For the Detroit River, the following binational coastal wetland goal was established (Pearsall et al., 2012):

> By 2030 coastal wetlands in the Detroit River will comprise at least 25% of their historical area.

If we assume that the 1796 map is a good representation of the historical area of wetlands (i.e., a total of 1,968 ha of coastal wetlands), then meeting the 2030 LEBCS goal would require 508 ha of coastal wetlands. Again, current National Wetlands Inventory data show only 56 ha of connected wetlands remain. That means that the Detroit River would have to achieve a net gain of 452 ha of coastal wetlands over the approximately next 10 years.

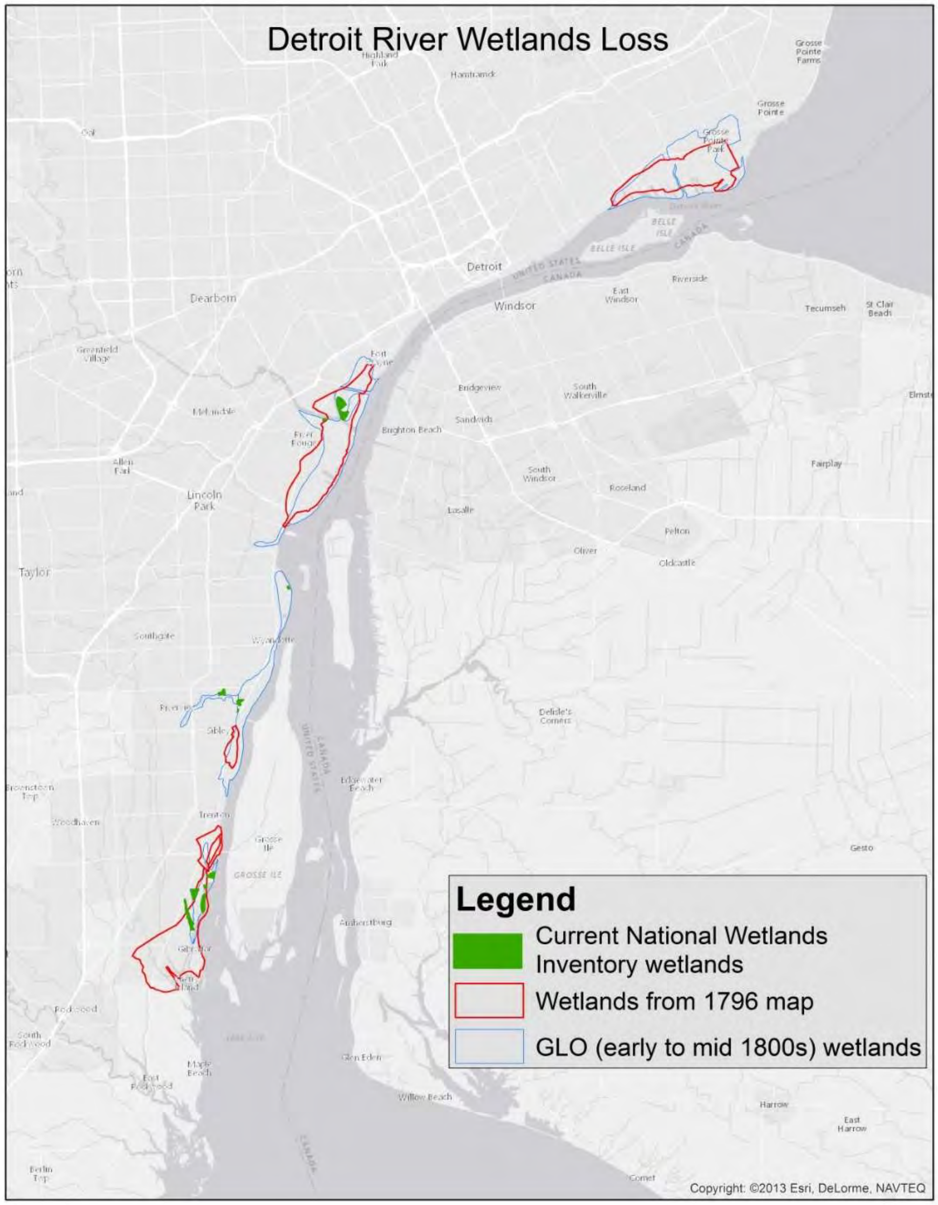


Figure 3. Extent of wetlands loss along the U.S. mainland of the Detroit River (base map credit: map created using ArcGIS® software by ESRI) (Hartig and Bennion, 2017).

Management Next Steps

Consistent with "A Conservation Vision for the Lower Detroit River Ecosystem," coordinated efforts are needed to protect, in perpetuity, remaining marshes, coastal wetlands, islands, and natural shorelines from development, and to rehabilitate degraded marsh, wetland, island, and shoreline habitats (Metropolitan Affairs Coalition, 2001). Additional management actions could include:

- developers and communities should be encouraged to protect remaining wetlands in the Detroit River watershed through adoption of best management practices;

- any new development along the Detroit River should be required to achieve a net gain of wetlands sufficient to address stormwater generated by the project;

- nonprofit organizations like International Wildlife Refuge Alliance and Friends of the Detroit River should foster volunteer programs that utilize local expertise and interest, along with governmental technical assistance, to protect and enhance coastal wetlands on a watershed scale;

- governments should maintain a publicly accessible, comprehensive coastal wetland inventory that tracks changes in total wetland area;

- communities and private landowners should further wetland restoration using soft engineering and other techniques on river shoreline redevelopment projects; and

- regulatory agencies should proactively enforce wetland protection laws and stop the encroachment of development into flood plains.

To address the fourth action listed above, the Great Lakes Commission and The Nature Conservancy have established Coastal Wetland issue within the Blue Accounting information hub: https://www.blueaccounting.org/issue/coastal-wetlands. Blue Accounting tracks investments and progress towards shared goals for coastal wetlands, as established by the Great Lakes Coastal Assembly. As of this writing, total wetland area has not been built out, but it is a metric that Blue Accounting and the Coastal Assembly will develop in collaboration with the broader Great Lakes community.

In the LEBCS, Pearsall et al., (2012) recommended five high priority biodiversity conservation strategies for Lake Erie, including the Detroit River:

- reducing the impact of agricultural nonpoint source pollutants;

- preventing and reducing the impact of invasive species;

- preventing and reducing the impacts of incompatible development and shoreline alterations;

- reducing the impacts of urban nonpoint and point source pollutants; and

- improving habitat connectivity by reducing the impact of dams and other barriers.

Applied specifically to coastal wetlands, the third strategy listed above could encompass activities including legal protection, restoration (from non-wetland to wetland), and enhancement (improving an existing wetland), in addition to activities that would prevent loss and degradation. To inform restoration actions, the U.S. Geological Survey in 2017 completed a Great Lakes Coastal Wetlands Restoration Assessment along the U.S. shoreline of the Detroit River (accessible online at https://glcwra.wim.usgs.gov/). Some areas within mapped historical wetlands have been rated as medium to high restorability (Figure 4) and represent opportunities for local investment to meet the LEBCS goal.

An additional resource is being developed by Michigan Tech Research Institute (MTRI). Having already mapped *Phragmites* and coastal wetland vegetation basin-wide (Bourgeau-Chavez et al., 2015; see https://mtri.org/coastal_wetland_mapping.html), MTRI is augmenting that georeferenced imagery with connectivity modeling to distinguish coastal wetlands from those not connected to the Detroit River or the Great Lakes (Figure 4). Teasing out these hydrologic connections has been a substantial challenge to mapping coastal wetlands, and this effort will provide very useful information.

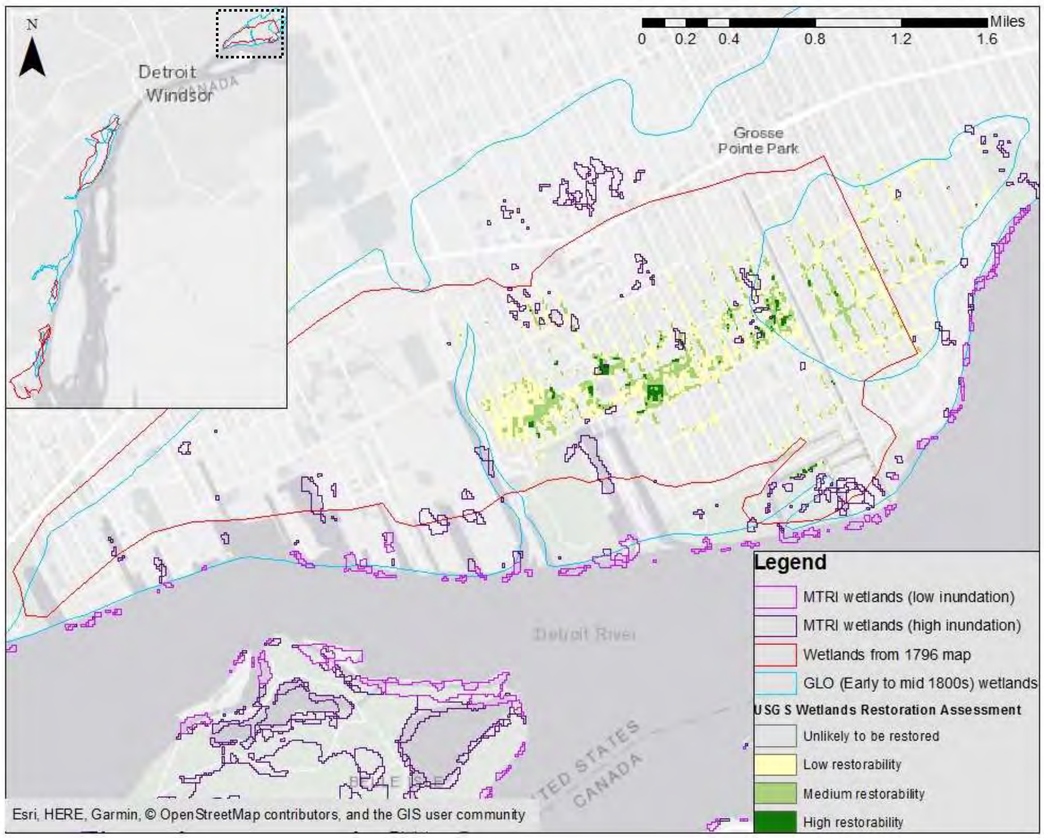


Figure 4. Historical coastal wetlands from a 1796 map and the GLO, and areas that could be restored to coastal wetlands based on a USGS assessment of restorability within a historical coastal wetland footprint and connected wetlands at low and high inundation levels identified by MTRI (base map credit: map created using ArcGIS® software by Esri)(Bourgeau-Chavez et al., 2015).

Research/Monitoring Needs

There is a need to increase research and monitoring programs to quantify wetland losses, establish cause-and-effect relationships, evaluate and select appropriate wetland rehabilitation techniques, and quantify ecosystem services of wetlands (Tulen et al., 1998). The Great Lakes Coastal Assembly is developing an ecosystem services' valuation for coastal wetlands from Saginaw Bay to Sandusky Bay, including the Detroit River (U.S. only). When available, this valuation should help inform wetland restoration and conservation projects. Further, wetland restoration and conservation projects should be treated like adaptive management experiments that explicitly link research/monitoring with restoration and management of wetlands. Finally, available data on ways to protect and enhance wetland ecological functions need to be pooled and synthesized to prioritize the most successful tools. For example, resource managers could:

- assess the quality of wetland habitats for production of fish and wildlife to better rank candidate sites for wetland protection and enhancement;
- describe and characterize biodiversity in Detroit River coastal wetlands, and habitats they provide for young fish and wildlife; and,
- quantify economic, social, and ecological benefits resulting from wetland restoration and conservation projects.

References

Bourgeau-Chavez, L., Endres, S., Battaglia, M., Miller, M.E., Banda, E., Laubach, Z., Higman, P., Chow-Fraser, P., Marcaccio, J., 2015. Development of a Bi-National Great Lakes Coastal Wetland and Land Use Map Using Three-Season PALSAR and Landsat Imagery. Remote Sens. 7, 8655-8682. https://www.mdpi.com/2072-4292/7/7/865

Hartig, J.H., Bennion, D., 2017. Historical Loss and Current Rehabilitation of Shoreline Habitat Long an Urban-Industrial River – Detroit River, Michigan, USA. Sustainability 9, 5, 828-848. http://www.mdpi.com/2071-1050/9/5/828

Manny, B.A., 2003. Setting priorities for conserving and rehabilitating Detroit River habitats, in: Hartig, J.H. (Ed.), Honor Our Detroit River, Caring for Our Home. Cranbrook Institute of Science, Michigan, pp. 79-90.

Manny, B.A., Edsall, T.A., Jaworski, E., 1988. The Detroit River, Michigan: An Ecological Profile. U.S. Fish and Wildlife Service, Biological Report 85 (7.17). Ann Arbor, Michigan, USA.

Metropolitan Affairs Coalition, 2001. A Conservation Vision for the Lower Detroit River Ecosystem. Detroit, Michigan, USA.

Pearsall, D., Carton de Grammont, P., Cavalieri, C., Chu, C., Doran, P., Elbing, L., Ewert, D., Hall, K., Herbert, M., Khoury, M., Kraus, D., Mysorekar, S., Paskus, J., Sasson, A., 2012. Returning to a Healthy Lake: Lake Erie Biodiversity Conservation Strategy. Technical Report. A joint publication of The Nature Conservancy, Nature Conservancy of Canada, and Michigan Natural Features Inventory. Lansing, Michigan, USA.

Tulen, L.A., Hartig, J.H., Dolan, D.M., Ciborowski, J.J.H., 1998. Rehabilitating and Conserving Detroit River Habitats. Great Lakes Institute for Environmental Research, University of Windsor, Windsor, Ontario, Canada.

This page intentionally left blank.

7.21 Dissolved Oxygen Levels in the Rouge River

Annette DeMaria, Executive Director, Alliance of Rouge Communities, ademaria@ectinc.com

Noel Mullett Jr., Technical Projects Coordinator, Wayne County Department of Public Services – Water Quality Management Division, mullett@co.wayne.mi.us

Background

The Rouge River watershed in southeast Michigan is largely urbanized, spans approximately 1,210 km^2, is home to over 1.5 million people in 48 communities and three counties, and is a tributary to the Detroit River. From the very beginning, the Rouge River has been recognized for its strategic location and beneficial uses. Native people settled along the shores of the river to use it as a transportation route, take advantage of the water supply, and benefit from the incredible fishing and hunting (Bean et al., 2003). In 1701, the French built their fort and established the first permanent settlement in the region. Later in the eighteenth century, gristmills would be established on main forks in the river and shipyards established on the lower river. The lower Rouge River was dredged in the early 1900s to accommodate shipbuilding and the rapidly growing automobile industry. Henry Ford consolidated automobile manufacturing operations into one geographical area to create efficiencies and synergies, turning Zug Island and the lower Rouge River into the heartland of the Industrial Revolution. The Rouge River became the recipient of waste oil and other industrial pollutants.

Mass production of automobiles and subsequent intense urbanization of the Rouge River watershed placed additional stresses on the river, including stormwater runoff and other diffuse sources. Chief among these were sanitary sewer overflows and combined sewer overflows that discharged untreated sanitary waste into the river during wet weather conditions. A study of the Rouge River in the early 1970s (Jackson, 1975) reported, "approximately 64 km of the Rouge River were characterized by very poor water quality as evidenced by a macroinvertebrate community dominated by animals tolerant of severely polluted waters. The principal contaminants at that time were raw sewage and inorganic sediment entering the river via combined and/or storm sewers."

As industrial point sources of pollution were being addressed during the 1960s and 1970s through both federal and state regulatory initiatives, it soon became clear that more would need to be done to address nonpoint sources of pollution (i.e., pollution which cannot be traced back to a single origin or source such as stormwater runoff, water runoff from urban and agricultural areas, and failed septic systems). The Rouge River was still highly polluted during the 1970s; raw sewage from combined sewer overflows (CSOs) and sanitary sewer overflows was being discharged, there were odor problems, and fish were dying. Urbanization of the watershed had significantly increased the impervious surfaces in the watershed resulting in significant increases in the volume and amount of energy in the runoff waters after wet weather events.

CSOs and polluted stormwater runoff result in many water quality problems, including extreme flow variations, streambank erosion, flooding, loss of habitat, high bacteria levels, and low dissolved oxygen. Polluted stormwater runoff contains bacteria, heavy metals, nutrients, oil, and pesticides. Minimizing the impact of both CSOs and polluted stormwater is critical to the restoration of the Rouge River and its impact on the Detroit River.

Dissolved oxygen is an important parameter in defining the health of aquatic ecosystems. When dissolved oxygen concentrations are below 4.0 mg/L, there are potentially adverse impacts on aquatic life. To protect aquatic life, State of Michigan water quality standards specify that dissolved oxygen must be greater than 7 mg/L at all times in streams designated as cold-water fisheries and must be greater than 5 mg/L at all times in streams designated as warmwater fisheries. All of the Rouge River and its tributaries are designated as warm water streams except for Johnson Creek, which is designated as a cold-water fishery.

Therefore, dissolved oxygen levels in the Rouge River have been identified as a key indicator of environmental quality and a key indicator that tracks effectiveness of water pollution control programs. It should be noted that this indicator is important to both the restoration of the Rouge River and its subsequent impact on the Detroit River.

Status and Trends

Many initiatives have taken place in support of forging a holistic approach to watershed management for the Rouge River. The Rouge River Remedial Action Plan (RAP) process began in 1985 with the recognition that state government had the authority to force corrective action, but due to the diffuse nature of the problem and large expense, public awareness and local community commitment, cooperation, and involvement were essential to restoring the Rouge (Bean et al., 2003). The Rouge River Basin Committee was established to work with local governments and stakeholder groups to bring about local ownership of the RAP. All 48 communities in the watershed participated on the Rouge River Basin Committee along with other stakeholders.

The initial Rouge River RAP was completed in 1988. The RAP focused heavily on sanitary sewer overflows and CSOs because approximately 31 billion gallons of untreated combined sewage was being discharged into the Rouge River during rain events annually. It is important to note, however, that although the 1988 RAP recommendations focused on sanitary sewer capacity and CSO controls, it also recognized polluted stormwater from separated sewers as a significant problem across the entire watershed. In addition, it allowed for the formation of the Rouge Remedial Advisory Council (RRAC) who oversee implementation of the RAP.

Between 1992 and 2014, the Rouge River National Wet Weather Demonstration Project (Rouge Project) was managed by the Rouge Program Office with $350 million in funding from the U.S. Environmental Protection Agency (Cave, 2014), plus millions more from local communities. The Rouge Project recognized that to be cost-effective, pollution problems in the river must be addressed collaboratively by all of the local governments, the counties, and the other stakeholders, and with flexibility across the regulatory programs. Decisions should be made and success evaluated based on resource results, and/or based on creating the capacity to better manage the resource, and not solely on meeting permit compliance requirements and timelines. This comprehensive watershed restoration effort dealt with the problems of CSOs, sanitary sewer overflows (SSOs), and polluted stormwater runoff. Regulatory policy, programs, and financial institutional arrangements were also major accomplishments of the Rouge Project. Outcomes of the Rouge Program Office and its successor, the Alliance of Rouge Communities (ARC), include the following (Cave, 2014):

- Completion of 88 CSO/SSO projects;
- Completion of 47 stormwater control projects;
- Completion of 48 riparian corridor improvements;
- Discovery and removal of over 2,000 illicit discharges;
- Discovery and correction of almost 900 failed septic systems;
- Reconnection of 446 km (279 miles) of river and tributary streams to the Great Lakes;
- Installation of 40,000 native trees, shrubs and plants resulting in numerous acres of green stormwater infrastructure;
- Engagement of 54,000 volunteers and outreach to more than 125,000 residents;
- Development of watershed-based plans to comply with current stormwater permitting requirements;
- Passage of the Watershed Alliance legislation which allowed for the establishment of the Alliance of Rouge Communities (ARC) in 2006;
- Comprehensive monitoring for the Rouge River watershed; and
- Collaboration among the state, counties, municipalities, nonprofits, researchers and residents to restore a once heavily damaged river system.

Today, CSOs and SSOs continue to be addressed by the local communities, while managing stormwater runoff, educating the public, and restoring the river have been the focus of the ARC, Friends of the Rouge (FOTR), and the Rouge River Advisory Council.

For the purposes of this indicator report, it was decided to focus on one of the best long-term indicators of environmental quality – dissolved oxygen levels at three locations in the Rouge River: Main and Upper subwatersheds in Detroit which includes drainage from 56% of the watershed, the Middle subwatershed in Dearborn Heights (24% of the watershed), and the Lower subwatershed in Dearborn (20% of the watershed). Each of these sites are located in the lower (most downstream) ends of the Rouge River. Consequently, these sites are the recipient of all the upstream impacts from human activity, and historically have been the portion of the river that has had the poorest water quality.

Figures 1-3 present the long-term trends of dissolved oxygen for three sub-watersheds of the Rouge River. The earliest dissolved oxygen data for the Main Branch from the 1973 study showed that only 24% of the values were above the State of Michigan's water quality standard of 5 mg/L (Jackson, 1975). In the 1990s, the average percent compliance was 67%. This increased to 89% in the 2000s and 97% in the 2010s (Figure 1).

Similar improvements have been seen on the Middle Branch where 90% of the dissolved oxygen values were above the water quality standard in the 1990s. The average percent compliance jumped to 97% and 98% in the 2000s and 2010s, respectively (Figure 2).

The situation is a little different on the Lower Branch where intermittent SSOs problems have resulted in the most recent dissolved oxygen values to be lower than in previous years. On the Lower Branch, 54% of the values were below the water quality standard in the 1990s. The 2000s saw a dramatic increase with 91% of the values above the standard. However, unlike the other subwatersheds, the average percent compliance was only 92% in the 2010s (Figure 3). This is largely due to the low concentrations found in 2017 when sewage was unknowingly being discharged to the river at two different locations. These discharges occurred because of: 1) mechanical failure on a combined sewer lift station which allowed sewage to drain down the bank of the river; and 2) blockage of a sanitary sewer which allowed sewage to discharge to the river via a high-level overflow connection to a storm sewer. Both issues were subsequently corrected in September 2017.

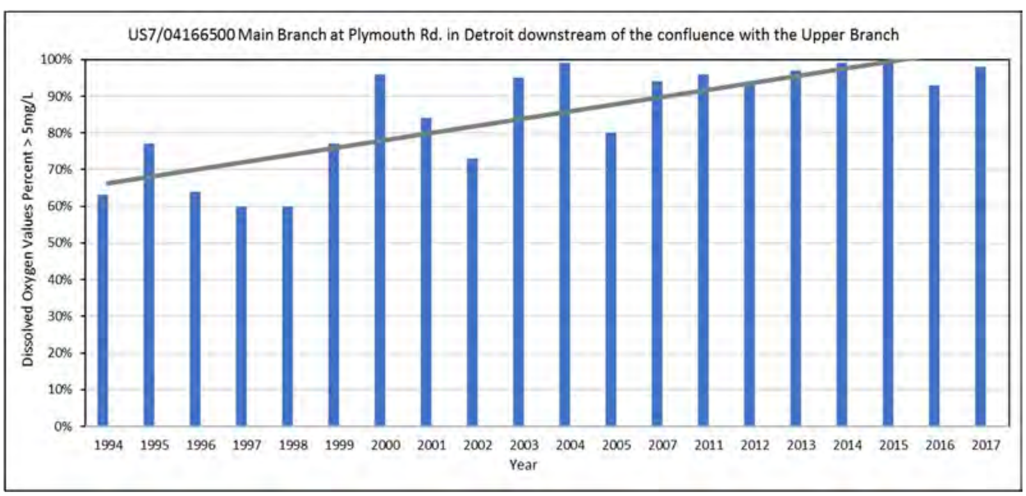


Figure 1. The percentage of dissolved oxygen measurements in Main and Upper subwatershed of the Rouge River that exceed the Michigan standard of 5 mg/L for protection of a warmwater fishery. A higher percentage in recent years indicates that this subwatershed more frequently exceeds the standard and dissolved oxygen conditions are improving.

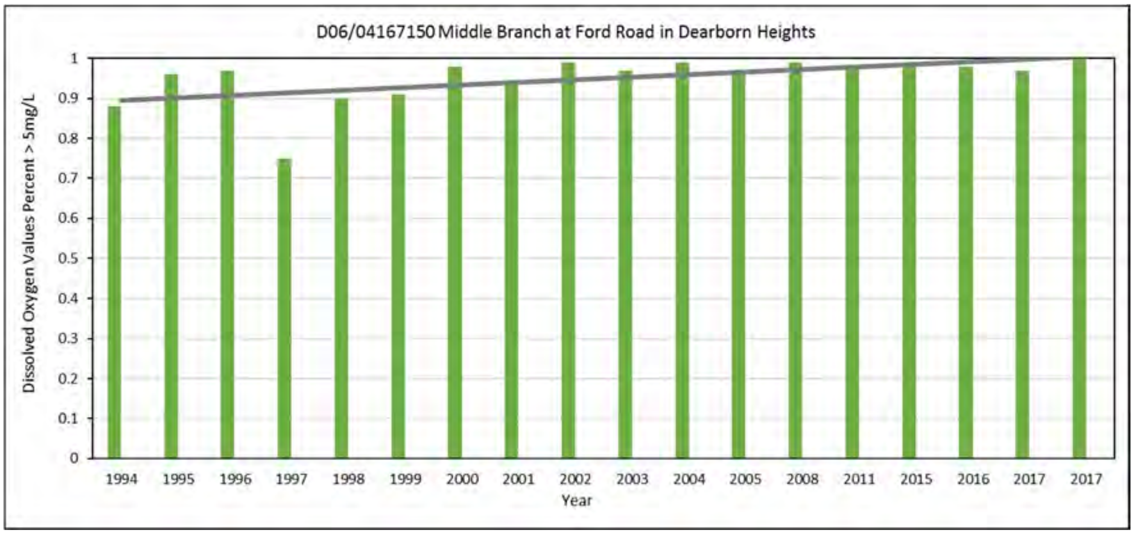


Figure 2. The percentage of dissolved oxygen measurements in Middle subwatershed of the Rouge River that exceed the Michigan standard of 5 mg/L for protection of a warmwater fishery. A higher percentage in recent years indicates that this subwatershed more frequently exceeds the standard and dissolved oxygen conditions are improving.

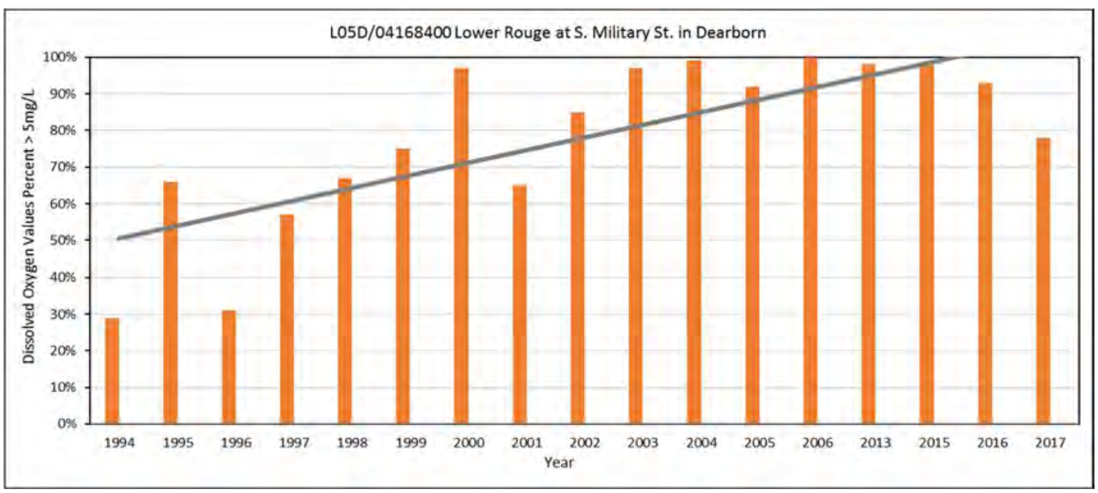


Figure 3. The percentage of dissolved oxygen measurements in Lower subwatershed of the Rouge River that exceed the Michigan standard of 5 mg/L for protection of a warmwater fishery. A lower percentage in 2017 indicates that this subwatershed more frequently violated the standard and that dissolved oxygen conditions need to be monitored to ensure the recovery of the river.

Despite the challenges in the Lower Branch, the dissolved oxygen trends document that substantial improvements are occurring in most of the watershed as a result of the river restoration measures.

It is recognized that many indicators are needed to fully assess the health of the Rouge River watershed. In 2013, the RRAC updated the Rouge River Report Card which summarized the progress of the Rouge River RAP. The 2013 Report Card indicates that the footprint of nine of the ten beneficial use impairments is shrinking (RRAC, 2013). This means that the river is responding to restoration efforts beyond the improvements in dissolved oxygen conditions. This is demonstrated by fewer algal blooms, fewer restrictions on fish consumption, healthier fish communities, improved fish and wildlife populations, and fewer aesthetics concerns. The only indicator that did not improve in 2013 was sediment contamination. However, the U.S. EPA and private partners are currently in the process of dredging contaminated sediments from the Rouge River Old Channel around Zug Island. Likewise, despite vast reductions in *E. coli* densities, bacterial contamination persists in the river system as demonstrated by a lack of compliance with Michigan's full body contact standards for recreational waters (ECT, 2018).

Management Next Steps

Key management actions for the Rouge River watershed include:

- Continue to implement long term control plans to address CSOs;
- Continue sanitary sewer capacity improvements;
- Sustain the watershed-wide implementation of public education, illicit discharge elimination, and water quality monitoring programs initiated by the Rouge Project and continued under the ARC and FOTR;
- Promote the use of green stormwater infrastructure to reduce peak flows in the river;
- Promote the economic importance of the region's water resources and green spaces to encourage adequate public investment in continued watershed restoration and protection efforts; and
- Ensure sufficient collaboration among the watershed communities and counties, nonprofits, and the State Legislature to secure adequate funding to continue cost-effective restoration efforts (this includes establishment of stormwater utilities to generate sustainable funding for stormwater management).

Research/Monitoring Needs

Monitoring is essential for proper watershed management. The level of water quality monitoring in the Rouge has significantly decreased in the absence of the Rouge Project. Priority must be given by State and Federal agencies to ensuring sufficient monitoring to be able to adequately evaluate effectiveness of programs and to make midcourse corrections. This includes the monitoring of water quality, flow, benthic macroinvertebrates, and other aquatic species. Further, research on rapid microbial source tracking techniques could be helpful in tracking down human and animal sources of bacteria that are leading to water quality impairments.

References

Bean, C.J., Hartig, J.H., Mullett, N., 2003. Watershed planning and management: The Rouge River experience, in: Hartig, J.H. (Ed.), Honoring Our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, MI, pp. 185-198.

Cave, K., 2014. Rouge River Restoration Summary – Wayne County Rouge River National Wet Weather Demonstration Project 1992-2014. Wayne County Department of Environment. Detroit, Michigan, USA.

Environmental Consulting & Technology, Inc., 2017. Rouge River Ecosystem Monitoring and Assessment Report. Canton, Michigan, USA.

Jackson, G., 1975. A biological investigation of the Rouge River, Wayne and Oakland counties, May 17-October 19, 1973. Department of Natural Resources. Lansing, Michigan, USA.

Rouge River Advisory Council, 2013. Rouge River Watershed Great Lakes Area of Concern Beneficial Use Impairment 2013 Report Card. Canton, Michigan, USA.

This page intentionally left blank.

7.22 Fall Raptor Migration at Holiday Beach Conservation Area, Amherstburg, Ontario

Dave Oleyar, Senior Scientist, HawkWatch International, doleyar@hawkwatch.org

John Hartig, Visiting Scholar, Great Lakes Institute for Environmental Research, University of Windsor, jhhartig@uwindsor.ca

Background

Fall migrating birds have used the north shore of Lake Erie since the Wisconsin Glacier retreated. More recently casual observers have recorded large numbers of hawks at Holiday Beach Conservation Area (HBCA) east of Amherstburg, Ontario, Canada and nearby sites since the 1950s. More systematic observations began in the 1970s, when evidence indicated that hawks and other birds were experiencing dramatic population declines. Over two million raptors have been counted at this site during the past over 40 years.

Since 1974, from September through November, qualified volunteer observers, members of Holiday Beach Migration Observatory (HBMO), have worked enthusiastically (600 hours seasonal average) toward a goal of identifying and recording all migrant raptors passing the count site. The information collected is analyzed locally in cooperation with Hawk Migration Association of North America (HMANA) (Chartier and Stimac, 2002). HMANA was organized to help standardize count procedures and identification, and to educate the public.

Birds of prey can be indicators of ecosystem health because of their terminal position in the food web. Since a number of contaminants biomagnify through food webs, avian predators are usually the first wild species to show ill effects, such as failure to reproduce, egg shell thinning and nesting failure, or death through poisoning. Heavy metals and chlorine-based pesticides such as DDT, aldrin, dieldrin, and heptachlor have been implicated in causing such wildlife impacts. Trends in raptor numbers over time can indicate build up or removal of such toxins, the condition of the landscapes they live in, or other impacts to be investigated.

As the raptors move south from their eastern Canadian breeding areas, the north shores of Lakes Erie and Ontario become migration barriers due to the fact that large bodies of water do not create updrafts of warming air upon which the birds depend for gliding and soaring. Therefore, the best “lift” is over land areas. The birds are forced to follow the Lake Erie shoreline westward and are funneled into a narrow migration avenue with Lakes St. Clair and Huron boarding to the north. The birds are able to cross the Big Creek marsh west of the count site and cross the Detroit River on their flight southwestward. After crossing the Detroit River, the majority of these birds are recounted by Detroit River Hawk Watch located at Lake Erie Metropark and Point Mouillee.

Each fall at HBCA, observers tally between 600,000 and 750,000 migrant birds from ducks to warblers with an average of 75,000 of these being hawks. HBCA has received the status of an Important Bird Area (IBA) because of the large numbers of fall migrants that use this region for their trek southward. Birds in the area generally start flying at sunrise and continue throughout the day. The biggest factor influencing whether a bird is counted or not is wind direction. North component winds (NNW, NW, N, NE, NNE) force the birds to follow more closely to the north shore of the lake and therefore within range of being counted. South component winds tend to move the birds more north of the count site out of range of viewing and therefore are not counted. Consequently, there may be large variations in total numbers within a species from year to year, however, over a long period these differences are minimal. Analysis of population trends must take into account this wind-influencing factor.

Status and Trends

The Raptor Population Index (RPI) is a partnership between four leading hawk watch and migration research organizations: the Hawk Migration Association of North America (HMANA), Hawk Mountain Sanctuary (HMS), HawkWatch International (HWI), and Bird Studies Canada (BSC).

Accurate knowledge of population status and change is fundamental for bird conservation. Lack of reliable information on populations of many raptors forms a conspicuous gap in North American bird monitoring. The vision of the RPI partners is to contribute to effective conservation of migratory raptors through continent-wide long-term monitoring of raptor migration, scientifically sound assessments of population status, and public outreach and education. RPI analyzes count data from monitoring sites across the country in a standardized way and identifies recent (10-year), 20-year, and long-term (life of site) trends in migrants counted. See http://rpi-project.org/2016/ for results of the most recent analysis for all sites, and for detailed methodology.

The data below come from the 2016 RPI analysis for the HBCA. Results are for 10 years (2006-2016, 'recent') and the life of the site (1979-2016, 'long-term').

Species with increasing counts:

Counts of the following species are increasing over the long-term at the HBCA based on RPI results: Bald Eagle, Golden Eagle, Merlin, Peregrine Falcon, and Turkey Vulture (Figure 1). Bald Eagle are the only species with recent increasing counts (2006-2016).

Species with decreasing counts:

RPI analyses indicate long-term declines in counts of migrating American Kestrels, Sharp-shinned Hawk, Northern Goshawk, Broad-winged Hawk, Red-shouldered Hawk, Red-tailed Hawk, and Rough-legged Hawk (Figure 1).

Also concerning were recent declines for 9 of the 15 species at the HBCA, including American Kestrel, Golden Eagle, Cooper's Hawk, Osprey, Peregrine Falcon, Sharp-shinned Hawk, Red-tailed Hawk, Northern Harrier, and Northern Goshawk.

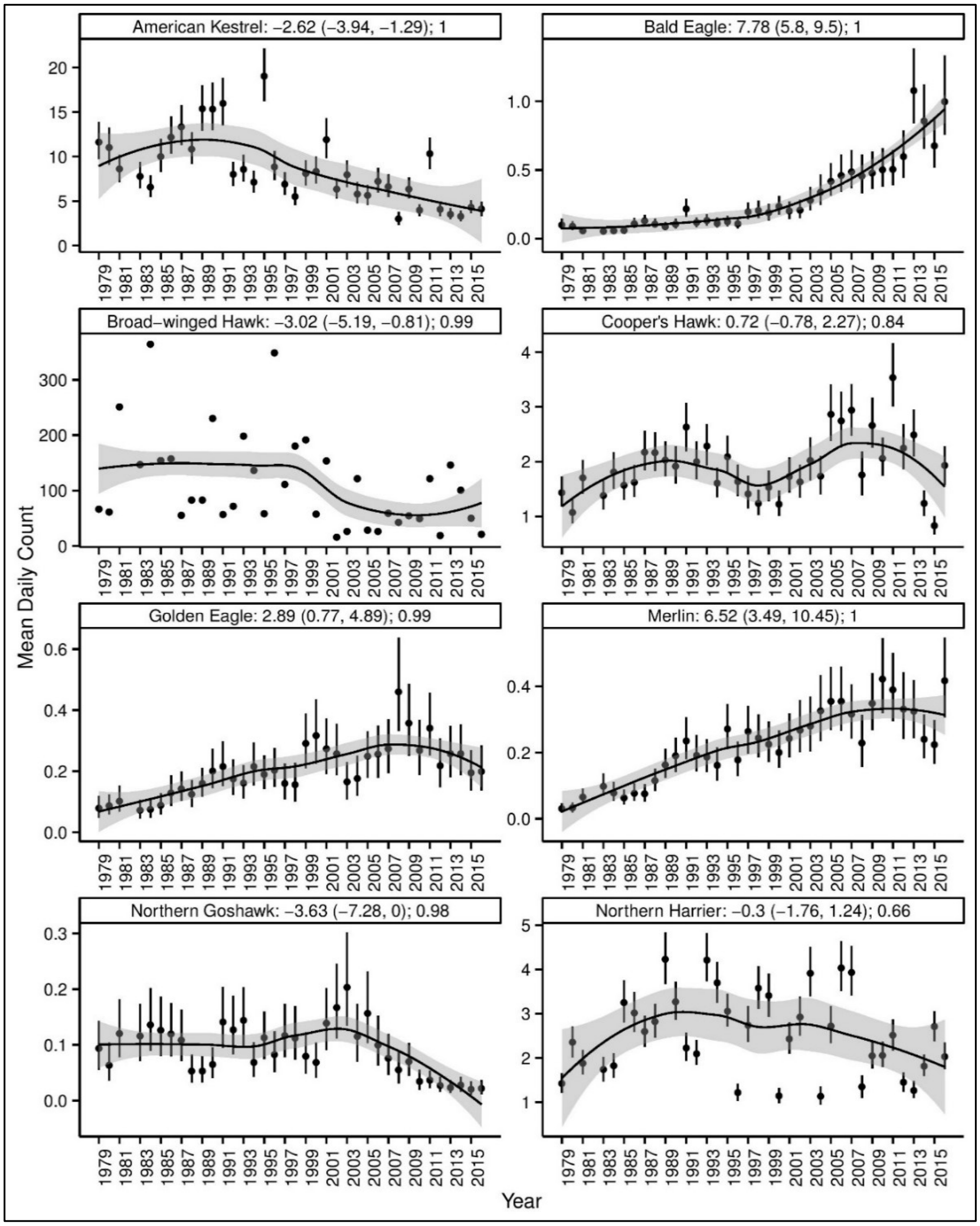


Figure 1. Trends in major raptor species as measured by Holiday Beach Migration Observatory. Heading for each plot includes: estimated trend slope of line (negative values indicating declines and positive value indicating increases); 95% credible intervals for the trend estimate; and posterior probability (i.e., probability an event will happen after all evidence or background information has been taken into account) of that trend (weight of support for the trend—a value greater than or equal to 0.95 indicated a strongly supported trend, greater than equal to 0.9 a supported trend, less than 0.9 indicates the trend is not well supported (no trend)), 1991-2016 (http://rpi-project.org/2016/).

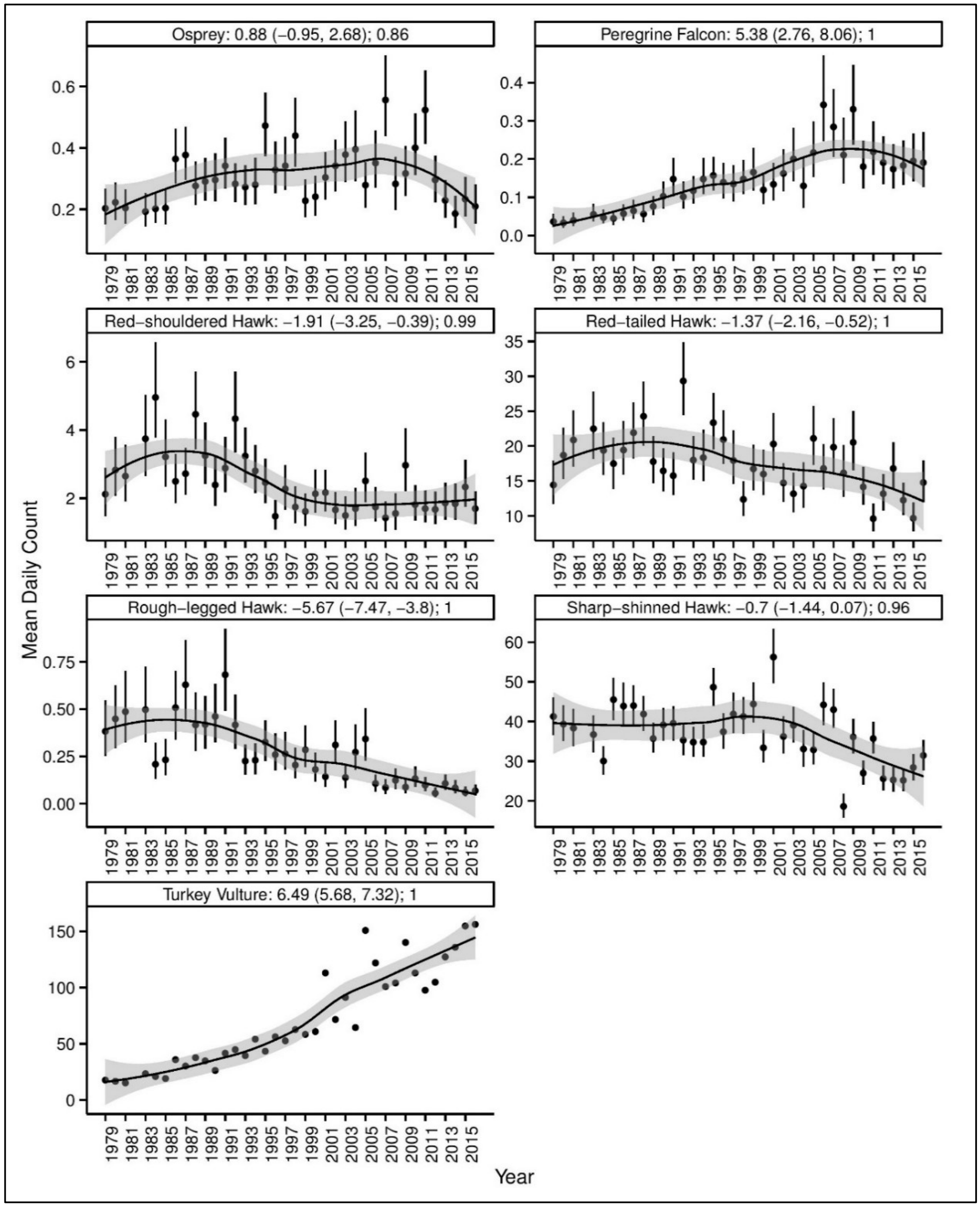


Figure 1. Trends in major raptor species as measured by Holiday Beach Migration Observatory, continued.

Management Next Steps

Reaching long-term goals of sustainable raptor populations will require increasing the amount of foraging and nesting habitats conserved and restored for a number of species. For example, management of Red-shouldered Hawks requires conservation and restoration of habitats such as damp woods, river bottomlands, and swamps with tall trees where they can nest 6-18 m above the ground. Efforts to decrease threats to raptor species (and other wildlife), including habitat loss and alteration, contaminants, electrocution, vehicle and structure collisions, and direct persecution, will contribute towards these goals.

While long-term monitoring such as that at the HBCA will not identify the drivers of declines and increases, they are essential to understanding the effectiveness of management efforts and policies designed to benefit raptors and other wildlife. Without the continuity of such efforts, any changes to trends will go unnoticed—both conservation successes and new or continued declines. Continued priority must be placed on recruitment of volunteers, as well as consistent funding for paid staff (counters and banders) and greater public outreach. Findings from this monitoring effort should steer focused research elsewhere to understand if recent declines indicate actual population decline, a shift in migration paths, or a shift in the proportion of populations that migrate.

References

Chartier, A., Stimac, D., 2002. Hawks of Holiday Beach: A Guide to their Identification, Occurrence, and Habits at Holiday Beach Conservation Area, Ontario, Canada, 2nd Edition. pp. 3-8.

Links for more information

Holiday Beach Migration Observatory (HBMO): http://www.hbmo.org

The Raptor Population Index: http://rpi-project.org/2016/

This page intentionally left blank.

7.23 Fall Raptor Migration Trends at the Detroit River Hawk Watch

Dave Oleyar, Senior Scientist, HawkWatch International, doleyar@hawkwatch.org

John Hartig, Visiting Scholar, Great Lakes Institute for Environmental Research, University of Windsor, jhhartig@uwindsor.ca

Background

Birds of prey can be indicators of ecosystem health because of their terminal position in the food web. Since a number of contaminants biomagnify through food webs, avian predators are usually the first wild species to show ill effects, such as failure to reproduce, eggshell thinning and nesting failure, or death through poisoning. Heavy metals and chlorine-based pesticides such as DDT, aldrin, dieldrin, and heptachlor have been implicated in causing such wildlife impacts. Trends in raptor numbers over time can indicate build up or removal of such toxins, the condition of the landscapes they live in, or other impacts that require further investigation.

The geography of the eastern Great Lakes, combined with the migratory preferences of North American birds of prey, provide unique opportunities to monitor status and trends of raptor populations at the mouth of the Detroit River. The Detroit River is at the intersection of the Atlantic and Mississippi Flyways making it a unique area to survey migrating birds, especially raptors. As raptors move south from their eastern Canadian breeding grounds, they are blocked by the north shore of Lakes Erie and Ontario. Thermals (i.e., rising columns of warm air) do not form over water so the birds are forced in one of two directions: east around Lake Ontario or west around Lake Erie. Those that move west follow the north shore of Lake Erie, until they reach the mouth of the Detroit River. Turning back is not an option so the birds fly over a 6.4-km (four-mile) span of water to southeast Michigan, specifically near Lake Erie Metropark and Pointe Mouillee State Game Area. They lose altitude as they cross, making it easier for them to be observed. Volunteer monitoring programs such as the Detroit River Hawk Watch (DRHW) have proven invaluable in monitoring fall raptor migrations. Migration monitoring at the DRHW occurred each fall from September through November for the last 28 years and 23 raptor species have been observed (16 regularly occurring species).

<u>History of Detroit River Hawk Watch</u>

DRHW gets its origin from the Lake Erie Metropark Hawk Watch in Brownstown, Michigan that was founded in 1983. Counters discovered that the boat launch at Lake Erie Metropark and nearby Pointe Mouillee State Game Area Headquarters were viable sites for counting hawks crossing Lake Erie. In 1998 the Lake Erie Metropark Hawk Watch gained nonprofit status and became the Southeast Michigan Raptor Research. During these early years, DTE Energy generously provided support for a full-time hawk counter. In 2007, additional funding from the Detroit River International Wildlife Refuge helped compile the data and upload them to hawkcount.org, a database maintained by the Hawk Migration Association of North America (HMANA). In 2008, U.S. Fish and Wildlife Service took over responsibility for the hawk watch as part of the Detroit River International Wildlife Refuge, with support from its Friends Organization called the International Wildlife Refuge Alliance. That same year the hawk watch's name was officially changed to DRHW. Federal funds and funds raised through the International Wildlife Refuge Alliance were made available to compile and analyze data collected since 1991 (Panko and Battaly, 2011). The Detroit River Hawk Watch Advisory Committee was formed in 2010 to help develop a site protocol with U.S. Fish and Wildlife Service, and provide recommendations for managing data, analyses, partnerships, and cooperative projects. In 2010, DRHW developed a new website (see http://detroitriverhawkwatch.org/).

Status and Trends

The Raptor Population Index (RPI) is a partnership between four leading hawk watch and migration research organizations: the Hawk Migration Association of North America (HMANA), Hawk Mountain Sanctuary (HMS), HawkWatch International (HWI), and Bird Studies Canada (BSC).

Accurate knowledge of population status and change is fundamental for bird conservation. Lack of reliable information on populations of many raptors forms a conspicuous gap in North American bird monitoring. The vision of the RPI partners is to contribute to effective conservation of migratory raptors through continent-wide long-term monitoring of raptor migration, scientifically sound assessments of population status, and public outreach and education. RPI analyzes count data from monitoring sites across the country in a standardized way and identifies recent (10-year), 20-year, and long-term (life of site) trends in migrants counted. See http://rpi-project.org/2016/ for results of the most recent analysis for all sites, and for detailed methodology.

The data below come from the 2016 RPI analysis for the DRHW. Results are for 10 years (2006-2016, 'recent') and the life of the site (1991-2016, 'long-term').

Species with increasing counts:

Counts of the following species are increasing over the long-term at the DRHW based on RPI results: Bald Eagle, Merlin, and Turkey Vulture (Figure 1). Results show no species with increasing counts over the last 10 years.

Species with decreasing counts:

Long-term declines in counts of migrants are strongly supported for Rough-legged Hawk and somewhat supported for American Kestrel, Northern Goshawk, and Osprey at the DRHW (Figure 1).

More concerning are declining counts for eight of the 14 species that we estimated trends for at the DRHW over the last 10 years, including American Kestrel, Golden Eagle, Cooper's Hawk, Osprey, Peregrine Falcon, Sharp-shinned Hawk, Red-shouldered Hawk, and Red-tailed Hawk.

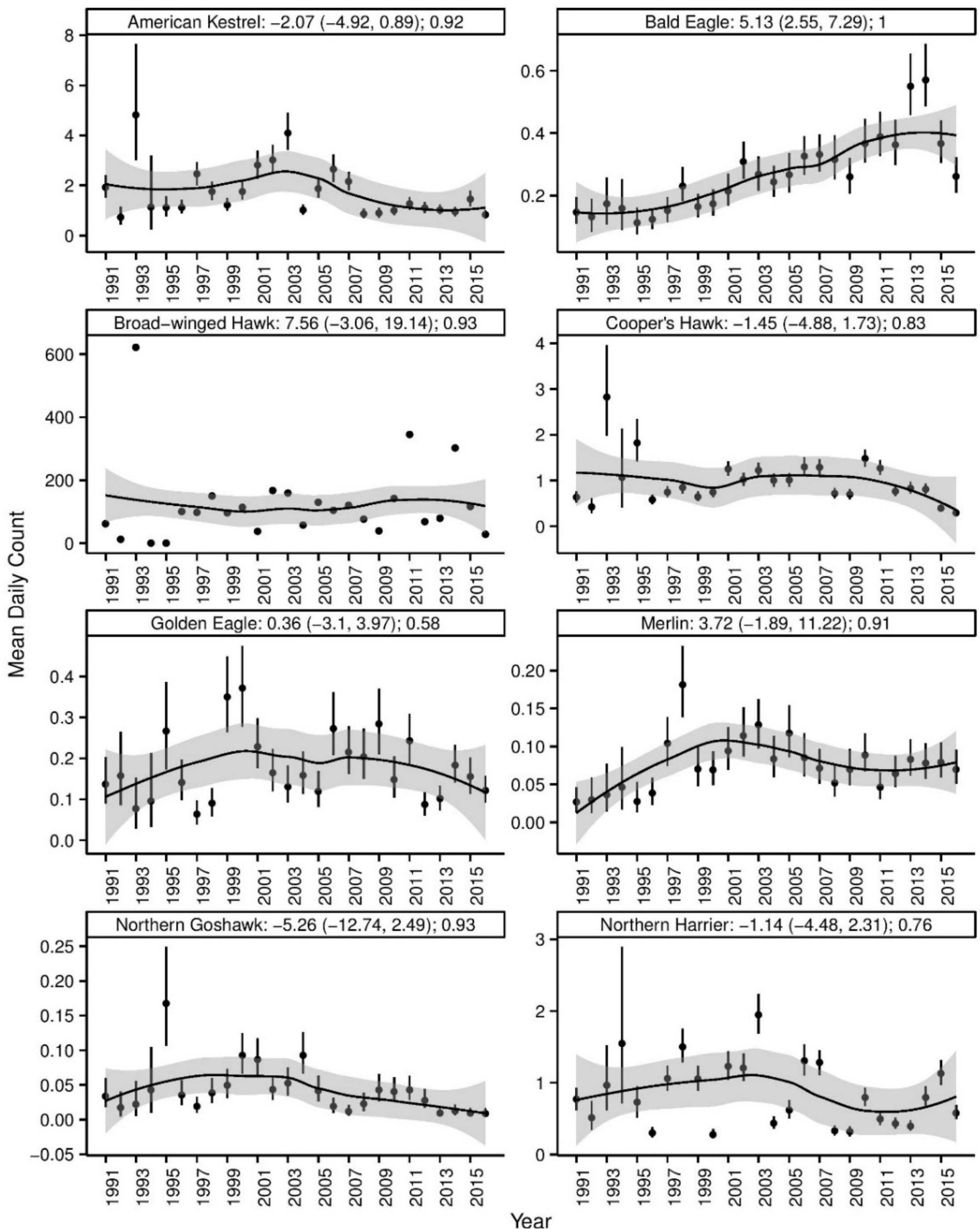


Figure 1. Trends in major raptor species as measured by Detroit River Hawk Watch. Heading for each plot includes: estimated trend slope of line (negative values indicating declines and positive value indicating increases); 95% credible intervals for the trend estimate; and posterior probability (i.e., probability an event will happen after all evidence or background information has been taken into account) of that trend (weight of support for the trend–a value greater than or equal to 0.95 indicated a strongly supported trend, greater than equal to 0.9 a supported trend, less than 0.9 indicates the trend is not well supported (no trend), 1991-2016 (http://rpi-project.org/2016/).

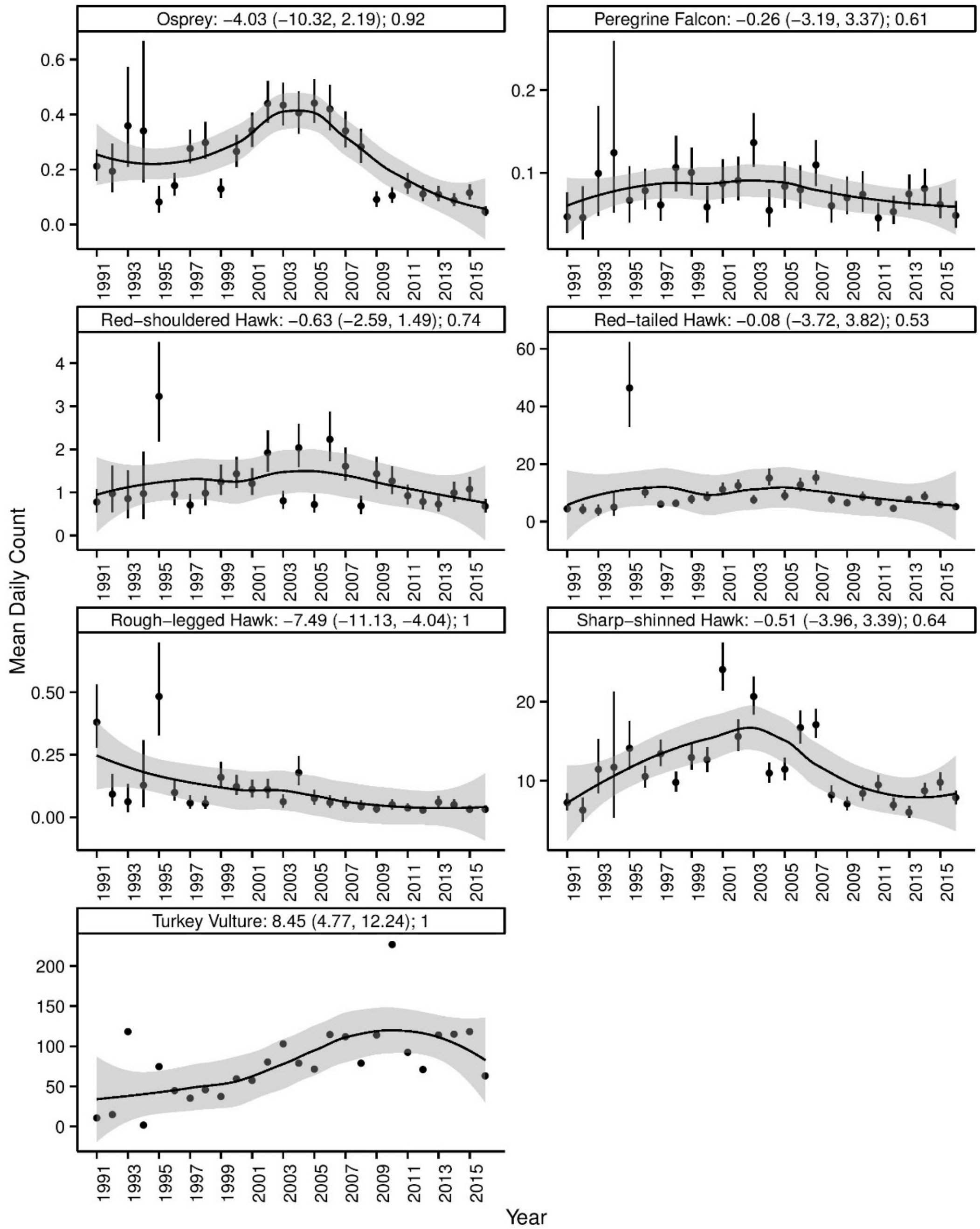


Figure 1. Continued.

Reaching long-term goals of sustainable raptor populations will require increasing the amount of foraging and nesting habitats conserved and restored for a number of species. For example, management of Red-shouldered Hawks requires conservation and restoration of habitats such as damp woods, river bottomlands, and swamps with tall trees where they can nest 6-18 m above the ground. Efforts to decrease threats to raptor species (and other wildlife), including habitat loss and alteration, contaminants, electrocution, vehicle and structure collisions, and direct persecution, will contribute towards these goals.

While long-term monitoring such as that at the DRHW will not identify the drivers of declines and increases, they are essential to understanding the effectiveness of management efforts and policies designed to benefit raptors and other wildlife. Without the continuity of such efforts, any changes to trends will go unnoticed—both conservation successes and new or continued declines. Continued priority must be placed on recruitment of volunteers, as well as consistent funding for paid staff (counters and banders) and greater public outreach. Findings from this monitoring effort should steer focused research elsewhere to understand if recent declines indicate actual population decline, a shift in migration paths, or a shift in the proportion of populations that migrate.

References

Panko, D. Battaly, G., 2010. Detroit River International Wildlife Refuge-raptor monitoring: Compilation and analysis of Hawk Watch data, Lake Erie Metropark and Pointe Mouillee, 1991-2008. Report to Detroit River International Wildlife Refuge, Grosse Ile, Michigan, USA.

Links for more information

Detroit River Hawk Watch: detroitriverhawkwatch.org
The Raptor Population Index: http://rpi-project.org/2016/

This page intentionally left blank.

7.24 Harmful Algal Blooms in Western Lake Erie

Tom Bridgeman, Lake Erie Center, University of Toledo,
Thomas.Bridgeman@utoledo.edu

Background

In the 1950s and 1960s, population growth and industrialization in the Lake Erie watershed led to increases in municipal and industrial waste discharges to tributaries leading to the Lake. These waste streams were rich in phosphorus and nitrogen (nutrients) which act as fertilizers for the growth of algae and toxic cyanobacteria (also known as blue-green algae). Moderate levels of nutrients support the growth of beneficial algae that serve as the base of the Lake Erie food web. Excessive nutrients, however, favor the growth of nuisance green algae (*Cladophora* sp.) and toxic cyanobacteria. Cyanobacteria growth, typically greatest in late summer, increased until large swaths of western Lake Erie were covered for a few weeks each summer. These massive growths of cyanobacteria became known as Harmful Algal Blooms (HABs) and adversely affected the ecology of the lake – contributing to the popular notion of Lake Erie as a 'dead lake' in the late 1960s (Beeton, 1961). The prevalence of HABs led to the creation of the Great Lakes Water Quality Agreement (GLWQA) between the U.S. and Canadian governments in 1972 that greatly limited the annual input of phosphorus into the lake by controlling phosphorus in discharges from wastewater treatment plants and industrial sources, and by eliminating phosphorus in laundry detergents. The GLWQA was successful in reducing phosphorus inputs to the lake and consequently the late 1970s-early 1990s were a period of greatly improved water quality with HABs appearing only infrequently and being small in size.

Status and Trends

Unfortunately, in the mid-1990s, phosphorus inputs (known as 'loads') to Lake Erie began to rise, particularly in the form of dissolved phosphorus, and particularly from largely agricultural watersheds such as the Maumee and Sandusky River watersheds (Figure 1; Ohio Department of Agriculture, Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and Lake Erie Commission, 2013).

As annual phosphorus loads increased, HABs began to return to Lake Erie in the late 1990s. Availability of satellite imagery beginning in 2002 has allowed NOAA to track the blooms each year, and to compare overall bloom size and severity between years. A suite of models developed by NOAA and others attempt to predict the severity of the annual HAB based on past years and the springtime loading of phosphorus to Lake Erie in the current year (Figure 2). The severity of blooms generally increased throughout the 2000s to the present. Most of the phosphorus delivered to Lake Erie from tributaries is believed to be the result of fertilizer runoff from farmlands during rain events. Occasional small bloom years (2012, 2016) coincide with severe dry springtime conditions.

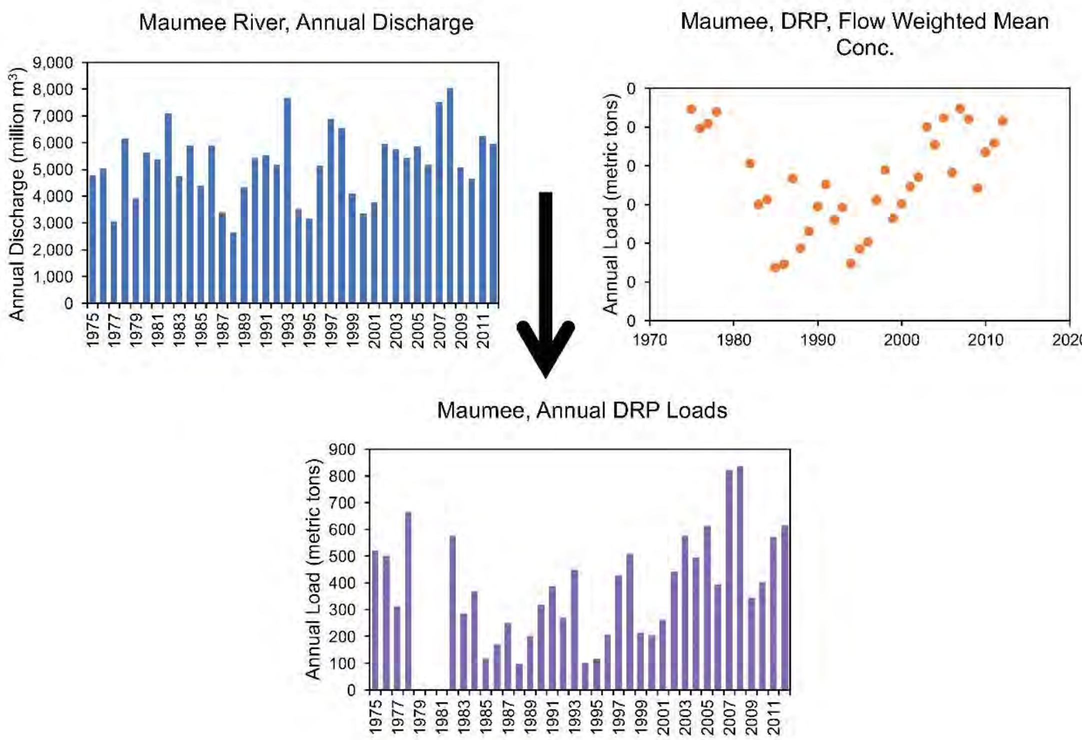


Figure 1. Annual discharge and dissolved reactive phosphorus concentrations and loadings of the Maumee River, 1975-2012.

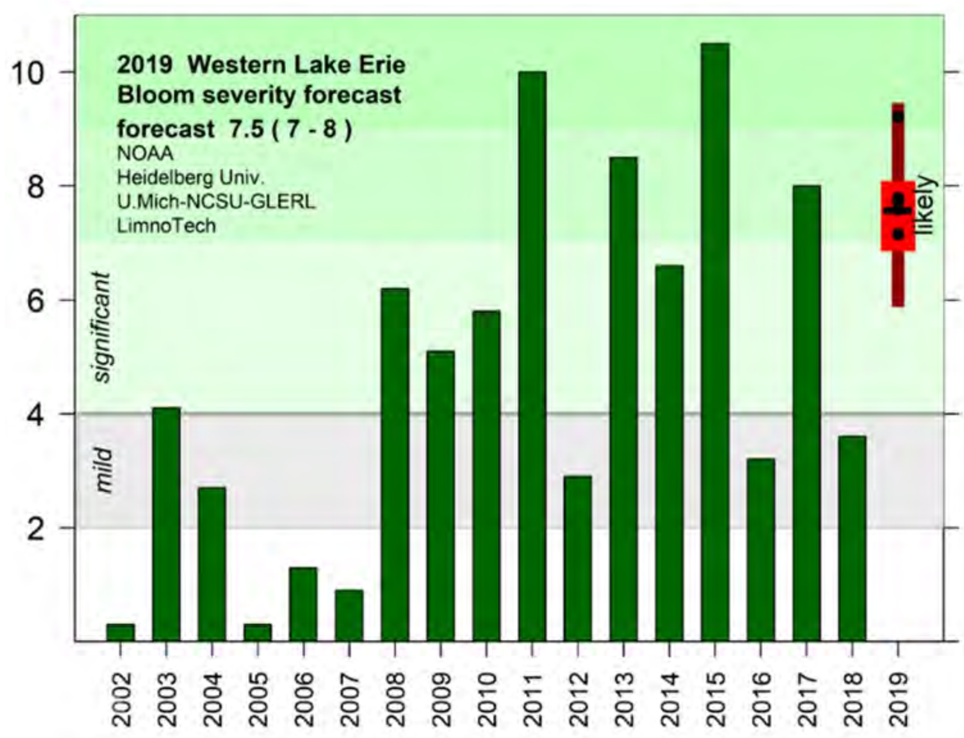


Figure 2. Western Lake Erie algal bloom severity forecast (National Oceanic and Atmospheric Administration, Heidelberg University, University of Michigan, and LimnoTech).

In August of 2014, a bloom of the cyanobacterium *Microcystis* sp. resulted in a 'Do Not Drink' advisory in the City of Toledo for two days due to levels of the toxin microcystin in finished drinking water that exceeded safety guidelines recommended by the World Health Organization. The 2014 bloom, while not the largest bloom of the decade, had several unfortunate characteristics that precipitated the water crisis:

1. Persistent strong northeast winds pushed the bloom against the Ohio shoreline, concentrating it in the vicinity of the Toledo Lake Erie water intake located 4.8 km from the south shore.

2. The strength of the wind circulated bloom-rich water from the surface to the lake bottom where the city intake is located.

3. There is evidence that a virus (bacteriophage) was present in the bloom that may have attacked the cyanobacterial cells, causing them to release dissolved toxin into the water (Steffen et al., 2017). Dissolved toxin is much more difficult for water treatment plants to remove.

4. Water treatment plants had no early warning capability in 2014 and could not react fast enough to the rapid increase in lake water toxin levels.

5. Overall, the bloom was more highly toxic in 2014 compared to other years. That is, there was more toxin per cyanobacterial cell in 2014 than in previous years.

Early Warning System and Rapid Response

Since 2014, in an effort to prevent any future drinking water incidents, several measures have been introduced. Lake Erie now has a robust early warning system of buoys that detect cyanobacterial blooms and their movements. Robotic sensors are also being developed that can automatically measure toxin levels in the lake and transmit data to the internet in near real-time. Water treatment plants have increased their capacity to respond quickly and with redundant measures to remove any algal toxins. The issue of bloom toxicity is an active area of research at present. Scientists are able to predict bloom size and hope in the future to be able to predict bloom toxicity and perhaps develop early warning of viruses that may cause cyanobacterial cells to release toxin.

Open Water Impairment

In 2018, following several years of large algal blooms in the western basin, the State of Ohio declared the Ohio open waters of the western basin to be officially "Impaired" for recreational use. The impairment designation followed the recommendation of a committee of lake researchers that created a set of criteria based on bloom size and duration that was used to define the impairment designation. These criteria can also be used to remove the impairment designation in the future if conditions improve (Davis et al., 2019).

References

Beeton, A.M., 1961. Environmental Changes in Lake Erie. Transactions of the American Fisheries Society. 90, 153-159.

Davis, T.W., Stumpf, R., Bullerjahn, G.S., McKay, R.M.L., Chaffin, J.D., Bridgeman, T.B., Winslow, C., 2019. Science Meets Policy: A Framework for Determining Impairment Designation Criteria for Large Waterbodies Affected by Cyanobacterial Harmful Algal Blooms. Harmful Algae. 81(January), 59-64.

Ohio Department of Agriculture, Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and Lake Erie Commission. 2013. Ohio Lake Erie Task Force II: Final Report. Columbus, Ohio, USA.

Steffen, M.M., Davis, T.W., McKay, R.M.L., Bullerjahn, G.S., Krausfeldt, L.E., Stough, J.M.A., Neitzey, M.L., Gilbert, N.E., Boyer, G.L., Johengen, T.H., Gossiaux, D.C., Burtner, A.M., Palladino, D., Rowe, M.D., Dick, G.J., Meyer, K.A., Levy, S., Boone, B.E., Stumpf, R.P., Wynne, T.T., Zimba, P.V., Gutierrez, D., Wilhelm, S.W., 2017. Ecophysiological Examination of the Lake Erie Microcystis Bloom in 2014: Linkages Between Biology and the Water Supply Shutdown of Toledo, OH. *Environmental Science & Technology. 51,* 12, 6745-6755.

7.25 *Hexagenia* Density and Distribution in the Detroit River

Jan Ciborowski, University of Windsor, cibor@uwindsor.ca

Background

The abundance of the different types of aquatic invertebrates in various places of the Detroit River is controlled largely by the current and its effects on the river bottom (Ciborowski, 2003a). These differences in habitat must be taken into account when one attempts to evaluate potential effects of human-related activities on the benthic community.

Status and Trends

Currents in the main part of the river wash away fine sediments, leaving a substrate composed mainly of stones and hard clay (erosional areas). Some animals can shelter beneath or between the stones, but the most abundant species can attach themselves to the substrate or build shelters for themselves (e.g., net-spinning caddisflies, limpets, dreissenid mussels, flatworms).

Slower-flowing parts of the Detroit River (depositional areas) have a muddy or sandy bottom. These are also the areas where debris carried from upstream settles out. The benthic animals living here burrow into the mud and feed upon the organic debris and the attached bacteria and fungi present in the sediments. When the organic content of the sediments is high, bacterial respiration can remove much of the oxygen from the water, making the habitat suitable only for tolerant species. These are also regions where pollutants that aren't water-soluble tend to collect. Because oils and trace amounts of metals adhere to the organic matter in the mud, the zoobenthos of depositional zones tend to bioaccumulate these materials from their food.

The most common benthic animals living in depositional zones are worms (Oligochaeta), midge larvae (Chironomidae), and *Hexagenia* mayfly nymphs (Ephermeroptera) (Figure 1). *Hexagenia* is a dominant component of the benthic fauna of muddy and silty sediments in mesotrophic lakes and rivers.

Historically, *Hexagenia* mayflies were abundant throughout the Huron-Erie Corridor and the western basin of Lake Erie. Mayfly nymphs dig U-shaped burrows. They undulate their abdomen and wave their feather-like gills which forces oxygen-rich water through the burrow. Because mayflies can't survive in water that lacks oxygen, they are good indicators of the amount of organic pollution (e.g., sewage). For example, when water quality conditions are good, one expects to find 100 *Hexagenia* larvae/m^2 or more in clean muddy sediments of Lake Erie (Wright and Tidd, 1933). *Hexagenia* mayflies have been proposed as an ecosystem indicator of mesotrophic conditions in soft-sediment habitats of the Great Lakes (Reynoldson et al., 1989). The Ohio Lake Erie Commission's (2004) *Hexagenia* index classifies conditions as excellent where sediments contain 200-300 larvae/m^2. Areas dominated by worms and midges, rather than mayflies, are classed as having degraded water quality or benthic conditions.

Thornley and Hamdy (1984), Hudson et al., (1986), Manny et al., (1988), and Farara and Burt (1993) all reported *Hexagenia* as an indicator of relatively undegraded benthic conditions in the soft sediments of the Detroit River. *Hexagenia* densities of less than 20/m^2 in depositional habitats suggest degradation (Thornley and Hamdy, 1984; Ciborowski, 2003b). However, Edsall et al., (2001) reported that *Hexagenia* production (i.e., a combined estimate of growth and abundance) was a more sensitive indicator of suitable ecological conditions than density alone.

Figure 1. Hexagenia mayfly adult (Ephermeroptera) (photo credit: Nick Laferriere).

Larval Distribution

Some of the earliest Great Lakes zoobenthos surveys were conducted in 1929-1930 by Wright and Tidd (1933) in western Lake Erie and at the mouth of the Detroit River, as well as other Lake Erie tributaries. Among other zoobenthos, they reported snails, fingernail clams, and worms. However, mayfly larvae were conspicuously absent, indicating light to moderate pollution at the Detroit River mouth.

The Trenton Channel has long been identified as a degraded area based on zoobenthos composition and abundance. Surveys conducted between 1949 and 1956 showed that the lower Detroit River and the western Trenton Channel were dominated by pollution-tolerant forms, indicating a decrease in water quality from the 1929-1930 surveys. Carr and Hiltunen (1965) showed that the spatial extent and severity of degradation at the mouth of the Detroit River had increased substantially from that described by Wright and Tidd (1933). Later surveys reported that although the Detroit River mouth contained only very pollution-tolerant organisms (worms and leeches), zoobenthos composition and abundance upstream of Belle Isle was indicative of good water quality (Vaughn and Harlow, 1965).

Several surveys of the bottom fauna of the Detroit River were conducted between the 1960s and 1990 (Thornley, 1985; Hudson et al., 1986; Ferrara and Burt, 1993).

In 1968, the bottom fauna over large tracts of the Detroit River suggested that sediments and water quality were degraded. Mayflies were found in only about 25% of the locations sampled, and then only in low numbers (10-20/m^2, Thornley and Hamdy, 1984). Mayflies were completely absent from the United States shoreline except near the upstream end of Belle Isle (Figure 2). Almost no zoobenthos could be found in the vicinity of Zug Island.

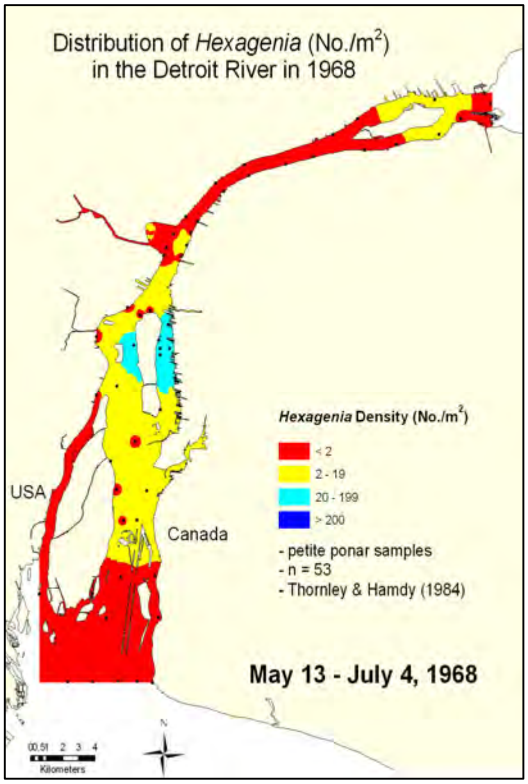


Figure 2. Density of Hexagenia in the Detroit River in 1968 interpolated from data compiled from Thornley and Hamdy (1984). Areas that have fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

Pollution controls put in place during the 1970s resulted in improved water and sediment quality in many areas. When the river was surveyed again in 1980, mayflies were found at over 70% of the locations examined, and they were five times more abundant than in 1968 (Thornley, 1985; Figure 3). Densities exceeded 20/m^2 in both the upper and lower reaches of the Detroit River, being absent mainly south of Zug Island and in the Trenton Channel.

Few changes in either the distribution or abundance of mayfly nymphs were seen between the 1980 survey, a 1983 investigation (Hudson et al., 1986), and a study done in 1991 (Farara and Burt, 1993). In 1991, *Hexagenia* mayflies were found at about 60% of locations sampled, at densities of between 8 and 100 nymphs/m^2 (Figure 4). However, more of the river supported densities slightly less than the 20/m^2 criterion suggested to indicate impairment (Ciborowski, 2003b) than had been observed in 1980. Worms and midges remained the most common invertebrates along the United States shoreline of the river downstream from Zug Island.

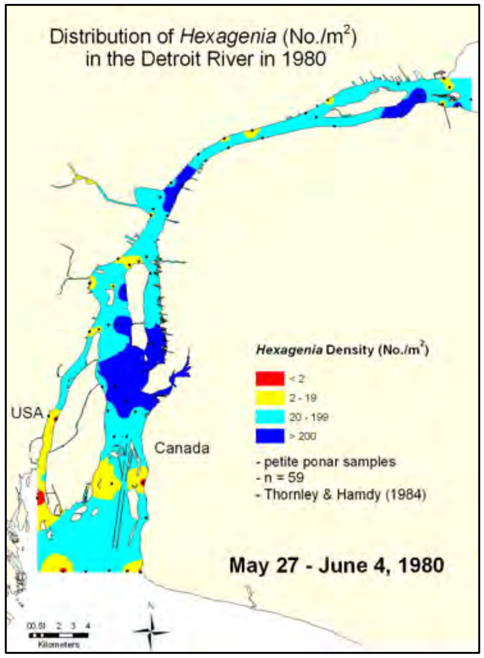


Figure 3. Density of Hexagenia in the Detroit River in 1980 interpolated from data compiled from Thornley and Hamdy (1984). Areas that have fewer than 20 nymphs/m^2, indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

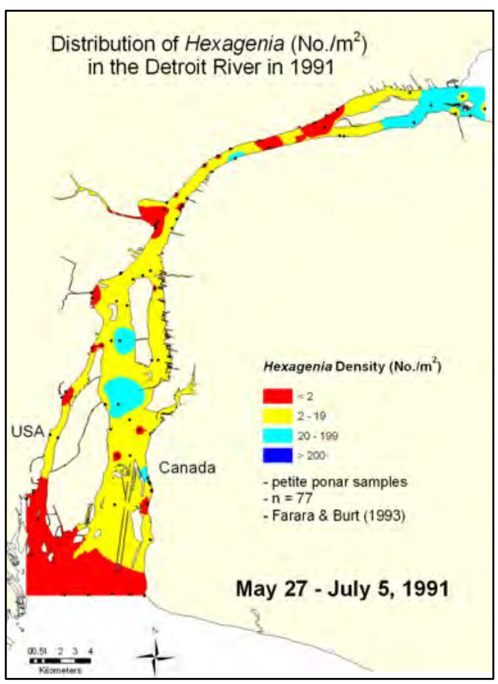


Figure 4. Density of Hexagenia in the Detroit River in 1991 interpolated from data compiled from Farara and Burt (1993). Areas that have fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

Little benthic sampling was conducted in the Detroit River through most of the 1990s, so information on health of the zoobenthic community during this time is scarce. However, the flying adult stages of *Hexagenia* and other aquatic insects became more numerous along both the Canadian and United States sides of the river and along the shores of Lake Erie (Ciborowski and Corkum, 1988; Kovats, 1990; Kovats et al., 1996; Corkum et al., 1997) suggesting that some improvements in river condition had been occurring.

The Detroit River was next intensively studied in 1999. Samples were collected from almost 150 locations (Wood, 2002; Figure 5). Densities exceeded the 20 nymph/m^2 impairment threshold at the head of the river and on the Canadian side of the lower reaches. Few nymphs were collected in the mid-reaches, however.

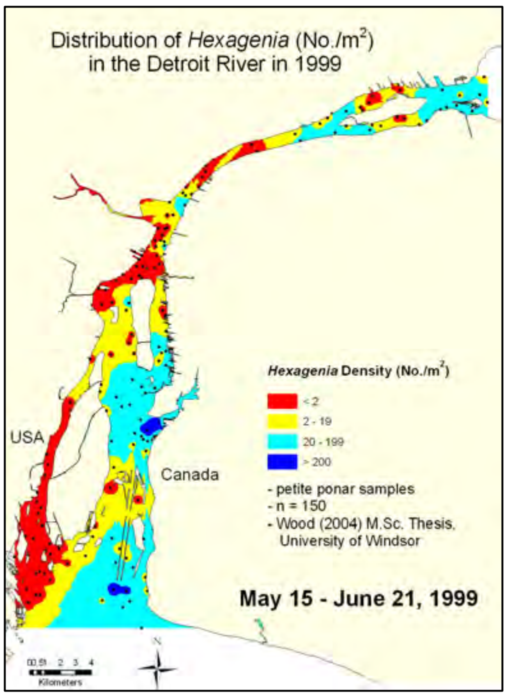


Figure 5. Density of Hexagenia in the Detroit River in 1999 interpolated from data compiled from Wood (2002). Areas containing fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

The entire Huron-Erie Corridor was sampled in 2004. A suite of 20 randomly-selected locations sampled in July and August 2004 produced a distributional pattern similar to that observed in 1968 (Zhang, 2008; Figure 6). However, this was partly due to the timing of sampling. In 2004, many samples were collected in July after the period of maximum emergence, but before nymphs representing the next generation had hatched from their eggs. Densities were moderate or high in much of Lake St. Clair and lower reaches of the St. Clair River (Figure 7). No comprehensive, reliable benthic sampling has been conducted in the Detroit River mainstem since 2004.

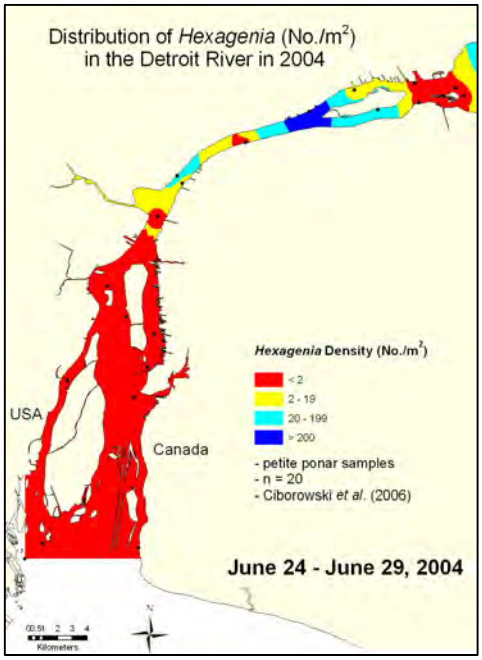


Figure 6. Density of Hexagenia in the Detroit River in 2004 interpolated from data compiled from Zhang (2008). Areas having fewer than 20 nymphs/m², indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

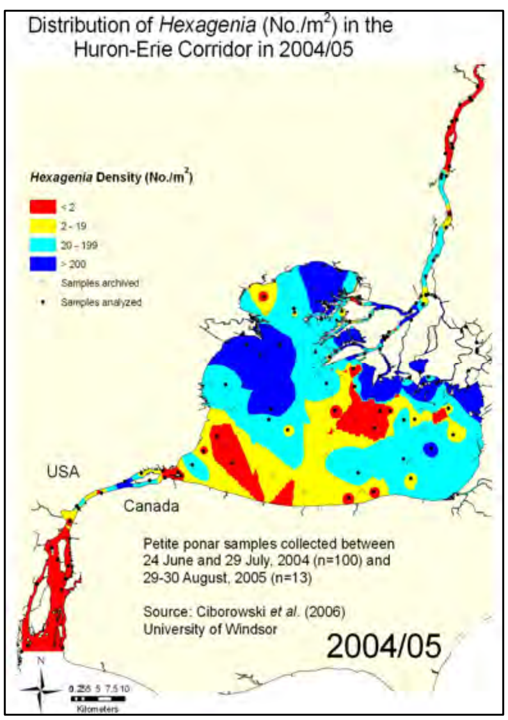


Figure 7. Density of Hexagenia in the Huron-Erie Corridor in 2004/05 interpolated from data compiled from Zhang (2008). Areas having fewer than 20 nymphs/m², indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.

River-wide Frequency and Abundance

Figure 8 summarizes the trends in average *Hexagenia* abundance all samples for surveys conducted since 1968. *Hexagenia* mayfly nymphs were found in 70% of the 59 stations sampled in 1980 compared to only 26% of 53 stations in 1968 (Thornley and Hamdy, 1984). The greatest changes in occurrence occurred along the Canadian shoreline. The mean density of *Hexagenia* in 2004 was 20/m^2 but distribution was restricted to fewer locations than previously (Ciborowski et al., 2006), partly due to timing of sampling, as indicated above.

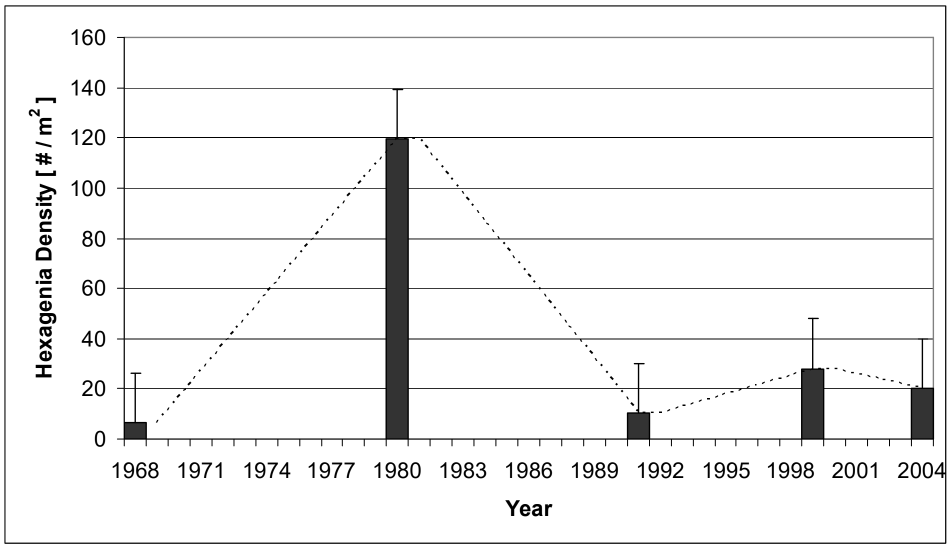


Figure 8. Mean ±SE density of Hexagenia in the Detroit River between 1968 and 2004. The number of sites sampled each year is indicated. Data compiled from Thornley and Hamdy (1984), Farara and Burt (1993), Wood (2004), and Zhang (2008).

Adult Abundance and Contaminant Burdens:

Improvements in Detroit River water quality have been most obviously shown in the numbers of night-flying insects that are attracted to streetlights and storefronts along the river during warm summer evenings. Both *Hexagenia* mayflies and moth-like caddisflies emerge from the river in summer to mate and lay their eggs. Emerging *Hexagenia* (commonly called fishflies or June bugs) are most abundant for a few weeks from the middle of June until mid-July. Strong winds can carry the insects long distances inland from the river, but typically, most travel only a few hundred meters (Kovats et al., 1996).

Although the insects are a nuisance, they are an important food for birds and fishes during their emergence period. They also provide a valuable tool for monitoring contaminant levels in the river. On a warm evening, a black light placed beside the river will quickly attract enough biomass to provide a sample that can be analyzed for PCBs, heavy metals, and other pollutants associated with contaminated sediments (Corkum et al., 1995). Ciborowski and Corkum (1988), Kovats (1990), and Corkum et al., (1997) analyzed organic contaminant burdens in *Hexagenia* mayflies emerging at the head of the Detroit River near Peche Island. Concentrations of PCBs, pesticides, and other organochlorine compounds were virtually identical in 1986, 1989, and 1994. Yet, the numbers of emerging insects, and their distribution along the river, have continued to increase through the 1990s (Corkum et al., 1997).

Contaminant burdens (PCBs, pesticides, and other organochlorine compounds) of *Hexagenia* adults collected from the shorelines of western Lake Erie in 1994 were elevated relative to collections made in offshore areas. Adults collected from Monroe Michigan, adjacent to the mouth of the Detroit River had the highest burdens of any samples. Burdens of trace metals were not unduly elevated. *Hexagenia* larvae collected from the vicinity of Middle Sister Island in western Lake Erie had high burdens of organochlorine compounds and polycyclic aromatic hydrocarbons (Corkum et al., 1997). Similarly, Smits et al. (2006) found much higher burdens in *Hexagenia* adults from Monroe, Michigan than in adults captured near Point Pelee, Ontario.

Management Next Steps

The available data show which portions of the river have historically been most heavily degraded by organic enrichment and those that are still affected by nutrient-rich water, primarily sewage and stormwater. The present-day distribution of *Hexagenia* nymphs suggests that current sediment and water quality conditions have not improved enough to permit nymphs to develop in those degraded areas. However, surveys have been conducted too infrequently to permit us to ascertain the extent to which year-to-year variation in distribution reflects changing pollution status versus normal fluctuations in the mayfly population. Continued attention to point sources of pollution will be necessary to permit *Hexagenia* to populate all of the depositional habitats in the Detroit River.

Research/Monitoring Needs

Hexagenia surveys have been conducted too infrequently to permit one to ascertain whether the temporal patterns represent changing environmental conditions or random interannual variation. Ideally, sampling should be conducted yearly, and surveys should be completed in the spring, prior to the period of adult emergence (ideally during the months of April and May). Sampling methods (collection times, determination of site locations, number of sites sampled) should be standardized across years to improve the precision of river-wide density estimates.

References

Carr, J.F., Hiltunen, J.K., 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. Limnology and Oceanography. 10, 551-569.

Ciborowski, J.J.H., Corkum, L.D., 1988. Organic contaminants in adult aquatic insects of the St. Clair and Detroit Rivers, Ontario, Canada. Journal of Great Lakes Research. 14, 148-156.

Ciborowski, J.J.H., 2003a. Lessons from sentinel invertebrates: mayflies and other species, in: Hartig, J.H. (Ed.), Honoring our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, pp. 107-120.

Ciborowski, J.J.H., 2003b. Technical comments on delisting criteria for the Detroit River area of concern – Beneficial use impairment #6: Degradation of Benthos, in: Dolan, D., Murray, P. (Eds.), Workshop on Delisting Criteria for the Detroit River Area of Concern. Detroit River Canadian Cleanup Committee, Windsor, pp. 78-87.

Corkum, L.D., Ciborowski, J.J.H., Kovats, Z.E., 1995. Aquatic insects as biomonitors of ecosystem health in the Great Lakes area of concern, in: Butterworth, F.M., Corkum, L.D., Guzmán-Rincón, L.J. (Eds.), Biomonitors and Biomarkers as Indicators of Environmental Change: A Handbook. Plenum Publishing Company, New York, pp. 31-44.

Corkum, L.D. Ciborowski, J.J.H., Lazar, R., 1997. The distribution and contaminant burdens of adults of the burrowing mayfly, *Hexagenia* in Lake Erie. Journal of Great Lakes Research. 23, 383-390.

Edsall, T.A, Haas, R.C., Adams, J.V., 2001. Annual production of burrowing mayfly nymphs (*Hexagenia* spp.) in U.S. waters of Lake St. Clair. Journal of Great Lakes Research. 27, 449-456.

Farara, D.G., Burt, A.G., 1993. Environmental assessment of Detroit River sediments and benthic macroinvertebrate communities – 1991. Report prepared for the Ontario Ministry of Environment and

Energy by Beak Consultants Limited, Brampton, Ontario, Canada.

Hudson, P.L., Davis, B.M., Nichols, S.J., Tomcko, C.M., 1986. Environmental studies of macrozoobenthos, aquatic macrophytes, and juvenile fishes in the St. Clair-Detroit River system, 1983-1984. U.S. Fish and Wildlife Service, Great Lakes Fish Lab, Administrative Report No. 86-7, Ann Arbor, Michigan, USA.

Kovats, Z.E., 1990. Adult aquatic insects as biomonitors of organochlorine contamination in freshwater habitats. M.Sc. Thesis, University of Windsor, Ontario, Canada.

Kovats, Z.E., Ciborowski, J.J.H., Corkum, L.D., 1996. Inland dispersal of adult aquatic insects. Freshwater Biology. 36, 265-276.

Manny, B.A., Edsall, T.A., Jaworski, E., 1988. The Detroit River, Michigan: An ecological profile. U.S. Fish and Wildlife Service, Biological Report 85, Ann Arbor, Michigan, USA.

Reynoldson, T.B., Schloesser, D.W., Manny, B.A., 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes waters. Journal of Great Lakes Research. 15, 4, 669-686.

Smits, J.E., Bortolotti, G.R., Sebastian, M., Ciborowski, J.J.H., 2005. Spatial, temporal, and dietary determinants of organic contaminants in nestling tree swallows in Point Pelee National Park, Ontario, Canada. Environmental Toxicology and Chemistry. 24, 3159-3165.

Thornley, S., Hamdy, Y., 1984. An assessment of bottom fauna and sediments of the Detroit River. Ontario Ministry of Environment, Toronto, Ontario, Canada.

Thornley, S., 1985. Macrozoobenthos of the Detroit and St. Clair rivers with comparison to neighboring waters. Journal of Great Lakes Research. 11, 290-296.

Vaughn, R.D., Harlow, G.L., 1965. Report on pollution of Detroit River, Michigan waters of Lake Erie, and their tributaries. U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Water Supply and Pollution Control. U.S. Government Printing Office, Washington, D.C., USA.

Wood, S., 2002. Benthic community and persistent contaminant distributions in the Detroit River. M.Sc. Thesis, University of Windsor, Ontario, Canada.

Wright, S., Tidd, W.M., 1933. Summary of limnological investigations in western Lake Erie in 1929 and 1930. Transactions of the American Fisheries Society. 63, 271-285.

Zhang, J., 2008. Zoobenthic indicators of environmental conditions in the L. Huron-L. Erie corridor. M.Sc. Thesis, University of Windsor, Windsor, Ontario, Canada.

7.26 Invasive Species

Dr. Hugh J. MacIsaac, University of Windsor, Great Lakes Institute for Environmental Research, hughm@uwindsor.ca

Emma M. De Roy, University of Windsor, Great Lakes Institute for Environmental Research, deroye@uwindsor.ca

Background

Numerous stressors threaten the health of the Laurentian Great Lakes in general, and Lake Erie in particular (Figure 1). The Great Lakes are replete with non-indigenous species (NIS), with over 180 species currently established (Ricciardi, 2006) (Figure 2); Lake Erie supports the greatest number of AIS (USGS, 2012). Arguably, NIS that cause profound ecological and economic damage - invasive species – are the leading stressor in Lake Erie (Allan et al., 2013). Numerous pathways are responsible for NIS release including commercial shipping, live species trade, and unauthorized introductions (Ricciardi, 2006). Ballast water release from commercial shipping has been the primary pathway for species introductions since 1959 (Ricciardi, 2006).

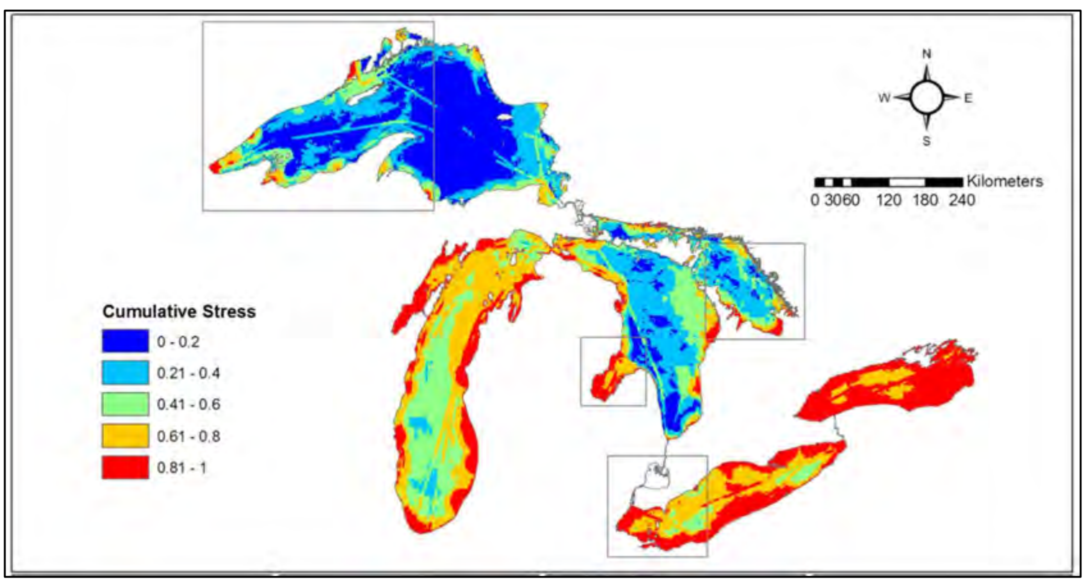


Figure 1. Cumulative environmental stress experienced in each of the Great Lakes, including invasive species. Data are pooled from 34 total stressors (Allan et al., 2013).

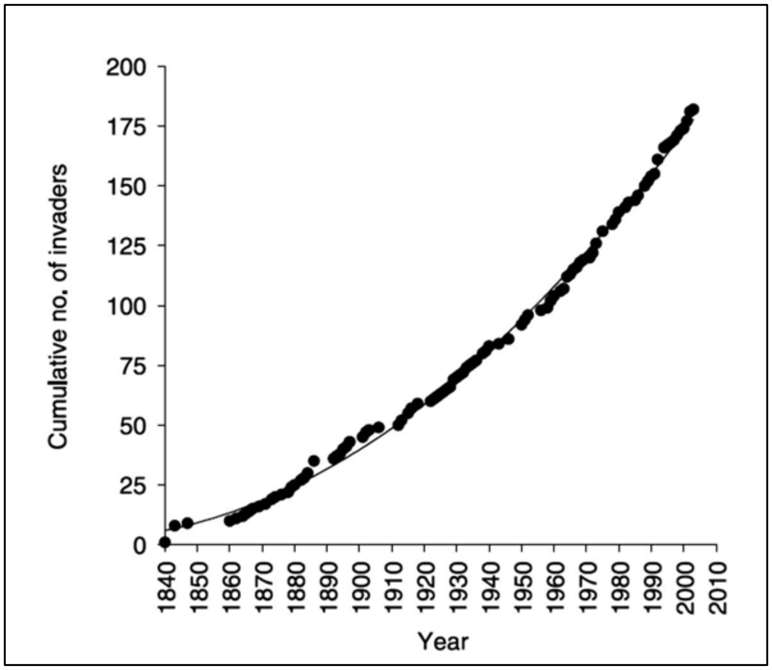


Figure 2. Cumulative number of non-indigenous species in the Great Lakes (Ricciardi, 2006).

Status and Trends

The number of new NIS was seemingly reduced following mandatory ballast water flushing regulations for foreign ships entering the Great Lakes (Bailey et al., 2011). Despite this, four new invertebrate NIS (copepods *Thermocyclops crassus* and *Mesocyclops pehpeiensis*, cladoceran *Diaphanosoma fluviatile* and rotifer *Brachionus leydigii*) have been reported since 2014 in Lake Erie (Connolly et al., 2017; Connolly et al., 2018; Connolly et al., 2019; Lower and Sturtevant, 2019). Some of these NIS were reported previously in ship's ballast water (Johengen et al., 2005), suggesting that they may have entered via this pathway. *Mesocyclops* is associated with aquaculture and the ornamental plant trade (Connolly et al., 2019). Alternative pathways – e.g., aquarium trade – also introduce species (Duggan et al., 2018) and, without proper management, are likely to dominate longer-term invasions in the Great Lakes as ballast water treatment becomes mandatory. Caution needs to be exercised in attribution of pathways when new NIS are reported, as the new NIS in Lake Erie could have entered prior to implementation of ballast water management even though they were discovered recently (i.e., time lags), or if more than one pathway could potentially introduce a species.

Management Next Steps

Coordinated NIS regulations and management are needed in this region. For example, intensive grass carp eradication is of utmost importance given their expanding range in the southern part of western Lake Erie, and the high risks associated with the species (Cudmore et al., 2016; Embke et al., 2016).

The IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments will require all vessels to have on-board water treatment systems by 2024, and places limits on the permissible abundance of discharged organisms (IMO, 2016). It is important that these regulations apply to the domestic 'laker' fleet as well to reduce inter-lake dispersal of NIS. In addition, the efficacy of ballast treatment should be verified through comprehensive sampling on the Great Lakes. Enactment of regulations relevant to alternative pathways also requires immediate attention region-wide.

Research/Monitoring Needs

Species-specific methods of control and impact mitigation are needed, but lacking (Wilkie et al., 2018). Furthermore, the region requires consistent monitoring programs to detect and eradicate invasive species if introduced - i.e., the killer shrimp (*Dikerogammarus villosus*) and golden mussel (*Limnoperna fortunei*) (Zhang et al., 2019) - or those undergoing range expansion, such as the Eurasian tench (*Tinca tinca*) (Avlijaš et al., 2018). Should any of these species establish, detection at low densities is essential when eradication might be feasible. Environmental DNA (eDNA) sampling can assist with this endeavor. Species distribution models predict species presence given information on range and climatic suitability and may be used to direct sampling efforts.

For newly established invasive species, long-term monitoring is essential to assess impacts on Lake Erie. The New Zealand Mud Snail (*Potamopyrgus antipodarum*) was reported in Lake Erie for the first time in 2007, where it is now considered established (Illinois-Indiana Sea Grant, 2019). Its impacts are unknown in this region but may be significant. Regular monitoring can also allow managers to assess whether invasion rate changes over time by reducing time lags.

References

Allan, J.D., McIntyre, P.B., Smith, S.D., Halpern, B.S., Boyer, G.L., Buchsbaum, A., Burton, G.A., Campbell, L.M., Chadderton, W.L., Ciborowski, J.J., Doran, P.J., 2013. Joint analysis of stressors and ecosystem services to enhance restoration effectiveness. Proceedings of the National Academy of Sciences. 110, 372-377.

Avlijaš, S, Ricciardi, A., Mandrak, N.E., 2017. Eurasian tench (*Tinca tinca*): the next Great Lakes invader. Canadian Journal of Fisheries and Aquatic Sciences. 75, 169-79.

Bailey, S.A., Deneau, M.G., Jean, L., Wiley, C.J., Leung, B., MacIsaac, H.J., 2011. Evaluating Efficacy of an Environmental Policy to Prevent Biological. Environmental Science and Technology. 45, 2554-2561.

Connolly, J.K., Watkins, J.M., Hinchey, E.K., Rudstam, L.G., Reid, J.W., 2017. New cyclopoid copepod (*Thermocyclops crassus*) reported in the Laurentian Great Lakes. Journal of Great Lakes Research. 43, 198-203.

Connolly, J.K., Watkins, J.M., Marshall, C.C., Adams, J.M., Rudstam, L.G., Błędzki, L.A., 2018. *Brachionus leydigii* (Monogononta: Ploima) reported from the western basin of Lake Erie. Journal of Great Lakes Research. 44, 1123-1126.

Connolly, J.K., Watkins, J.M., Hinchey, E.K., Rudstam, L.G., Reid, J.W., 2019.

The Asian cyclopoid copepod *Mesocyclops pehpeiensis* (Hu 1943) reported from the western basin of Lake Erie. Journal of Great Lakes Research. 45, 196-201.

Cudmore, B., Jones, L.A., Mandrak, N.E., Dettmers, J.M., Chapman, D.C., Kolar, C.S., Conover, G., 2016. Ecological Risk Assessment of Grass Carp (*Ctenopharyngodon idella*) for the Great Lakes Basin. Fisheries and Oceans Canada. Burlington, Ontario, Canada.

Duggan, I.C., Champion, P.D., MacIsaac, H.J., 2018. Invertebrates associated with aquatic plants bought from aquarium stores in Canada and New Zealand. Biological Invasions. 20, 3167-3178.

Embke, H.S., Kocovsky, P.M., Richter, C.A., Pritt, J.J., Mayer, C.M., Qian, S.S., 2016. First direct confirmation of grass carp spawning in a Great Lakes tributary. Journal of Great Lakes Research. 42, 899-903.

Illinois-Indiana Sea Grant, 2019. New Zealand mudsnail: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, and NOAA Great Lakes Aquatic Nonindigenous Species Information System, Ann Arbor, Michigan, USA https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?SpeciesID=1008&Potential=N&Type=1&HUCNumber=DHuron, Revision Date: 9/25/2012 (accessed: 1 July 2019).

International Marine Organization (IMO), 2016. International convention for the control and management of ships' ballast water and sediments. International Maritime Organization, London.

Johengen, T., Reid, D.F., Fahnenstiel, G.L., MacIsaac, H.J., Dobbs, F.C., Doblin, M., Ruiz, G., Jenkins, P.T., 2005. A final report for the project: assessment of transoceanic NOBOB vessels and low-salinity ballast water as vectors for non-indigenous species introductions to the Great Lakes. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, and University of Michigan, Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, Michigan, USA.

Lower, E.I., Sturtevant, R., 2019. *Diaphanosoma fluviatile* Hansen 1899. U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, and NOAA Great Lakes Aquatic Nonindigenous Species Information System, Ann Arbor, MI, https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?SpeciesID=73&Potential=Y&Type=2&HUCNumber=DGreatLakes, Revision Date: 8/10/2018 (accessed: 6 June 2019).

Ricciardi, A., 2006. Patterns of invasion in the Laurentian Great Lakes in relation to changes in vector activity. Diversity and Distributions. 12, 425— 433.

U.S. Geological Survey (USGS), 2012. Nonindigenous Aquatic Species Database, Gainesville, Florida, USA.

Wilkie, M.P., Hubert, T.D., Boogaard, M.A., Birceanu, O., 2018. Control of invasive sea lampreys using the piscicides TFM and niclosamide: Toxicology, successes & future prospects. Aquatic Toxicology. 211, 235-252.

Zhang, H., Rutherford, E.S., Mason, D.M., Wittmann, M.E., Lodge, D.M., Zhu, X., Johnson, T.B., Tucker, A., 2019. Modeling potential impacts of three benthic invasive species on the Lake Erie food web. Biological Invasions. 21, 1697-1719.

This page intentionally left blank.

7.27 Lake Level Changes in Lake Erie

Erin Maher, Great Lakes Integrated Sciences + Assessments, University of Michigan, eemaher@umich.edu

Kimberly Channell, Great Lakes Integrated Sciences + Assessments, University of Michigan, kimchann@umich.edu

Background

While sea levels have risen gradually in response to warming global surface temperatures, the response of water levels in the Great Lakes is more variable and unpredictable. Fluctuations in Great Lakes water levels can be seen on both long- and short-term time scales. Seasonally, the primary drivers of these fluctuations are precipitation, evaporation, and runoff (Deacu et al., 2012). Longer-term variability is more difficult to predict, leading to uncertainty about how Lake Erie water levels will fluctuate in the future.

The Great Lakes system is complex and interconnected. While Lake Erie is a hydrologically distinct lake, it is connected to both Lakes Huron and Ontario. Water flows from Lake Huron into Lake Erie though the Huron-Erie Corridor, which consists of the St. Clair River, Lake St. Clair, and the Detroit River. Water from Lake Erie then flows over Niagara Falls into Lake Ontario. Water levels on Lake Erie are therefore connected to water levels of the entire Great Lakes System, adding to the complexity of water level predictions.

It is important to consider and monitor changes in water levels in Lake Erie as changes in lake levels have many different impacts. High water levels can cause flooding, property inundation, and coastal erosion, while low water levels can lead to negative impacts on shipping and navigation, seasonal recreation, and coastal wetland habitats for birds and fish (Gronewold et al., 2013).

In the following section, historical water levels in Lake Erie are visualized and discussed using data from the Great Lakes Environmental Research Laboratory (GLERL), which compiles monthly data from the U.S. Army Corps of Engineers (NOAA Great Lakes Environmental Research Laboratory; Hunter and Croley, 1993; Quinn and Kelley, 1983). The use of data sourced from GLERL allows for high confidence in the analyses of these data.

Status and Trends

Variability of water levels in Lake Erie is observed on many different time scales, including seasonal, annual, and decadal. Figure 1 below shows monthly average water levels compared with the historical long-term average. Long-term fluctuations in Lake Erie water levels are evident in this figure, with decades of above- and below-average water levels.

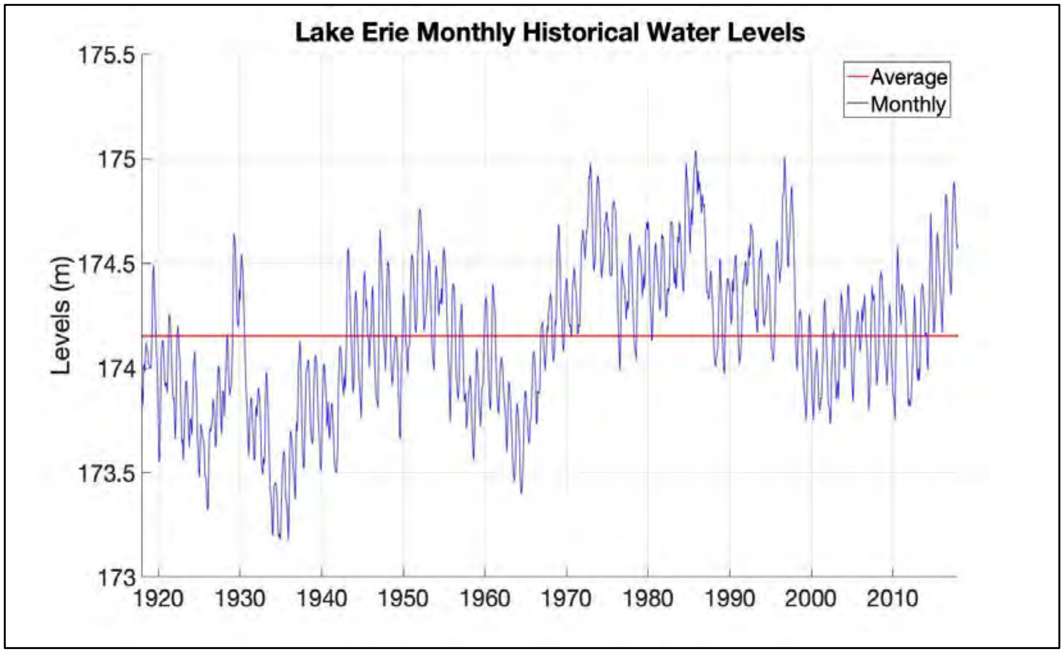


Figure 1. Monthly average water levels for Lake Erie (blue) from 1918-2018 shown here with the historical average (red) to demonstrate variability of lake levels.

Lake levels experience annual cycles and multi-year periods of high and low levels. To demonstrate this, Figure 2 presents a truncated version of Figure 1, on a shorter timescale, with added annotations and an additional line displaying annual average lake levels. The periods of sustained highs and lows are variable in length, which is indicative of the unpredictability of lake level variability.

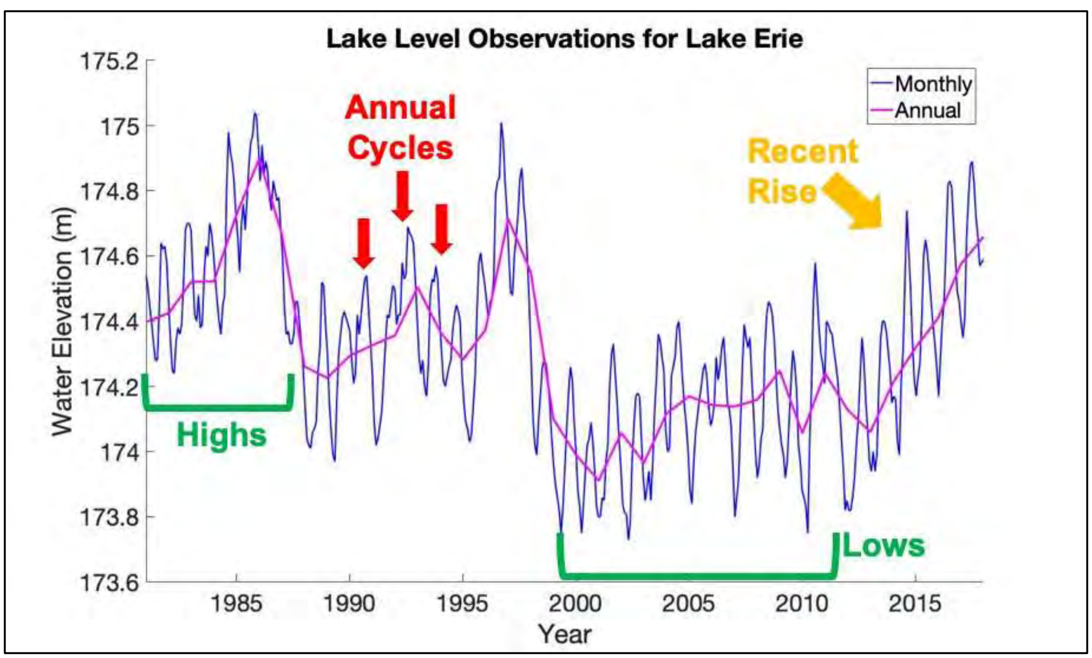


Figure 2. Monthly (blue) and annual (pink) average lake levels for Lake Erie with added annotations denoting annual cycles, highs, lows, and the recent rise.

Along with historical highs, lows, and annual cycles, a recent rise in lake levels is also evident in Figure 2. The Great Lakes, including Lake Erie, have recently experienced a period of rising water levels, which follows an approximately ten-year period of low levels. This trend goes against previously predicted decreases in water levels. Such predictions were made with methods that used atmospheric temperatures as a proxy for evaporation rates, which have since been found to have overestimated projections for evaporation and lake level declines (Hayhoe et al., 2010; Lofgren and Rouhana, 2016).

This deviation from previously predicted patterns is consistent with evidence that supports the idea that variability in lake level fluctuations will increase (Gronewold and Rood, 2019). Although Lake Erie is currently experiencing a rise in lake levels, it is uncertain as to how long this will continue.

The variability of water levels in Lake Erie can be demonstrated using decadal averages, as seen in Figure 3. Overall, earlier decades, such as the 1930s and 1940s, had lower lake levels than later decades, such as the 1980s and 2010s. The current decade (2010s) of higher water levels occurred after a period of low lake levels, as mentioned above.

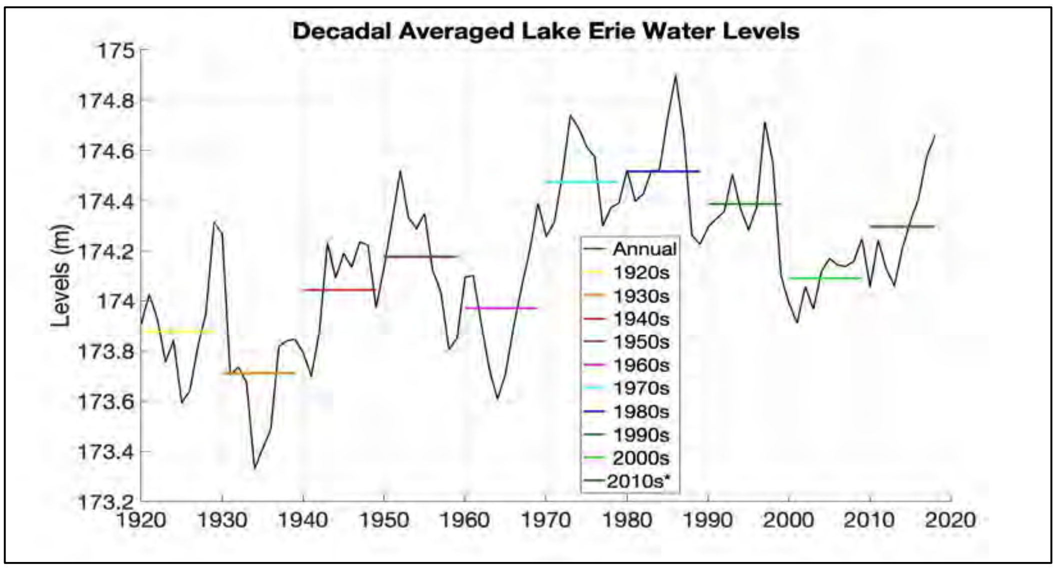


Figure 3. Decadal averaged water levels in Lake Erie (colored horizontal lines) plotted with annual time series (black).

*The decadal average for the 2010s is calculated using data from 2010-2018 as the data for 2019 was not yet available at the time of the analysis.

The current rise has not yet caused the levels to surpass the overall-record high level for Lake Erie, set in the late 1980s, however, several monthly average records have been set in 2019 (U.S. Army Corps of Engineers, 2019). Figure 4 shows these record monthly highs plotted with record monthly lows and average monthly water levels for Lake Erie. The record lows were set in the mid-1930s, and there has not been a period that came close to breaking these records since.

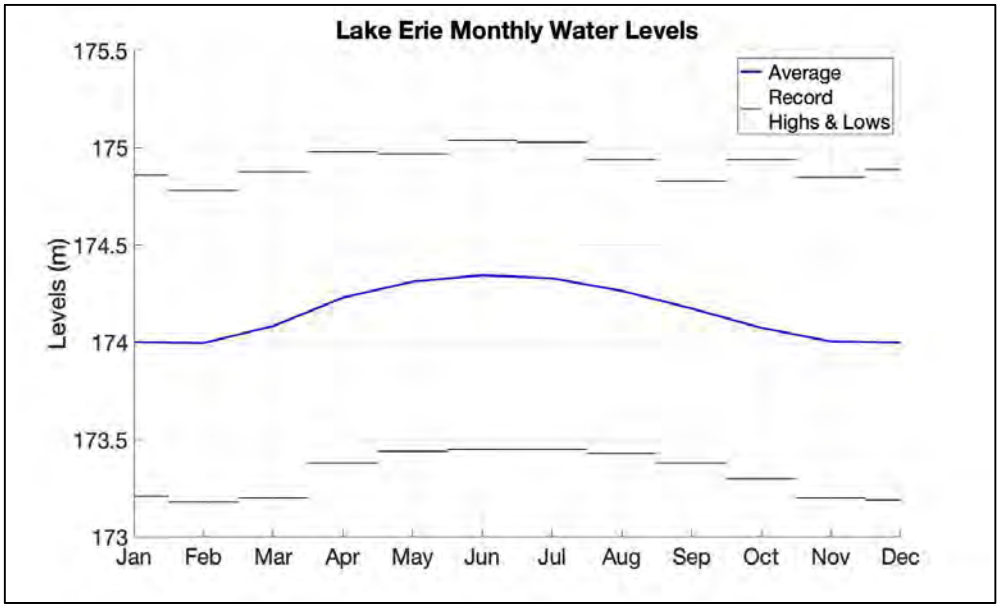


Figure 4. Monthly average water levels in Lake Erie (blue solid) plotted with monthly record highs and lows (black horizontal lines).

This figure also displays the annual cycle of water levels. Water levels on all Great Lakes rise in the spring and summer due primarily to snowmelt runoff and low evaporation rates and decline in the fall due to high evaporation rates from the temperature difference between the air (cold) and water (still warm from summer months). On average, the highest lake levels are seen between May and July, which are also reflected in the record highs and lows, as they follow a pattern consistent with that of the average water levels. If the recent rise were to result in a new overall record maximum, it will likely occur in the spring and summer months. However, as stated before, water levels in the Great Lakes are complex, variable, and difficult to predict.

Management Next Steps and Future Research Needs

In the future, water level changes in Lake Erie should continue to be monitored. This will allow for continued analysis of regional trends and planning for future impacts. Monitoring both annual and seasonal trends in lake levels will allow for better understanding of regional changes, and more informed decision making and planning.

Prediction of future lake levels is very difficult, but updates and improvements to modelling techniques are constantly underway. Current evidence indicates that there will be an increase in the variability of lake level fluctuations (Gronewold and Rood, 2019). Because of this, it is important to consider possible impacts in periods of both high and low lake levels.

Changes in water levels in Lake Erie can have a variety of impacts. Higher lake levels can lead to an increased number of flooding events in coastal areas (Gronewold et al., 2016). Flooding can present safety hazards, cause erosion, and damage infrastructure (Meadows et al., 1997; Winters et al., 2015). Lower lake levels can present problems for shipping, as ships are forced to take on less cargo to account for decreased lake depth, causing economic losses (U.S. Department of Commerce et al., 2019; Sousounis and Bisanz, 2000). Habitats for wildlife and plants area also impacted by fluctuating lake levels, particularly those that rely on coastal wetlands for their breeding zones (Erwin, 2009). All these impacts are important considerations for the management of Lake Erie.

References

Deacu, D., Fortin, V., Klyszeijko, E., Spence, C., Blanken, P.D., 2012. Predicting the Net Basin Supply to the Great Lakes with a Hydrometeorological Model. Journal of Hydrometeorology. 13, 1739-1759.

Erwin, K.L., 2009. Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecol. Manage. 17, 71–84.

NOAA Great Lakes Environmental Research Laboratory, Great Lakes Hydro-climate Dashboard Project, https://www.glerl.noaa.gov/data/dashboard/data/levels/1918_PRES/ (accessed: 1 May 2020.

Gronewold, A.D., Rood, R.B., 2019. Recent water level changes across Earth's largest lake system and implications for future variability. Journal of Great Lakes Research. 45, 1-3.

Gronewold, A., Fortin, V., Lofgren, B., Clites, A., Stow, C.A., Quinn, F., 2013. Coasts, water levels, and climate change: A Great Lakes perspective. Climatic Change. 120, 697–711.

Gronewold, A. D., Bruxer, J., Durnford, D., Smith, J.P., Clites, A.H., Seglenieks, F., Qian, S.S., Hunter, T.S., Fortin, V., 2016. Hydrological drivers of record-setting water level rise on Earth’s largest lake system. Water Resour. Res. 52, 4026-4042.

Hayhoe, K., VanDorn, J., Croley, II, T., Sclegal, N., Wuebbles, D., 2010. Regional climate change projections for Chicago and the US Great Lakes. Journal of Great Lakes Research. 36, 7-21.

Hunter, T.S., Croley, II, T.E., 1993. Great Lakes Monthly Hydrologic Data. NOAA Data Report ERL GLERL, National Technical Information Service, Ann Arbor, Michigan, USA.

Lofgren, B.M., Rouhana, J., 2016. Physically Plausible Methods for Projecting Changes in Great Lakes Water Levels under Climate Change Scenarios. Journal of Hydrometeorology. 17, 2209-2223.

Meadows, G.A., Meadows, L.A., Wood, W.L., Hubertz, J.M., Perlin, M., 1997. The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage. Bulletin of the American Meteorological Society. 78, 675-684.

Quinn, F.H., Kelley, R.N., 1983. Great Lakes Monthly Hydrologic Data. NOAA Data Report ERL GLERL-26, National Technical Information Service, Ann Arbor, Michigan, USA.

Sousounis, P., Bisanz, J.M., 2000. Preparing for a Changing Climate. The Potential Consequences of Climate Variability and Change: Great Lakes. University of Michigan, Atmospheric, Oceanic and Space Sciences Department, Ann Arbor, Michigan, USA.

U.S. Army Corps of Engineers, 2019. Monthly Bulletin of Great Lakes Water Levels. Lake Erie Water Levels - October 2019. Detroit, Michigan, USA.

U.S. Department of Commerce, 2019. "Great Lakes Ice Cover." Ice Cover: NOAA Great Lakes Environmental Research Laboratory. www.glerl.noaa.gov/data/ice/#overview (accessed 1 May 2020).

Winters, B.A., Angel, J., Ballerine, C., Byard, J., Flegel, A., Gambill, D., Jenkins, E., McConkey, S., Markus, M., Bender, B.A., O'Toole, M.J., 2015. Report for the Urban Flooding Awareness Act. 89 pp., Illinois Department of Natural Resources. http://hdl.handle.net/2142/78150 (accessed: 1 May 2020).

7.28 Lake Sturgeon Population

Justin A. Chiotti, U.S. Fish and Wildlife Service, justin_chiotti@fws.gov

James C. Boase, U.S. Fish and Wildlife Service, james_boase@fws.gov

Background

The lake sturgeon (*Acipenser fulvescens*), a remnant of the dinosaur age, is considered a species of special concern by the U.S. Fish and Wildlife Service, a threatened species in North America by the American Fisheries Society, a globally rare species by the Nature Conservancy, and a threatened species in the State of Michigan (Figure 1). The lake sturgeon population in Michigan is estimated to be about one percent of its former abundance (Tody, 1974; Michigan Sea Grant, 2005). The Huron-Erie corridor was, at one time, one of the most productive waters for lake sturgeon in North America.

Figure 1. Lake sturgeon (Acipenser fulvescens) (Photo Credit: U.S. Fish and Wildlife Service).

In Lake Erie in the 1800s, sturgeon frequently caused heavy damage to fishing gear in nearshore waters. As a result, they were perceived as a nuisance and frequently killed upon capture to eradicate them (Hartman, 1973). In Lake Erie in the 1860s, lake sturgeon was destroyed in large numbers as bycatch of the gill net fishery (Regier and Hartman, 1973). Years following, the value of sturgeon increased as their eggs and smoked flesh became a delicacy. In 1890, a "caviar factory" was located in Algonac, Michigan on the St. Clair River (Harkness and Dymond, 1961). Populations quickly plummeted due to over harvesting, limited reproduction, and destruction of spawning habitats. Female lake sturgeon don't reproduce until they are approximately 20 years old and even then they only spawn once every few years. Spawning sites also disappeared due to extensive dredging to create and maintain shipping channels in the Huron-Erie corridor. For example, the construction of the Livingstone Channel greatly decreased lake sturgeon and lake whitefish spawning habitats in Canadian waters, southeast of Stony Island.

Lake sturgeon are an indicator of ecosystem health because they are very sensitive to human disturbances, such as habitat destruction and pollution, as shown by their sharp decline in the late 1800s and early 1900s. They were present in the Huron-Erie corridor before European settlers inhabited the area. Lake sturgeon are considered a keystone species in the Detroit River ecosystem.

Status and Trends

In 1880, Lakes Huron and St. Clair produced over 1,820,000 kg (four million pounds) of lake sturgeon (Hay-Chmielewski and Whelan, 1997). In 1890, Lake Erie produced over 272,000 kg (600,000 pounds) of lake sturgeon in Canadian waters. During the spawning period in June 1890, upwards of 4,000 adult lake sturgeon were caught in Lake St. Clair and the Detroit River on setlines and in pond-nets (Post, 1890; Harkness and Dymond, 1961; Figure 2). Today, there is no active commercial fishery for lake sturgeon in the Huron-Erie corridor, sport fishing harvest is now restricted in the St. Clair River and Lake St. Clair, and no sturgeon may be possessed by anglers from Michigan or Ontario waters of the Detroit River (Great Lake Fishery Commission, 2003; Michigan Department of Natural Resources, 2005; Ontario Ministry of Natural Resources, 2005).

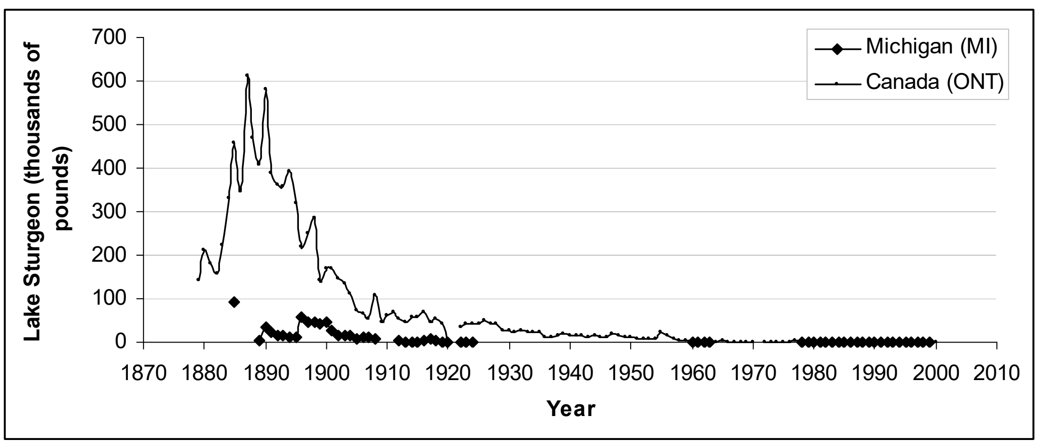


Figure 2. Lake Eire commercial fish catch in Michigan and Ontario waters, 1879-2000; data source U.S. Fisheries Commission Report - Fishing industry for the Great Lakes Appendix 11 to the 1926 report by W. Koelz and in Baldwin et al., 2002.

Currently there is no commercial harvest of lake sturgeon in waters regulated by the State of Michigan to help restore the population. From 1970s to 1999 no lake sturgeon spawning was reported in the Detroit River which, at one time, was one of the most productive sturgeon spawning grounds in the United States (Roseman et al., 2011). Then in 2001, lake sturgeon spawning was documented on a coal cinder pile near Zug Island in the Detroit River for the first time in over 20 years (Caswell et al., 2004). Based on research and monitoring, fishery biologists and managers concluded that lake sturgeon reproduction in the 2000s was now more limited by habitat than environmental quality.

In response, nine fish spawning reefs were constructed in the Detroit River in suitable areas that provided proper conditions and were in close proximity to requisite nursery habitats (Table 1). All were successful (Fischer et al., 2018). Each of these spawning reef projects were treated as experiments and included significant post-project assessment of effectiveness.

Table 1. Fish spawning reefs constructed in the Detroit River and post-project assessments of effectiveness (Hartig et al., 2018).

Spawning Reef and Year	Size/ Description	Post-Project Assessment
McKee Park, Windsor, Ontario – 2003	135 m of enhanced shoreline with 1,660 m^2 of barrier islands/ submerged shoals (30-90 cm limestone)	One gillnet set was conducted in April 2007 with gizzard shad (*Dorosoma cepedianum*) and northern hogsucker (*Hypentelium nigricans*) captured (USFWS unpublished data).
Fort Malden, Amherstburg, Ontario – 2004	280 m of enhanced shoreline with barrier islands and submerged shoals (30-60 cm limestone)	Limited setline assessments (n = 5) were conducted in the spring of 2007 with two adult lake sturgeon being captured (USFWS unpublished data). Egg mat sampling showed egg deposition of walleye (*Sander vitreus*) during spring 2007 and 2008, and lake whitefish (*Coregonus clupeaformis*) eggs during fall 2006 and 2007 (Prichard et al., 2017).
Belle Isle, Detroit, Michigan (Just S.E. of the head of the Island) – 2004	Total area 1,130 m^2; Three distinct reefs (2.5-7.5 cm coal cinders, 40-60 cm broken limestone, 15-25 cm cobble stone)	Pre-construction assessment indicated three fish species using the site. Post-construction assessment in 2005 and 2006 identified 16 species of native fish spawning at the site, including lake whitefish, a first in over 90 years, walleye, and Catostomidae species. Three other species were documented using the site, including two state-listed species, lake sturgeon and the northern madtom (*Noturus stigmosus*; Manny, 2006). This site and adjacent area continue to support the largest density of northern madtom in the Detroit River (Manny et al., 2014).
Fighting Island, LaSalle, Ontario – 2008	Total area 3,240 m^2; 12 individual reefs, 4 rock types (10-50 cm limestone, 5-10 cm	Pre-construction assessment failed to document spawning by lake sturgeon at the site. Post-construction assessment showed an immediate response with lake sturgeon spawning in the first and second springs (2009-2010; Roseman et al., 2011; Bouckaert et al., 2014) and multiple years thereafter (Prichard et al., 2017). Monitoring found adult lake

Table 1. Fish spawning reefs constructed in the Detroit River and post-project assessments of effectiveness (Hartig et al., 2018).

Spawning Reef and Year	Size/ Description	Post-Project Assessment
	limestone, 5-10 cm rounded igneous stone, and the three rock types combined), plus boulder field	sturgeon in spawning condition (ripe), fertilized eggs, and emerging larvae on and downstream of the reef in 2009 and 2010. In 2010, age-0 juvenile lake sturgeon were collected in bottom trawls in the river channel 2-5 km downstream of the reef. Egg assessment surveys also collected eggs of other fishes, including walleye, lake whitefish, white sucker (*Catostomus commersoni*), shorthead redhorse (*Moxostoma macrolepidotum*), and troutperch (*Percopsis omyscomaycus*; Roseman et al. 2011; Prichard et al., 2017). Fighting Island Reefs continue to support a population of northern madtoms (Manny et al., 2014). D-frame net collections of larval lake sturgeon did not detect significant difference in the number of larvae captured below each rock type used to construct reefs, indicating all reef materials performed equally well (Bouckaert et al., 2014).
BASF, Riverview, Michigan – 2008	4,050 m^2 (30-90 cm limestone)	Assessment limited to setlines and minnow traps. Each spring since 2008 spawning ready lake sturgeon continue to be captured at the Riverview site (Briggs et al., 2015, 2016; Schmidt et al., 2016).
Fighting Island, LaSalle, Ontario – 2013	4,860 m^2 expansion of the 2008 reefs), one reef bed, one rock type (15- 30 cm limestone)	Assessment included spring egg mats, setlines, minnow traps, and gillnets, and fall gillnets and egg mats. Lake sturgeon, walleye, lake whitefish, Catostomidae species, and troutperch eggs were collected over the first spawning season available and continue to be collected (Prichard et al., 2017; Fischer et al., In press). Adult lake sturgeon catch-per-effort continues to be highest in the Detroit River at these reefs and associated channel. Gillnet and minnow trap assessments captured 20 native fishes, including commercially and recreationally important species. For the first time in the Detroit River burbot (*Lota lota*) were captured each year since 2015 at this site (Briggs et al., 2015, 2016; Schmidt et al., 2016).
Grassy Island, Wyandotte, Michigan – 2015	1.62 ha one continuous reef (upstream of Grassy Island, one rock type (10-20 cm limestone)	Pre- and post-construction assessment included spring and fall egg mats, minnow traps, and gillnets. Lake sturgeon, walleye, and lake whitefish (Fischer et al., In press), and Catostomidae eggs, were collected over the constructed reef. Monitoring of adults for three indicator species (walleye, white sucker, and redhorse) showed no statistical differences detected between pre- and post-construction assessments. However, post-construction gillnetting showed general trends of

Table 1. Fish spawning reefs constructed in the Detroit River and post-project assessments of effectiveness (Hartig et al., 2018).

Spawning Reef and Year	Size/ Description	Post-Project Assessment
		increasing numbers of most species. A total of 10 species were captured (Briggs et al., 2015, 2016; Schmidt et al., 2016).
Belle Isle, Detroit, Michigan (Three reefs located N and NE of head of Island) – 2016	Total area 1.62 ha; Three individual reefs, one rock type (10-20 cm limestone)	Pre-construction assessments included spring and fall egg mats, minnow traps, and gillnets. A total of 12 species were captured with minnow traps and gillnets (Briggs et al., 2015, 2016; Schmidt et al., 2016). Lake sturgeon eggs were not collected prior to reef construction, but were observed in 2017, following reef construction. Walleye and Catostomidae eggs were also collected over the reefs.
Fort Wayne, Detroit, Michigan – 2018	1.62 ha one continuous reef, one rock type (10-20 cm limestone)	Reef constructed in the spring of 2018; post-project monitoring will begin in fall of 2018
River wide assessments – 2005-2017		2005-2016 data indicated lake sturgeon eggs were almost exclusively collected at artificial reef sites and that there was a statistically higher number of eggs collected at artificial reef sites than elsewhere in the St. Clair-Detroit River System (Fischer et al., 2018). Conversely, fewer walleye and lake whitefish eggs were collected at artificial reef sites compared to natural spawning areas sampled concurrently. Genetic analysis of larval lake sturgeon hatched from eggs collected over the Middle Channel (St. Clair River) and Fighting Island Reefs from 2009-2012 indicated the number of spawning adults using the reefs is large enough to maintain genetic diversity and population persistence (Marranca et al., 2015).

Since 2006, the U.S. Fish and Wildlife Service has annually been conducting population assessments of lake sturgeon in the Detroit River. Over this time 523 lake sturgeon have been tagged and 34 have been recaptured. Based on these mark-and-recapture data, the estimated population size of lake sturgeon utilizing the Detroit River is 4,422 individuals with a 95% confidence interval of 2,758-6,087.

The Michigan Department of Natural Resources has established a rehabilitation goal of 750 sexually mature individuals to ensure self-sustaining populations (Hayes and Caroffino, 2012). Based on the current estimate of 4,422 individuals using the Detroit River, this would be considered a large, stable population meeting the goal of 750 sexually active individuals. However, this species still needs to be protected and fishery biologists and managers have built the nine reefs to help expand the lake sturgeon population. This will add resilience to the population, increase recruitment, and provide “egg donor” stock for other areas of the Great Lakes.

Management Next Steps/Research/Monitoring Needs

The long-term goal is to maintain a healthy, self-sustaining lake sturgeon population in the Detroit River. Short-term recommended actions include:

- enforcing conservative sturgeon harvest regulations throughout the Huron-Erie corridor;
- protecting sturgeon habitat in the Detroit River, including the nine reefs constructed since 2003;
- controlling pollution from combined sewer overflows and other sources within the watershed;
- undertaking regular sturgeon population assessments, including the use of telemetry, to decipher spawning sites; and
- establishing a Sturgeon Guarding Program, with active, progressive, public involvement.

Continued research and assessment are warranted to ensure the lake sturgeon population is stable or expanding and resilient, that recruitment is sufficient for population stability, and that the sex ratios of lake sturgeon utilizing the Detroit River are sufficient to ensure population stability.

References

Baldwin, N.A., Saalfeld, R.W., Dochoda, M.R., Buettner, H.J., Eshenroder, R.L., 2002. Commercial Fish Production in the Great Lakes 1867-2000. Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Bouckaert, E.K., Auer, N.A., Roseman, E.F., Boase, J., 2014. Verifying success of artificial spawning reefs in the St. Clair-Detroit River System for lake sturgeon (*Acipenser fulvescens* Rafinesque, 1817). Journal of Applied Ichthyology 30, 1393-1401.

Briggs, A.S., Chiotti, J.A., Boase, J.C., 2015. 2014 native species report. U.S. Fish and Wildlife Service, Alpena Fish and Wildlife Conservation Office – Waterford Substation, Report No. 01, Waterford, Michigan, USA.

Briggs, A.S., Kaulfersch, L.A., Chiotti, J.A., Johnson, J.L., Boase, J.C., 2016. 2015 native species report. U.S. Fish and Wildlife Service, Alpena Fish and Wildlife Conservation Office – Waterford Substation, Waterford, Michigan, USA.

Caswell, N.M., 2003. Population Characteristics, Spawning Sites, and Movements of Lake Sturgeon (*Acipenser fulvescens*) in the Detroit River. Master's Thesis, Central Michigan University, Mount Pleasant, Michigan, USA.

Caswell, N.M., Peterson, D.L., Manny, B.A., Kennedy, G.W., 2004. Spawning by lake sturgeon (*Acipenser fulvescens*) in the Detroit River. Journal of Applied Ichthyology 20, 1-6.

Fischer, J.L., Pritt, J.J., Roseman, E.F., Prichard, C.G., Craig, J.M., Kennedy, G.W., Manny, B.A., 2018. Lake sturgeon, lake whitefish, and walleye egg deposition patterns with response to fish spawning substrate restoration in the St. Clair-Detroit River System. Transactions of the American Fisheries Society. 147, 79-93.

Great Lakes Fishery Commission, 2003. Lake sturgeon in the Great Lakes; Lake sturgeon, the giant of the Great Lakes. Great Lake Fisheries Commission, Ann Arbor, Michigan, USA.

Harkness, W., Dymond, J., 1961. The Lake Sturgeon. Ontario Dept. of Lands and Forests, Fish and Wildlife Branch, Ontario, Canada.

Hartig, J.H., Sanders, C., Wyma, R.J.H., Boase, J.C., Roseman, E.F., 2018. Habitat rehabilitation in the Detroit River Area of Concern, Aquatic Ecosystem Health & Management. 21, 4, 458-469.

Hartman, W.L., 1973. Effects of Exploitation, Environmental Changes, and New Species on the Fish Habitats and Resources of Lake Erie. Great Lakes Fishery Commission, Technical Report Number 22. Ann Arbor, Michigan, USA.

Hay-Chmielewski, E., Whelan, G., 1997. Lake sturgeon rehabilitation strategy. Fish. Division, Michigan Department of Natural Resources, Special Report Number 18, Ann Arbor, Michigan, USA.

Hayes, D.B., Caroffino, D.C., (Eds.) 2012. Michigan's lake sturgeon rehabilitation strategy. Michigan Department of Natural Resources, Fisheries Special Report 62, Lansing, Michigan, USA.

Holey, M, Baker, E., Thuemler, T., Elliott, R., 2000. Research and assessment needs to restore lake sturgeon in the Great Lakes. Results of a workshop sponsored by the Great Lakes Fishery Trust, June 27-28, 2000, Muskegon, Michigan, USA.

Koelz, W., 1926. Fishing Industry of the Great Lakes. Appendix XI to the Report of the U. S. Commissioner of Fisheries for 1925, United States Bureau of Fisheries Document Number 1001, Ann Arbor, Michigan, USA.

Manny, B.A., Daley, B.A., Boase, J.C., Horne, A.N., Chiotti, J.A., 2014. Occurrence, habitat, and movements of the endangered northern madtom (*Noturus stigmosus*) in the Detroit River, 2003-2011. Journal of Great Lakes Research. 40, 118-124.

Manny, B.A., 2006. Monitoring element of the Belle Isle/Detroit River Sturgeon Habitat Restoration, Monitoring, and Education Project. Report to Michigan Sea Grant, Ann Arbor, Michigan, USA.

Marranca, J.M., Welsh, A.B., Roseman, E.F., 2015. Genetic effects of habitat restoration in the Laurentian Great Lakes: an assessment of lake sturgeon origin and genetic diversity. Restoration Ecology 23, 455-464.

Michigan Department of Natural Resources, 2005. Fishing Regulations, Lake Sturgeon. Lansing, Michigan, USA.

Michigan Sea Grant, 2005. Lake Sturgeon Habitat Protection Background. Ann Arbor, Michigan, USA.

Ontario Ministry of Natural Resources (OMNR), 2004. Regulatory options for managing the sport fishery of lake sturgeon in Ontario. Fisheries Section. Ontario Ministry of Natural Resources. Peterborough, Ontario, Canada.

OMNR, 2005. Fishing regulations for the province of Ontario. Toronto, Ontario, Canada.

Post, H., 1890. The sturgeon; some experiments in hatching. Trans. Amer. Fish. Soc. 19, 36-40.

Prichard, C.G., Craig, J., Roseman, E.F., Fischer, J.L., Manny, B.A., Kennedy, G., 2017. Egg deposition by lithophilic spawning fishes in the St. Clair-Detroit River System, USA, 2005-2014. U.S. Geological Survey Scientific Investigations Report 2017–5003, Ann Arbor, Michigan, USA.

Raymakers, C., Hoover, C., 2002. Acipenseriformes: CITES implementation from Range States to consumer countries. Journal of Applied Ichthyology. 18, 629-638.

Regier, H.A., Hartman, W.L., 1973. Lake Erie's Fish Community: 150 Years of Cultural Stresses. Science. 180, 4092, 1248-1255.

Roseman, E. Manny, B., Boase, J., Child, M., Kennedy, G., Craig, J., Soper, K., Drouin, R., 2011. Lake sturgeon response to a spawning reef constructed in the Detroit River. Journal of Applied Ichthyology. 27, 2, 66-76.

Schmidt, B.A., Wigren, P.L, Johnson, J.L., Fischer, L.A., Chiotti, J.A., Boase, J.C., 2017. 2016 Native Species Report. U.S. Fish and Wildlife Conservation Office-Waterford Substation, Waterford, Michigan, USA.

Tody, W.H., 1974. Whitefish, sturgeon, and the early Michigan commercial fishery. Michigan Fisheries Centennial Report 1873-1973. Michigan Department of Natural Resources, Lansing, Michigan, USA.

7.29 Lake Whitefish Spawning

Edward Roseman, U.S. Geological Survey, eroseman@usgs.gov

Robin DeBruyne, University of Toledo, robin.debruyne@utoledo.edu

Background

During the late 19th and early 20th centuries, large numbers of lake whitefish (Figure 1) and cisco (formerly referred to as lake herring) entered the Detroit River in the fall to spawn. Whitefish prefer to spawn on rock, honeycomb limestone, gravel or sand substrates (Hart, 1930; Ihssen et al., 1981). Natural bedrock (spawning grounds of lake whitefish, cisco, walleye, and trout) was blasted and removed during the construction of the Livingstone Channel from approximately 1907 to 1916. Historic reports imply that the lower river was a prolific spawning area prior to the construction of the shipping channel (Goodyear et al., 1982). The timing of this construction coincides with the demise of whitefish stock in the river; this alteration in river hydrology and habitat represents a major disconnection in the linkage between river spawning and incubation areas and productive nursery habitats in western Lake Erie. Spawning runs of lake whitefish into the Detroit River almost disappeared by the early 1900s due to overfishing, loss and degradation of habitat, and eutrophication (Trautman, 1957; Goodyear et al., 1982; Hartman, 1972).

Figure 1. Adult lake whitefish (Coregonus clupeaformis) (left photo; left fish) caught in November 2005 and lake whitefish eggs (right) collected in the Detroit River (photo credit: U.S. Geological Survey).

Lake whitefish feed on organisms on the bottom of the lake, primarily on *Diporeia* and chironomids, in the western Lake Erie basin. They are cold stenotherms (narrow temperature tolerance), requiring cold, adequately oxygenated bottom waters for summer habitat, and relatively silt-free river or lake spawning areas for successful reproduction (Hartman, 1973). Lake Erie is the southern edge of the species' zoogeographical range. Lake whitefish are recognized as an indicator of ecosystem health and an integral component of the Great Lakes food web.

Status and Trends

By the 1960s and 1970s lake whitefish abundance was at an all-time low for a variety of reasons: overexploitation, predation by and competition with invasive species, degradation of water quality and habitat, and the loss of *Diporeia*, a major nutrient-rich food source. Reduced phosphorus loading to the lake resulted in more favorable conditions for whitefish by the early 1980s, following the implementation of the 1972 Great Lakes Water Quality Agreement (Mohr and Nalepa, 2005).

The persistence of remnant self-sustaining lake whitefish stocks in Lakes Huron and Erie, coupled with habitat rehabilitation efforts, allowed the Lake Erie population to begin to recover in the early 1980s (Coldwater Task Group, 2018; Roseman et al., 2012). Throughout the 1980s and 1990s the species reached above average catches in Lakes Michigan and Huron (Mohr and Nalepa, 2005). Whitefish growth rates in Lake Erie after the recovery appear to be similar to rates prior to the period when populations reached all-time lows (Coldwater Task Group, 2018). For Lake Erie as a whole, growth and condition of whitefish have remained stable, but current landings' values are below the range of historical means (Coldwater Task Group, 2018) inhibiting achievement of a self-sustaining population that can support a viable fishery (Ryan et al., 2003).

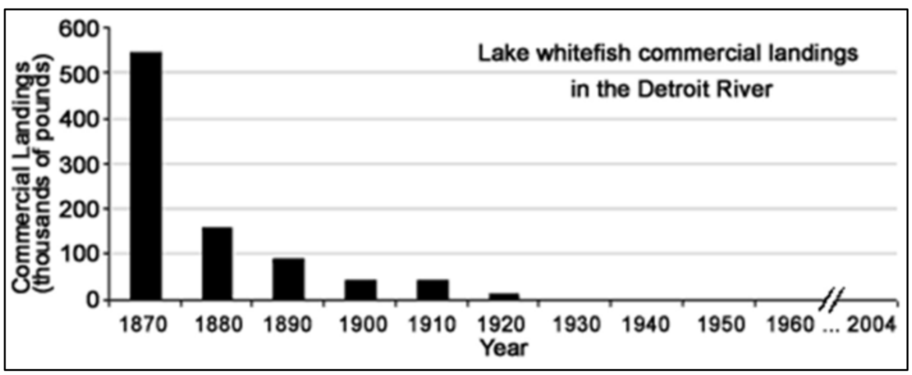


Figure 2. Lake whitefish commercial landings in the Detroit River. Catch is measured in thousands of pounds from 1870-2004 (data from Baldwin et al., 1979 and subsequently collected by U.S. Geological Survey).

Harvest in the Detroit River exceeded a half million pounds in the late 1800s and declined through the early part of the 20th century (Figure 2). Overharvest and habitat degradation resulted in very low catches after about 1910. The decline of the lake whitefish coincided with the decline of the walleye, blue pike, and cisco. The Lake Erie whitefish fishery lasted in the east end of the lake until the 1960s. After an absence of approximately 20 years, commercial fishing for lake whitefish in Lake Erie increased to over one million pounds per year during the late 1990s and early 2000s (Figure 3). Landings during 2010 through 2017 have declined slightly to approximately 122,727 kg (270,000 pounds). This is evidence that a large proportion of young Lake Erie lake whitefish are dying prior to being large enough for harvest. The cause of this population reduction is currently unknown.

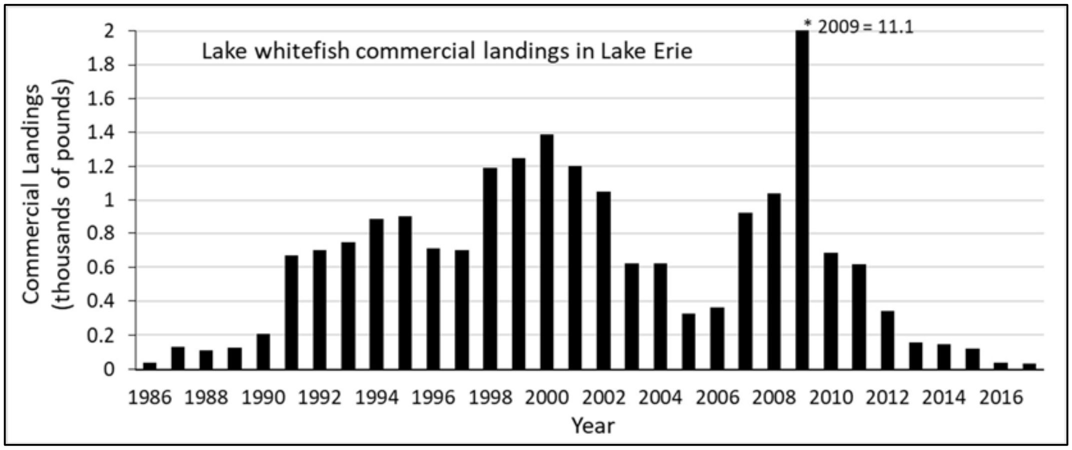


Figure 3. Lake whitefish commercial landings in Lake Erie. Catch is measured in millions of pounds from 1986-2017 (data from Coldwater Task Group 2018).

Since 2005, when U.S. Geological Survey (USGS) researchers in partnership with the U.S. Fish and Wildlife Service documented lake whitefish spawning in the Detroit River (Roseman et al., 2007), annual surveys of fall egg deposition and spring larval drift show continued use of the Detroit River for reproduction (Roseman et al., 2012). Assessments of constructed fish spawning reefs showed use by lake whitefish, but that egg abundances were generally higher at natural rocky river bottoms (Fischer et al., 2018). Estimates of larval lake whitefish exported from the Detroit River to western Lake Erie ranged from 29 million in 2010 to 83 million in 2011 (Roseman et al., In press). Continued monitoring and research will focus on measuring the contributions of Detroit River lake whitefish to the overall Lake Erie population using fisheries stock assessment models and genetics.

Management Next Steps

It is recommended that management agencies continue to monitor lake whitefish populations in the Detroit River and Lake Erie to ensure the continued recovery and achievement of sustainable stocks. Emphasis should continue to be placed on controlling invasive species, such as dreissenids, which cause food web disruptions that influence whitefish abundance, growth, and condition. Management agencies should continue to assess maturation and fish use of spawning habitats in the Detroit River following completion of the fish spawning habitat constructed during 2010-2018 (Vaccaro et al., 2016).

Research/Monitoring Needs

Through intensive research and standardized assessment surveys, scientists continue to learn more about lake whitefish life history, habitat requirements, and their ecological niche in Lake Erie and its tributaries, including the Detroit River. However, current conditions of the physical and biological characteristics of essential whitefish habitat and key information on yield, diet, growth, recruitment, and reproduction rates are still unknown or understudied. These types of information are critical for the successful management of fisheries in the Detroit River and its connecting waters. Further, efforts to rehabilitate fisheries habitat in the Detroit River rely on knowledge of habitat availability and function to use as a benchmark for restoration goals (Coldwater Task Group, 2018). Research projects should be designed to measure biotic and abiotic factors influencing different life history stages of lake whitefish. Such research could include:

- Developing biological reference points for Lake Erie lake whitefish (Coldwater Task Group, 2018);
- Identifying spawning sites of multiple fish species;
- Describing the physical characteristics of spawning areas;
- Quantifying relative egg abundance and survival;
- Assessing egg viability and physiological condition;
- Assessing predation of fish eggs by fishes and invertebrates;
- Assessing spawning stock characteristics to include genetics; and
- Exploring nursery habitat in the river.

Research and assessment of fish spawning habitats, egg deposition, and larval drift will continue in the Detroit River and western Lake Erie basin during 2019 and 2020. Finally, there is a need to further develop models to better predict and evaluate lake whitefish recovery.

References

Baldwin, N.S., Saalfeld, R.W., Ross, M.A., Buettner, H.J., 1979. Commercial fish production in the Great Lakes. Great Lakes Fisheries Commission Technical Report Number 3, Ann Arbor, Michigan, USA.

Coldwater Task Group, 2018. Report of the Lake Erie Coldwater Task Group, March 2018. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission. Markham, Ontario, Canada.

Fischer, J.L., Pritt, J.J., Roseman, E.F., Prichard, C.G., Craig, J.M., Kennedy, G.W., Manny, B.A., 2018. Lake sturgeon, lake whitefish, and walleye egg deposition patterns with response to fish spawning substrate restoration in the St. Clair-Detroit River System. Transactions of the American Fisheries Society. 147, 79-93.

Goodyear, C.D., Edsall, T.A., Ormsby-Dempsey, D.M., Moss, G.D., Polanski, P.E., 1982. Atlas of spawning and nursery areas of Great Lakes fishes. FWS/OBS-82/52. Volumes 1-14, U.S. Fish and Wildlife Service, Washington, DC.

Hart, J.L., 1930. Spawning and early life history of whitefish (*Coregonus clupeaformis*) in the Bay of Quinte, Ontario. Contributions to Canadian Biology and Fisheries. 40, 165-214.

Hartman, W.L., 1972. Lake Erie: effects of exploitation, environmental changes, and new species on the fishery resources. Journal Fisheries Research Board of Canada. 29, 931-936.

Hartman, W.L., 1973. Effects of exploitation, environmental changes, and new species on the fish habitats and resources of Lake Erie. Great Lakes Fishery Commission Technical Report Number 22, Ann Arbor, Michigan, USA.

Ihssen, P.E., Evans, D.O., Christie, W.J., Rechahn, J.A., DesJardine, D.L., 1981. Life history, morphology, and electrophoretic characteristics of five allopatric stocks of lake whitefish (*Coregonus clupeaformis*) in the Great Lakes region. Canadian Journal of Fisheries and Aquatic Sciences. 38, 1790-1807.

Knight, R.L., 1997. Successful interagency rehabilitation of Lake Erie walleye. Fisheries. 22, 16-17.

Mohr, L.C., Nalepa, T.F., (Eds.), 2005. Proceedings of a workshop on the dynamics of lake whitefish (*Coregonus clupeaformis*) and the amphipod *Diporeia* spp. in the Great Lakes. Great Lakes Fishery Commission Technical Report 66. Ann Arobr, Michigan, USA.

Roseman, E.F., Kennedy, G.W., Boase, J., Manny, B.A., Todd, T.N., Stott, W., 2007. Evidence of lake whitefish spawning in the Detroit River: implications for habitat and population recovery. Journal of Great Lakes Research. 33, 397-406.

Roseman, E.F., Kennedy, G., Manny, B.A., Boase, J., McFee, J., 2012. Life history characteristics of a recovering lake whitefish *Coregonus clupeaformis* stock in the Detroit River, North America. Advances in Limnology. 63, 477-501.

Roseman, E.F., DuFour, M. Pritt, J., Fischer, J., DeBruyne, R.L., Bennion, D., In press. Export of pelagic fish larvae from the Detroit River. Accepted to Advances in Limnology.

Ryan, P.A., Knight, R., MacGregor, R., Towns, G., Hoopes, R., Culligan, W., 2003. Fish-community goals and objectives for Lake Erie. Great Lakes Fish. Comm. Spec. Publ. 03-02. Ann Arbor, Michigan, USA.

Trautman, M.B., 1957. The Fishes of Ohio. Ohio State University Press. Columbus, Ohio, USA.

Vaccaro, L., Bennion, D., Boase, J., Bohling, M., Chiotti, J., Craig, J., Fischer, J., Kennedy, G., Manny, B., Read, J., Roseman, E.F., 2016. Science in action: Lessons learned from fish spawning habitat restoration in the St. Clair and Detroit Rivers. University of Michigan Water Center Report, Ann Arbor, Michigan, USA.

This page intentionally left blank.

7.30 Lead Poisoning in Detroit, Michigan

Lyke Thompson, Director, Center for Urban Studies, Wayne State University (lykethompson@gmail.com)

Lauren Meloche, Research Assistant, Center for Urban Studies, Wayne State University (as2271@wayne.edu)

Background

Lead is a highly toxic metal that has significant adverse health effects. Despite lead's toxic characteristics, it has been used for centuries in products such as paint, gasoline, ceramics, pipes, batteries, cosmetics, toys, and pesticides (Figure 1). The presence of lead hazards in our environment resulting from these uses creates a problem that it is still considered a major public health concern.

Figure 1. Deteriorated lead-based paint is one of the leading causes of lead poisoning in Detroit children (credit: Center for Urban Studies).

Lead enters the body through swallowing or breathing lead particles and can then accumulate in the blood, tissues, and organs. The amount of lead in blood is referred to as blood lead level (BLL) and is measured in micrograms of lead per deciliter of blood (µg/dL). Any amount greater than 5 µg/dL is considered an elevated blood lead level (EBLL), a reference point set by the Centers for Disease Control and Prevention (CDC). However, there is no known safe blood lead level, and irreversible health damage can occur at BLLs below 5 µg/dL (CDC, 2012).

Exposure to lead has serious neurological and behavioral consequences, particularly for children. According to the American Academy of Pediatrics (2005), the best studied effects of lead poisoning are cognitive impairments measured by IQ tests, but other aspects of brain or nerve function, especially behavior, may also be affected. Students with elevated lead levels are found to be hyperactive, disorganized, less attentive, and have difficulty following directions. Other consequences of lead poisoning are motor development delays, impaired growth, and hearing dysfunction. Beyond effects on cognitive function, lead can produce negative cardiovascular, immunological, and endocrine effects (CDC, 2012). According to the CDC, health consequences of lead poisoning can also have physical symptoms such as headaches, stomachaches, sleeping or eating disorders, attention deficit disorders, and weakness or clumsiness can also occur (CDC, 2012).

Children under age six are especially vulnerable to lead poisoning (ATSDR, 2007). The National Health and Nutrition Examination Survey conducted by the CDC National Center for Health Statistics reported that 2.6% of children between ages one and five had elevated blood lead levels (EBLLs) of 5 µg/dL. This translates to approximately half a million lead poisoned children nationwide.

Status and Trends

In the City of Detroit during 2016, 2,073 children under six years old were tested for lead poisoning and found to have an EBLL at or above 5 ug/dL (MDHHS, 2018). Fewer than half (40.4%) of all Detroit children under six were tested, so it is unknown how many of the 34,903 untested children also have EBLLs. As shown in Table 1, the number of tested children with an EBLL increased by 27.9% in 2016 compared to 2015. This was the first year since 2005 that the number of tested children with BLL at or above 5ug/dL increased compared to the prior year. Provisional data for 2017 show that 1,632 children were found to have an EBLL, equivalent to 7.4% of the children tested. Although fewer than in 2016, this is still slightly higher than the 1,620 children with EBLLs identified in 2015. The persistently high number of children found to have an EBLL and the recent spike in tested children with lead poisoning signal that lead hazards still pose a significant danger to Detroit's children.

The true extent of childhood lead poisoning in Detroit remains unknown as a result of low testing rates. Despite efforts to increase regular lead screening among children in Detroit, fewer than half of children under age six are tested for BLL each year, as shown in Figure 2. The proportion of tested children with elevated BLLs has declined substantially from a high incidence rate of 64.6% in 1998, the first year that monitoring data were available. However, the proportion of tested children with an EBLL sharply increased in 2016 compared to the prior year, following several years where the annual rate of decline had leveled out. Although provisional numbers for 2017 show a reduction compared to the prior year, the number of tested children with an EBLL is still higher than 2015 numbers, and the proportion of tested children with an EBLL is only 0.1% lower than the corresponding rate for 2015.

Table 1. Lead poisoning statistics for children under age six living in Detroit, MI, 1998-2017.

Year	Population Under Age 6*	Percent of Population Under Age 6 Tested	Percent of Tested Children with BLL ≥ 5 ug/dL	Number of Tested Children**	Number Tested with BLL ≥ 5 ug/dL**
1998	111,844	24.0%	64.6%	26,790	17,307
1999	109,594	23.6%	55.9%	25,865	14,465
2000	93,365	26.2%	47.2%	24,417	11,530
2001	93,365	33.1%	49.4%	30,886	15,253
2002	93,365	34.9%	43.9%	32,540	14,290
2003	93,365	35.0%	34.5%	32,698	11,282
2004	93,365	35.3%	33.3%	32,973	10,994
2005	73,566	44.5%	33.7%	32,705	11,032
2006	71,125	46.7%	27.2%	33,190	9,019
2007	69,805	47.3%	26.0%	33,010	8,571
2008	64,757	49.6%	19.7%	32,105	6,326
2009	80,726	39.6%	16.5%	31,969	5,266
2010	61,422	50.2%	13.0%	30,812	3,999
2011	59,769	48.0%	10.2%	28,674	2,928
2012	57,504	47.5%	8.5%	27,298	2,327
2013	58,896	42.5%	8.0%	25,026	1,996
2014	55,684	41.0%	8.2%	22,842	1,876
2015	57,945	37.2%	7.5%	21,548	1,620
2016	62,825	37.7%	8.8%	23,662	2,073
2017***	58,434	37.9%	7.4%	22,165	1,632

Note: BLL = blood lead levels. Reflects capillary tests, venous tests, and unknown.

*Source: Michigan Information Center, Population Estimate by Single Year of Age for Michigan and Counties (years 1998-1999); U.S. Census Bureau, 2000 Census (years 2000-2004); U.S. Census Bureau, American Community Survey 1-year estimates (years 2004-2017)

**Source: Michigan Department of Health and Human Services, Childhood Lead Poisoning Prevention Program annual reports

*** Data for 2017 are provisional.

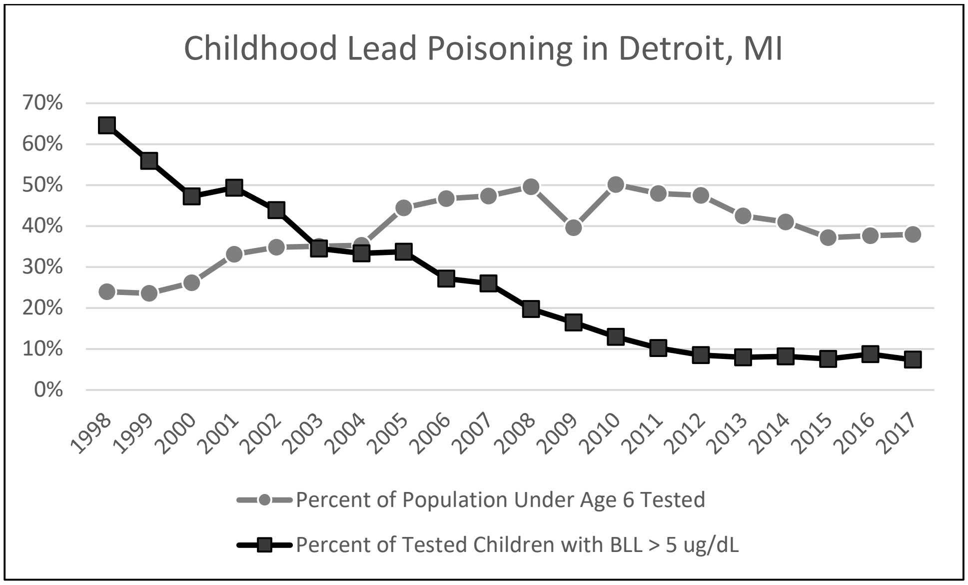


Figure 2. Longitudinal trends of lead poisoning of children under age six living in Detroit, MI, 1998-2017.

Sources: Michigan Department of Health and Human Services, Childhood Lead Poisoning Prevention Program annual reports; Michigan Information Center, Population Estimate by Single Year of Age for Michigan and Counties (years 1998-1999); U.S. Census Bureau, 2000 Census (years 2000-2004); U.S. Census Bureau, American Community Survey 1-year estimates (years 2004-2017)

Note: Data for 2017 are provisional.

Across Wayne County each year between 2011 and 2016, Detroit zip codes consistently reported the highest numbers of tested children with elevated blood lead levels. The Detroit zip codes with the highest rates of childhood lead poisoning in 2016 are shown in in Figure 3. In 2016, zip code 48206 in central Detroit had the highest proportion of lead poisoned children, with 22.2% of tested children having EBLLs >= 5 mg/dL. Provisional data for 2017 indicate zip code 48206 ranked highest again, with 19.2% of tested children having an EBLL. Zip Code 48206 also ranked highest each year from 2011 through 2014. In 2015, zip code 48206 shared the third rank with neighboring 48202, both having a rate of 13.9% that year. Provisional data show that 48202 also ranked third in 2017, with 13.5% of tested children having EBLLs. Zip code 48214 on Detroit's east side has ranked in the top three zip codes each year between 2011 and 2016, having the highest rate of lead poisoned children in 2015 (17.2%) and the second highest rate in 2016 (16.4%). Provisional data for 2017 shows zip code 48214 continues to rank second highest, with 16.1% of tested children having an EBLL. Zip code 48204 ranked fourth highest in 2016 (15.1%) and kept that ranking in 2017 according to preliminary data.

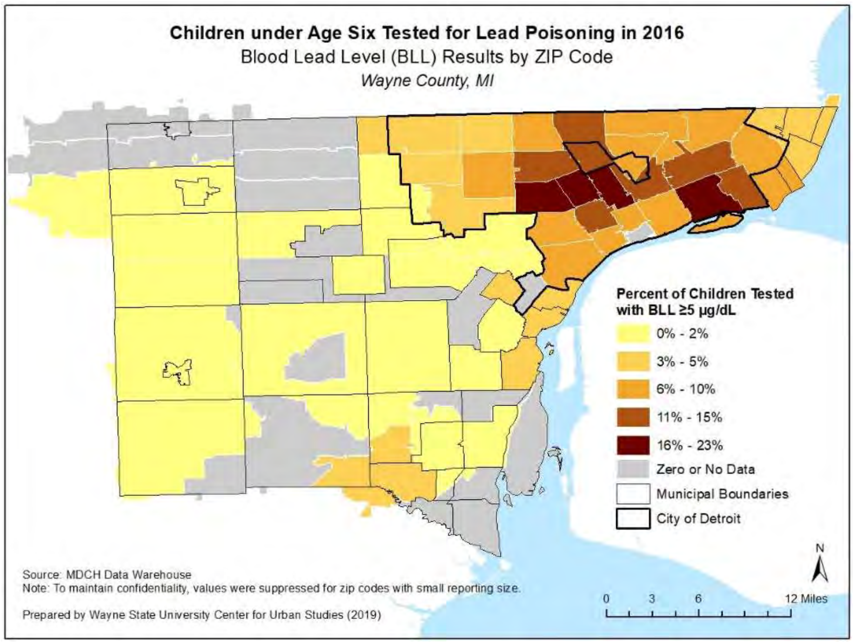


Figure 3. Map of Childhood Lead Poisoning in Wayne County Zip Codes, 2016.

Several sources of lead have contributed to contamination and childhood lead poisoning in the City of Detroit. These sources include:

- Lead-based paint that is deteriorated or poorly maintained, creating paint chips or dust (Figure 1);
- Lead dust that has been washed into the soil from houses during rainfall;
- Lead dust from demolitions has been spread across neighborhoods;
- Lead dust from leaded gasoline is still present in soil samples across the area;
- Contaminated soil around former smelters located at or near residential areas that have released lead into the air during operations, which has now deposited on the soil;
- Food and liquids stored in lead crystal or lead-glazed pottery;
- Water that runs in lead plumbing; and
- Automotive emissions absorbed from leaded gasoline, in use before 1986.

Lead was used in paint until 1978 because it improved durability and adhesive qualities. Although use of lead-based paint was banned in 1978, it is the primary source of lead poisoning in children today because it is still present in older cities like Detroit where 91.8% of the housing stock was built prior to 1978 (U.S. Census Bureau, 2017; American Community Survey 5-year estimates). Of Wayne County children under age six tested in 2016, 54% lived in Detroit. Of Wayne County children under-age found with an EBLL in 2016, 82% lived in Detroit (MDHHS, 2018).

As lead paint is often found inside and outside of houses and apartments in the city, young children are at risk of becoming lead poisoned by swallowing paint chips and inhaling lead dust. Given that lead-based paint was used outdoors as well as indoors, lead dust can also wash off to the soil surrounding a home and poison a child during play. Children under three years of age are most susceptible to being exposed to lead because they crawl and play on floors where paint chips and dust are deposited.

Other important sources of lead contamination in the City of Detroit are former sites of lead smelters, foundries, and alloy makers in certain residential areas. It is at such former smelter sites where both adults and children have been exposed to long-term emissions of lead dust that settled in the soil around the industrial site and the surrounding neighborhoods.

Although exposure to lead from ceramics and the past use of leaded gasoline are not currently considered major sources of lead poisoning in Detroit, they are factors that must be considered. Lead was added to gasoline as a fuel additive to improve engine performance and octane ratings in the 1920s. It was phased out by government order, for public health reasons, starting in 1975 and concluding in 1986, resulting in a direct correlation with drops in elevated blood lead levels nationwide (Kovarik, 2003). An issue of concern in Southwest Detroit is the use of bean pots among residents of this community because some dishes and clay cookware contain high levels of lead in their glaze or decoration. Their use provides a direct and dangerous source of lead poisoning.

Water that runs through pipes that contain lead is another potential source of lead exposure in homes where the old lead plumbing materials have not been replaced. As many as 125,000 Detroit homes are reported to have water lines that may contain some lead. City officials have long added chemicals to Detroit's water that produce a liner to water pipes that is intended to contain any lead in the lines and keep it out of drinking water. The action level for lead levels in drinking water is set by the U.S. Environmental Protection Agency at 0.015 mg/L (U.S. Environmental Protection Agency, 2005). However, the Michigan Department of Environment, Great Lakes, and Energy will set a stricter standard of 0.012 mg/L, which will take effect in 2025. Plumbing systems that may contribute lead to the household drinking water supply have been systematically tested since 1992. Each year since 1992, a small number of homes are selected for water sampling to monitor lead levels in the municipal water system. However, the sampling strategy used for these monitoring activities is insufficient for individual households to draw conclusions about their risk of lead exposure through drinking water, particularly because the plumbing materials used in the interior of a home can substantially contribute that household's risk of lead-contaminated water.

Management Next Steps

Given the various sources of lead which contribute greatly to the number of children with lead poisoning, efforts are being made by health, government, and nonprofit and community development organizations to prevent and respond to lead poisoning in the City of Detroit.

Primary prevention efforts are essential to reducing the number of children who become lead poisoned. Primary prevention focuses on identifying and removing lead hazards like lead-based paint and plumbing materials. These prevention activities include:

- Abatement (permanent removal) of lead hazard sources, where possible (i.e., replacement of components or fixtures that contain lead or are painted with lead-based paint, removal of contaminated soil, washing lead dust off of items and surfaces that are contaminated).

- Where permanent abatement is not possible, temporarily removing or reducing lead hazards through the use of interim controls (i.e., enclosure or encapsulation of lead-based paint to prevent dust or chipping, covering lead-contaminated soil, use of water filters, relocating residents to locations with lower risk of exposure to lead hazards).

- The City has passed and is now enforcing provisions to its Property Maintenance Code that require landlords to first test and then eliminate lead from rental properties using either abatement or interim control or both sets of techniques.

- CLEARCorps Detroit is experimenting with relocating children and their families from homes with lead to others that have been abated or were built after 1978.

- All inspection, testing, preparation, cleanup, disposal, and post-abatement clearance testing activities associated with such abatement or interim control measures must be undertaken by a certified inspector.

While primary prevention activities can reduce the risk of future lead exposure and poisoning, it is also highly important to detect and respond to cases where lead poisoning has occurred. After a child has been exposed to lead, the immediate identification and removal of lead hazards from the child's environment can prevent further exposure. Aftercare interventions can help minimize the impact of lead exposure on the child's health and quality of life. In cases of severe lead poisoning, chelation therapy may be needed to lower the amount of lead in the blood. Increasing the amount of calcium, iron, and vitamin C in the child's diet can help prevent lead from being absorbed into the body (ATSDR, 2007). Education and counseling may also help counteract learning and behavioral problems that can result from lead poisoning. To ensure children exposed to lead receive crucial aftercare support, first they must be tested to determine if they have been poisoned. Annually, fewer than half of Detroit children under six years old are tested for lead poisoning (MDHHS, 2018). Policy changes and outreach activities are still needed to achieve universal testing, which would improve early detection and intervention in cases of lead poisoning.

At the state level, the Child Lead Exposure Elimination Commission (CLEEC) was established in 2017 to coordinate long-term strategies for eliminating childhood lead poisoning in Michigan, building upon the work of previous commissions. CLEEC produced a five-year Action Plan in 2018, with a focus on recommendations for primary prevention. This includes identifying lead in homes before children are poisoned and abating those hazards. Enhanced testing is a main focus of the Action

Plan, with recommendations for universal BLL testing for children under 36 months of age, as well as expanded soil and water testing. Action Plan recommendations also include expanding public education efforts, adopting a statewide housing code enforcement model, improving data collection, and using data to inform activities and better target prevention efforts. At a policy level, CLEEC recommends requiring lead inspection and risk assessments for high-risk rental housing, childcare and adult care facilities, and residential properties built before 1978 in advance of their sale or lease. Additionally, CLEEC suggests updating policies related to landlord penalties, household action limits for water, and certification for contractors seeking a building or renovation permit for a pre-1978 home. The successful implementation of the Action Plan will rely on the availability of sustainable funding sources to carry out these recommendations.

Research/Monitoring Needs

Continued research and monitoring are warranted to track this key indicator of children's health in order to minimize childhood exposure to lead. Wayne State University's Center for Urban Studies suggests that research should continue to focus on ways to target funding for testing, abatement, relocation, and prevention, and to identify which programs will contribute to reductions in lead poisoning more efficiently and effectively. Further research is also warranted on human health effects of lead poisoning. Such human health research, coupled with childhood monitoring and mitigation of lead exposure, must be sustained until childhood lead exposure in Detroit is no longer considered a threat.

References

Agency for Toxic Substances and Disease Registry (ATSDR), 2007. Toxicological profile for Lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Atlanta, Georgia, USA.

American Academy of Pediatrics, 2005. Lead Exposure in Children: Prevention, Detection and Management. Policy Statement. 116, 4, 1036-1046.

Centers for Disease Control and Prevention (CDC), 2016. Childhood Lead Poisoning Data, Statistics, and Surveillance. Atlanta, Georgia, USA.

Centers for Disease Control and Prevention (CDC), 2012. Low level lead exposure harms children: a renewed call for primary prevention: report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention. Atlanta, GA: US Department of Health and Human Services, CDC. Atlanta, Georgia, USA.

Childhood Lead Exposure Elimination Commission. 2018. 2018 Annual Report. Lansing, Michigan, USA.

Detroit Water and Sewage Department, 2004. Water Quality Report. Detroit, Michigan, USA.

Kovarik, W., 2003. The Ethyl War, Forbidden Fuel and Public Poison, The Ethyl War Summary: Leaded Gasoline History and Current Situation. Radford University, Radford, Virginia, USA.

Lam. T., Wendlandbowyer, W., 2003a. Potential of danger at 16 sites brings little action. Detroit Free Press, Detroit, Michigan, USA.

Lam. T., Wendlandbowyer, W., 2003b. Old sites forgotten, ignored. Detroit Free Press, Detroit, Michigan, USA.

Lewis, J., 1985., Lead Poisoning: A Historical Perspective. U.S. Environmental Protection Agency. Washington, D.C., USA.

Michigan Department of Health and Human Services (MDHHS), 2018. Childhood Lead Poisoning Prevention Program annual reports. Lansing, Michigan, USA.

Raymond, J., Brown M.J., 2017. Childhood Blood Lead Levels in Children Aged <5 Years — United States, 2009–2014. MMWR Surveillance Summary 2017; 66, No. SS-3, 1–10. Centers for Disease Control and Prevention, Atlanta, Georgia, USA.

U.S. Environmental Protection Agency, 2005. Drinking Water Contaminants and Maximum Contaminant Levels. Washington, D.C., USA.

Wayne State University (WSU), 2003. Lead Poisoning Research at the Center for Urban Studies. Detroit, Michigan, USA.

This page intentionally left blank.

7.31 Management of Common Reed (*Phragmites australis*) at Erie Marsh Preserve

Chris May, The Nature Conservancy, cmay@tnc.org

Background

Coastal marshes and other wetlands in the western Lake Erie basin have been heavily impacted by landuse changes; more than 95% of the original 400,000 ha (988,421 acres) of coastal marshes have been drained or converted to other uses (Herdendorf, 1987; 1992). More recently, non-native plant species have invaded coastal marshes, posing a serious threat to the quality and ecosystem function of these wetlands.

Erie Marsh Preserve is located in southern Monroe County in North Maumee Bay on the western shore of Lake Erie. It is an 897-ha (2,217-acre) natural area owned by The Nature Conservancy and managed in partnership with the Erie Shooting and Fishing Club and U.S. Fish and Wildlife Service. Erie Shooting and Fishing Club, which purchased the property in the 1870s, managed the marsh to maximize waterfowl hunting opportunities. The Club generously donated the preserve to the Conservancy in 1978 and continues to lease the hunting rights and actively manage a central diked area of about 404 ha (1,000 acres).

Erie Marsh is a globally important stopover site for migrating waterfowl, land birds, and shorebirds, is home to the state threatened eastern fox snake (*Pantherophis gloydi*), is a breeding area for bald eagles, and provides habitat for other rare plant and animal species.

Vegetation in the marsh was relatively stable from the early part of the last century until the early 1970s (Hunt and Mickelson, 1976). Over this period, the marsh was characterized by "large stands of cattail, spike rush (*Eleocharis*) in the low areas, roundstem in the transition from water to marsh land, clumps of willow on high ground, thistles and weeds on the dikes, and bodies of shallow water with muddy bottom" (Douglass, 1934; as reported by Pirnie and Foster, 1964).

Status and Trends

Recent decades have seen Erie Marsh Preserve invaded by non-native plants, including purple loosestrife (*Lythrum salicaria*), narrow-leaved cattail (*Typha angustifolia*), and common reed (*Phragmites australis*), which has become one of the primary threats to native wetlands throughout the Great Lakes basin (Figure 1). Purple loosestrife is no longer a threat to Erie Marsh (and many other wetlands) following the releases of a biological control (*Galerucella* sp.) in Michigan during the mid-late 1990s (Landis et al., 2003). Narrow-leaved cattail continues to be a problem but has remained under control through a combination of herbicide treatments, water level management, and unexplained die-offs.

Common reed was reported at low densities in the 1950s (Hunt, 1957), though we do not know whether the plants were native or nonnative types. The native type of common reed was first documented at Erie Marsh in 2004. While the exact period of invasion by the non-native type is unknown, this probably occurred in the late 1980s-early 1990s. An assessment of aerial photographs from 1984 to 2003 indicates a dramatic increase in the coverage of common reed. In the 1984 photographs there were no clearly distinguishable invasive types of common reed. Conservative interpretation of the 1998 and 2003 imagery reveals at least 72 ha (180 acres) and 132 ha (325 acres) of invading common reed in those years, respectively (Table 1).

Figure 1. Common reed (Phragmites australis) and purple loosestrife (Lythrum salicaria) at Erie Marsh (photo credit: The Nature Conservancy).

Table 1. Area of dense coverage of common reed at Erie Marsh Preserve.

Year	Area (ha)
1984	5
1998	72
2003	132
2009	122
2018	60

Sustained management efforts for non-native common reed have been ongoing since 2010, following the establishment of the Detroit River-Western Lake Erie Cooperative Weed Management Area (DRWLE CWMA), a collaborative focused on managing invasive plants and improving the quality of coastal wetlands of Wayne and Monroe Counties, Michigan. During the past nine years, the DRWLE CWMA has used a combination of herbicide treatments, mowing, and water level management to reduce the abundance of common reed at Erie Marsh Preserve.

DRWLE CWMA uses GPS technology to track areas of invasion and treatment. In 2018, dense coverage of non-native common reed occurred across 60 ha (148 acres) (Table 1).

Management Next Steps

DRWLE CWMA will continue to manage common reed and other invasive plants at Erie Marsh Preserve using a combination of herbicide application, mowing, and flooding, possibly supplemented with prescribed fire. In addition, since 2010, The Nature Conservancy has been implementing a large-scale restoration plan of 390 ha (965 acres) of the diked wetland. When completed, the restoration will allow better water level management, which will in turn allow better management of common reed. The restoration project has also re-established a hydrologic connection between the diked wetland and North Maumee Bay, providing fish access to an area that was separated for more than 60 years. The ultimate goal of the restoration is to increase the quality and diversity of wetland community types at the preserve.

Research/Monitoring Needs

Emphasis continues to be placed on surveys, monitoring, and research with the goal of improving strategies and management actions under an adaptive management framework. Data on water quality, vegetation, birds, herpetofauna, and fish are collected every few years. Erie Marsh Preserve is a benchmark site for the Great Lakes Coastal Wetland Monitoring Program (https://www.greatlakeswetlands.org/Home.vbhtml). The Nature Conservancy also encourages research at the preserve and has permitted at least six projects over the past eight years on topics ranging from vegetation surveys to sampling and tracking land bird migrants and other wetland species.

References

Herdendorf, C.E., 1987. The Ecology of the Coastal Marshes of Western Lake Erie: A Community profile. U.S. Fish and Wildlife Service Biological Report 85 (7.9). Ann Arbor, Michigan, USA.

Herdendorf, C.E., 1992. Lake Erie Coastal Wetlands: An Overview. Journal of Great Lakes Research. 18, 533-551.

Hunt, G.S., 1957. Report of Surveys on the Erie Shooting Club Area. Erie Research Committee. Monroe County, Michigan, USA.

Hunt, G.S., Mickelson, P.G., 1976. Ecological studies at the Erie Shooting and Fishing Club Marsh and their management implications, Monroe County, Michigan, USA.

Landis, D.A., Sebolt, D.C., Haas, M.J., Klepinger, M., 2003. Establishment and impact of *Galerucella calmariensis* L. (Coleoptera: Chrysomelidae) on *Lythrum salicaria L.* and associated plant communities in Michigan. Biological Control. 28, 78-91.

Pirnie, M.D., Foster, J., 1964. Report of Erie Researches, 1960 through 1963. Erie Research Committee & Wildlife Management Foundation. Ann Arbor, Michigan, USA.

This page intentionally left blank

7.32 Mercury in Lake St. Clair Walleye

Ontario Ministry of the Environment, Conservation and Parks, Toronto, Ontario, Canada

Background

In 1969, the Ontario Water Resources Commission (the predecessor of the Ontario Ministry of the Environment, Conservation and Parks) discovered elevated levels of mercury in sediments of the St. Clair River. Follow up monitoring of mercury in fish by government and university scientists found sufficient mercury contamination to close the fishery from southern Lake Huron to Lake Erie in 1970. The St. Clair commercial fisheries were substantial, providing about 40 small family companies with $1-2 million worth of fish per year. This became known as the "Mercury Crisis of 1970" (Hartig, 1983).

The main historic source of mercury to the river was identified as the Dow Chemical Chlor-Alkali Plant in Sarnia, Ontario which operated between 1949 and 1970. Mercury is a naturally occurring metal, familiar to most people through the use of thermometers. It is used in some industrial processes and in the manufacture of some types of electrical apparatus. At one time, mercury was widely used as an antifouling agent in paints and as a controller of fungal diseases of seeds, flower bulbs, and other vegetation. It is still used as an antimicrobial agent.

Mercury is also toxic. It is found in the environment in different chemical and physical forms, the most toxic being methylmercury. In its elemental form, mercury is not regarded as a major contaminant in water because it is almost completely insoluble in water. However, elemental mercury in sediments can be transformed by microorganisms into a form which is much more water soluble, biologically mobile, and toxic than other forms. Certain fishes have been found to accumulate mercury in their tissues at concentrations 5,000 to 50,000 times greater than in surrounding waters.

Status and Trends

Since 1970, Ontario Ministry of the Environment, Conservation and Parks (previously called Ontario Ministry of the Environment) has systematically monitored mercury in walleye using standard sampling and analytical techniques (Figure 1). In 1970, mercury in Lake St. Clair walleye was approximately 2.3 mg/kg. That same year Dow Chemical of Canada was directed by the Ontario Water Resources Commission to install treatment facilities to eliminate mercury discharges to the St. Clair River. Later, Dow Chemical voluntarily shut down its mercury cell plants in Sarnia and Thunder Bay, Ontario (Hartig, 1983). Another mercury cell plant that discharged to the Detroit River in Wyandotte, Michigan was also shut down in 1972.

Figure 1. A 6-kg Walleye caught in the Detroit River (photo credit: Downriver Walleye Federation).

Authorities estimated that the effluent from the Sarnia plants ran as high as 50 mg/L at times, amounting to a release of approximately 91 metric tons of mercury into the St. Clair River, which flowed downstream to Lake St. Clair, the Detroit River and Lakes Erie and Ontario. Since the chlor-alkali plant was taken offline, Dow has spent over $75 million to control mercury sources in sewers, drains and landfills. Between 2001 and 2005, Dow remediated approximately 14,000 m^3 of historically contaminated sediments in the river directly adjacent to the former Dow chemical facility at the cost of approximately $18 million USD.

A 1999 water and sediment study revealed that the current mercury distribution was quite even throughout the Detroit River, instead of the historic pockets of high concentration (Kreis et al., 2001). Mercury concentrations found in Detroit River fish were slightly lower than in the same species from Lake St. Clair. However, health advisories remain in effect for certain sizes of some fish species from both Lake St. Clair and the Detroit River. Today, the primary source of mercury is contaminated sediment from historic discharges (Michigan Department of Natural Resources and Ontario Ministry of Environment, 1991) and atmospheric loadings.

Since the elimination of mercury inputs into the St. Clair River, the mercury content in Lake St. Clair walleye has decreased more than 80% (Figure 2). Similar reductions have occurred in other fish species.

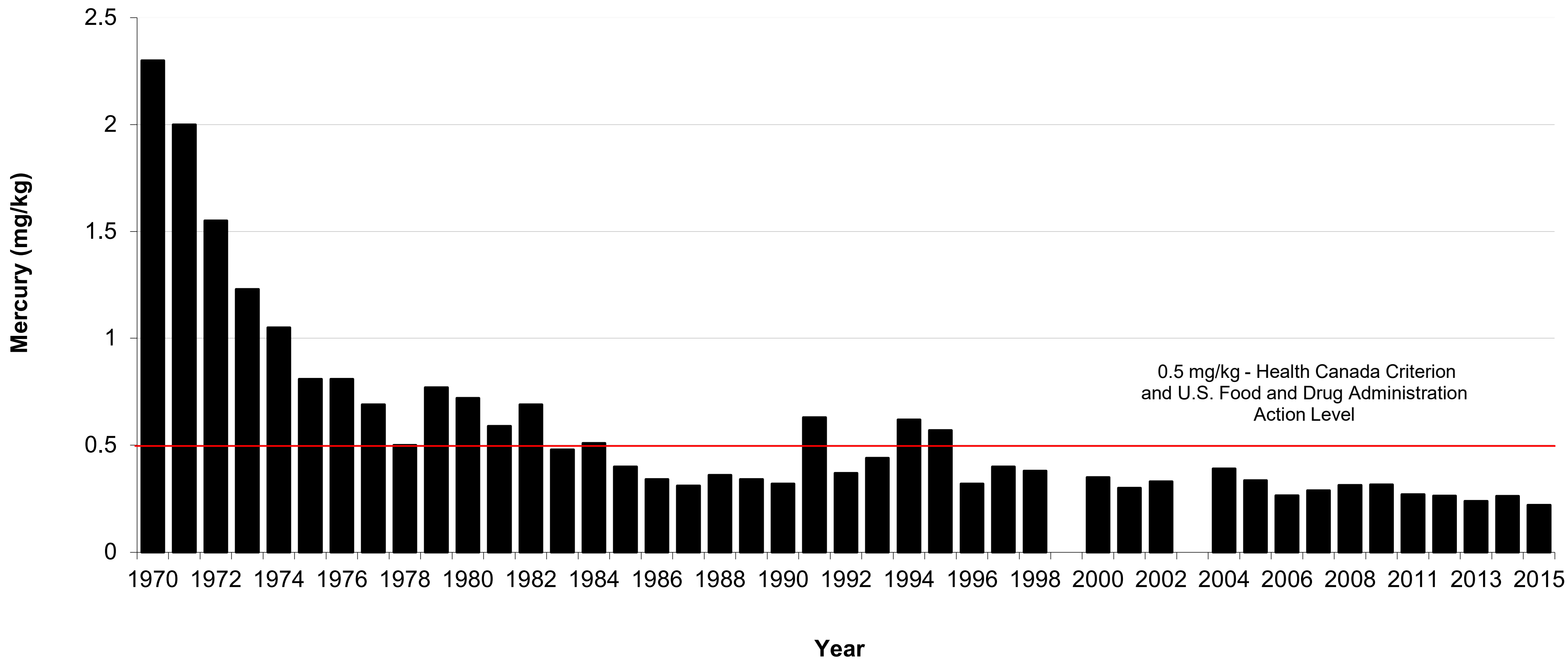


Figure 2. The concentration of mercury in 45 cm walleye in Lake St. Clair, 1970-2004 (data collected by Ontario Ministry of the Environment, Conservation and Parks)

Management Next Steps

Control of mercury at its source is the primary imperative for action. The Canada-U.S. Great Lakes Water Quality Agreement calls for zero discharge of persistent bioaccumulative toxic substances such as mercury. Priority should be given to reducing loadings from active sources such as power plants and incinerators. Elimination of coal-fired electricity in the Province of Ontario in 2014 should contribute to recovery of the system. However, remediating mercury-contaminated sediment hot spots throughout the corridor may be necessary to make meaningful reductions in the fish mercury levels. Work is being initiated to deal with three remaining priority contaminated areas between Sarnia and Stag Island.

Research/Monitoring Needs

Monitoring of mercury in walleye should continue. Mercury isotope measurements are being performed to delineate sources of sedimentary mercury from other sources. This method can also be used to understand if historically deposited mercury is still entering the food web. Sources-fate-transport-effects modeling should be considered to evaluate further remedial options and make mid-course corrections sufficient to remove mercury related health advisories on fish from the St. Clair River, Lake St. Clair, Detroit River, and Lake Erie.

References

Hartig, J. H., 1983. Lake St. Clair: Since the Mercury Crisis. Water Spectrum, 15, 1, 18-25.

Kreis, R.G. Jr., Haffner, G.D., Tomczak, M., 2001. Contaminants in Water and Sediments. State of the Strait: Status and Trends of the Detroit River Ecosystem. University of Windsor, Windsor, Ontario, Canada.

Michigan Department of Natural Resources and Ontario Ministry of Environment, 1991. Stage 1 Remedial Action Plan for the Detroit River. Lansing and Sarnia, Ontario, Canada.

7.33 Oligochaete Densities and Distribution

Jan Ciborowski, University of Windsor, cibor@uwindsor.ca

Background

Members of the class Oligochaeta include common earthworms. But the aquatic sludge worms (family Tubificidae) are best known for their value as environmental indicators. The name Oligochaeta means "few bristles", which refers to the small bundles of hair-like bristles (setae) that occur on each body segment (Figure 1). Tubificid worms have long been recognized as pollution tolerant because of their ability to thrive under poor water quality conditions. Their blood contains haemoglobin, which enables them to survive in waters where oxygen is lacking. Haemoglobin (the same oxygen transporting protein in our blood) absorbs and retains oxygen from the water. Because oligochaetes are small and relatively immobile, they lack the ability to escape environmental stress (e.g., contaminated sediments), making them a useful indicator of local benthic conditions (Farara and Burt, 1993). Howmiller and Scott (1977) showed that low oligochaete diversity occurs in unpolluted, undisturbed environments.

However, low densities of worms do not always indicate clean water conditions. Sediments severely polluted with toxic materials may be degraded to the point where even oligochaete survival is unlikely and densities may be low for this reason (Ciborowski, 2003). Typically, benthic environments rich in organic materials (such as algae and bacteria stimulated by sewage or nutrient runoff) support a disproportionately large abundance of oligochaetes (Hynes, 1971).

Figure 1. Aggregate of Tubificid Oligochaete worms.

A healthy aquatic ecosystem supports a balanced benthic community made up of a mix of benthic species and is not dominated by oligochaetes. When an area becomes disturbed, species diversity declines and pollutant tolerant organisms such as oligochaetes and chironomid midge larvae replace pollutant sensitive species (Farara and Burt, 1993). Wright (1955) suggested that the degree of pollution in Great Lakes locations could be characterized by aquatic oligochaete abundance. Worm densities of 100-999/m^2 were said to indicate light pollution, moderately polluted areas supported 1,000–5,000 worms/m^2, and densities of worms exceeding 5,000/m^2 were representative of heavily polluted areas. When oligochaete worms are used as pollution descriptors, they are often evaluated in reference to the bottom sediment from which they are found. Lafont (1984) compared oligochaete communities from fine sediments of polluted rivers to toxicity measurements in the water. He found that the fewest oligochaete species and the highest relative abundance of Tubificidae occurred in the most polluted areas.

Milbrink (1983) developed an environmental index based on oligochaete abundance and species diversity, arguing that it is more useful to examine oligochaete community composition rather than using a single indicator species on its own. Milbrink's environmental index is based on the Saprobien System, which classifies organisms according to their tolerance to organic pollution in streams. The index characterizes the ecological requirements of each oligochaete species with respect to its tolerance of organic pollution or eutrophic conditions. This index has recently been refined and updated by Burlakova et al. (2018).

Status and Trends

The oligochaetes of western Lake Erie and the lower Detroit River have been studied since as early as 1929 when Wright and Tidd (1933) conducted a density survey of various zoobenthic fauna. At that time, areas with densities >5,000 worms/m^2 were found near the mouths of the Maumee River and River Raisin (Ciborowski, 2003).

Between the 1960s and early 1990s, oligochaete worms indicated that parts of the Detroit River were severely enriched. Downstream of Belle Isle, densities were approximately 500,000/m^2, and downstream of the confluence between the Detroit and Rouge rivers, densities were as high as one million per m^2 (Thornley and Hamdy, 1984). Both of these areas were likely affected primarily by effluents from sewage treatment plants.

Canadian shoreline water quality conditions were apparently less degraded at this time, as indicated by a more balanced benthic community structure (Thornley and Hamdy, 1984). Along the U.S. shoreline, worms accounted for 78% of the total number of organisms collected in both 1968 and 1980 (Thornley and Hamdy, 1984). In 1980, downstream of the mouth of the Rouge River, aquatic worms constituted 80-99% of the total number of invertebrates. *Tubifex tubifex* was the dominant species, reaching numbers as high as 1.5 and 1.9 million/m^2 at these locations. "The 1980 data were essentially unchanged from 1968 and represented a continuing major disruption of the benthos" (Thornley and Hamdy, 1984).

Zoobenthic community composition also suggested that the lower Detroit River was very degraded prior to the mid-1960s. In 1961, 99% of the oligochaete species collected in the Detroit River were Tubificidae (Carr and Hiltunen, 1965). Overall, oligochaetes were the most numerous zoobenthos collected (greatest abundance at all but three sites) and at only 10 stations did they contribute less than 50% of the total organisms (Carr and Hiltunen, 1965). Carr and Hiltunen (1965) used the above worm densities to estimate the area (km^2) of zones of pollution. They classified 12% of the Detroit River as lightly polluted, 53% as moderately polluted, and 35% as heavily polluted (compared to 1930 data in which no part of the Detroit River was heavily polluted).

Estimates of oligochaete abundance are available from five Detroit River surveys conducted between 1964 and 2004 (Figure 2). Because the data were collected and compiled from various sources there is variation in the number and location of sites sampled, and the times of year during which they were sampled. River-wide estimates of average densities have ranged from about 1,200 worms/m^2 (in 1999) to almost 7,000/m^2 (1990). Densities in 2004 were substantially higher than they were in 1999, suggesting that water quality was poorer in 2004 (Zhang, 2008). However, surveys have been conducted too irregularly to indicate whether the differences seen among years represent progressive changes in the river's condition or merely year-to-year variation. No comprehensive, reliable benthic survey has been conducted since 2004.

Oligochaete abundances are especially useful at showing the location of point source pollution "hot spots" (Figure 3). Sites located along the Trenton Channel and one site (Ecorse site) located just downstream of Ecorse Michigan (where U.S. Steel is

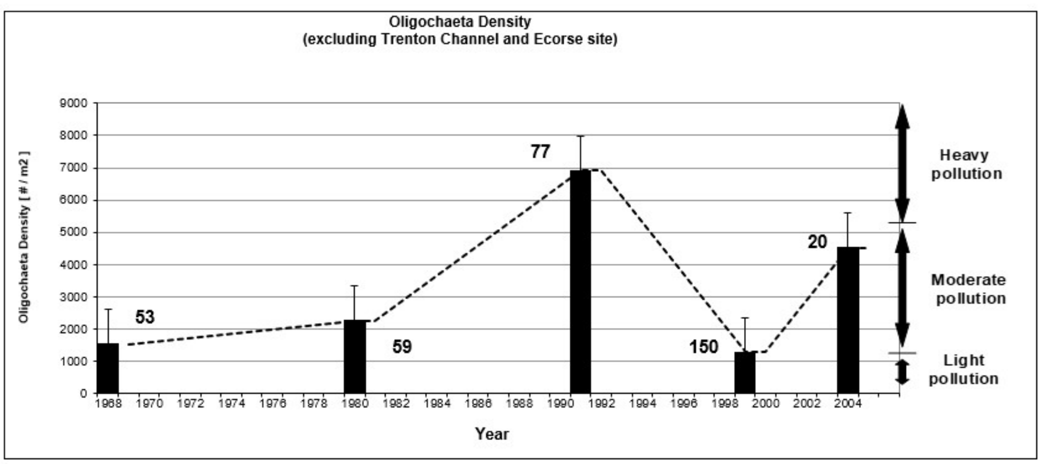


*Figure 2. Mean (+SE) density of oligochaetes in the Detroit River between 1968 and 2004. The number of sites sampled each year is indicated. *Data compiled from Thornley and Hamdy (1984), Farara and Burt (1993), Wood (2004), and Zhanb (2008). Ranges of eutrophication are based on Wright (1955).*

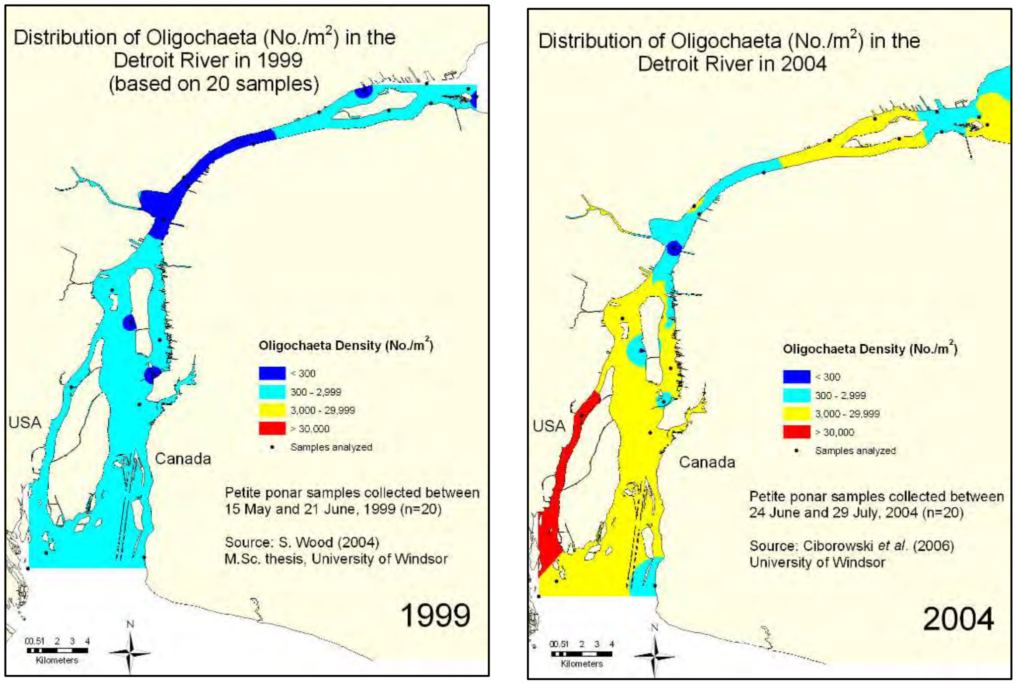


Figure 3. A: Density of Oligochaeta in the Detroit River in 1999 interpolated from data compiled from Wood (2002). B: Density of Oligochaeta in the Detroit River in 2004 interpolated from data compiled from Zhang (2008). Maps by Anita Kirkpatrick.

located) have historically been recognized as among the most polluted areas of the Detroit River due to urban and industrial development along the shorelines. Mean oligochaete densities at these sites greatly exceeded the designated heavy pollution value of 5,000/m^2 in all years except 1999. Prior to 1980, these locations had between 100,000 and 1 million worms/m^2 (Figure 4). Although conditions have dramatically improved and worm densities have been reduced by 80-90% since 1990, the numbers present suggest that these locations still fall in the 'heavily polluted' category.

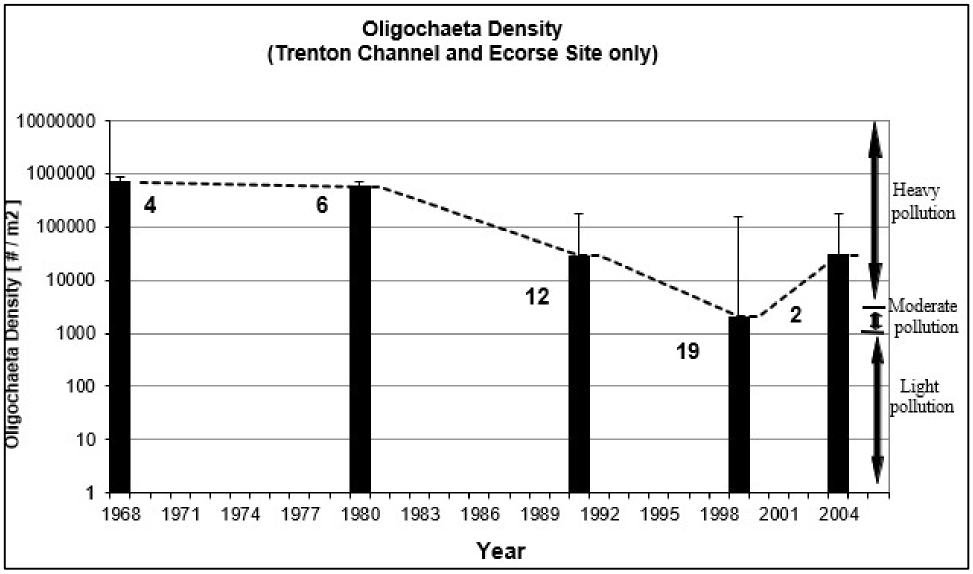


*Figure 4. Geometric mean (+SE) density of oligochaetes in the Trenton Channel and at one Ecorse site between 1968 and 2004 (note logarithmic scale). The numeral beside each bar indicates the number of sites sampled during that year. *Data compiled from Thornley and Hamdy (1984), Farara and Burt (1993), Wood (2004), and Zhang (2008).*

Some oligochaete data also exist for western Lake Erie. In 1982, oligochaete and sediment samples were collected at 40 stations along the coast of western Lake Erie and compared to samples collected at the same sites in 1961 (Schloesser et al., 1995). Total worm densities as well as species diversity were used to infer pollution levels. The comparison indicated improved water quality in the nearshore areas, but increased eutrophic substrate conditions in the western basin of Lake Erie near the mouth of the Detroit River (Schloesser et al., 1995).

Extensive benthic data were also collected during the Collaborative Science and Monitoring Initiatives (CSMI) for Lake Erie, conducted in 2004, 2010, and 2015. Data from a total of 604 benthic sample sites or dates were available for assessment (81 from 2004, 38 from 2010, 38 from 2015-2016). The data were summarized as a Benthic Tolerance Score whose value was highly correlated with the number of oligochaetes in a sample (Ciborowski, 2018). In 2004, sample sites ranged in condition from “Mesotrophic-Good” to “Very Eutrophic-Poor” through the western Basin. In 2004, 50±6% of the 81 western basin sites had tolerance scores in Mesotrophic-Good or better classes. Fewer western basin sites were sampled in 2010, but overall condition appeared to have improved. In all 76±7% of the 38 sites assessed in 2010 were classified as Mesotrophic-Good. Overall condition in the western basin in 2015 was equivalent to or better than that in 2010, with 87±5% classified as Mesotrophic-Good or better.

Management Next Steps

The available data clearly indicate portions of the river that have historically been most heavily degraded by organic enrichment and those that are still affected by nutrient-rich water, primarily sewage and stormwater. The oligochaete data show the extent to which river water quality in the Trenton Channel has improved between

1980 and the early 1990s. However, continued attention to point sources of pollution will be necessary to bring the oligochaete classification into the 'moderately polluted' category.

Research/Monitoring Needs

Oligochaete monitoring should be conducted yearly if precise time trends are to be determined. As well, sampling methods (collection times, site locations, number of sites sampled) should be standardized among years to improve the precision of river-wide density estimates.

An oligochaete species index has the potential to be an effective indicator of water quality issues. However, implementation relies on intensive and frequent sampling, in addition to the ability to identify Oligochaeta worms to genus and/or species level.

References

Bonacina, C., Bonomi, G., Monti, C., 1986. Oligochaete cocoon remains as evidence of past lake pollution. Hydrogiologia. 143, 1, 395-400.

Burlakova, L.E., Kovalenko, K.E., Schmude, K.L., Barbiero, R.P., Karatayev, A.Y., Lesht, B.M., 2018. Development of new indices of Great Lakes water quality based on profundal benthic communities. Journal of Great Lakes Research. 44, 4, 618-628.

Carr, J., Hiltunen, J., 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. Limnology and Oceanography. 10, 4, 551-569

Ciborowski, J.J.H., 2003. Lessons from sentinel invertebrates: mayflies and other species, in: Hartig, J.H. (Ed.), Honoring our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, pp. 107-120.

Ciborowski, J.J.H., Ives, J., 2018. Deriving and calibrating nearshore framework environmental and biological data for Lake Erie. Prepared for Nearshore Framework Task Group, Environment and Climate Change Canada. Toronto, Ontario, Canada.

Farara, D.G., Burt, A.G., 1993. Environmental assessment of Detroit River sediments and benthic macroinvertebrate communities -1991. Report prepared for the Ontario Ministry of Environment and Energy by Beak Consultants Limited, Brampton, Ontario, Canada.

Howmiller, R.P., Scott, M.A., 1977. An environmental index based on the relative abundance of oligochaete species. J. Water Pollut. Cont. Fed. 49, 809-815.

Hynes, H.B.N., 1971. The Biology of Polluted Waters. University of Toronto Press, Toronto.

Lafont, M., 1984. Oligochaete communities as biological descriptors of pollution in the fine sediments of rivers. Hydrobiologia. 115, 127-129.

Milbrink, G., 1983. An improved environmental index based on the relative abundance of oligochaete species. Hydrobiologia. 102, 89-87.

Thornley, S., Hamdy, Y., 1984. An assessment of bottom fauna and sediments of the Detroit river. Ontario Ministry of Environment Report, Toronto, Ontario, Canada.

Wright, S., 1955. Limnological survey of western Lake Erie. U.S. Fish and Wildlife Service, Spec. Sci. Rept. 139, Ann Arbor, Michigan, USA.

Wright, S., Tidd, W.M., 1933. Summary of Limnological Investigations in Western Lake Erie in 1929 and 1930. Transactions of the American Fisheries Society. 63, 271-85.

Zhang, J., 2008. Zoobenthic indicators of environmental conditions in the Lake Huron-Lake Erie corridor. M.Sc. Thesis, University of Windsor, Windsor, Ontario, Canada.

This page intentionally left blank.

7.34 Osprey Nesting Success in Southeast Michigan

John H. Hartig, Great Lakes Institute for Environmental Research, University of Windsor jhhartig@uwindsor.ca

Background

Osprey (*Pandion haliaetus*) are found worldwide and are a common sight soaring over shorelines, patrolling waterways, and standing on their large stick nests with their white heads gleaming. Also known as "fish hawks," "river hawks," and "sea hawks," they are one of the largest birds of prey in North America with a nearly 1.8-m (six-foot wingspan). They feed almost exclusively on fish and are considered a good indicator of aquatic ecosystem health.

Osprey is a superb predator on fish. While flying or hovering some 9.1-30.5 m (30-100 feet) above the water surface, they plunge feet-first into the water in search of their prey. They use gripping pads on their feet and curved claws to help pluck fish from the water and carry them off for great distances.

As with many other top predators like Bald Eagles and Peregrine Falcons, the use of the pesticide DDT in the years after World War II negatively affected osprey populations. The biomagnification of DDT and other pesticides in the Osprey's bodies resulted in brittle, extremely fragile eggshells. The body weight of the parents broke the eggs, and very few young were born. DDT use was subsequently banned in Michigan in 1969 and the remainder of the U.S. in 1972.

As a result, Osprey was listed as threatened in Michigan at one time (Michigan Department of Natural Resources, 2011). After Michigan's Osprey Reintroduction Project (1990-2000), the species rebounded enough to be upgraded to a species of special concern. Protections offered by the Migratory Bird Treaty Act of 1918 also helped bolster Osprey populations.

Status and Trends

In the 1960s, the Osprey population in Michigan declined rapidly (Postupalsky, 1977). By 2002, there was only one active nest in southern Michigan. To restore the Osprey population, Michigan Department of Natural Resources, with assistance from Huron Clinton Metropolitan Authority, the Detroit Zoological Society, and DTE Energy, established the Osprey Reintroduction Project of Southern Michigan (Michigan Department of Natural Resources, 1998). The goal of this Osprey Reintroduction Program was 30 nesting pairs in the southern half of Michigan's Lower Peninsula by 2020. This project involved moving 50 chicks from the northern parts of the state to areas in southern Michigan.

There are now more than 75 known nests in the southern Lower Peninsula, plus dozens of nests in the northern Lower Peninsula and the Upper Peninsula. Michigan Osprey, a citizen organization devoted to tracking and restoring the

Osprey population, reported the southern half of the Lower Peninsula achieved the goal of 30 nesting pair in 2010, 10 years ahead of schedule. In southeast Michigan alone (e.g., Wayne, Macomb, Oakland, Livingston, Washtenaw, Monroe, and St. Clair counties), there were 38, 50, and 52 nesting pairs in 2015, 2016, and 2017, respectively (Figure 1). It is interesting to note that in 2009 a pair of Osprey built a nest in a cell phone tower adjacent to the Gibraltar Wetlands Unit of the Detroit River International Wildlife Refuge along the lower Detroit River, representing the first time that osprey successfully nested in Wayne County since the 1890s.

Figure 1. An Osprey named Monroe Julie fledged from the Strong Unit of the Detroit River International Wildlife Refuge in 2016 (photo credit: Fred Drotar).

Clearly, this Osprey reintroduction program has been successful, but concerns remain. Osprey still need to be protected from killing or capture, especially in their wintering grounds in Florida, southwestern U.S., and Central America. For example, an Osprey named Monroe Spark that fledged from the Detroit River International Wildlife Refuge's Strong Unit in 2013 was fitted with a backpack satellite transmitter that tracked it to Cuba where it was probably killed by a fish farmer. This shows that international efforts are needed to protect this species. Some protection is provided to osprey under the Migratory Bird Treaty Act of 1918, however, greater international cooperation is needed.

Research/Monitoring Needs

The return of Osprey in southern Michigan is a conservation success story. Nearly absent from much of Michigan due to exposure to DDT and other pesticides, southern Michigan's Osprey population continues to rebound.

Yearly Osprey monitoring should continue throughout the Detroit River and western Lake Erie watersheds under the direction of Michigan Osprey and with support from the Michigan Department of Natural Resources and the U.S. Fish and Wildlife Service. Special emphasis should be placed on minimizing contaminant exposures, tracking health status, and protecting habitats to ensure long-term population sustainability. Contaminants of concern include organochlorine compounds and heavy metals, as well as emerging new generation compounds. Furthermore, additional laboratory and field studies may be necessary to further clarify the role of environmental endocrine disruptors on reproduction in avian populations. Osprey banding and tracking using GPS-equipped backpacks should continue to better understand seasonal migration patterns and daily movements of the young birds.

References

Michigan Department of Natural Resources, 1998. Osprey recovery plan. Lansing, Michigan, USA.

Michigan Department of Natural Resources, 2011. Michigan's Wildlife Action Plan: Highlights of the First Five Year. Lansing, Michigan, USA.

Postupalsky, S., 1977. Status of the Osprey in Michigan, in: Ogden, J.C., (Ed.), Transactions of the North American Osprey Research Conference. U.S. Department of Interior, National Park Service, Series 2, Washington, D.C., pp. 153-165.

This page intentionally left blank.

7.35 Peregrine Falcon Reproduction in Southeast Michigan

Christine K. Becher, Southeast Michigan Peregrine Falcon Nesting Coordinator, Michigan Department of Natural Resources, Peregrine_Notes@yahoo.com

John Hartig, Great Lakes Institute for Environmental Research, University of Windsor, jhhartig@uwindsor.ca

Background

Peregrine falcons (*Falco peregrinus*), known for their swift flight, have never been very abundant anywhere in the world due to very specific nest site requirements and their position at the top of the food web. A 1940 survey of eyries (nesting sites) estimated that the eastern U.S. population consisted of only 350 pairs. The upper Midwest population was estimated to be 109 pairs, before a dramatic decline in the 1950s. Historically, there were 13 known eyries in Michigan, all located in the cliffs of the Upper Peninsula (Huron Mountains, Pictured Rocks, Mackinac Island), except for some found in steep sand dunes on the Fox Islands in northern Lake Michigan. The last documented successful nesting in Michigan, before restoration began, was in 1957 at Burnt Bluff, a cliff on the Garden Peninsula in Delta County.

During the 1950s, the world population of peregrines was decimated, mostly due to the use of pesticides like DDT (Tordoff and Redig, 1997). When DDE, the breakdown product of DDT, accumulates in the bodies of many birds, it causes them to lay very thin-shelled eggs which broke during incubation. Studies show the peregrine falcon retains the highest DDT residue of all vertebrates, causing reproductive problems (Apple et al., 2002). A repeat of the 1940 survey of historically known eyries, conducted in 1964, found no breeding pairs or even a single adult peregrine east of the Mississippi River. As a result, the peregrine falcon was listed as an endangered species by the U.S. Fish and Wildlife Service in 1970. The peregrine falcon was also included in the first list of endangered species promulgated under Michigan's Endangered Species Act in 1974.

By the 1970s, DDT had been banned in both Europe and the U.S., partially due to data linking it to the decline of the peregrine falcon. In 1981, the Midwest Peregrine Falcon Restoration Team was created and charged with the task of developing a management plan to restore peregrine falcons as a nesting bird population in the upper Midwest.

A highly successful program for Midwest re-introductions into urban environments was started in 1982. Peregrine chicks of captive adults were raised in artificial structures and subsequently released into their new urban environment. These new homes, including buildings of all shapes and sizes, bridges, power plant stacks, all having success stories, so that in 2005, over 90 cities had peregrine falcons nesting efforts recorded in the Midwest. Peregrines feed exclusively on other birds which are abundant in urban areas, such as pigeons, mourning doves, starlings, flickers, and woodcocks (Apple et al., 2002). It is also thought that as these “urban” raised peregrines expanded their territories, they would naturally seek out some of the natural, more traditional sites, such as cliffs in the upper peninsula of Michigan.

By 1991, over 3,000 captive bred peregrines had been released throughout the U.S., including 400 in the upper Midwest, 139 in Michigan (108 in the Upper Peninsula and 31 in Grand Rapids and Detroit). As of 2005 more than 20 peregrines have been observed either nesting or attempting to nest in southeast Michigan (Figure 1). Birds released from Sudbury, Ontario and Pittsburgh, Pennsylvania formed a pair that became the first to successfully nest in Michigan, at the Book Building in downtown Detroit in 1993 (Yerkey, 2004).

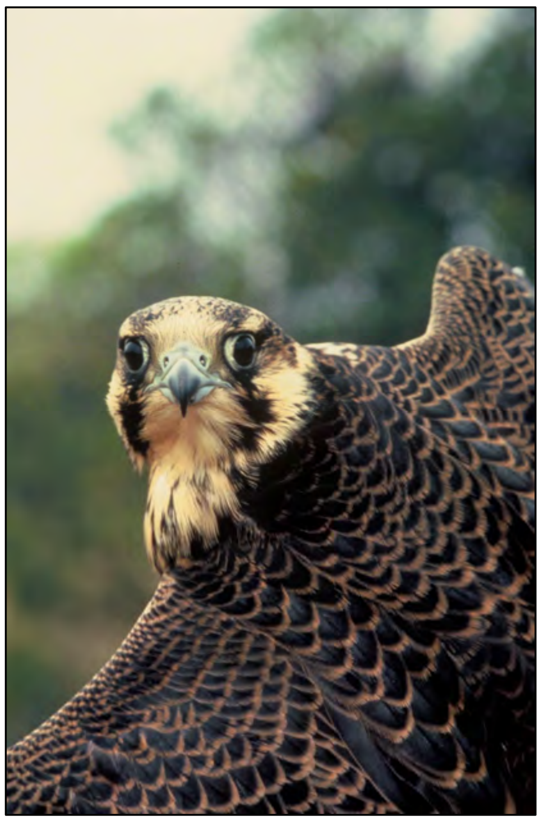


Figure 1. Peregrine Falcon (Falco peregrinus) (Photo Credit: U.S. Fish and Wildlife Service).

The year 1999 will be recognized as a milestone year for the restoration of endangered species. On August 20th, the peregrine falcon "soared" off the list of federally endangered species. This triumph is significant, due to the fact that the eastern population of peregrine falcons had been completely eliminated by the mid-1960s. At the time restoration began, the population of peregrines in the U.S. was probably down to about 10% of its original size. Reintroducing captive bred falcons into the wild proved to be successful in restoring a population of wild reproduced peregrines (Figure 2 and 3).

Figure 2. Hacking box with a peregrine falcon at The Fisher Building in downtown Detroit, 2006 (credit: Barb Baldinger).

Figure 3. Peregrine falcon young in a hacking box at The Fisher Building in downtown Detroit, 2006 (credit: Barb Baldinger).

Status and Trends

Michigan started the introduction program with a goal of 10 successful nesting pairs by 2000. The first release site was in Grand Rapids in 1986. In 1987, five peregrine falcon young were released in downtown Detroit. In 1988, one sub-adult pair was present when the five chicks were released; however, this pair did not successfully nest. For the next four years various pairs continued to "visit" each year with no nesting success. Then, in 1993, two young peregrines were successfully raised for the first time documented in Detroit's history, and the first in the Lower Peninsula in 37 years. The number of nesting sites in southeast Michigan, including the Ambassador Bridge, has increased from one in 1989-1992 to 13-20 in 2011-2016 (Figure 3). Further, the number of young produced in southeast Michigan increased from none in 1992 to 22-30 per year in 2011-2016 (Figure 4).

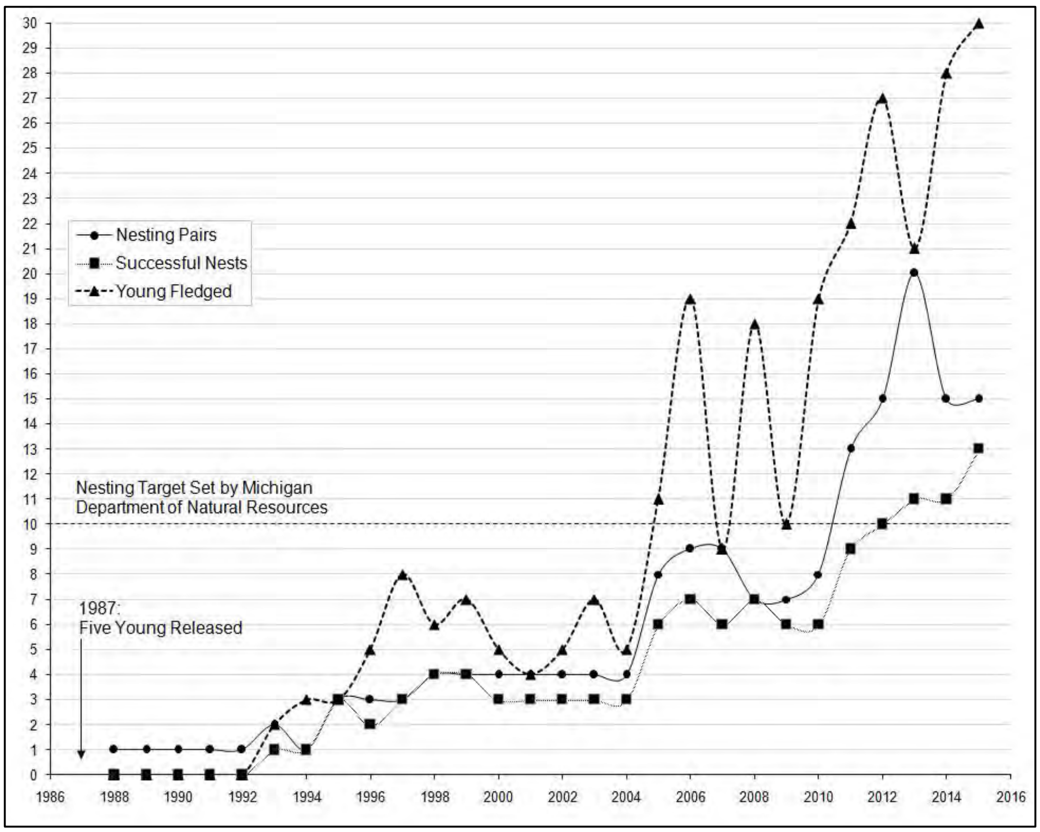


Figure 4. Trends in nesting pairs, successful nests, and young fledged of peregrine falcons in southeast Michigan (including the Ambassador Bridge), 1987-2016. Data were provided by Michigan Department of Natural Resources and The Canadian Peregrine Foundation.

Southeast Michigan, especially along the Detroit River and its connecting waterways, is a significant part of the peregrine habitat in Michigan. The increase in the number of successful peregrine falcon nest sites in southeast Michigan over time demonstrates an expansion in range. In addition, peregrine falcons began nesting on the Canadian side of the Ambassador Bridge in 2008, with the first young fledged in 2010. In 2016, five young were fledged from this Ambassador Bridge location.

Management Next Steps

In 1999, the U.S. Fish and Wildlife Service delisted the peregrine falcon as a federally endangered species. However, it remains protected federally under the Migratory Bird Treaty Act. In Michigan, peregrines remain listed as an endangered species under state law. The goal of the Michigan Department of Natural Resources' Natural Heritage Program (nongame wildlife) – to maintain a population of at least 10 nesting pairs of peregrine falcons in Michigan – has now been met.

The peregrine falcon is also identified as a Species of Greatest Conservation Need by the Michigan Wildlife Conservation Strategy (Eagle et al., 2005). Management next steps include developing, protecting, and enhancing nesting and fledging habitat structures, including artificial nests, in the Detroit Metropolitan Area. This will involve close cooperation with building managers to minimize disturbance and allow for volunteers to assist in peregrine behavior observations. This volunteer effort will extend to raptor rehabilitators that will assist in restoration of sick and injured peregrines back into the wild. To accomplish this, a larger coordinated volunteer effort will be needed where collaboration with many partners, including the U.S. Fish and Wildlife Service, the Detroit Zoo, and others. Where possible, young peregrines will be banded as a part of educational and outreach events.

Research/Monitoring Needs

The Michigan Department of Natural Resources' Wildlife Division has provided funding to monitor falcon populations in the metropolitan Detroit area to gain a better understanding of this unique raptor. A priority should be placed on sustaining this long-term monitoring program with support from Michigan Department of Natural Resources, U.S. Fish and Wildlife Service, and other conservation partners. In addition, a priority should be placed on building the capacity of this monitoring program using citizen science – where volunteers are recruited, trained, and equipped to sustain this valuable monitoring program.

There have been cases of mortality stressing the local population caused by bad weather, predators, such as the great horned owl, and incidental deaths. More research on the causes of mortality and improvements to decrease that mortality rate would be beneficial. Also, continued research of peregrine falcons throughout their current range could aid in a better understanding of nationwide environmental stressors and mortality. Additional research should be conducted on fledglings that are produced in metropolitan Detroit and leave the area to determine if they are reproducing successfully and where they nest.

References

Apple, L.M., Craves, J.A., Smith, M.K., Weir B., Zawiskie, J.M., 2002. Explore our Natural World: A Biodiversity Atlas of the Lake Huron to Lake Eire Corridor. Wildlife Habitat Council, Detroit, Michigan, USA.

Eagle, A.C., Hay-Chmielewski, E.M., Cleveland, K.T., Derosier, A.L., Herbert, M.E., Rustem, R.A., 2005. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources. Lansing, Michigan, USA.

Tordoff, H.B., Redig, P., 1997. Midwest peregrine falcon demography, 1982-1995. J. Raptor Res. 31 (4) :339-346.

Yerkey, J.M., 2004. Southeast Michigan Peregrines, 1987-2004. Unpublished report. Detroit, Michigan, USA.

Link for more information:

University of Michigan Museum of Zoology:
http://animaldiversity.ummz.umich.edu/site/accounts/information/Falco_peregrinus.html

7.36 Plankton Communities in Western Lake Erie

Douglas D. Kane, Defiance College, dkane@defiance.edu

Background

Plankton are small organisms that float, drift, or weakly swim in the water column of any water body. Studies of zooplankton and phytoplankton communities of the western basin of Lake Erie extend back to the late-19th/early-20th century (Herdendorf, 2005). Later, research associated with the 1970 "Project Hypo" study of the central basin provided important information on the spatial and temporal dynamics of both phytoplankton (Munawar and Munawar, 1976) and zooplankton (Watson, 1976) for the western basin as well. Further, data collected and analyzed from this period provide us with information regarding the western basin of Lake Erie at its most degraded state (Kane et al., 2008). Degradation of the plankton communities was already evident by the mid-20th century (Beeton, 1965), with evidence for increases in abundance of phytoplankton (Davis, 1964) and zooplankton (Bradshaw, 1964) associated with eutrophic conditions, and decreases in abundance of pollution-intolerant zooplankton taxa (i.e., *Limnocalanus macrurus*) (Kane et al., 2004). Since the late 1970s the U.S. Environmental Protection Agency has monitored the phytoplankton and zooplankton communities of western Lake Erie (Makarewicz, 1993a,b). The data available from the different studies mentioned above, combined with more recent data collected, allow for the determination of the biological integrity of the offshore waters of the western basin of Lake Erie.

One measure of the biological integrity of the offshore waters of the western basin of Lake Erie is the Planktonic Index of Biotic Integrity (P-IBI) (Kane et al., 2008). This indicator is based on the abundance and kinds of phytoplankton and zooplankton. The P-IBI integrates information about both phytoplankton and zooplankton communities in the open waters of western Lake Erie to determine their water quality (Figure 1).

Figure 1. Researcher taking a zooplankton sample in the western basin of Lake Erie near the Bass Islands. (photo credit: Doug Kane).

Status and Trends

The P-IBI uses five characteristics (metrics; Table 1). Values obtained for these plankton metrics are classified to reflect different levels of pollution by nutrients, especially phosphorus. Each metric is scored as a one, three, or five, with five representing the most oligotrophic conditions. Because both phytoplankton and zooplankton communities change throughout the year (Sommer et al.,1986), each metric has a specific time component during which it is measured (June-August; Table 1). The metric scores for all the months are then averaged.

Table 1. Metrics used to calculate the P-IBI.

METRICS	**Months Measured**
Phytoplankton Metrics	
Biomass of edible algae taxa	June
% *Microcystis*, *Anabaena*, and *Aphanizomenon* of total phytoplankton biomass	June
Zooplankton Metrics	
Zooplankton ratio (calanoid copepod abundance/ cyclopoid copepod + cladoceran abundance)	June, August
Limnocalanus macrurus density	July
Crustacean zooplankton biomass	August

The P-IBI suggests the overall condition of the western basin of Lake Erie's offshore waters for the most recent years is eutrophic (Figure 2; Kane et al., 2015). During the mid-to-late 1990s the P-IBI scores were higher, reflecting a more mesotrophic western basin (Figure 2). Since 2000 the P-IBI scores have been at or below 3, similar to the score for 1970 (Figure 2), reflecting eutrophic conditions. These scores reflect increased frequency of blooms of the toxic phytoplankter *Microcystis* (Budd et al., 2002), increases in phytoplankton community biomass (Conroy et al., 2005), and declines in the zooplankton ratio (Conroy et al., 2008). The P-IBI values have continued to decline in recent years (Kane et al., 2015). This decline is in large part because of cyanobacteria Harmful Algal Blooms (cHABs) that are larger in geographic extent, more frequent, and longer in duration, and are plaguing the western basin of Lake Erie nearly every year.

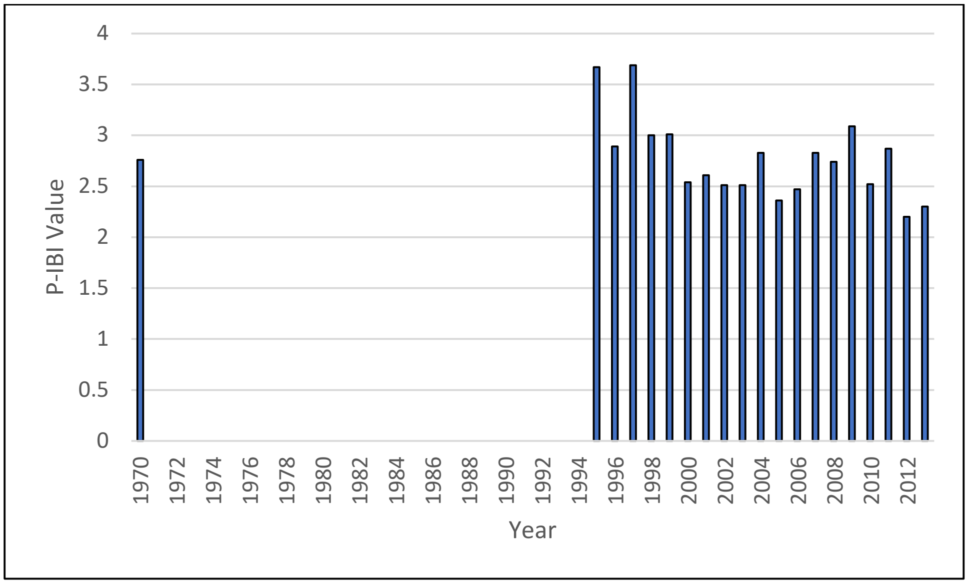


Figure 2. P-IBI scores in the western basin of Lake Erie, 1970 and 1995-2013. Trophic status classifications are based on IBI scores and utilize the scale of <3 reflecting eutrophic conditions, 3-4 reflecting mesotrophic conditions, and >4 reflecting oligotrophic conditions.

Management Next Steps

A number of different agencies and academic researchers collect plankton samples in the western basin of Lake Erie. However, there is no coordinated effort to maximize spatial and temporal coverage, standardize methods among research/management groups, or share the results among all interested parties. A binational "plankton monitoring summit" would be helpful for all the parties involved, as coordinated monitoring effort would have greater spatial and temporal coverage, greater comparability of data, and likely be more cost efficient.

A reduction in nutrient loading is a management goal for reducing cHABs and improving overall ecosystem health in the western basin of Lake Erie. A return to mesotrophic conditions is a best-case scenario for the western basin considering the shallowness of the basin and its high influence from large rivers flowing into the basin from agricultural and urban areas. The P-IBI mesotrophic range of 3-4 is a reasonable target to be considered by management agencies.

Research/Monitoring Needs

Phytoplankton and zooplankton are good indicators of changes in nutrient pollution over time in Lake Erie because they respond quickly to changes in nutrient input to the lake. Further, they can be sampled extensively in many locations with relative ease. Future monitoring of plankton dynamics in Lake Erie will enable us to evaluate the biological water quality of Lake Erie's offshore waters. The Ohio Department of Natural Resources in Ohio, the National Water Research Institute in Canada, and other state, provincial, and federal agencies have shown a long-term commitment to plankton monitoring, which has allowed for the calculation of P-IBI scores for nearly 18 years of data. This monitoring has also allowed for the early detection of invasive species new to the western basin of Lake Erie (i.e., *Cercopagis pengoi*)(Therriault et al., 2002) and needs to continue in the future in order to detect changes in the lake.

References

Beeton, A.M., 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. Oceanogr. 10, 240-254.

Bradshaw, J.S., 1964. The crustacean zooplankton picture: Lake Erie 1939-49-59, Cayuga 1910-51-61. Verh. Int. Ver. Theor. Angew. Limnol. 15, 700-708.

Budd, J.W., Beeton, A.M., Stumpf, R.P., Culver, D.A., Kerfoot, W.C., 2002. Satellite Observations of *Microcystis* blooms in Western Lake Erie. Verh. Int. Ver. Theor. Angew. Limnol. 27, 3787-3793.

Conroy, J.D., Kane, D.D., Culver, D.A., 2008. Declining Lake Erie Ecosystem Health? Evidence from a Multi-year, Lake-wide, Plankton Study, in: M. Munawar, M., Heath, R., (Eds.), Checking the Pulse of Lake Erie., Ecovision World Monograph Series, Burlington, ON, pp. 369-408.

Conroy, J.D., Kane, D.D., Dolan, D.M., Edwards, W.J., Charlton, M.N., Culver, D.A., 2005. Temporal Trends in Lake Erie plankton Biomass: Roles of External Phosphorus Loading and Dreissenid Mussels. J. Great Lakes Res. 31 (Supplement 2): 89-110.

Davis, C.C., 1964. Evidence for the Eutrophication of Lake Erie from Phytoplankton Records. Limnol. Oceanogr. 9, 275-283.

Herdendorf, C.E., 2005. Scientific Surveys of Lake Erie: a Historical Review. Ohio Sea Grant Technical Bulletin (TB-077). Columbus, Ohio, USA.

Kane, D. D., Gannon, J.E., Culver, D.A., 2004. The Status of *Limnocalanus macrurus* (Copepoda: Calanoida: Centropagidae) in Lake Erie. J. Great Lakes Res. 30, 22-30.

Kane, D.D., Gordon, S.I., Munawar, M., Charlton, M.N., Culver, D.A., 2008. A Planktonic Index of Biotic Integrity (P-IBI) for Lake Erie: a new technique for checking the pulse of Lake Erie, in: M. Munawar, M., Heath, R., (Eds.), Checking the Pulse of Lake Erie., Ecovision World Monograph Series, Burlington, ON, pp. 347-367.

Kane, D.D., Ludsin, S.A., Briland, R.D., Culver, D.A., Munawar, M., 2015. Ten+ years gone: Continued degradation of offshore planktonic communities in U.S. waters of Lake Erie's western and central basins (2003-2013). J. Great Lakes Res. 41, 930-933.

Makarewicz, J.C., 1993a. A lakewide comparison of zooplankton biomass and its species composition in Lake Erie, 1983-87. J. Great Lakes Res. 19, 2, 75-290.

Makarewicz, J.C., 1993b. Phytoplankton biomass and species composition in Lake Erie, 1970 to 1987. J. Great Lakes Res. 19, 258-274.

Munawar, M., Munawar, I.F., 1976. A lakewide study of phytoplankton biomass and its species composition in Lake Erie, April- December 1970. J. Fish. Res. Board Can. 33, 581-600.

Sommer, U., Gliwicz, Z.M., Lampert, W., Duncan, A., 1986. The PEG-model of seasonal succession of planktonic events in fresh waters. Arch. Hydrobiol. 106, 433-471.

Therriault, T.W., Grigorovich, I.A., Kane, D.D., Haas, E.M., Culver, D.A., MacIsaac, H.J., 2002. Range Expansion of the Exotic Zooplankter *Cercopagis pengoi* (Ostroumov) into Western Lake Erie and Muskegon Lake. J. Great Lakes Res. 28, 698-701.

Watson, N.H.F., 1976. Seasonal Distribution and Abundance of Crustacean Zooplankton in Lake Erie, 1970. J. Fish. Res. Board Can. 33, 612-621.

This page intentionally left blank.

7.37 Precipitation Changes in the Western Lake Erie Climate Division

Erin Maher, Great Lakes Integrated Sciences + Assessments, University of Michigan, eemaher@umich.edu

Kimberly Channell, Great Lakes Integrated Sciences + Assessments, University of Michigan, kimchann@umich.edu

Background

Changes in precipitation patterns have been observed in the Great Lakes basin as a result of the region's overall changing climate. In the Western Lake Erie climate division, there has been an overall increase in annual precipitation since 1951. Using combined data from three National Oceanic and Atmospheric Administration (NOAA) U.S. climate divisions in the Western Lake Erie area (displayed in Figure 1), these trends are examined below (Vose et al., 2014). Both liquid precipitation and snowfall (calculated as snow-water equivalent) are accounted for in the data below. The use of data sourced from NOAA allows for high confidence in the analyses of these data.

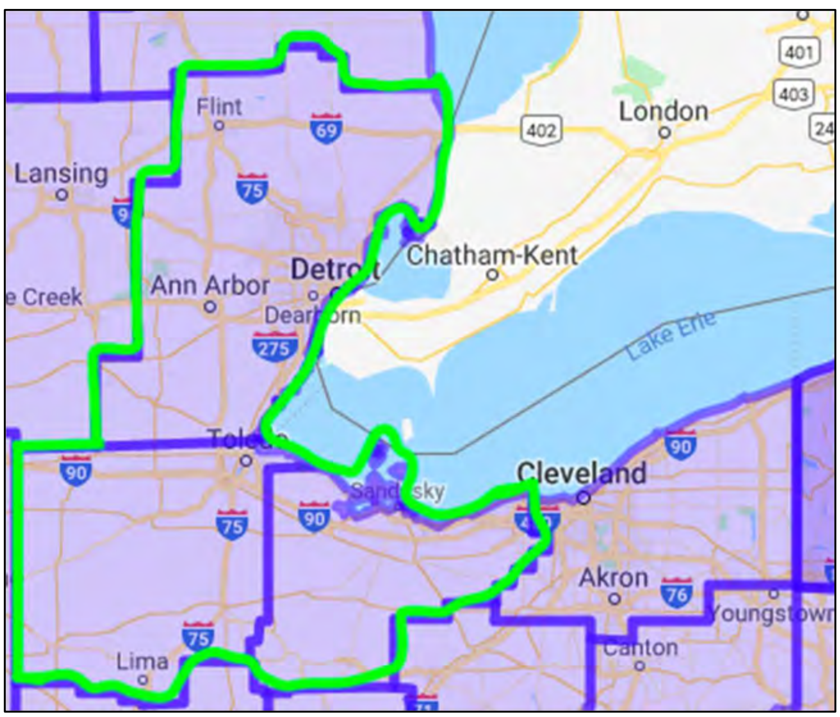


Figure 1. The green outline shows the area of the three NOAA Climate Divisions used for analysis of precipitation trends in the Western Lake Erie climate division.

Changing trends in precipitation have had and will continue to have various impacts on the region. These impacts include increased runoff (possibly containing phosphorus or other chemicals) and flooding, amongst others (Wuebbles et al., 2019). Because of this, it is important to consider and monitor the changes in precipitation.

Status and Trends

An overall increase in annual precipitation totals has been observed in the Western Lake Erie climate division since 1951. Looking solely at the annual increase in total precipitation does not tell the whole story, making it important to examine seasonal trends. The annual trend is broken down seasonally in Figure 2. Each season exhibits an increase in precipitation since 1951, with fall showing the greatest increase and spring showing the smallest increase. It is interesting to note that the percent increase in fall precipitation is well above the annual average, while the percent increase in spring precipitation is well below the annual average.

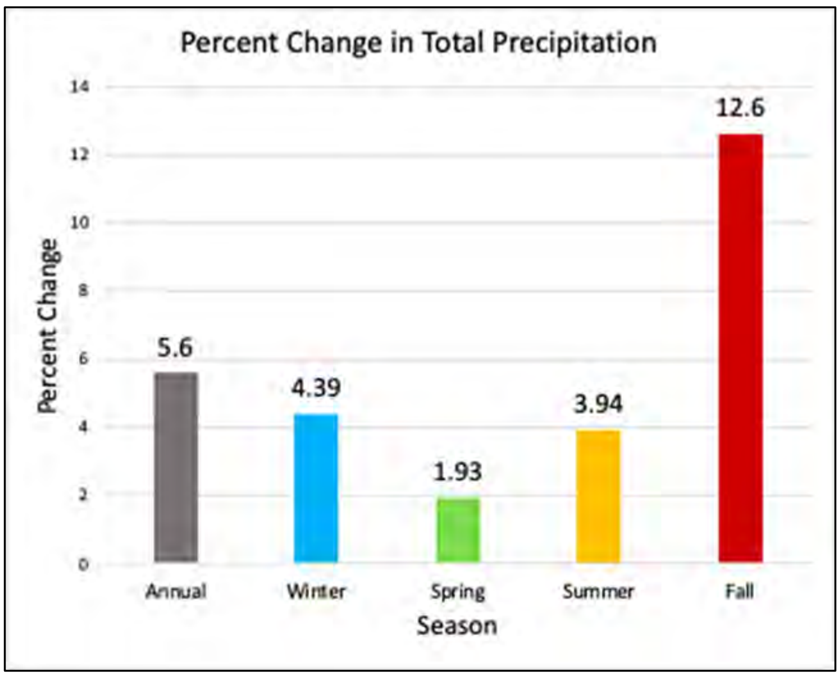


Figure 2. Changes in total average and seasonal precipitation, shown by percentages, in the Western Lake Erie climate division. Calculated as the difference between the 1951-1980 average and the 1951-2017 average, divided by the 1951-1980 average.

It is important to recognize that these values are for average annual or seasonal precipitation. While the overall trend is upward, it is still possible to have extreme precipitation events that appear to be outside of this trend. Extreme precipitation events can include extreme lack of precipitation (drought) or extreme excess of precipitation. Individual seasons exhibit variations in precipitation totals over periods of time. Figure 3 demonstrates this variability, showing the ten-year running averages of seasonal precipitation from 1951 to 2018.

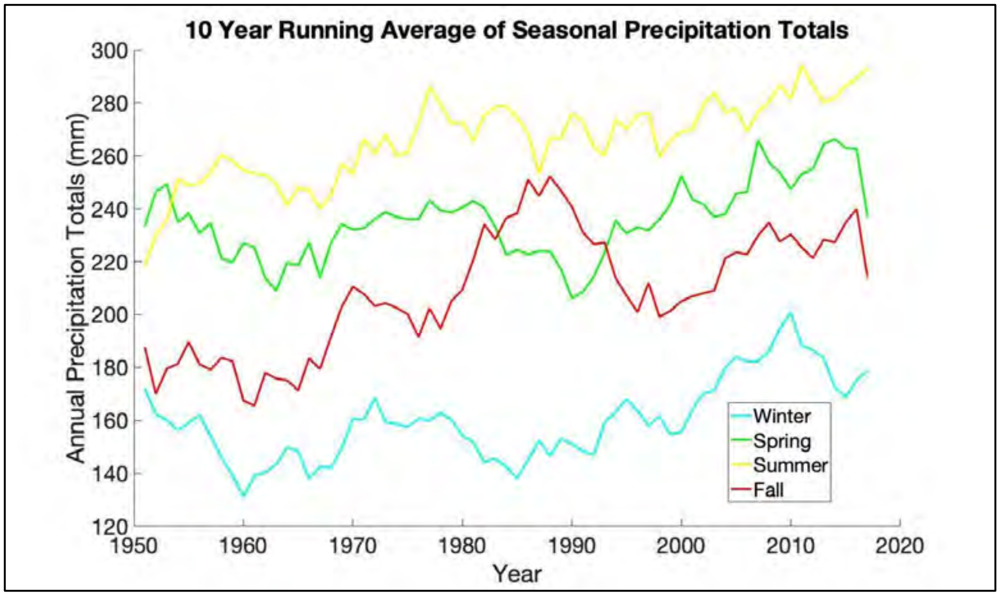


Figure 3. Ten-year running average of individual seasonal precipitation totals plotted together for comparison and demonstration of variability. Each color represents a different season, corresponding with those used in Figure 2.

While the variability is evident, it is also clear that the overall trends are consistent with the data presented in Figure 2. The greatest increase seen in both figures is that of the total precipitation in the fall.

Variability and extremes are also important to consider on an annual time scale. Figure 4 shows the ten-year running average of annual precipitation totals from 1950 to 2018, with individual annual totals represented by black circles that demonstrate annual variability. While the general trend is positive, there are years that have anomalously high or low precipitation.

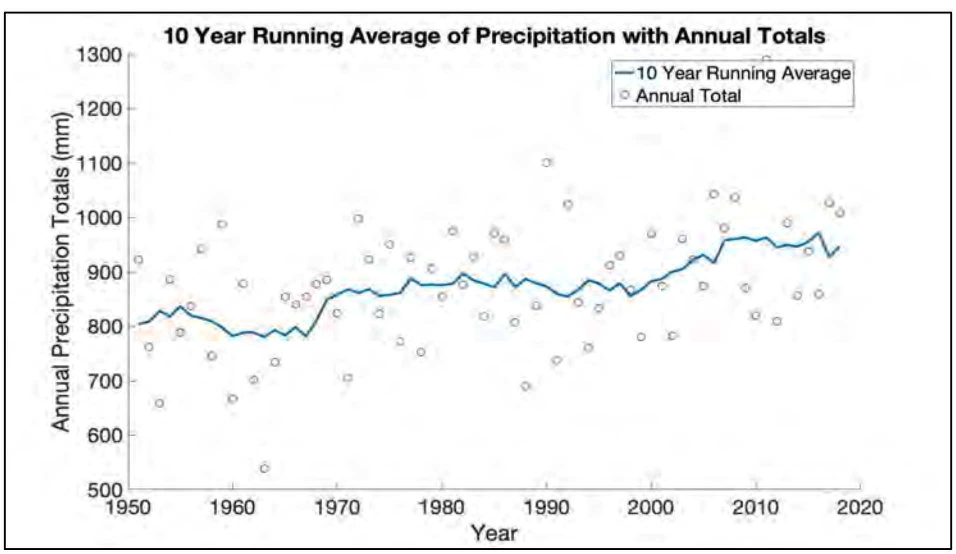


Figure 4. *Comparison of ten-year running average (blue solid) with annual averages (black circles) to demonstrate variability of precipitation.*

Along with an overall increase in total annual precipitation, there has been an increase in the frequency of extreme precipitation events. These events bring high amounts of precipitation in relatively short periods of time. To analyze trends in days with extreme precipitation, days per year above two total precipitation thresholds (i.e., 25 mm and 40 mm) are shown in Figure 5 below. Heavy precipitation is generally observed more at a local, rather than regional scale, so Toledo, OH was chosen to represent a local look at historical heavy precipitation.

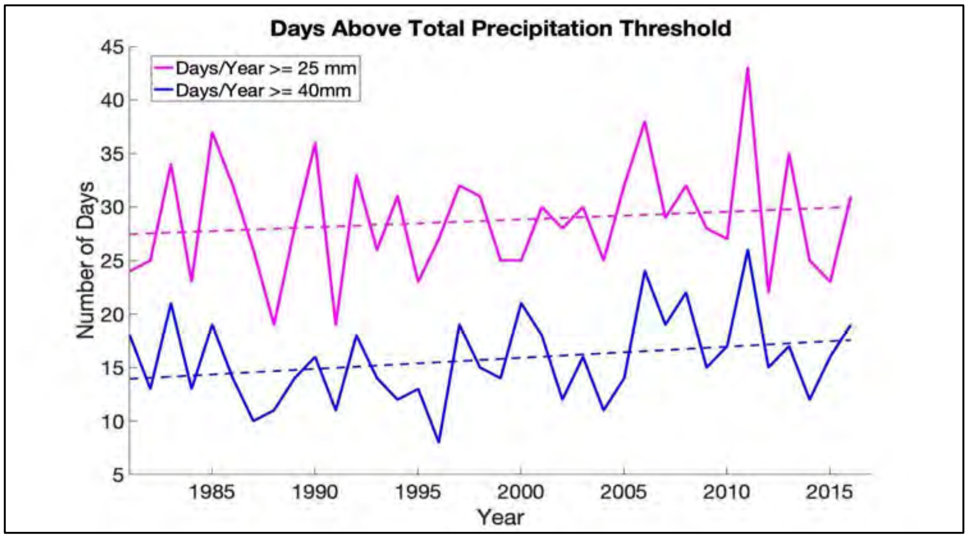


Figure 5. Days above 25 mm (pink) and 40 mm (blue) over time between 1981 and 2016 in Toledo, OH. The solid lines represent the number of days per year at or above the given thresholds while the dashed lines represent linear trendlines.

Aside from slight overall increase in high precipitation days, there is variability in the number of days over 25 mm and 40 mm yearly. This shows that different years can have anomalously high or low numbers of high precipitation days. These days can be hazardous and the possibility of several days with precipitation above these thresholds needs to be considered.

Management Next Steps and Future Research Needs

In the future, total precipitation changes in the Western Lake Erie climate division should continue to be monitored. This will allow for continued analysis of regional trends and planning for future impacts. Monitoring both annual and seasonal trends in total precipitation, along with heavy precipitation days, will allow for better understanding of the changes, and more informed decision making and planning.

Increases in extreme precipitation events impact a range of sectors in the Western Lake Erie climate division. Higher volumes of precipitation can lead to flooding and erosion of coastal areas (Winters et al., 2015). Soil moisture, surface waters, and groundwater supplies could be affected by more frequent summer drought (Wuebbles et al., 2006; Hayhoe et al., 2007; Karl et al., 2009). In addition, runoff has increased in the Lake Erie watershed, leading to the deposition of excess nutrients from agricultural and urban lands, such as phosphorus and nitrogen, into the lake (Michalak et al., 2013). The combined effects of increased atmospheric temperatures, lake water temperatures, and precipitation can also exacerbate harmful algal bloom (HAB) formation (Reutter et al., 2011; Mackey, 2012; Ficke et al., 2007). More runoff from storms leads to higher nutrient loading in Lake Erie. Warmer surface water temperatures, that are influenced by warmer atmospheric temperatures, lead to higher stratification (less vertical mixing) in the lake, which allows these nutrients to stay in the warm surface waters and help form algal blooms (Shuter et al., 2009). All these impacts are important considerations for the management of the Western Lake Erie climate division.

References

Ficke, A.D., Myric., C.A., Hansen, L.J., 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries. 17, 4, 581-613.

Hayhoe K., Wake, C.P., Huntington, T.G., Luo, L., Schwartz, M.D., Sheffield, J., Wood, E., Anderson, B., Bradbury, J., DeGaetano, A., Troy, T.J., Wolfe, D., 2007. Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics 28, 381-407.

Karl, T.R., Melillo, J.M., Peterson, T.C., 2009. Global Climate Change Impacts in the United States. U.S. Global Climate Change Research Program. Cambridge University Press, Cambridge, Massachusetts, USA.

Mackey, S. D., 2012. Great Lakes Nearshore and Coastal Systems, In: Winkler, J., Andresen, J., Hatfield, J., Bidwell, D., Brown, D., (Coordinators), U.S. National Climate Assessment Midwest Technical Input Report.. Available from the Great Lakes Integrated Sciences and Assessments (GLISA) Center, Ann Arbor, Michigan, USA.

Michalak, A.M., Anderson, E.J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloglu, I., Depinto, J.V., Evans, M.A., Fahnenstiel, G.L, He, L., Ho, J.C., Jenkins, L., Johengen, T.H., Kuo, K.C., Laporte, E., Liu, X., McWilliams, M.R., Moore, M.R., Posselt, D.J., Richards, R.P., Scavia, D., Steiner, A.L., Verhamme, E., Wright, D.M., Zagorski, M.A., 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. Proceedings of the National Academy of Sciences. 110, 16, 6448-52.

Reutter, J.M., Ciborowski, J., DePinto, J., Bade, D., Baker, D., Bridgeman, T.B., Culver, D.A., Davis, S., Dayton, E., Kane, D., Mullen, R.W., Pennuto, C.M., 2011. Lake Erie Nutrient Loading and Harmful Algal Blooms: Research Findings and Management Implications. Final Report of the Lake Erie Millennium Network Synthesis Team. Ohio Sea Grant College Program, The Ohio State University. Lake Erie Millennium Network, Windsor, Ontario, Canada.

Shuter, B.J., Trumpickas, J., Minns, C.K., 2009. Forecasting impacts of climate change on Great Lakes surface water temperatures. Journal of Great Lakes Research. 35, 454-463.

Vose, R.S., Applequist, S., Squires, M., Durre, I., Menne, M.J., Williams, Jr, C.N., Fenimore, C., Gleason, K., Arndt, D., 2014. NOAA's Gridded Climate Divisional Dataset (CLIMDIV). MID10, OHD01, OHD01. NOAA National Climatic Data Center. doi:10.7289/V5M32STR. Asheville, North Carolina, USA.

Winters, B.A., Angel, J., Ballerine, C., Byard, J., Flege. A., Gambil, D., Jenkins, E., McConkey, S., Markus, M., Bender, B.A., O'Toole, M.J., 2015. Report for the Urban Flooding Awareness Act. Illinois Department of Natural Resources, Springfield, Illinois, USA.

Wuebbles D., Kling, G., 2006. Executive Summary Updated 2005. Confronting Climate Change in the Great Lakes Region. Union of Concerned Scientists, Washington, D.C., USA.

Wuebbles, D., Cardinale, B., Cherkauer, K., Davidson-Arnott, R., Hellmann, J., Infante, D., Johnson, L., de Loe, R., Lofgren, B., Packman, A., Seglenieks, F., Sharma, A., Sohngen, B., Tiboris, M., Wilson, R., Kunkel, K., Ballinger, A., 2019. An Assessment of the Impacts of Climate Change on the Great Lakes. Environmental Law & Policy Center, Chicago, Illinois, USA.

7.38 Projected Bird Impacts of Climate Change

Cavan Harpur, Ecologist, Parks Canada, cavan.harpur@canada.ca

Joanna Wu, Biologist, National Audubon Society, jwu@audubon.org

Background

Point Pelee National Park is located in southwest Ontario 80 km from Windsor. It is one of Canada's smallest national parks, but internationally renowned for its bird watching each spring and rated one of the premier birding locations in North America (Harrison, 1976). Each spring, nearly 57,000 visitors, including nearly 20,000 bird watchers, come to Point Pelee National Park during the northward migration of birds. Considerable tourism benefits are associated with this annual birding phenomenon.

Birds are useful indicators of ecological changes because they are highly mobile, occupy a broad range of ecological niches, and are generally conspicuous. As climate changes in any given place, the suitability of the area may worsen for some bird species and improve for others. These changes in climate may create the potential for local extirpation (wiping out or elimination) or new colonization. Parks Canada, National Audubon, and Bird Studies Canada have partnered to evaluate projected changes in climate suitability for birds by 2050 at Point Pelee National Park under two climate change scenarios (see Langham et al., 2015 and Wu et al., 2018 for more information regarding how climate suitability is characterized).

The Intergovernmental Panel on Climate Change (IPCC) high-emissions pathway (RCP8.5) represents a future in which little action is taken to reduce global emissions of greenhouse gases (Leggett et al., 1992). The intermediate-emissions pathway (RCP4.5) incorporates efforts to reduce emissions. These emissions' pathways are globally standardized and established by the IPCC for projecting future climate change. The findings presented in this indicator report are model-based projections of how species' distributions may change in response to climate change and are based on the present climate tolerances of each species. A 10-km buffer was applied to the park to match the spatial resolution of the species distribution models (10 x 10 km), and climate suitability was taken as the average of all cells encompassed by the park and buffer. Trends in climate suitability for all species currently reported in the park are based on both Parks Canada and Bird Studies Canada observational data (Nature Counts, 2018), plus those species for which climate at the park is projected to become suitable in the future.

Status and Trends

Trends in Climate Change Impacts on Birds

Adequate models were available for 117 of the 165 species currently found at the park in summer and 113 of the 130 species currently found at the park in winter. Climate change is expected to alter the bird community at the park, with greater impacts under the high-emissions pathway than under the intermediate-emissions pathway (Parker et al., 2019; Figure 1). Improving climate suitability indicates that climate in this park may change in ways that are increasingly favorable to a species. Worsening climate suitability indicates that climate may change in ways that make persistence more difficult for a species.

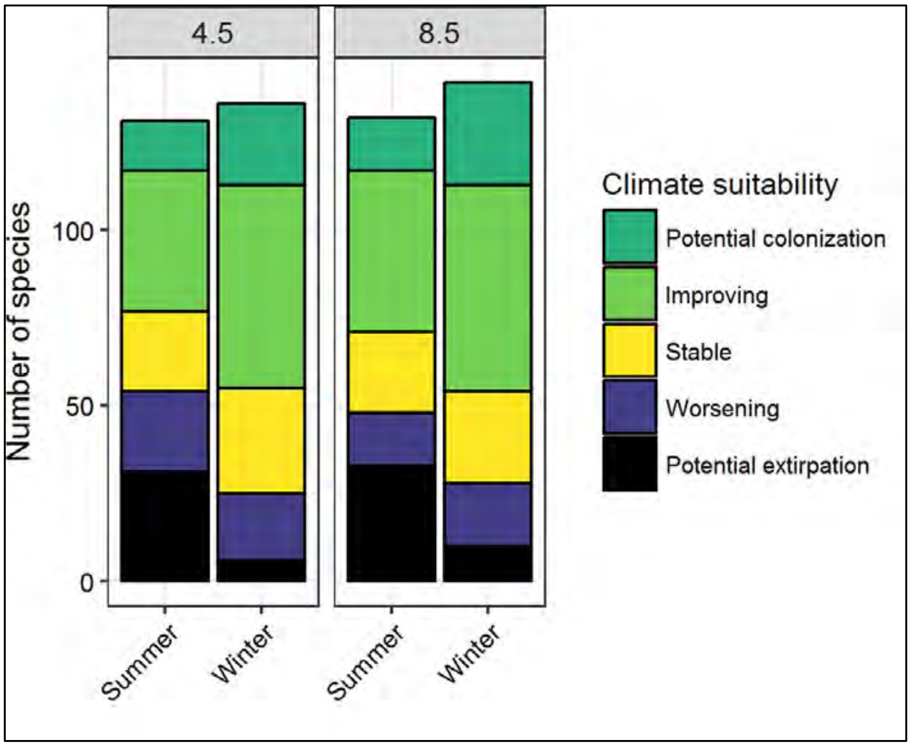


Figure 1. Projected changes in climate suitability for birds at the park, by RCP emissions pathway and season (Parker et al., 2019). Potential colonization indicates species not currently found at the park but may find suitable climate here in the future. Potential extirpation is a subset of species for which climate suitability worsens so much they may no longer persist at the park.

Summer

Among the species likely to be found at the park today, climate suitability in summer under the high-emissions pathway is projected to improve for 46, remain stable for 23, and worsen for 15 species. The climate in the park will no longer be suitable for 33 species in summer, potentially resulting in extirpation of those species from the park. Climate is projected to become suitable in summer for 15 species not found at the park today, potentially resulting in local colonization.

Winter

Climate suitability in winter under the high-emissions pathway is projected to improve for 59, remain stable for 26, and worsen for 18 species. The climate in the park will no longer be suitable for 10 species in winter, potentially resulting in extirpation from the park. Climate is projected to become suitable in winter for 29 species not found at the park today, potentially resulting in local colonization.

Potential Turnover Index

Potential bird species turnover for the park between the present and 2050 is 35% in summer and 29% in winter under the high-emissions pathway. Potential species turnover becomes 31% in summer and 25% in winter under the intermediate-emissions pathway. Turnover index was calculated based on the theoretical proportions of potential extirpations and potential colonizations by 2050 relative to today, and therefore assumes that all potential extirpations and colonizations are realized. According to this index, no change would be represented as 0, whereas a complete change in the bird community would be represented as 100%.

Climate Sensitive Species

The park is or may become home to 20 species that are highly sensitive to climate change across their range (i.e., they are projected to lose climate suitability in over 50% of their current range in North America by 2050; Table 1; Langham et al., 2015). While the park may serve as an important haven for 17 of these climate-sensitive species, three might be extirpated from the park in at least one season by 2050.

Table 1. Climate suitability projections by 2050 under the high-emissions pathway for all birds currently present at the park based on both Parks Canada and Bird Studies Canada observation data from 1980 to 2018, plus those species for which climate at the park is projected to become suitable in the future. "Potential colonization" indicates that climate is projected to become suitable for the species, whereas "potential extirpation" indicates that climate is suitable today but projected to become unsuitable. Omitted species were either not modeled due to data deficiency or were absent from the observation datasets. Observations of late-season migrants may result in these species appearing as present in the park when they may only migrate through. Species are ordered according to order, denoted by alternating background shading.

- Species not found or found only occasionally, and not projected to colonize by 2050

x Species not modeled in this season

^ Species that are highly climate sensitive

Common Name	Summer Trend	Winter Trend
Canada/Cackling Goose	x	Worsening
Mute Swan	x	Worsening
Wood Duck	x	Improving
Gadwall	Potential extirpation^	Improving

Common Name	Summer Trend	Winter Trend
American Wigeon	Potential extirpation^	Improving
American Black Duck	x	Worsening
Mallard	Worsening^	Worsening
Blue-winged Teal	Potential extirpation	Improving
Northern Shoveler	Improving^	Improving
Northern Pintail	Potential extirpation	x
Green-winged Teal	x	Improving
Canvasback	-	Improving
Ring-necked Duck	x	Stable
Greater Scaup	-	Improving^
Lesser Scaup	x	Stable
Surf Scoter	-	Improving
White-winged Scoter	-	Stable
Long-tailed Duck	-	Stable
Bufflehead	x	Improving
Common Goldeneye	-	Stable
Hooded Merganser	x	Improving^
Common Merganser	-	Worsening
Red-breasted Merganser	Potential extirpation	Stable^
Ruddy Duck	Improving	Improving
Northern Bobwhite	Potential colonization	Potential colonization
Wild Turkey	x	Stable
Red-throated Loon	-	Improving
Pacific Loon	-	Stable
Common Loon	-	Improving^
Pied-billed Grebe	x	Improving
Horned Grebe	x	Improving
Double-crested Cormorant	x	Improving
American White Pelican	x	Potential colonization
Brown Pelican	-	Potential colonization^
American Bittern	Improving	Potential colonization^
Great Blue Heron	Stable	Improving

Common Name	Summer Trend	Winter Trend
Great Egret	Improving	Potential colonization
Little Blue Heron	Improving	-
Cattle Egret	Improving	-
Green Heron	Improving	-
Black-crowned Night-Heron	x	Improving
Yellow-crowned Night-Heron	Potential colonization	-
Black Vulture	Potential colonization	-
Turkey Vulture	x	Improving
Golden Eagle	-	Stable
Mississippi Kite	Potential colonization	-
Northern Harrier	Worsening^	Improving
Sharp-shinned Hawk	x	Improving
Cooper's Hawk	x	Worsening
Northern Goshawk	-	Potential extirpation
Bald Eagle	x	Stable
Red-shouldered Hawk	Improving	Improving
Red-tailed Hawk	Improving	Stable
Rough-legged Hawk	-	Worsening
Clapper Rail	-	Potential colonization
Virginia Rail	x	Improving
American Coot	x	Improving
Black-bellied Plover	-	Potential colonization
Killdeer	Improving	Improving
Greater Yellowlegs	-	Potential colonization
Willet	Potential colonization^	Potential colonization^
Marbled Godwit	-	Potential colonization
Ruddy Turnstone	-	Potential colonization^
Dunlin	-	Potential colonization^
Least Sandpiper	-	Potential colonization
Western Sandpiper	-	Potential colonization
Long-billed Dowitcher	-	Potential colonization
American Woodcock	x	Improving

Common Name	Summer Trend	Winter Trend
Laughing Gull	-^	Potential colonization
Ring-billed Gull	Worsening^	Improving
Herring Gull	Stable	Stable^
Great Black-backed Gull	x	Worsening
Black Tern	Potential extirpation	-
Forster's Tern	x	Potential colonization
Rock Pigeon	Worsening	Potential extirpation
Mourning Dove	Improving	Stable
Yellow-billed Cuckoo	Improving	-
Black-billed Cuckoo	Worsening	-
Eastern Screech-Owl	x	Worsening
Great Horned Owl	x	Stable
Snowy Owl	-	Worsening
Common Nighthawk	Improving	-
Chuck-will's-widow	Improving	-
Chimney Swift	Stable	-
Ruby-throated Hummingbird	Improving	-
Belted Kingfisher	Potential extirpation	Improving
Red-headed Woodpecker	Stable	Stable
Red-bellied Woodpecker	Improving	Improving
Yellow-bellied Sapsucker	-	Improving
Downy Woodpecker	Improving	Improving
Hairy Woodpecker	Improving	Stable
Northern Flicker	Stable	Worsening
Pileated Woodpecker	-	Potential colonization
American Kestrel	x	Improving
Merlin	x	Improving^
Peregrine Falcon	x	Improving
Eastern Wood-Pewee	Improving	-
Acadian Flycatcher	Improving	-
Alder Flycatcher	Potential extirpation	-
Willow Flycatcher	Potential extirpation	-

Common Name	Summer Trend	Winter Trend
Least Flycatcher	Potential extirpation	-
Eastern Phoebe	Stable	Improving
Great Crested Flycatcher	Improving	-
Eastern Kingbird	Stable	-
Scissor-tailed Flycatcher	Potential colonization	-
Loggerhead Shrike	Potential colonization	Potential colonization
Northern Shrike	-	Potential extirpation
White-eyed Vireo	Improving	-
Bell's Vireo	Potential colonization	-
Yellow-throated Vireo	Potential extirpation	-
Warbling Vireo	Stable	-
Red-eyed Vireo	Worsening	-
Blue Jay	Stable	Worsening
American Crow	Worsening	Stable
Fish Crow	Improving	Stable
Horned Lark	Potential extirpation	Worsening
Northern Rough-winged Swallow	Improving	-
Purple Martin	Improving	-
Tree Swallow	Potential extirpation	Potential colonization
Barn Swallow	Improving	-
Cliff Swallow	Stable	-
Carolina Chickadee	Potential colonization	Potential colonization
Black-capped Chickadee	Potential extirpation	Potential extirpation
Tufted Titmouse	Improving	x
Red-breasted Nuthatch	Potential extirpation	Potential extirpation
White-breasted Nuthatch	Stable	Stable
Brown Creeper	Potential extirpation^	Stable
House Wren	Worsening	-
Sedge Wren	Worsening	Potential colonization
Marsh Wren	x	Improving
Carolina Wren	Improving	Improving
Bewick's Wren	Potential colonization	-

Common Name	Summer Trend	Winter Trend
Blue-gray Gnatcatcher	Improving	-
Golden-crowned Kinglet	-	Stable
Ruby-crowned Kinglet	-	Improving
Eastern Bluebird	Stable	Stable
Hermit Thrush	Potential extirpation	Improving
Wood Thrush	Stable	-
American Robin	Worsening	Improving
Gray Catbird	Worsening	Improving
Brown Thrasher	Improving	Improving
Northern Mockingbird	Improving	Improving
European Starling	Worsening	Stable
American Pipit	-	Stable
Cedar Waxwing	Potential extirpation	Stable
Smith's Longspur	-	Potential colonization
Snow Bunting	-	Worsening
Ovenbird	Stable	-
Worm-eating Warbler	Improving	-
Northern Waterthrush	Potential extirpation	-
Blue-winged Warbler	Potential extirpation	-
Black-and-white Warbler	Stable	-
Prothonotary Warbler	Improving	-
Mourning Warbler	Potential extirpation	-
Kentucky Warbler	Improving	-
Common Yellowthroat	Stable	Improving
Hooded Warbler	Stable	-
American Redstart	Potential extirpation	-
Northern Parula	Potential colonization	-
Yellow Warbler	Potential extirpation	-
Chestnut-sided Warbler	Potential extirpation	-
Palm Warbler	-	Potential colonization^
Pine Warbler	-	Potential colonization
Yellow-rumped Warbler	-	Improving

Common Name	Summer Trend	Winter Trend
Yellow-throated Warbler	Potential colonization	-
Prairie Warbler	Potential colonization	-
Canada Warbler	Potential extirpation	-
Yellow-breasted Chat	Improving	-
Eastern Towhee	Improving	x
American Tree Sparrow	-	Worsening
Chipping Sparrow	Potential extirpation	Improving
Clay-colored Sparrow	Stable	-
Field Sparrow	Stable	Improving
Vesper Sparrow	Potential extirpation	-
Lark Sparrow	Improving	-
Savannah Sparrow	Potential extirpation	Improving
Grasshopper Sparrow	Improving	-
Le Conte's Sparrow	-	Potential colonization
Fox Sparrow	-	Improving
Song Sparrow	Potential extirpation	Worsening
Swamp Sparrow	Potential extirpation	Improving
White-throated Sparrow	-	Improving
Harris's Sparrow	-	Potential colonization
White-crowned Sparrow	-	Worsening
Dark-eyed Junco	-	Stable
Summer Tanager	Improving	-
Scarlet Tanager	Stable	-
Northern Cardinal	Improving	Improving
Rose-breasted Grosbeak	Stable	-
Blue Grosbeak	Improving	-
Indigo Bunting	Improving	-
Painted Bunting	Potential colonization	-
Dickcissel	Improving	-
Bobolink	Potential extirpation	-
Red-winged Blackbird	Stable	Improving
Eastern Meadowlark	Improving	Improving

Common Name	Summer Trend	Winter Trend
Rusty Blackbird	-	Improving
Brewer's Blackbird	-	Potential colonization
Common Grackle	Stable	Improving
Great-tailed Grackle	Potential colonization	Potential colonization
Brown-headed Cowbird	Improving	Improving
Orchard Oriole	Improving	-
Baltimore Oriole	Worsening	-
House Finch	Worsening	Potential extirpation
Purple Finch	Potential extirpation	Potential extirpation
White-winged Crossbill	-	Potential extirpation
Common Redpoll	-	Potential extirpation
Pine Siskin	Potential extirpation	Potential extirpation
American Goldfinch	Worsening	Improving
House Sparrow	x	Worsening

Management Next Steps

Parks differ in potential colonization and extirpation rates, and therefore different climate change adaptation strategies may apply. Under the high-emissions pathway, Point Pelee falls within the high turnover group. Parks anticipating high turnover can focus on actions that increase species' ability to respond to environmental change, such as increasing the amount of potential habitat, working with cooperating agencies and landowners to improve habitat connectivity for birds across boundaries, managing the disturbance regime, and possibly more intensive management actions. Furthermore, park managers have an opportunity to focus on supporting the 17 species that are highly sensitive to climate change across their range (Table 1; Langham et al., 2015) for which the park is a potential refuge. Monitoring to identify changes in bird communities will inform the selection of appropriate management responses.

Caveats

The species distribution models included in this study are based solely on climate variables (i.e., a combination of annual and seasonal measures of temperature and precipitation). Significant changes in climate suitability, as measured here, will not always result in a species response, and all projections should be interpreted as potential trends. Multiple other factors mediate responses to climate change, including habitat availability, ecological processes that affect demography, biotic interactions that inhibit and facilitate species' colonization or extirpation, dispersal capacity, species' evolutionary adaptive capacity, and phenotypic plasticity (e.g., behavioral adjustments). Ultimately, models can tell us where to focus our concern and which species are most likely to be affected, but monitoring is the only way to validate these projections and should inform any on-the-ground conservation action.

References

Parker, S., Bateman, B., Wu, J., Whitaker, D., Harpur, C., Gahbauer, M., 2019. Birds and climate change: Point Pelee National Park. Ottawa, Ontario, Canada.

Harrison, G.H., 1979. Bird watching: the fastest-growing family fun is an industry. Sci. Digest. 86, October, 74- 80.

Langham, G.M., Schuetz, J.G., Distler, T., Soykan, C.U., Wilsey, C., 2015. Conservation Status of North American Birds in the Face of Future Climate Change. PLOS ONE. 10, 9, e0135350.

Leggett, J., Pepper, W.J., Swart, R.J., Edmonds, J., Meira Filho, L.G., Mintzer, I., Wang, M.X., Watson, J., 1992. Emissions Scenarios for the IPCC: An update, in: Climate Change 1992: The Supplementary Report to The IPCC Scientific Assessment. Cambridge University Press, UK, pp. 68-95.

Nature Counts, 2018 (www.birdscanada.org/birdmon). Bird Studies Canada, Port Rowan, Ontario, Canada.

Wu, J.X., Wilsey, C.B., Taylor, L., Schuurman, G.W., 2018. Projected avifaunal responses to climate change across the U.S. National Park System. PLOS ONE. 13, 3, e0190557.

This page intentionally left blank.

7.39 Walleye Population of Lake Erie

T. Wills, Michigan Department of Natural Resources

S. Marklevitz, Ontario Ministry of Natural Resources and Forestry

M. Faust, Ohio Department of Natural Resources

Background

Walleye are top predators in the Lake Erie food web and they occupy habitat throughout the lake and its tributaries, including the Detroit River. As juveniles, they consume zooplankton (which are microscopic animals), aquatic insects, and other small fish, but as they mature and become the top predator their diets shift to predominately small bodied fish.

As a top predator, walleye have the ability to structure small-bodied prey fish communities within the lake through top-down pressure. Accordingly, instability in the walleye populations could also lead to instability of other fish populations with a potential to compromise the balance within Lake Erie's ecosystem. This role makes them a good indicator of ecological health.

In addition to their ecological role in Lake Erie, walleye also support important commercial and recreational fisheries in the U.S. and Canada. On average, approximately four million walleyes are harvested from the western and central basins of Lake Erie each year (Figure 1). The fisheries are cooperatively managed by the Lake Erie Committee (LEC) of the Great Lakes Fishery Commission. The LEC is a binational group, with representation from the Michigan Department of Natural Resources, the New York State Department of Environmental Conservation, the Ohio Department of Natural Resources, the Pennsylvania Fish and Boat Commission, and the Ontario Ministry of Natural Resources and Forestry.

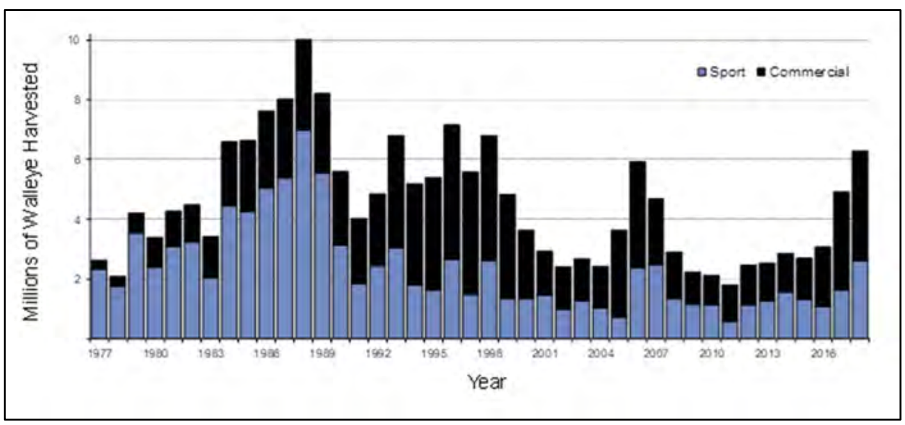


Figure 1. Annual harvest of Lake Erie walleye by fishery, 1977 to 2018.

Status and Trends

In 1970, walleye harvest was prohibited due to mercury contamination coming from the St. Clair and Detroit rivers. Walleye harvest reopened in 1972 after mercury concentrations declined. International harvest quotas were introduced in 1976 and the LEC began estimating walleye population size in Lake Erie in 1978 (Lake Erie Walleye Task Group, 2019). These annual population estimates are generated using statistical catch at age models, which incorporate data from annual gill net and bottom trawl surveys, along with estimated recreational and commercial fisheries effort and harvest.

Figure 2 presents the population estimate for age 2 and older walleye from Lake Erie from 1978 through 2018. These trend data show an increase from the late 1970s through the mid-1980s, followed by a decline which began in the late 1980s and lasted 10-15 years. A critical minimum in the walleye population was reached in 2000, causing declining angler interest and compromised commercial economics.

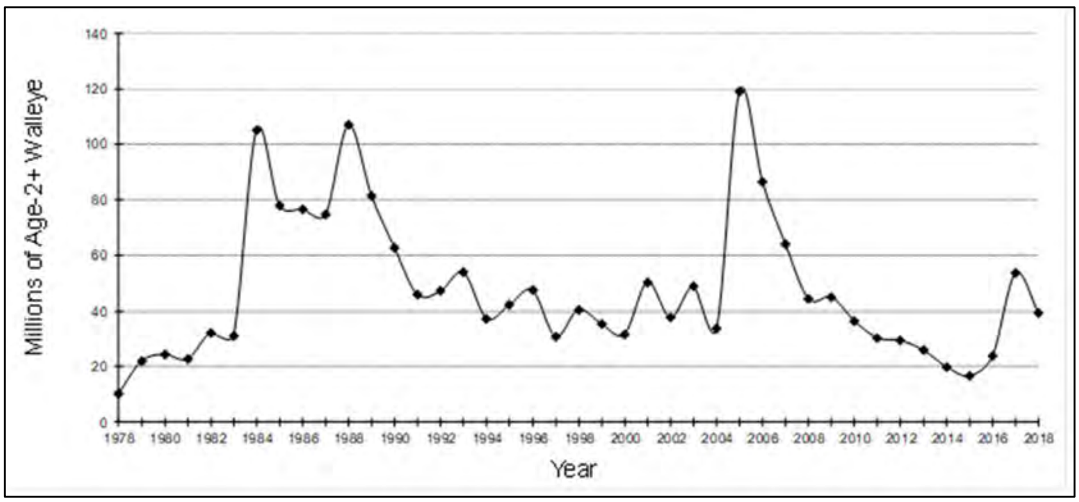


Figure 2. Population estimate of age 2 and older Lake Erie walleye, 1978-2018.

The declining population trajectory changed in 2005, with the recruitment of the large 2003-year class. The estimated abundance of age 2 and older walleye jumped, exceeding the peak estimates observed in the 1980s (Figure 2).

The walleye population experienced another declining trend through 2015 (Figure 2), as the 2003-year class aged. However, moderate to strong year classes were produced in 2014, 2015, and 2017, which have increased walleye abundance in recent years (Figure 2).

Management Next Steps

The first Lake Erie Walleye Management Plan (WMP)(Locke et al., 2005) was adopted in 2005, establishing fishery quality objectives that the LEC employed as a basis for walleye management. The WMP is a cooperative and collaborative product of the LEC member jurisdictions and an example of each jurisdictions' commitment to the ongoing sustainability and economic viability of this important fishery. This culture of collaboration is critical to the sustainable management of Lake Erie's walleye fishery.

The 2005 WMP identified limits and uncertainties on walleye management as well as sustainability thresholds and recognized the Fish Community Goals and Objectives for Lake Erie (Ryan et al., 2003), which indicate that a sufficient number of walleye need to be present to act as a keystone predator and allow stakeholders to realize a broad distribution of benefits throughout the lake (Kayle et al., 2015). The LEC also recognized the need to improve transparency and incorporate stakeholder input into structured and science-based walleye management decisions, including setting annual total allowable catch quotas, and began to consider mechanisms to support this. This was realized in 2011 with the formation of the Lake Erie Percid Management Advisory Group (LEPMAG), which developed an updated Walleye model that was implemented in 2013 (Lake Erie Walleye Task Group, 2019). The second WMP (Kayle et al., 2015) was adopted in 2014 and was recently extended for an additional five years, with a performance evaluation scheduled near the end of that period.

The following are the goal and objective from the Lake Erie's Fish Community Goals and Objectives (Ryan et al., 2003) that are relevant to walleye:

- Relevant Goal – Secure a balanced, predominantly cool water fish community with walleye as a key predator in the western basin, central basin, and the nearshore waters of the Eastern Basin.

- Relevant Objective – Provide sustainable harvests of walleye for all areas of the lake and maintain and promote genetic diversity by identifying, rehabilitating, conserving, and/or protecting locally adapted stocks.

Research/Monitoring Needs

To help ensure maintenance of walleye stock diversity and sustainability of the population, several areas of research and investigation must be addressed. These needs are reflected in the charges of the Lake Erie Walleye Task Group (WTG) and are addressed collaboratively by individual agencies as well as their federal and academic partners. In addition to maintaining and updating the centralized time series of datasets required for binational population models and assessment producing the annual Recommended Allowable Harvest, the WTG maintains a working knowledge of, and actively participates in, research relating to walleye abundance estimation and forecasting, age/size/spatial stock structure (migration rates), recruitment, and mortality. The WTG also provides evaluation and guidance for incorporating new research into Lake Erie walleye management to produce the most scientifically sound and reliable population models.

References

Kayle, K., Oldenburg, K., Murray, C., Francis, J., Markham, J., 2015. Lake Erie Walleye Management Plan 2015-2019. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Lake Erie Walleye Task Group, 2019. Report for 2018 by the Lake Erie Walleye Task Group. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Ryan, P., Knight, R., MacGregor, R., Towns, G., Hoopes, R., and Culligan, W., 2003. Fish Community Goals and Objectives of Lake Erie. Great Lakes Fishery Commission Special Publication 03-02, Ann Arbor, Michigan, USA.

Contact Information regarding Walleye Population of Lake Erie

Questions regarding the Lake Erie walleye population can be addressed to individual fisheries management agencies in the LEC jurisdictions of Michigan, New York, Ohio, Ontario, and Pennsylvania. More information on Lake Erie walleye is also available on the Great Lakes Fishery Commission LEC website: http://www.glfc.org/lake-erie-committee.php.

7.40 West Nile Virus

Emerging and Zoonotic Infectious Diseases Section

Michigan Department of Health and Human Services

517-335-8165; www.michigan.gov/emergingdiseases

Background

West Nile virus is a mosquito-transmitted disease that was first discovered in Uganda in 1937. It is considered an "Emerging Infectious Disease" because of the spread beyond its traditional geographic range. In recent years West Nile virus has caused illness in birds, horses, and humans in Europe, and now the United States after it was first discovered in the U.S. in 1999 in New York City. Today, West Nile virus is found in all 48 contiguous states and is the most common cause of mosquito-borne disease in the U.S.

West Nile virus is a disease of birds that is transmitted to humans by the bite of an infected mosquito. Mosquitoes that transmit West Nile virus are almost exclusively of the genus *Culex*, which are commonly found in urban environments, and lay their eggs in stagnant water that is rich in organic matter. Most humans infected with West Nile virus develop no symptoms of illness, however about 20 percent may become sick with a fever, headache, and body aches three to 14 days after receiving a bite from an infected mosquito. Rarely, persons infected with West Nile virus may develop more severe disease, including encephalitis and sometimes death. Severe disease can occur in people of any age. However, people over 60 years of age are at the greatest risk for severe disease. People with certain medical conditions, such as cancer, diabetes, hypertension, kidney disease, and people who have received organ transplants, are also at greater risk for serious illness.

Individuals presenting with encephalitis, meningitis, or other acute neurologic illness in which an infectious etiology is suspected should be tested for mosquito-borne diseases, including West Nile virus, during the mosquito season. Testing is available free of charge at the Michigan Department of Health and Human Services Bureau of Laboratories through Michigan healthcare providers. Symptoms of encephalitis (inflammation of the brain) and meningitis (inflammation of the spinal cord and brain linings) include severe headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, muscle weakness, convulsions, and paralysis.

Status and Trends

In response to the threat of West Nile virus in Michigan, the West Nile Virus Working Group (i.e., a multi-agency work group) emerged from the Arbovirus Core Group in 2000 (Michigan Department of Community Health, 2006b). In 2001, a toll-free hotline was established for citizens to report dead crows, as monitoring death amongst these birds can be an early indicator of virus activity in an area. As a result of this effort, West Nile virus was first detected in Michigan in August 2001 in dead crows.

Human illness due to West Nile virus in Michigan was first documented in 2002, when a large-scale outbreak occurred in the Upper Midwest. Human cases were preceded by a massive die-off in resident corvid (crows, blue jays, ravens) populations. From early May to late October 2002, the Michigan Department of Community Health received over 10,000 reports of dead birds from the public. Southeast Michigan was particularly affected, accounting for 531 of 644 West Nile virus illnesses and 51 deaths statewide confirmed by public health authorities that year.

Although West Nile virus is now well-established in Michigan, we continue to maintain a multi-agency work group, with members from the Michigan departments of Natural Resources (MDNR), Agriculture and Rural Development (MDARD), the Environment, Great Lakes, and Energy (EGLE), Health and Human Services (MDHHS), and from Michigan State University. We also continue to ask citizens to monitor the health of wildlife by reporting sick, dead, or dying animals to the MDNR Wildlife Disease Laboratory. Wildlife submitted to the MDNR are tested for arboviruses by the Michigan State University Veterinary Diagnostic Laboratory. In 2018, 197 avian cases were reported, providing early warning of local West Nile virus activity. West Nile virus also affects horses and suspected cases are reportable to MDARD, who can coordinate testing for West Nile virus and other mosquito-borne viruses; in 2018, two horses were reported with West Nile virus.

Mosquito Management

Mosquito surveillance for West Nile virus has been conducted in Michigan since 2001. In 2018, over 4,000 mosquito pools were tested for the virus, and 159 pools were found to be positive. The West Nile Virus Community Surveillance Project provides training and equipment for mosquito trapping and testing in several local health jurisdictions in southeast Michigan and in Kent county. Mosquito control districts in Bay, Midland, Saginaw, and Tuscola counties additionally conduct their own surveillance to identify mosquitoes and test them for the presence of viruses.

There are many species of mosquito in Michigan, and some are more competent at transmitting West Nile virus than others. In the eastern United States, the primary vectors are within the genus *Culex*. These mosquitoes are active in the summer, and peak biting times are dusk and dawn. These mosquitoes are also more common in urban environments, where they reproduce readily in man-made containers containing nutrient-rich water. These habitats may include sewer catch basins, bird feeders, unused swimming pools, scrap tires, or practically any other man-made container.

Since it is not feasible to control the virus within wild bird populations, our best target for control is the mosquito. The use of licensed larvicides which kill the immature mosquitoes (larvae) in water have been shown to reduce mosquito populations and disease risk when used within an integrated mosquito management program. It is unlikely that individual treatment by citizens in a piecemeal fashion will reduce the risk, because mosquitoes can breed nearby in areas that are untreated.

Management Next Steps

The MDHHS considers West Nile virus an emerging disease issue and devotes considerable resources to surveillance, management, and public education. No human vaccine against West Nile virus is currently available so the most effective way to prevent the disease is to prevent mosquito bites. Effective practices include:

- Use U.S. Environmental Protection Agency (EPA)-registered insect repellents when you go outdoors. Repellents containing DEET, picaridin, IR3535, and some oil of lemon eucalyptus and para-menthane-diol products provide longer-lasting protection.
- Wear long sleeves and pants from dusk through dawn when many mosquitoes are most active.
- Install or repair screens on windows and doors. If you have it, use your air conditioning.
- Help reduce the number of mosquitoes around your home. Empty standing water from containers such as flowerpots, gutters, buckets, pool covers, pet water dishes, discarded tires, and birdbaths at least once a week.

Research/Monitoring Needs

Testing will continue to be conducted in order to provide community-based information about West Nile virus activity in birds and mosquitoes. The State of Michigan compiles surveillance information on the “Emerging Diseases” website, which can be viewed at: www.michigan.gov/westnilevirus.

The public can also report sick or dead birds at https://www2.dnr.state.mi.us/ORS/Home, with feedback as to whether the bird is needed for surveillance purposes. Communities can use this information to target their intervention and prevention strategies to areas where West Nile virus activity has been detected. Michigan health workers are implementing a system of animal and human disease surveillance that utilizes geographic information system mapping capabilities to detect outbreaks more rapidly. Research continues on a possible human vaccine and health treatment options.

References

Centers for Disease Control and Prevention, 2019. National Center for Emerging and Zoonotic Infectious Diseases, Division of Vector-Borne Diseases: West Nile Virus Prevention. Lansing, Michigan, USA. http://www.cdc.gov/westnile/prevention/index.html. (accessed September 2019).

Michigan Department of Health and Human Services, 2019. Emerging Disease Issues: West Nile Virus. https://www.michigan.gov/emergingdiseases/0,4579,7-186-76711_76752---,00.html (accessed September 2019).

Links for More Information

Michigan Department of Health and Human Services:
https://www.michigan.gov/westnile

Centers for Disease Control and Prevention:
https://www.cdc.gov/westnile/index.html

7.41 Canadian Habitat Restoration in the Detroit River

Jacqueline Serran, Detroit River Canadian Cleanup, serran@detroitriver.ca

Claire Sanders, Detroit River Canadian Cleanup, sanders@detroitriver.ca

Background

The Detroit River is a 51-km connecting channel that links Lake St. Clair to the western basin of Lake Erie. The river runs through two major urban areas (Detroit, Michigan and Windsor, Ontario) and has long been used for industrial and recreational purposes. Over the past 100 years, the river, its shoreline, and watershed were impacted by considerable industrial, urban, and agricultural development. As these pressures became more intense, habitat for species began to disappear and become degraded. The construction of shipping channels, dumping of dredge spoils, hardening of the shoreline, and destruction of shallow wetlands all contributed to the loss and modification of habitat on the Detroit River (Manny et al., 1988). For example, spawning habitat for lake whitefish and lake sturgeon removed during dredging of the river bottom for navigational purposes, resulted in large population decreases and near extirpation for both species (Roseman et al., 2007). The loss of habitat in the Detroit River and on its shores is one of the factors that led to the river to be designated a Great Lakes Area of Concern in 1985 (Green et al., 2010). The Detroit River Canadian Cleanup (DRCC) partnership and the agencies responsible for implementing the Remedial Action Plan that addresses habitat loss and other concerns in the river, have been exploring and implementing actions to reduce the impacts of habitat loss. Actions include protecting remaining habitat, replacing lost habitats through restoration, or enhancing or improving the function of existing natural features.

Status and Trends

Delisting Criteria for the Habitat Beneficial Use Impairment (BUI)

The following four categories of delisting criteria are identified for the “Loss of Fish and Wildlife Habitat” beneficial use impairment (BUI) for the Canadian side of the Detroit River: coastal wetlands; aquatic and riparian habitat; shoreline softening; and terrestrial habitat. The delisting criteria state that the “Loss of Fish and Wildlife Habitat” BUI will be considered not impaired on the Canadian side of the Detroit River when the following criteria have been achieved:

a) “Coastal wetlands: protect existing coastal wetland habitat and restore wetland function in priority areas of the AOC and its watershed.

b) Aquatic and riparian habitat: protect existing deep water, coastal spawning, and tributary fish and aquatic wildlife habitat and restore ecosystem function in priority areas in, and hydrologically connected to, the Detroit River.

c) Shoreline softening: develop and begin to implement a shoreline management strategy to soften and naturalize Detroit River Canadian shoreline, whenever opportunities arise.

d) Terrestrial habitat: protect existing natural terrestrial corridors and restore ecosystem function between the Detroit River and the Ojibway Prairie Complex, the LaSalle Candidate Natural Heritage sites, and other major identified habitat sites."

Identifying and Prioritizing Habitat Restoration

As part of the Remedial Action Plan, strategies to prioritize habitats within the Detroit River and its watershed for potential restoration or protection, where possible, were developed to guide future habitat-related actions. The Ontario Ministry of Natural Resources (1993) developed a survey of candidate sites on both the St. Clair and Detroit rivers for Potential Habitat Rehabilitation/Enhancement. More recently, the Detroit River Canadian Cleanup Habitat Work Group created the Canadian Habitat Priorities Report (2007) outlining priority habitat sites within the river. This includes 18 sites with significant habitats located in the river and its watershed where future efforts can be focused on protection, restoration, or acquisition.

Priority has been placed on creation of habitat historically lost in shallow, coastal, in-river areas within the Canadian side of the Detroit River proper. To determine the feasibility of the restoration of some of these areas, a study was commissioned in 2015 to assess the potential of seven habitat creation sites within the Detroit River. This study examined the non-biological characteristics of restoring and enhancing each potential habitat site, as well as the feasibility of the potential project, while taking into account physical habitat, hydrography, cost, and navigational hazards. These seven sites were located from upstream Detroit River (two at Peche Island), to midstream Detroit River (three at Fighting Island), to downstream Detroit River (two at Boblo Island). The proposed in-water works consist of constructing a mixture of sheltering islands, shoals, and reefs at these sites to create wetlands for wildlife and fish, as well as establish aquatic vegetation in backwater areas to provide fish spawning and nursery areas. A decision matrix is being used to rank proposed restoration sites using ecological, logistical, and economic factors.

Habitat Restoration on the Canadian Side of the Detroit River

The location of habitat restoration projects in the Detroit River and its watershed can be found in Figure 1.

Shoreline Softening

On the Canadian side of the Detroit River, 19 habitat restoration/enhancement projects have been or are planned to be implemented by many Detroit River Canadian Cleanup (DRCC) partners, including Environment and Climate Change Canada through the Great Lakes Sustainability Fund, Ontario Ministry of Natural Resources and Forestry through the Canada-Ontario Agreement, Essex Region Conservation Authority (ERCA), and others (Table 1). To date, the majority of habitat restoration on the Canadian side of the river has been via shoreline softening. A total of 14 shoreline softening projects have been completed on the Canadian shoreline of the Detroit River (Table 1). These softening projects involve putting in rocks, plants, and other materials to stabilize the shoreline. Unlike sheet steel and other 'hard' shoreline stability methods, soft shorelines not only reduce shoreline erosion, but also provide an ecological benefit (Sanders, this report: 7.55). Some of the shoreline softening projects also incorporated other habitat features such as shoals, offshore sheltering islands, and root wads, to further enhance habitat (Table 1).

Reefs

In addition to the shoreline softening projects, reef, fish habitat, and wetland enhancement projects have been constructed in the Detroit River. In 2008, a sturgeon reef was constructed at the northeast tip of Fighting Island. The project was a binational effort, with both American and Canadian partners committing resources to the project. The reef was expanded in 2013, creating a total of 0.84 hectares (0.36 hectares in 2008 and 0.48 hectares in 2013) of aquatic, deep water habitat. The first stage of the project (2008) constructed a boulder field and 12 individual reefs made up of four different rock types. The expansion phase of this project (2013) constructed one reef bed made up of one type of stone (15.2-30.5 cm limestone).

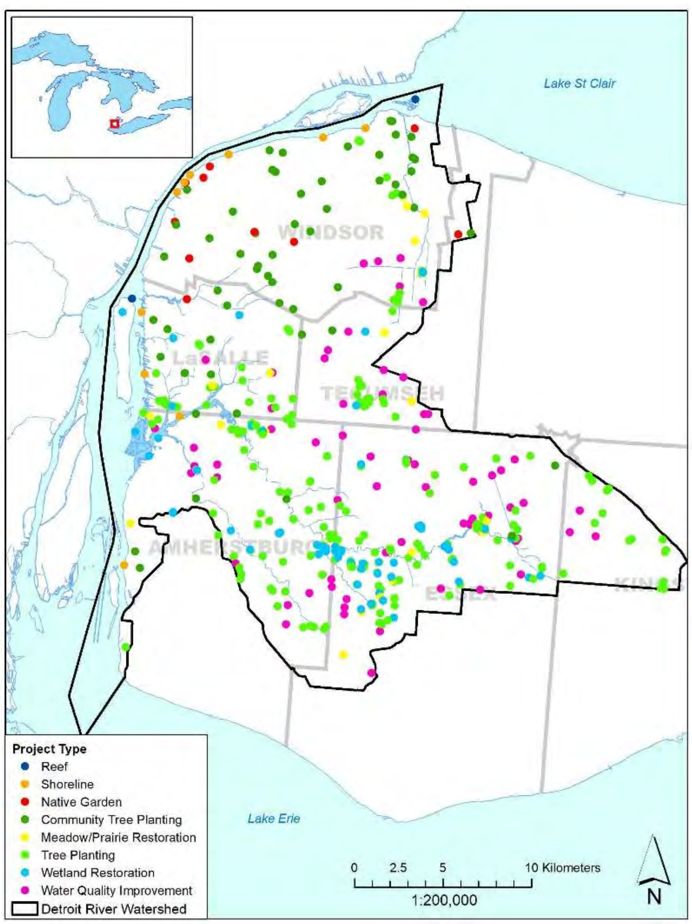


Figure 1. Location of habitat restoration projects on the Canadian side of the Detroit River and its watershed from 2000 to 2019.

Table 1. Habitat projects implemented on the Canadian side of the Detroit River, 1996-2019 (partners included: ERCA, Ministry of Natural Resources and Forestry, Environment and Climate Change Canada, City of Windsor, Town of LaSalle, Town of Amherstburg, Parks Canada, Windsor Port Authority, University of Windsor, Lafarge Canada, Dean Construction, Swim, Drink, Fish, and BASF Corporation). Modified from Hartig et al. (2018).

Location	Project Description	Date
Ruwe Marsh Restoration Project	Repaired existing finger dike structure to protect existing, ecologically important Detroit River habitat. The restoration efforts resulted in the repair of 1,125 m of deteriorated dike protecting 366 ha of downstream wetland as well as providing additional protection to the dike walls of the enclosed wetland.	1995
NE Shore of Fighting Island, LaSalle	Increased shoreline sinuosity by constructing groins that increased stability and enhanced habitat	1996
Dean Construction, LaSalle	Naturalized 550 m of shoreline; established 0.45 ha storm water pond to treat runoff	1999
Goose Bay, Windsor	Stabilized 200 m of shoreline with riprap and native plants, and enhanced fish habitat	1999–2000
St. Rose Beach Park, Windsor	Stabilized 200 m of shoreline and reconstructed shallow beach area; replaced concrete retaining wall with riprap and added fish habitat	2000–2001
Windsor Riverfront (Langlois to Moy Aves.) and the Hatch Wildflower Garden	Created a sloping rock revetment along 472 m of shoreline and rock beach with a shoal with native vegetation	2001
McKee Park, Windsor	Protected and enhanced 135 m of shoreline; constructed 0.17 ha of offshore barrier islands and submerged shoals to reduce high energy currents and to improve fish habitat	2003
Fort Malden, Amherstburg	Stabilized 300 m of shoreline and constructed a rock revetment and offshore deepwater rock/cobble shoals to enhance fish habitat and create lake sturgeon spawning habitat	2004
NW Shore of Fighting Island, LaSalle	Stabilized shoreline to a depth of 37 cm with five-cm crushed limestone bound together with the Elastocoast product	2007
Sturgeon Spawning Reef at Fighting island	Created a 0.84-hectare spawning reef at the northeast tip of Fighting island.	2008, expansion 2013
Windsor Riverfront (Elm to Caron Aves.)	Created rock revetment, cobble and sand beach, sheltering structures, and submerged shoal. Stabilized approximately 250 m of shoreline	2007
Riverdance Park, LaSalle	Removed old marina; stabilized shoreline (approximately 175 m of shoreline) and enhanced wetland and fish habitat	2009-2010

Table 1. Habitat projects implemented on the Canadian side of the Detroit River, 1996-2019 (partners included: ERCA, Ministry of Natural Resources and Forestry, Environment and Climate Change Canada, City of Windsor, Town of LaSalle, Town of Amherstburg, Parks Canada, Windsor Port Authority, University of Windsor, Lafarge Canada, Dean Construction, Swim, Drink, Fish, and BASF Corporation). Modified from Hartig et al. (2018).

Location	Project Description	Date
Windsor Central Riverfront (Glengarry to Langlois)	Restored 550 m of shoreline and enhance habitat using a diversity of substrate types and sizes	2011
River Canard Park, Amherstburg	Removed concrete shore protection structure and restored 200 m of shoreline and habitat	2012
Lafarge Inc., Windsor	Stabilized and increased sinuosity of 360 m of shoreline using a diversity of rock types to increase overall shoreline length at the site and offer a diversity of interstitial spaces	2013
HMCS Hunter at Mill Street, Windsor	Placed sloped armor stone along 175 m of shoreline to improve fish and aquatic habitat. Root wads were submerged in the calm water of the harbor to provide habitat for fish and turtles.	2015
Collavino wetland restoration	Refurbishment of existing dykes and installation of pumping infrastructure to manage water levels within the wetland.	2019
Peche Island Erosion Mitigation and Habitat Enhancement Project	Construction of sheltering islands on the north and northeast sides of the island to protect the island from erosion and create a 10.5 ha backwater area for fish spawning and habitat.	2020-2021

Post-construction monitoring of the first stage of this project found lake sturgeon spawning occurring in the first and second spring, and for multiple years afterwards. In addition, reef monitoring showed lake whitefish, walleye, and native sucker eggs present on the reef. This post-construction monitoring indicates that the reef has continued to increase the productive capacity of spawning habitat for lake sturgeon (and other fishes) in the Detroit River. Further, this project has provided additional opportunities to improve our understanding of the presence, distribution, and ecology of lake sturgeon in the Detroit River. In 2017, it was estimated that there are nearly 6,000 lake sturgeon in the Detroit River, and over 30,000 in the Lake Huron to Lake Erie corridor (J. Boase, personal communication).

Wetland Enhancement

Several wetland enhancements projects have been completed in the Detroit River to improve wetland habitat and associated ecosystem services to the river. In 1995, the existing finger dike structure at Ruwe Marsh was repaired in an effort to protect existing habitat in an ecologically important area of the Detroit River. More recently, in 2019, the DRCC and ERCA enhanced a 30-hectare coastal wetland in the Canard River, near where it meets the Detroit River. The enhancement involved refurbishing the existing outside berm, maintaining the containment berm along the eastern boundary of the wetland to permit improved water level management flexibility, and installing a pumping system. With these enhancements, the wetland water levels will be able to be manipulated and managed to control invasive species to improve habitat for waterfowl, amphibians, and aquatic vegetation.

Fish Habitat Enhancement

The DRCC and its partners are in the process of gaining appropriate permit approvals for an erosion mitigation and fish habitat enhancement project in the waters to the north and northeast of Peche Island. Peche Island is a 32-hectare island located in the upper Detroit River near Lake St. Clair. The island is a municipal park that is accessible by boat and has high biodiversity, including 22 species of rare native plants (235 plant species documented in total), two rare reptile species, critical habitat for species at risk, freshwater clams and mussels, and numerous birds (including bald eagles) that utilize the island for various life stages. The island has been designated an environmentally sensitive area and the marsh on the island is an Ontario provincially significant wetland.

This important island has been eroding at a rapid pace due to strong river currents and heavy wave action from Great Lakes freighter traffic. It is estimated that Peche Island has decreased in area by seven hectares from 1931 to 2015. The primary objective of this project is to create a series of nearshore and sheltering islands and a peastone (cobble) beach on the northeast side of Peche Island and a series of off-shore sheltering islands in the water lot on the north side of the Peche Island to protect it from further erosion. The proposed off-shore islands on the north side of the island will also create a calm-water embayment that will offer fish refuge and the opportunity for macrophytes to establish. It is projected that the entire calm water embayment area will act as a fish spawning and nursing area for the Detroit River, which may have spin-off benefits for the river further downstream. The area will also provide habitat for staging, nesting, brood rearing, and feeding areas for various species of waterfowl. Wading birds such as Great Blue Herons and Black-crowned Night Herons frequent the area and could use the beaches in the calm-water area for feeding. Shorebirds would also use the beaches in the calm-water area during spring and fall migration. In time, this embayment area is anticipated to provide valuable aquatic habitat for local fish and wildlife. This project is the single largest investment in structures that are designed to benefit fish in the Canadian Detroit River Area of Concern and construction of the project is expected to begin in summer 2020.

Terrestrial habitat

The ERCA conducts wetland and prairie restoration and tree planting activities on public and private lands in the Detroit River watershed. Since 2000, a total of 441 hectares (1,092 acres) of wetlands, prairie, and forest have been restored in the Detroit River watershed through this effort. In addition, the DRCC and ERCA work together to plant native gardens within the watershed. Approximate locations of these projects can be found in Figure 1.

Management Next Steps

Since the Detroit River was listed as an Area of Concern, there has been significant progress towards the restoration of fish and wildlife habitat. Large-scale restoration projects require many partnerships that take time to create. One of the primary challenges to implementing habitat restoration in the Canadian Detroit River is the large amount of privately-owned property along the shoreline. Projects are only possible if landowners are willing and there is a commitment of matching funds. Through various partnerships, the DRCC has been able to identify potential restoration sites and implement restoration at a number of priority sites. Of the 18 sites that were identified as priority sites in the 2007 document, habitat restoration actions have been completed at five of them, with work at one additional site in progress. Of the seven sites included in the aquatic feasibility study, one project is scheduled for construction to begin in 2020. One question that remains to be answered is: How much habitat is enough? We are currently in the process of creating sub-indicators that will help us answer this question.

Though there are still a number of projects to complete, approximately 3,300 m of shoreline has been softened, several reefs, shoals and sheltering islands have been constructed creating backwater areas for fish to spawn, and almost 400 ha of coastal wetlands have been enhanced to date in the Detroit River. Continued research, monitoring, and maintenance of restoration projects is needed to determine project success. Actions such as removing accumulated sediments from reefs and ensuring structures are stable can help achieve long-term success. In addition, research on the use rates of habitat structures and their effectiveness can help better design restoration projects in the future.

References

Detroit River Canadian Cleanup Habitat Work Group, 2007. Canadian Habitat Priorities Report. Essex, Ontario, Canada.

Green, N.D., Cargnelli, L., Briggs, T., Drouin, R., Child, M., Esbjerg, J., Valiante, M., Henderson, T., McGregrod, D., Munro, D., (Eds.). 2010. Detroit River Canadian Remedial Action Plan: Stage 2 Report. Detroit River Canadian Cleanup, Publication No. 1, Essex, Ontario, Canada.

Hartig, J. H., Sanders, C., Wyma, R. J. H., Boase, J. C., & Roseman, E. F., 2018. Habitat rehabilitation in the Detroit River Area of Concern. Aquatic Ecosystem Health & Management, 21, 4, 458-469.

Manny, B. A., Edsall, T. A., Jaworski, E., 1988. The Detroit River, Michigan: an Ecological Profile (Vol. 85, No. 7). U.S. Fish and Wildlife Service, U.S. Department of Interior, Ann Arbor, Michigan, USA.

Roseman, E. F., Kennedy, G. W., Boase, J., Manny, B. A., Todd, T. N., Stott, W., 2007. Evidence of lake whitefish spawning in the Detroit River: implications for habitat and population recovery. Journal of Great Lakes Research, 33, 2, 397-406.

This page intentionally left blank.

7.42 Canadian Laws and Policies to Address Algal Blooms

Claudia Tsang, University of Windsor, Faculty of Law, tsangi@uwindsor.ca

Patricia Galvao Ferreira, University of Windsor, Faculty of Law, patricia.galvao@uwindsor.ca

Background

Western Lake Erie has had a long-standing problem of harmful algal blooms ("HABs"), dating back to the 1950s (Bridgeman, this report: 7.24). HABs occur when colonies of algae (simple plant-like organisms that live in the sea and freshwater) grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. It has been difficult to create a comprehensive solution to HABs in a lake that is a shared resource among many jurisdictions (e.g., Ontario, Michigan, Ohio, and Pennsylvania). Since Lake Erie borders several states and a province in two countries, it is necessary for legislators and policymakers to use a transnational approach when developing laws and policy to respond to the algal blooms.

Over the past five decades, Canada and the United States have created several agreements in order to find a solution to reduce algal blooms in western Lake Erie, under the auspices of the International Joint Commission ("IJC"). The IJC is an administrative body created by the 1909 Boundary Waters Treaty ("BWT") signed between the United States and Canada to promote cooperative management measures to protect the Great Lakes and other Boundary Waters. The BWT provides the principles and mechanisms for preventing and resolving disputes concerning water quantity and quality along the entire border. Through the BWT both the United States and Canada must agree to any project that would change the natural levels or flows of any boundary waters. The BWT also states that that waters shall not be polluted on either side of the border to the injury of health or property on the other side.

While a significant legal instrument, the BWT is a set of guiding principles as opposed to mandatory law. The BWT provides guidelines for the IJC to resolve disputes regarding project approvals and transboundary issues that are applied on a case-to-case basis, and to promote joint action. A major shortcoming of the BWT is that it does not provide standards that the Canadian and U.S. governments are obligated to follow to fully prioritize the protection of the Great Lakes.

In 1972, Canada and the United States signed the first Great Lakes Water Quality Agreement ("GLWQA") after the IJC released reports on pollution issues in the Great Lakes. One of the driving factors of the GLWQA was algal blooms that occurred as a result of excess phosphorus loadings to the Great Lakes and particularly Lake Erie. This spurred new laws in both Canada and the United States that stipulated phosphorus limitations in household detergents and established phosphorus limits on the discharges from municipal wastewater treatments plants.

These measures did reduce the algal bloom problem for many years, although new sources of pollution and stressors such as agricultural runoff and climate change have brought the problem back in the last few years.

Since its inception, the GLWQA has gone through several revisions to improve restoration efforts in the Lake Erie Basin (Table 1). The Parties (i.e., Canadian and U.S. federal governments) report on progress under the GLWQA and the IJC performs an independent review and evaluation of that progress on a triennial basis.

Table 1. An overview of key IJC milestones related to controlling phosphorus inputs and algal blooms.

Date	GLWQA Milestone
1972	The first GLWQA was signed committing Canada and the U.S. to a coordinated approach to limiting phosphorus inputs to control cultural eutrophication.
1978	The GLWQA was revised to reflect a broadened goal "to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem." The two significant changes were the introduction of the "ecosystem approach" and the call for "virtual elimination" of toxic substances.
1987	The Protocol to the GLWQA was signed incorporating new commitments to reduce toxic pollutants through development and implementation of Lakewide Management Plans for each lake and to clean up Areas of Concern through the implementation of Remedial Action Plans.
2012	A revised GLWQA focused on preventing environmental threats before they cause ecological harm, while continuing to support work on existing threats to the quality of the waters of the Great Lakes. The revised Agreement included 9 specific goals and 10 annexes, including Annex 4 that addresses nutrients and algal blooms.
2015	Ontario, Michigan, and Ohio signed a pact agreeing to reduce phosphorus by 40% by 2025, with an interim goal of a 20% reduction by 2020.
2017	Canada and the United States committed to present their own progress report every three years at the Great Lakes Public Forum in 2016. IJC reviews these reports before publishing a unified assessment. The first Triennial Assessment of Progress was released in November 2017.
2019	A second Progress Report was released and was discussed at the 2019 Great Lakes Public Form. The Nutrients Annex specifically refers to the reduction of excess nutrients and algal blooms. In 2018, Canada and the United States finalized and began implementation of domestic action plans. The steps Canada has taken to develop legislation, regulation, and policy will be further discussed below. In 2019, a Lake Erie Binational Phosphorous Reduction Strategy was finalized to track progress towards binational targets.

While international assessment and cooperation are essential, each of the respective governments need to implement IJC's recommendations by enacting domestic laws and policies. This indicator provides an overview of Canadian laws and policies designed to address algal blooms.

Status and Trends

In Canada, the authority to regulate discharges that contribute to the harmful algal blooms is distributed between the federal level and the provincial level, although provinces hold the bulk of authority to regulate environmental and agricultural matters in Canada (Benedickson, 2017). A brief overview of the Canadian legislation and regulations that have been enacted is provided below.

Provincial Action

Nonpoint sources of pollution are currently considered the main contributors to the Lake Erie algal bloom problem on the Canadian side. Nonpoint sources refer to runoff that enters into the water systems through precipitation, land runoff, and drainage that flows into bodies of water such as groundwater, lakes, rivers, and wetlands. The main nonpoint source of phosphorus in Windsor-Essex County is the agricultural industry. Fertilizers and herbicides enter into the rivers flowing into Lake Erie. In 2015, Ontario passed the Great Lakes Protection Act ("GLPA"), setting a target to reduce phosphorus loading into Lake Erie by 40% by 2025. The Act focuses heavily on commitments and goal setting and does not include binding standards. The Act has great potential but requires further emphasis on implementation schemes to accomplish its purposes.

In February 2018, the federal government and the provincial government of Ontario launched the Canada-Ontario Lake Erie Action Plan ("Lake Erie Action Plan"). The plan reaffirmed the goal of reducing 40% of phosphorous run off into Lake Erie by 2025. The Lake Erie Action Plan was developed in partnership with a number of conservation authorities, agricultural organizations, municipalities, and non-governmental organizations. It provides project funding for supporting organizations, such as the Canada Plan and Infrastructure Canada, to take innovative measures to reduce phosphorus runoff from agricultural land. Canada and Ontario also signed a bilateral agreement implementing the Canadian Agricultural Partnership in 2018 to make environmental sustainability and climate change priorities in Lake Erie agriculture. However, it is unclear what implementation and enforcement mechanisms are used to ensure that targets are being met. Further research should illuminate this point.

The Lake Erie Action Plan was created to help Ontario meet their commitments set out in the Made-in-Ontario Environment Plan ("Made-in-Ontario"). Made-in-Ontario is a roadmap developed by the Ontario government to promote a healthy environment and a healthy economy. Protection of the Great Lakes and reduction of algal blooms is one of the key areas of action identified in the plan. There is other relevant provincial legislation that addresses phosphorus runoff, including the Nutrient Management Act and the Drainage Act. However, these provincial acts do not address algal blooms specifically.

Municipal Action

Municipalities and cities are important actors in inducing behavioral change to protect the environment. In accordance with international subsidiarity principles, municipalities are able to implement regulatory schemes and adjust them to their constituencies, where necessary. Three specific actions, which affect municipalities directly, are set out in the Lake Erie Action Plan:

1. Limit loadings from municipal sewage treatment plant discharges and better manage stormwater;

2. Encourage effective techniques to keep phosphorus on farmland; and

3. Restore natural wetlands.

The third goal of restoring natural wetlands is notable, particularly to the Windsor-Essex County region. In March 2019, Ontario lifted the "significant wetland" designation for 20 ha (50 acres) of a woodlot in the County. The previous designation meant that no residential developments would be permitted to take place. Removal of this designation now allows for urban growth that can pose as a potential threat to a number of wildlife species. This created additional obstacles to any potential restoration of wetlands as the Windsor-Essex County region already has the greatest rate of wetland and woodland loss in Ontario, resulting in only 3% of original trees and 1.5% of original wetlands remaining, a disproportionate percentage based on the area the county covers.

To address the issue of the algal blooms in western Lake Erie, Essex Region Conservation Authority (ERCA) is taking a series of actions, including cost-share programs, watershed monitoring, research projects, education and outreach programs specifically reaching agricultural parties, and implementation of a Regional Phosphorous Reduction Strategy. What can bolster these algal bloom reduction programs is more coordinated efforts between all actors and buy-in from all parties. Areas that require additional research include how to improve regulation and management of drainage systems and better manage flat lands.

Federal Legislation

Canada has a few federal laws that impact algal blooms. Under the Canada Environmental Protection Act (CEPA), phosphorus concentration levels were included as a CEPA regulated toxic in 2010, however the standards apply only for point sources of pollution including household detergents. This regulation is therefore not effective to address algal blooms, as currently the main causes of the problem in Ontario were identified as being nonpoint sources of pollution from agricultural runoff. The approach to reduce nonpoint sources of pollution was through data collection and the promotion of agricultural stewardship programs to support farmers in best management practices, a more collaborative approach than CEPA. Canada Water Act ("CWA") provides broad guidelines, rather than enforceable standards that policymakers can rely on, so it does not set limits to phosphorous or other nonpoint sources of pollution. The Canada-Ontario Lake Erie Action Plan is now the main direct policy and regulation on nonpoint sources of pollution in Lake Erie at the Federal level, relying heavily on action undertaken at the provincial and municipal levels.

Management Next Steps

Some areas for future research include how to improve law and policy regulations at the provincial, municipal and federal levels.

Provincial and/or Municipal Action

a. Nutrient Act

As the Great Lakes ecosystems constantly change, nutrient management must constantly adapt to address challenges to Lake Erie (Environment Canada, 2013).

Climate change and invasive species have, for example, compounded the challenge of preventing HABs (Thornton, et al., 2013). In-depth research to investigate whether the Ontario Nutrient Act is fit for the purpose of addressing the algal bloom problem in the 2020 context is needed. This research should also take into consideration the role of industry-led initiatives to address nutrient management such as the 4R Nutrient Stewardship strategy by Fertilizer Canada, which seeks to raise awareness on the sustainable use of fertilizers around Canada (Whyte, 2015).

b. Drainage Act

To address algal blooms, many environmental advocates suggest that new drainage infrastructure should be implemented. Potential projects can include two-stage ditch systems for subsurface drainage and implementation of upgraded sewage treatment technology.

In Ontario, drains are regulated by municipalities. The Drainage Act provides mainly for implementation and maintenance requirements. As a next step, further research among scientists, environmentalists, engineers, the agriculture sector, and policymakers will be required to identify how to efficiently prevent runoff and what upgrades to existing infrastructure or new infrastructure are needed.

c. Wetland Restoration

Wetlands are a living filter that purifies water naturally. In areas where there is nutrient-rich water, wetlands absorb and filter the excess nutrients and sediment before it enters open water. Wetland restoration is one of the action steps set out in the Canada-Ontario Lake Erie Action Plan. Wetland restoration has been proposed by Bill Mitsch, a renowned ecologist specializing in wetlands. Mitsch and his colleagues found that potentially reverting as little as 10% of the Great Black Swamp back to its natural state could help reduce algal blooms significantly in the Maumee River watershed in Ohio. As previously discussed, some wetlands in the Windsor-Essex County region are no longer protected by the wetland designation. Legislation can be used to recognize the value of wetlands and create limits where urban growth will threaten the ecological health and sustainability of these designated areas.

In the long-term, restoring wetlands is more cost effective than other options for agricultural industries. There would also be positive impacts on tourism and provide other benefits. Farmers could work with governmental agencies to promote "wetaculture" to merge sustainable practices, switching land use from farmland to wetland every 10 years. Mandatory federal funding can be used to finance a wetlands project, a step that can be enacted within federal legislation.

Federal Action

While a unified national piece of legislation is desirable, Canada faces jurisdictional obstacles. The environment is an area that does not fall well within either provincial or federal jurisdiction under the Constitution Act, 1867. As the causes of algal blooms are activities concentrated within the provinces, issues of jurisdictional conflict can arise if the federal government tries to assert its regulatory power too broadly. Hence the approach adopted by the federal government is to work collaboratively with the province of Ontario. Whether it is possible to enact federal laws to address algal blooms remains an open question. To preserve jurisdictional boundaries according to the division of powers in the Constitution Act, 1867, Canada should be cautious that any federal laws designed to reduce algal blooms do not infringe too much on areas of provincial jurisdiction such as industries, agriculture, natural resources, and provincial waterways.

With this disclaimer, federal legislation designed to specifically address phosphorus runoff from nonpoint sources could ensure a consistent and efficient way of reaching the target goals set out in the Canada-Ontario Lake Erie Action Plan. In the United States, the federal government enacted The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014. The reauthorization of the Act will allow for federal funds to be directed towards programs and research conducted to combat algal blooms deemed as of "national significance". In addition to funding research and innovation, a national assessment will be completed every five years to monitor the progress in reduction efforts.

Research to understand whether the Lake Erie Action Plan provides the same tools as the U.S. 2014 Act, or if a similar legal instrument specific to algae blooms would be beneficial in Canada, would be helpful. Is the Lake Erie Action Plan, as currently designed and implemented, able to support the research and project funding needed to ensure that Ontario and municipalities can properly address the algal blooms within their jurisdiction? Despite the challenges, if designed in collaboration with provinces and municipalities, there could be a chance to approve a strong federal legal instrument while avoiding jurisdictional conflicts.

References

Legislation:

Canadian Environmental Protection Act, 1999, S.C. 1999, c. 33.
Clean Water Act, 33 U.S.C. §1251 et seq. (1972).
Drainage Act, R.S.O. 1990, c. D. 17.
Great Lakes Protection Act, 2015, S.O. 2015, c. 24.
The Harmful Algal Bloom and Hypoxia Research and Control and Hypoxia Research and Control Amendments Act. 33 U.S.C. §1254 (2013).

Benidickson, J., 2017. The Evolution of Canadian Water Law and Policy: Securing Safe and Sustainable Abundance. McGill Journal of Sustainable Development Law, 13, 1, 61-104.

Environment and Climate Change Canada and the Ontario Ministry of the Environment and Climate Change, 2018. Canada-Ontario Lake Erie Action Plan. https://www.canada.ca/content/dam/eccc/documents/pdf/great-lakes-protection/dap/action_plan.pdf (accessed 17 Dec. 2019).

Government of Canada, 2012. Great Lakes Water Quality Agreement. https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/2012-water-quality-agreement.html/ (accessed 14 Dec. 2019).

Government of Canada, (n.d.). Canada-U.S. Boundary Waters Treaty. https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/north-america/canada-united-states-boundary-waters-treaty.html/ (accessed 14 Dec. 2019).

Government of Canada and the Government of the United States of America, 2019. Progress Report of the Parties. https://binational.net/wp-content/uploads/2019/10/Final-2019-PROP-English-Oct.23.pdf (accessed 16 December 2019).

Government of Ontario, 2019. Canada-Ontario Lake Erie Action Plan. https://www.ontario.ca/page/canada-ontario-lake-erie-action-plan/ (accessed 16 Dec. 2019).

Great Lakes Commission, (n.d.). Reducing Phosphorous into Lake Erie. https://www.glc.org/work/eriestat/phosphorus/ (accessed 17 Dec. 2019).

Great Lakes Protection Act Alliance, 2017. Protecting and Restoring the Ecological Health of Our Waters. https://d36rd3gki5z3d3.cloudfront.net/wp-content/uploads/2017/05/FINAL_ProtectingRestoringEcologicalHealthofWaters-1.pdf?x82561/ (accessed 16 Dec. 2019).

Henry, T., 2019. Economics might support grandiose Great Black Swamp restoration. The Toledo Blade. https://www.toledoblade.com/local/environment/2019/08/03/great-black-swamp-restoration-lake-erie-algae-bloom/stories/20190803126/ (accessed 12 Oct. 2019).

International Joint Commission, (n.d.). History of the Great Lakes Water Quality Agreement. https://www.ijc.org/en/what/glwqa-history/ (accessed 5 Dec. 2019).

International Joint Commission, (n.d.). The IJC and the Great Lakes Water Quality Agreement. https://www.ijc.org/en/what/glwqa-ijc/ (accessed 5 Dec. 2019).

McCandless, M., 2019. Canada could take inspiration from U.S. environmental policy preventing algal blooms. https://www.iisd.org/library/us-policy-algal-blooms/ (accessed 7 Nov. 2019).

Mahl, U. H., Tank, J. L., Roley, S. S., Davis, R. T., 2015. Two-Stage Ditch Floodplains Enhance N-Removal Capacity and Reduce Turbidity and Dissolved P in Agricultural Streams. Journal of the American Water Resources Association. Journal of the American Water Resources Association, 51, 4, 923-940.

Ministry of Environment, Conservation, and Parks, 2018. A Made-in-Ontario Environment Plan. https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan.pdf (accessed 16 Dec. 2019).

Pan, F., 2019. Part of Windsor wetland now potentially open to development. CBC News. https://www.cbc.ca/news/canada/windsor/south-cameron-woodlot-windsor-wetlands-flood-1.5038392/ (accessed 7 Nov. 2019).

Stammler, K., 2019. Eutrophication and Algal Blooms. State of the Strait. Talk presented at the 2019 State of the Strait conference, Windsor, Ontario, Canada.

Thornton, J.A., Harding, W.R., Dent, M., Hart, R.C., Lin, H., Rast, C.L., Rast, W., Ryding, S.O., Slawski, T.M., 2013. Eutrophication as a 'wicked problem'. Lakes and Reservoirs: Research and Management, 18, 298–316.

Whyte, G., 2015. Fertilizer Canada Response to Bill 66, Great Lakes Protection Act, 2015. http://fertilizercanada.ca/ontario-great-lakes-protect-act-submission/ (accessed 7 February 2020).

7.43 Climate Change Adaptation in Windsor, Ontario

Karina Richters, Environmental Sustainability and Climate Change, Windsor, Ontario, krichters@citywindsor.ca

Background

Regardless of the cause, the average temperature in Windsor has increased by almost 1°C since 1940. Scientists predict that by 2050, the average annual temperature in Ontario will increase by 2.5°C to 3.7°C from the 1961-1990 baseline average. This change, along with predictions that the number of "hot" days (over 30 °C/86 °F) in Windsor could almost quadruple by 2071-2100, are cause for concern. Heat related illnesses place a strain on our health care services and energy used to cool our buildings is expensive. In addition, this shift in the average weather for the region allows for the survival of invasive species and the expansion or introduction of insect vectors that carry disease.

As air temperature increases, so does the capacity of the air to hold more water. This can lead to more intense rainfall events, which Windsor has already experienced in recent years. In 2011, Windsor experienced the wettest year on record, measuring 1,568 mm of rain compared to the average annual rainfall of 844 mm. Increased temperature and intense rainfall events are two climate change impacts that have resulted in direct costs to Windsor residents through basement flooding and heat related illness expenses. Municipalities have a significant role to play in climate change adaptation as many climate change impacts will directly affect the services provided by the City of Windsor and its agencies.

Status and Trends

The Environment Canada weather station, located at Windsor Airport, has been monitoring and recording weather data since 1941. Since this time, the average annual temperature has increased by almost 1°C (Figure 1).

As air temperatures increases, so does the capacity of the air to hold more water leading to more intense rainfall events. Since 1970, there has been increasing evidence of heavier short duration (24 hours or less) rain events in southern Ontario.

Using the meteorological data obtained from the Windsor Airport station, an increasing trend in annual precipitation has also been documented (Figure 2). Based on a Canadian Climate Change Scenarios Network model (City of Windsor, 2012), precipitation is projected to increase, with winter and spring projected to get significantly wetter and a slight decline in the summer (Table 1). As noted above, these changes in our climate will result in an increase in heat-related illnesses, energy consumption, extreme precipitation events, flooding damage, and more.

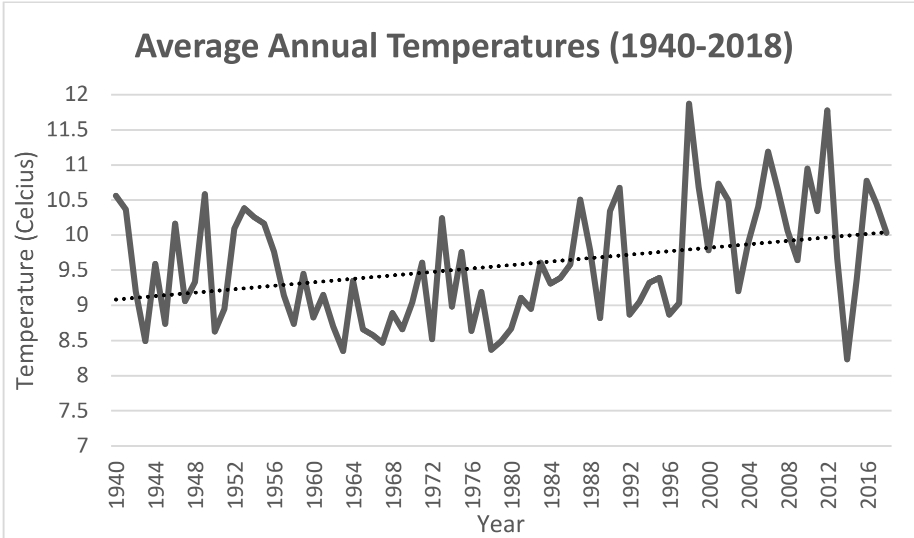


Figure 1. Average annual temperature at the Windsor Airport as measured by Environment and Climate Change Canada, 1940-2018.

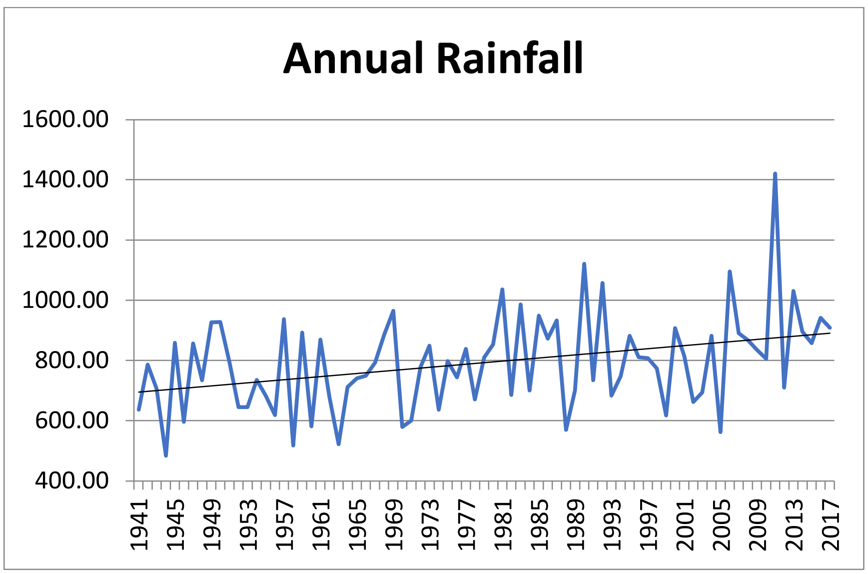


Figure 2. Average annual precipitation (mm) in Windsor, 1941-2017.

Table 1. Mean annual precipitation projections for the City of Windsor, baseline period through 2080 (City of Windsor, 2018).

Year	Mean Annual Precipitation
Baseline (1971-2000)	918.1 mm
2020	938.6 mm
2050	969.1 mm
2080	994.1 mm

Management Next Steps

Climate Change Adaptation in Windsor

As stated in the City of Windsor's Environmental Master Plan, "the City of Windsor is committed to be a leader through its daily actions and services to enhance the environment for present and future generations" (City of Windsor, 2017a). This is shown through the commitment of City Council and City administration on the development of the 2012 Climate Change Adaptation Plan (City of Windsor, 2012). As one of the first municipalities in Ontario and Canada to undergo adaptation planning. Windsor has committed to building a more resilient and livable community.

The focus of the 2012 climate change adaptation plan is on the following five potential climate change impacts which were rated as posing substantial risk and therefore may result in the greatest impact on municipal operations:

1. Increase in operating/maintenance demands to deal with climate extremes.
2. Increased chance of flooding to basements, roads, and other infrastructure.
3. Increase in demand to all areas of operations when responding to an increase in severe storms (during and after).
4. Increase in public health risks due to extreme heat.
5. Implementation of development policies which were created in the absence of climate change considerations, which may increase our vulnerability.

Proposed short-term adaptation actions to reduce risks associated with increased precipitation include:

- Mandatory downspout disconnection;
- Mandatory backwater valve installation;
- Enhance sewer maintenance and camera inspections;
- Consideration of additional off-line storage;
- Increase the use of flow restrictors on catch basins;
- Update the rainfall intensity duration frequency (IDF) curves;
- Seal manhole covers;
- Undertake public education on sewer use and wastewater treatment;
- Target education towards homeowners with suspected cross-connections;
- Use social media and other communication tools to warn public of the risk of basement flooding; and

- Enhance maintenance and inspection of road and sidewalks during snow or extreme weather events.

Proposed short-term adaptation actions to reducing risks associated with increased precipitation and temperatures include:

- Develop a green roof policy;
- Install rain gardens as pilot projects;
- Develop pilot projects for the use of porous pavement;
- Improve and enhance green space; and
- Increase tree planting.

Proposed short-term actions to reduce risks associated with increased temperature include:

- Increase capital for shade structures;
- Increase heat education at community centers/pools; and
- Complete an urban heat island study.

Other general short-term actions include:

- Develop clear policies for weather response; and
- Create an Extreme Weather Fund Reserve.

While these short-term actions may help reduce Windsor's current vulnerability, the City also needs to develop on-going strategies that will continue to address the changing climate over the long-term. The following strategies should be undertaken to ensure that the City of Windsor continues to be a leader on adaptation well into the future:

1. Incorporate climate change adaptation into city policies and high-level plans;
2. Create internal mechanisms to "ask the climate question" for all new major infrastructure projects;
3. Monitor climate change, evaluate the effectiveness of adaptation strategies, and adjust as needed (adaptive management);
4. Use best available science to analyze how the climate is changing locally and how this may impact the community;
5. Routinely review the City of Windsor's vulnerability to climate change;
6. Continuously conduct risk assessments to identify priority impacts requiring adaptation actions; and
7. Engage the public, business, and other stakeholder groups.

The City of Windsor has been extremely successful in the implementation of the Climate Change Adaptation Plan with almost all actions completed or underway.

In the summer of 2017, the Federation of Canadian Municipalities (FCM) issued a call for Climate Adaptation Partner Grants under the Municipalities for Climate Innovation Program (MCIP). International Council for Local Environmental Initiatives Canada submitted a successful grant application to undertake the Adaptation Changemakers project and solicited applications for municipalities to participate in the project. The purpose of the Adaptation Changemakers Project is to:

- Build capacity in the selected municipalities for integrating adaptation across the municipality and the wider community;
- Develop opportunities to collaborate with local stakeholders to carry out climate change vulnerability and risk assessments, prioritize impacts and develop a local community climate adaptation action plan; and
- Create a network of adaptive communities located within Ontario, British Columbia, and Newfoundland.

On March 26, 2018, Windsor City Council approved participation in this project.

To date, the Environment Sustainability and Climate Change Office has been working with City departments and the community to determine current and future climate change impacts, as well as carry out vulnerability and risk assessments for those impacts. The final goal of this project is to have a redeveloped Climate Change Adaptation Plan. The intent of the updated Climate Change Adaptation Plan is to identify the risks posed to the corporation, as well as to the community, and to identify adaptation actions that can be undertaken by the Corporation and the Windsor community to reduce those risks. The actions taken today by the City of Windsor to proactively adapt to the changing climate will enhance community resilience to climate change, while reducing the human and economic costs of climate-related impacts. Adaptation actions can often lead to great cost savings as intense storm events and extreme heat can result in devastating expenses to repair infrastructure, mitigate basement flooding, and minimize health care costs.

Climate Change Mitigation in Windsor

In addition to adapting to the changing climate, the City of Windsor is taking steps to help the global effort to reduce greenhouse gas emissions. The City of Windsor has been tracking Corporate and Community emissions for a number of years. Greenhouse gas emissions are projected to continue to increase by approximately 22% from 2014 and 2041 (Figure 3).

The City of Windsor's Community Energy Plan (2017) aims to create economic advantage, mitigate climate change, and improve energy performance. It strives to position Windsor as an energy center of excellence that boasts efficient, innovative, and reliable energy systems that contribute to the quality of life of residents and businesses (City of Windsor, 2017b).

The City of Windsor, through this plan, has set ambitious and transformative targets to support the global effort to keep global temperature increases within 1.5C. Through the implementation of the plan (City of Windsor (2017b) the Windsor Community will reduce per capita energy use and per capita CO_2 emissions by 40% between 2014 and 2041.

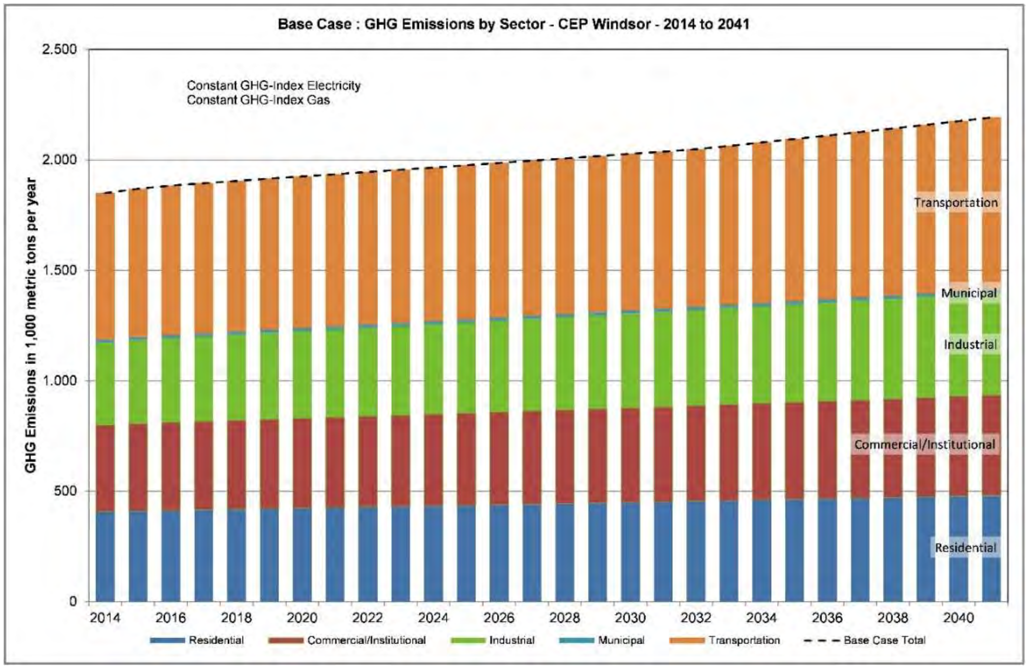


Figure 3. Greenhouse gas (GHG) emissions in Windsor, 2014-2041.

References

City of Windsor, 2012. Climate Change Adaptation Plan. Windsor, Ontario, Canada.

City of Windsor, 2017a. Environmental Master Plan. Windsor, Ontario, Canada.

City of Windsor, 2017b. Community Energy Plan. Windsor, Ontario, Canada.

City of Windsor, 2018. Future climate projections. Windsor, Ontario, Canada.

7.44 Combined Sewer Overflow Controls in Southeast Michigan

Suzanne Coffey, Great Lakes Water Authority, Suzanne.Coffey@glwater.org

Majid Khan, Great Lakes Water Authority, Majid.Khan@glwater.org

Ed Hogan, Wade Trim, ehogan@wadetrim.com

Imad Salim, Wade Trim, isalim@wadetrim.com

Background

Most large, older cities in the Great Lakes basin were located on the banks of rivers or lakes to meet the needs for transportation and commerce. Detroit was no exception. During the 1700s and 1800s, the streets were primarily dirt or gravel and they frequently remained muddy after rainfall. Citizens of Detroit and similar cities grew tired of muddy streets and urged the local government to do something about this inconvenience.

The immediate solution was to build sewers to drain stormwater off the streets during wet weather so that they would not remain muddy for long periods of time. These sewers were either open ditches or pipes buried underground. As communities grew, these sewers needed to be quite substantial in size to carry away the stormwater. Remember, of course, that the vehicles on these roads were horses and carriages, and that the horses left behind more than footprints. At that time, domestic water use was relatively low, but the domestic wastewater was simply dumped in the gutter where it would be flushed away during the next rain. During these rains, both domestic wastewater and manure from the streets were flushed into the sewers, where they were transported directly to the nearest waterway. This created both odor problems and pollution of waterways.

A new kind of sewer, called an interceptor sewer, was built to address these problems. They were primarily built parallel to waterways to carry wastewater further downstream. It was common and acceptable up to the late 1800s and early 1900s to move this wastewater further downstream where there were fewer or no people to complain. In the early 1900s, domestic use of water increased rapidly with human population growth and resulted in increased domestic wastewater discharges. Since the sewers at that time were originally designed to carry away stormwater, the increased domestic wastewater from the growing population could exceed sewer capacity during heavy rains and snow melt. However, because of budget constraints, the sewers at that time were sized to intercept only the domestic waste during dry weather conditions. Therefore, one of two things had to happen during a rainstorm. Either the sewers would exceed their capacity and flood the streets or there needed to be a relief discharge directly into a waterway near these populated areas. Structures, called regulators, were constructed to provide this relief. They operate when the flow rises above the height of the overflow weir, allowing the combined storm and sanitary sewer flow to overflow into the receiving waterway – thus causing what has come to be called a combined sewer overflow (CSO).

As time went by, the idea of building sewers that handled both the sanitary wastewater and the stormwater gave way to the concept of building a separate system just for sanitary wastes. These separate sewers came to be called sanitary sewers and the original type of sewer came to be called combined sewers. Today, these combined sewers are found only in older, larger cities where combined stormwater and wastewater are treated during dry weather, but it overflows directly into rivers during and after wet weather events. When many of these combined sewers were constructed, they were simply called "sewers." Later on, in the 1930s and 1940s, the distinction between storm sewers, sanitary sewers, and combined sewers became well accepted.

Status and Trends

In 1972, the U.S. Congress passed the Clean Water Act which launched a major effort to control pollution from industrial and municipal sources. The law required each state to issue discharge permits to regulate the quantity and concentration of pollutants from municipal and industrial treatment facilities to meet state water quality standards.

By the mid-1980s virtually all of the over 400 municipal wastewater treatment plants in Michigan had achieved compliance with the Clean Water Act requirement to provide secondary treatment of all flows. Michigan's treatment plants were also required to disinfect the wastewater prior to discharge and reduce phosphorus loadings to control nutrient impacts in the Great Lakes basin.

As the discharges from wastewater treatment plants came under control, attention began to focus on water quality problems attributable to intermittent wet weather discharges from combined sewer systems. CSO discharges can be a significant source of pollution to receiving waters since they consist of a diluted mixture of untreated sanitary wastewater and stormwater runoff. Water quality problems attributable to uncontrolled CSOs include public health threats from bacterial contamination and pathogenic organisms, dissolved oxygen depletion, aesthetic problems, nutrient loading, and residues from sanitary trash and floatable materials.

CSOs were a particularly significant problem in southeast Michigan because of the high population and the fact that CSO discharges were impacting small urban waterways such as the Rouge River and its tributaries. Within the service area of the Detroit wastewater treatment plant (now identified as the Great Lakes Water Authority (GLWA) Water Resource Recovery Facility (WRRF)), more than 25% of the service area utilizes combined sewer systems.

Within the city of Detroit there are 35,924 hectares (88,770 acres) served by combined sewers and an additional 24,186 hectares (59,764 acres) in suburban communities in Wayne, Oakland, and Macomb counties (Figure 1). Uncontrolled CSO discharges were identified as a major source of pollution throughout much of the Rouge River basin, the Clinton River basin, and portions of the Lake St. Clair and Detroit River shoreline.

In 1985, work began on the development of Remedial Action Plans for these watersheds to define alternatives for improving water quality and protecting public health. The Rouge River Remedial Action Plan was adopted in 1988 and called for substantial investment in facilities to control CSOs in Detroit, Wayne County, and Oakland County. Similar control efforts were initiated along the Clinton River and Red Run Drain basin, and the shoreline areas of Lake St. Clair and the Detroit River.

The recommendations of the Remedial Action Plans were the basis for new permit requirements to eliminate or adequately treat CSO discharges throughout southeast Michigan. The southeast Michigan CSO control program received support from the federal government when Congress approved the Rouge River National Wet Weather Demonstration Project in 1992. Under this program, municipalities in the Rouge River watershed served as a pilot program to demonstrate the effectiveness of various CSO control measures. The program also instituted a variety of other pollution control activities related to stormwater discharges, streambank erosion control, wetland preservation, public education, and other measures.

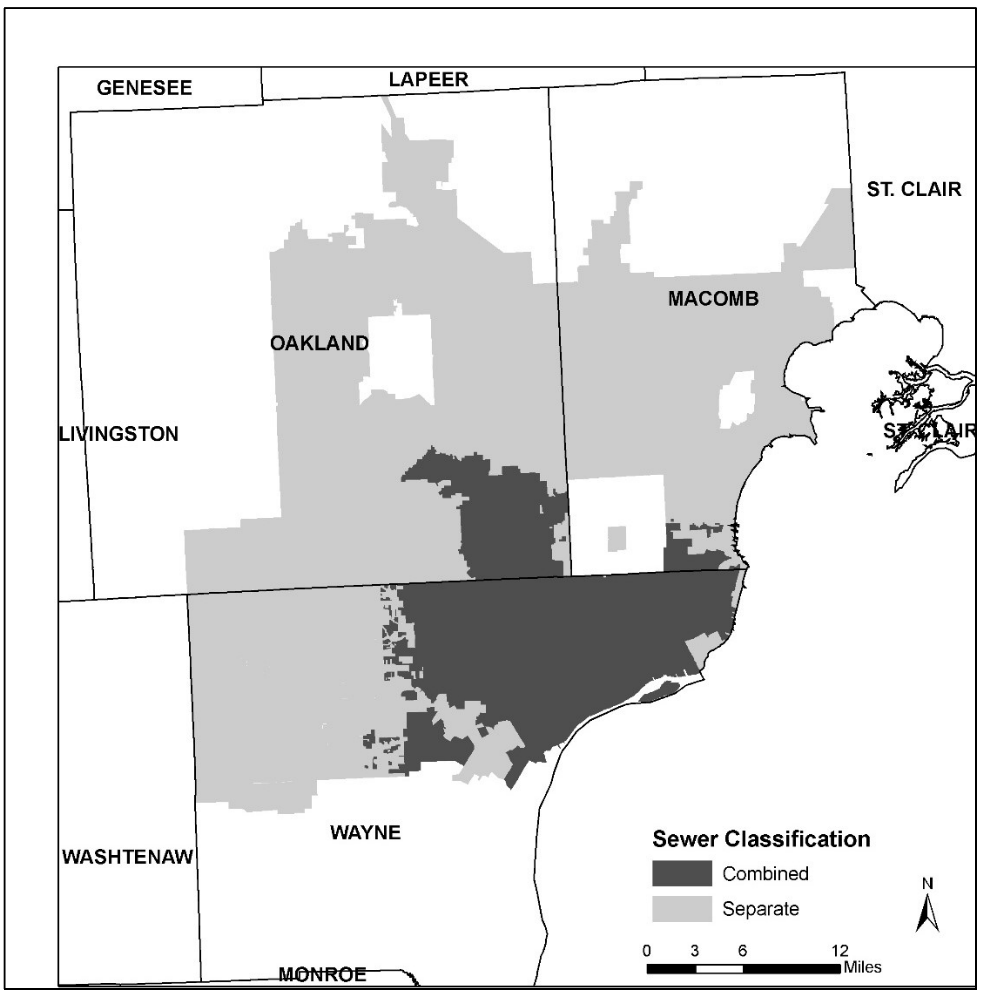


Figure 1. Areas of Wayne, Oakland, and Macomb counties that have combined and separate sewer systems.

Prior to 1990, there were more than 170 uncontrolled CSOs in existence in 35 municipalities in southeast Michigan. The quantity of untreated combined sewage discharged annually at that time is estimated at more than 119 billion liters per year (over 31 billion gallons per year), although the actual quantity of the discharge varies in response to climatic conditions and rainfall patterns. CSO discharges typically occurred about 50 times per year throughout the region and the pollutant load from these discharges was significant. Numerous water quality studies in the area documented serious impairments and water quality standards violations during and after wet weather events when CSO discharges occurred. Dissolved oxygen levels in some areas were depleted, making it difficult for the watersheds to support aquatic life and fish.

In response to the regulatory initiative to control CSOs, southeast Michigan communities in the GLWA service area have committed to the construction of projects totaling nearly $1.8 billion to eliminate, capture, or treat combined sewage, with more than an additional $400 million supporting the study, design, and oversight of the CSO construction projects. A list of the CSO control projects is included in Table 1. The debt obligation to pay for these capital improvements has had a significant impact on local sewer rates, even though many facilities were financed with low interest loan assistance from the State Revolving Loan Fund, and the initial projects received grant support through the National Wet Weather Demonstration Project.

Table 1. CSO investment of southeast Michigan as of May 2007 a. DWSD = Detroit Water and Sewerage Department.

Name of the Facility	Ownership	Status	Storage Volume: million liters (million	Construction Cost[b]
Detention Basins				
Belle Isle	DWSD	Operational	1.14 (0.30)	Est. $16,100,000
Conner Creek	GLWA	Operational	119.24 (31.50)	$201,000,000
Hubbell-Southfield	GLWA	Operational	83.28 (22.00)	$54,884,000
Hubbell Southfield Improvements	GLWA	Operational		$14,500,000
Oakwood Pump Station	GLWA	Operational	34.07 (9.00)	Est. $168,700,000
Puritan – Fenkell	GLWA	Operational	15.52 (4.10)	$18,194,000
Seven Mile	GLWA	Operational	11.73 (3.10)	$29,948,000
Acacia Park	Oakland	Operational	15.14 (4.00)	$10,681,000
Bloomfield Village	Oakland	Operational	37.85 (10.00)	$21,994,000
Birmingham	Oakland	Operational	20.82 (5.50)	$26,252,000
GWK	Oakland	Operational	350.91 (92.70)	$165,068,000
Chapaton	Macomb	Operational	105.99 (28.00)	$25,817,000
Martin	Macomb	Operational	32.55 (8.60)	$7,471,000
Milk River	Wayne	Operational	71.92 (19.00)	$31,200,000
Dearborn Heights	Dearborn	Operational	10.22 (2.70)	$18,678,000
Inkster	Inkster	Operational	11.73 (3.10)	$18,592,000
Redford Township	Redford	Operational	7.19 (1.90)	$14,300,000
SUBTOTAL			929.32	$843,379,000
Treatment/Capture Shafts				
Capture Shaft 013	Dearborn	In	27.25 (7.20)	$28,895,000
Capture Shaft 014	Dearborn	In	38.23 (10.10)	$33,097,000
Disinfection Facility for Capture Shaft 013 and 014	Dearborn	In Constructio	Included Above	$4,397,000
Capture Shaft 015	Dearborn	In	9.08 (2.40)	$10,528,000
Original CSO Shafts	Dearborn	Constructed	Included	$26,000,000
Treatment Shafts 1 5	Dearborn	In Design	98.80 (26.1)	$170,000,000
Treatment Shaft 016	Dearborn	In	12.49 (3.30)	$25,997,000
Treatment Shaft 017	Dearborn	In	24.61 (6.50)	$36,791,000
SUBTOTAL			210.47 (55.60)	$335,705,000
Screening & Disinfection Facilities				
Baby Creek (Including VR-7)	GLWA	Operational	115.08 (30.4)	$76,100,000
Leib	GLWA	Operational	31.42 (8.3)	$33,400,000
St. Aubin	GLWA	Operational	9.20 (2.43)	$19,821,000
SUBTOTAL			155.69 (41.13)	$129,321,000

Name of the Facility	Ownership	Status	Storage Volume: million liters (million	Construction Cost[b]
Tunnels				
Upper Rouge Tunnels	GLWA	Terminated	760.87 (201.00)	$22,300,000
SUBTOTAL			760.87	$22,300,000
In-System Storage Facilities (Dams and Gates)				
Conner Creek Influent Storage Gates	GLWA	Operational	152.93 (40.40)	$15,000,000
Wyoming Relief (ISD001)	GLWA	Operational	23.24 (6.14)	
Weatherby (ISD002)	GLWA	Operational	11.92 (3.15)	
Upper Livernois Relief (ISD003)	GLWA	Operational	9.24 (2.44)	
Joy (ISD004)	GLWA	Operational	13.55 (3.58)	
Clark Summit (ISD005)	GLWA	Operational	15.06 (3.98)	
First Hamilton (ISD006)	GLWA	Operational	34.14 (9.02)	
First Hamilton (ISD007)	GLWA	Operational	16.77 (4.43)	
First Hamilton (ISD008)	GLWA	Operational	14.99 (3.96)	
First Hamilton (ISD009)	GLWA	Operational	16.20 (4.28)	
First Hamilton (ISD010)	GLWA	Operational	5.38 (1.42)	
Conant Mt. Elliott (ISD011)	GLWA	Operational	34.18 (9.03)	
Six Mile Rd. (ISD012)	GLWA	Operational	8.86 (2.34)	$26,469,000
Seven Mile Rd. (ISD013)	GLWA	Operational	13.51 (3.57)	
6 Mile & 6 Mile Relief Outfall Gates	GLWA	Operational	26.12 (6.90)	$7,708,000
Puritan Outfall Gates	GLWA	Operational	1.14 (.30)	
Lyndon Outfall Gates	GLWA	Operational	6.44 (1.7)	
Lahser Outfall Gates	GLWA	Operational	5.30 (1.4)	$3,400,000
W. Chicago Outfall Gates	GLWA	Operational	19.68 (5.2)	
Tireman Outfall Gates	GLWA	Operational	21.58 (5.7)	
Rouge District In-System Storage Gates Retrofit-Rehab	GLWA	Operational		$1,400,000
Bloomfield Hills, Birmingham, Acacia Park	Oakland County	Operational	18.17 (4.8)	$1,552,000
GWK Influent Weir Storage	Oakland County	Operational	124.92 (33.00)	Included w/GWK Basin
Frisbee Sewer	City of	Operational	7.19 (1.9)	$2,043,000
SUBTOTAL			600.52	$56,172,000

Name of the Facility	Ownership	Status	Storage Volume: million liters (million	Construction Cost[b]
Equalization Basins (as part of CSO Elimination Program)				
Farmington	Farmington	Operational	12.11 (3.20)	$5,000,000
City of Wayne	Wayne	Operational	8.71 (2.30)	$3,827,000
Livonia	Livonia	Operational	8.33 (2.20)	$1,029,000
SUBTOTAL			29.15 (7.70)	$9,856,000
Sewer Separations/Relief Sewers and Collection System Upgrades				
Carbon Outfall and Fort St Outfall Elimination				$100,000
Area 25	City of	Operational		$221,000
Areas 19, 20, 23	City of	Operational		$2,454,000
Area 18	City of	Operational		$82,000
Farmington	Farmington	Operational		$9,000,000
Midtown West	Garden City	Operational		$9,727,000
Midtown East	Garden City	Operational		$6,435,000
South Venoy	Garden City	Operational		$1,228,000
Sewer Separations/Relief Sewers and Collection System Upgrades				
Merriman	Garden City	Operational		$459,000
Perrin & Middlebelt	Garden City	Operational		$10,848,000
Robinson Subdivision	Plymouth Township	Operational		$557,000
Districts 30, 31, & 32	Plymouth Township	Operational		$341,000
Area 42	Westland	Operational		$346,000
Area 38	Westland	Operational		$1,364,000
Area 10 (Contract 1 & 2)	Westland	Operational		$4,010,000
Area 10 (Contract 3)	Westland	Operational		$1,874,000
Area 10 (Contract 4)	Westland	Operational		$768,000
Grosse Pointe Farms	Grosse Pointe	Operational		$10,000,000
Grosse Pointe Park	Grosse Pointe Park	Operational		$18,600,000
Eastpointe Roseville Separation	Macomb County	Operational		$4,184,000
So. Macomb Relief Sewers	Macomb County	Operational		$15,269,000
So. Macomb Pump Station/Bypass Structure	Macomb County	Operational		$22,827,000
Area Tributary to CSO 016	Dearborn	In Constructio		$6,380,000
Miller Rd. Pump Station Renovation	Dearborn	Operational		$8,000,000
SUBTOTAL				$135,074,000

Name of the Facility	Ownership	Status	Storage Volume: million liters (million	Construction Cost[b]
Operational Elements				
Fischer PS Improvements & St. Aubin Effluent Mods	GLWA			$4,600,000
Fairview Pump Station	GLWA	Operational		$6,072,000
VR-15 (Conant Mt. Elliott)	GLWA	Operational		$6,902,000
VR-17 (Shiawassee Gate)	GLWA	Operational		$198,000
VR-8 (Hubbell-Southfield)	GLWA	Operational		$800,000
PC-713 Instrumentation and Control Devices	GLWA	Operational		$16,000,000
SUBTOTAL				$34,572,000
Detroit WWTP				
Primary Clarifiers No. 17, 18	GLWA	Operational		$101,200,000
PS-2A (Additional Pump)	GLWA	Operational		$2,048,000
Original Detroit River Outfall	GLWA	Operational		$88,200,000
Modified Detroit River Outfall	GLWA	Operational		$7,100,000
Rouge River Outfall Segment 1	GLWA	In-Constructio		$46,000,000
SUBTOTAL				$244,548,000
TOTAL EXPENDITURE				$1,800,927,000

[a] Listing does not include facilities to control sanitary sewer overflows (SSOs) from separated sewer systems except for equalization basins which were built to retain excess wet weather flows in newly separated combined sewer systems.

[b] Construction cost reflects the cost to build the facility (as-bid contractor's cost plus or minus change orders) and has not been adjusted to account for inflation since the project was built. Costs do not include engineering, administrative, land acquisition or legal expenses.

The benefits of this massive CSO expenditure have become apparent as water quality throughout southeast Michigan continues to improve. The volume of uncontrolled CSOs has decreased substantially, and further improvements will be achieved as projects currently in design and construction are completed and placed into service. As shown in Figure 2, the quantity of uncontrolled CSO discharges have been reduced by 95%, on average, with completion of all core elements of CSO Control Program. As the program moves into the final phases, the remaining control measures are focused at fully complying with the Michigan Water Quality Standards.

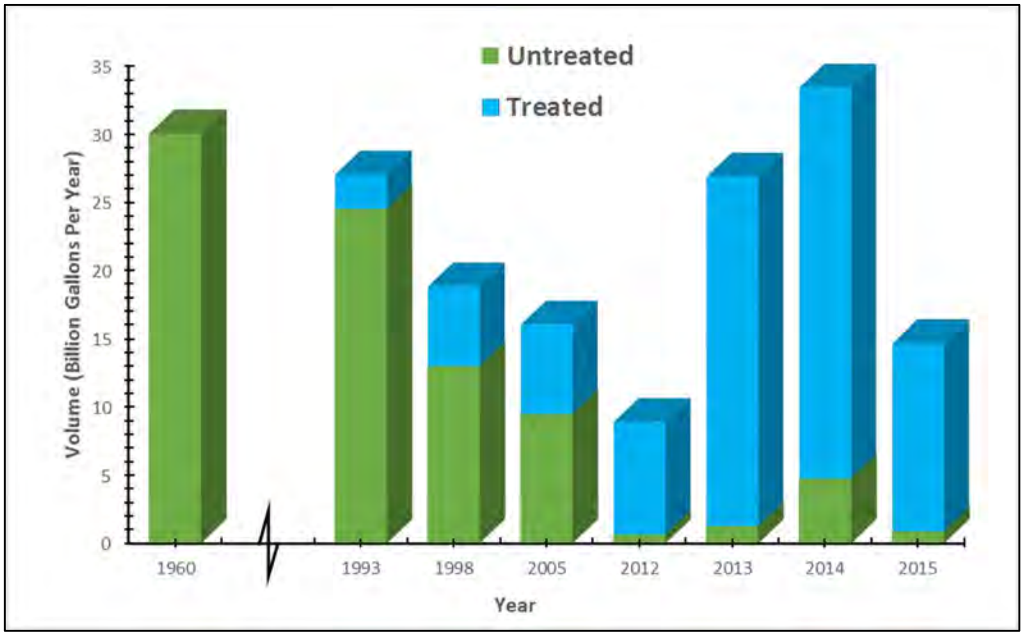


Figure 2. Historical and projected effects of Detroit Water and Sewerage Department's, Great Lakes Water Authority, and customers' efforts to reduce and treat CSOs.

Dissolved oxygen levels in receiving waters throughout southeast Michigan have shown steady improvement, and fish and aquatic life surveys document that area waterways are markedly improved. Because the CSO control projects typically include disinfection to control bacteria, recreational users benefit from improved public health protection practices, and beach closures in response to wet weather events have become increasingly infrequent.

While the effort to control wet weather pollution from CSOs is not yet complete, the progress achieved to date demonstrates that significant water quality improvements are achievable in urban areas when CSO controls are constructed. The overall health of the watersheds in southeast Michigan has experienced significant improvement and is continuing to improve. In large measure this is a result of the work by local government to control pollution from combined sewer systems throughout the area.

Management Next Steps

Key management actions for southeastern Michigan watersheds include:

- Complete the GLWA long-term Wastewater Master Plan;
- Continue City of Detroit Green Infrastructure Program;
- Continue to strategically identify, evaluate, and plan for the remaining CSO control projects;
- Continue sanitary sewer capacity improvements;

- Promote the economic importance of the region's "Green" (plants) and "Blue" (waters) infrastructure to encourage adequate public investment in continued restoration and protection efforts;

- Ensure sufficient collaboration among all watershed communities, all watershed counties, Michigan Department of Environment, Great Lakes, and Energy, and the U.S. Environmental Protection Agency to secure adequate funding to sustain and expand a collaborative illicit discharge elimination effort and a public education and watershed monitoring program; and

- Integrate the CSO and the stormwater permit programs with receiving stream water quality for all southeastern Michigan watersheds.

Research/Monitoring Needs

Monitoring is essential for proper watershed management. Priority must be given to ensuring sufficient monitoring to be able to adequately evaluate effectiveness of programs and to make midcourse corrections. Further, research is needed on innovative funding mechanisms for stormwater, CSOs, and watershed management in order to maintain the momentum for restoration and protection efforts.

Links for More Information
Great Lakes Water Authority
www.glwater.org

Detroit Water and Sewerage Department
www.detroitmi.gov/dwsd

Rouge River National Wet Weather Demonstration Project
www.rougeriver.com

7.45 Connecting United States and Canadian Greenways

Gwen Gell, Taubman College of Architecture and Urban Planning, University of Michigan, ggell@umich.edu

Kevin Berk, Osgoode Hall Law School, kevinberk@osgoode.yorku.ca

John Hartig, Great Lakes Institute for Environmental Research, University of Windsor, jhhartig@uwindsor.ca

Background

In 2016, a U.S.-Canadian partnership released a binational greenways vision map to connect emerging international greenways, trails, and bike lanes. The goal of this project was to establish safe and convenient routes for pedestrians and bicyclists (Figure 1). The partners included: Bike Friendly Windsor Essex, Canadian Consulate General, City of Detroit, City of Windsor, Community Foundation for Southeast Michigan, Detroit Greenways Coalition, Detroit Metro Convention & Visitors Bureau, Detroit Riverfront Conservancy, Detroit/Wayne County Port Authority, Downtown Detroit Partnership, Essex County, Essex Region Conservation Authority, National Park Service, Tourism Windsor Essex Pelee Island, U.S. Fish and Wildlife Service, Wheelhouse Detroit, and Windsor Bicycling Committee.

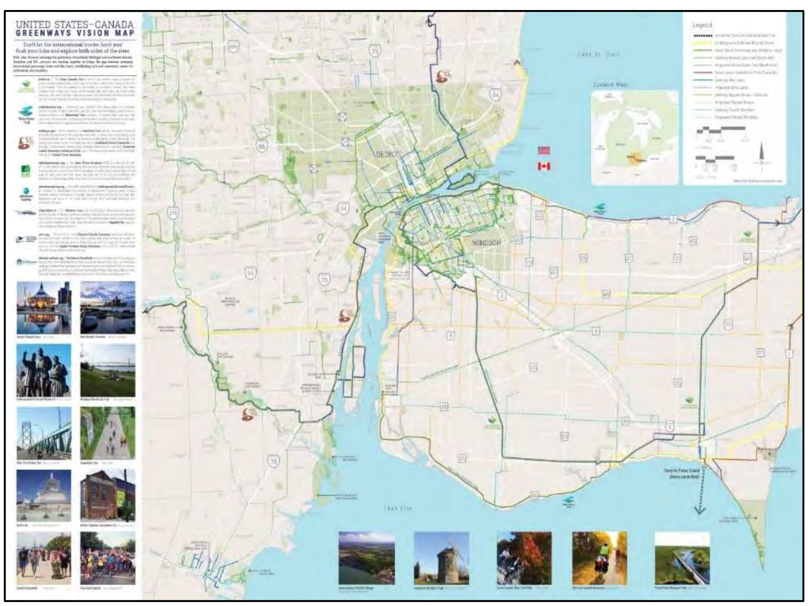


Figure 1. U.S.-Canada Greenways Vision Map.

Status and Trends

The vision of these Canadian and U.S. partners is to encourage stronger linkages between emerging greenways of southwest Ontario and southeast Michigan via a future dedicated bike lane on the new Gordie Howe Bridge, improvements to the Detroit-Windsor Tunnel Bus to accommodate cyclists, and a possible future ferry system between Windsor and Detroit.

Greenways are connections that link communities, parks, nature areas, cultural features, economic centers, and historic sites. Based on experience throughout the world, greenways promote outdoor recreation, catalyze ecotourism and economic development, promote healthier lifestyles, provide safe alternatives to motorized transportation, increase adjacent property values, celebrate historical and cultural assets, promote conservation and environmental education, and improve quality of life.

Windsor and Detroit share the same ecosystem and have much in common culturally, socially, economically, and historically. Each has a unique greenway system.

Windsor Greenways

In many respects, Windsor's greenways have been an inspiration for the development of Detroit's greenways. Windsor's Department of Parks and Recreation maintains 1,214 ha (3,000 acres) of green space, 180 parks, and over 64 km (40 miles) of trails (City of Windsor, 2019). Beginning in the 1960s, Windsor started creating a 43-km (27-mile), shared-usage, trail network called the "Windsor Loop" that circumnavigates around the entire city and connects to neighboring communities. The longest greenway trail in this network is the Roy A. Battagello River Walk (built in the late 1960s, and upgraded/widened several times), stretching from west of the Ambassador Bridge to the historical Hiram Walker Distillery, a distance of about 8 km (five miles). This trail also connects to other trails leading to key natural areas and city parks, including Ojibway Park and Ojibway Prairie Provincial Nature Reserve, Malden Park, Spring Garden Area of Natural Scientific Interest, and others. Other key extensions of this greenway trail network include the Ganatchio Trail (built in 1971), its Little River Extension (built in 1996), the Devonwood Bike Trail (built between the mid-1980s and the early 1990s), the Rt. Hon. Herb Gray Parkway trails that offer an additional 19 km (12 miles) of greenways (opened in 2016), and the 22-km (13.7-mile) rail trail called the Cypher Systems Group Greenway that was completed in 2017 (connecting Essex to Amherstburg).

Detroit Greenways

Detroit has over 320 km (200 miles) of bike routes and greenways, including the Detroit RiverWalk that won an Excellence in the Waterfront Award from The Waterfront Center, the Dequindre Cut Greenway that links the waterfront with Detroit's Eastern Market and many neighborhoods, the Joseph Compeau Greenway that is under construction and will connect the RiverWalk with neighborhoods, the May Creek Greenway that is in development that will connect the RiverWalk with Michigan Central Station and neighborhoods of southwest Detroit, and the Joe

Louis Greenway that is a 51-km (32-mile) greenway trail from the Detroit RiverWalk to Highland Park, Dearborn, and Hamtramck (projected to be completed in 2022)(City of Detroit, 2018). Detroit's greenways are connected to over 1,600 km (1,000 miles) of greenway trails in southeast Michigan.

Cross-Border Connections

In response to the 2016 U.S.-Canada Greenways Vision Map, the Windsor-Detroit Bridge Authority committed to including a dedicated bicycle and pedestrian lane on the new Gordie Howe Bridge projected to be completed in 2024 (Figure 2). Further, improvements have been made to the Windsor-Detroit Tunnel Bus to accommodate bicycles. Greenway organizations continue to advocate for a cross-border ferry system that would provide an additional greenway linkage. Although there are numerous obstacles, the Detroit/Wayne County Port Authority has received a $2.4-million federal grant to explore the feasibility of such a cross-border ferry, and if feasible, undertake a pilot project.

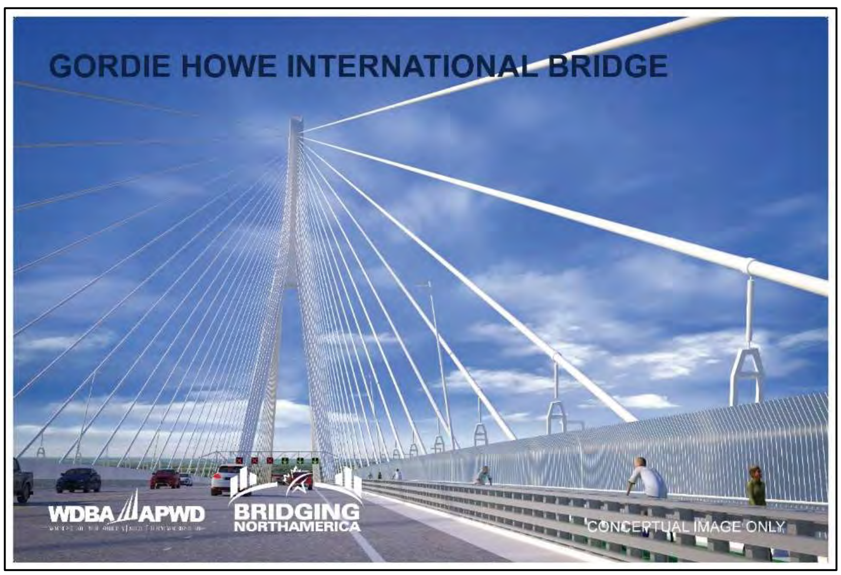


Figure 2. The Gordie Howe International Bridge projected to be completed in 2024 (credit: Windsor-Detroit Bridge Authority).

Extensions Beyond Detroit and Windsor

Detroit's greenways are part of Michigan's Iron Belle Trail that touches hundreds of municipalities and crosses through 48 counties in Michigan (Figure 3). Using existing trails, networks, and new connections, the trail extends more than 3,200 km (2,000 miles) from Ironwood, Michigan at the far western tip of the Upper Peninsula to Belle Isle in Detroit, with a route of bicycling, and a route of hiking. When complete it will link the wealth of natural and cultural resources in Michigan. In Detroit, the route heads south from Belle Isle via the Southwest Detroit Greenlink and through 10 Downriver communities, primarily following the emerging route of Downriver Linked Greenways Initiative. The biking route heads north from Belle Isle via the Conner Creek Greenway.

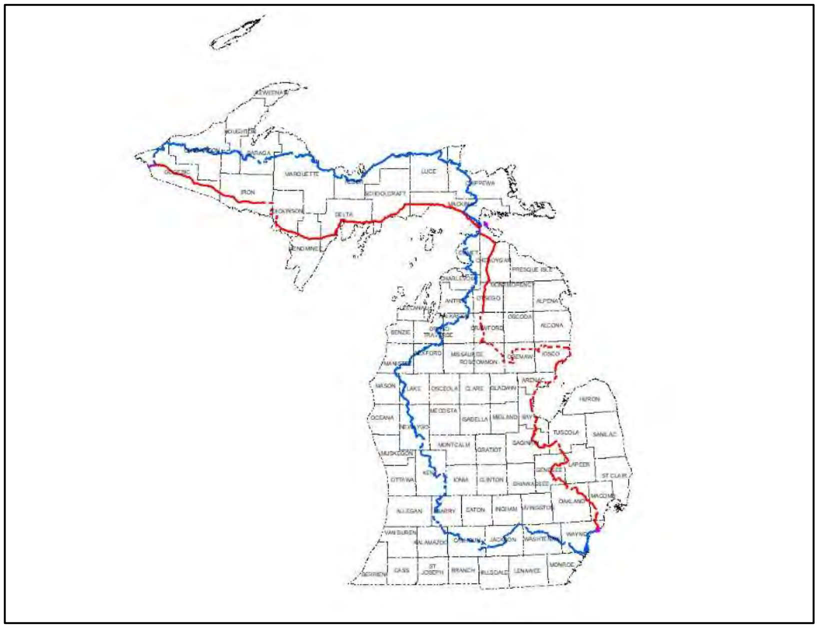


Figure 3. The Iron-Belle Trail (credit: Michigan Department of Natural Resources).

Windsor's greenways connect to Essex County greenways and are part of the Trans Canada Trail, officially renamed The Great Trail in September 2016 (Figure 4). It is a cross-Canada system of greenways, waterways, and roadways that stretches from the Atlantic to the Pacific to the Arctic oceans. The trail extends over 24,000 km (15,000 miles) and is the longest recreational, multi-use, trail network in the world. Trans Canada Trail is the name of the nonprofit organization that raises funds for the continued development of the trail, however, the trail is owned and operated at the local level. It should be noted that the Great Lakes Waterfront Trail, that stretches over 1,600 km (1,000 miles) along the shores of Lake Ontario, Lake Erie, Lake St. Clair, Lake Huron, and the St. Clair, Detroit, Niagara, and St. Lawrence rivers, is part of the Trans Canada Trail.

Figure 4. The trans-Canada trail named The Great Trail (credit: The Great Trail).

Management Next Steps

Both greenway systems in southwest Ontario and southeast Michigan are unique individually, but together and with the Iron Belle Trail and The Great Trail they are truly world-class. These greenway systems will continue to evolve. Continuous and vigorous oversight and advocacy will be needed to realize a common vision. Further, it is critically important that government agencies, educational institutions, businesses, environmental organizations, conservation clubs, faith-based organizations, and concerned citizens join forces to continue to work together to reconnect people to the land and water in urban areas through greenways. These partnerships have the ability to foster outdoor recreational and educational experiences that help to galvanize an appreciation and love for the outdoors. That, in turn, will help develop a strong sense of place that can inspire a stewardship ethic.

Possible next steps to raise awareness and build excitement include:

- offer free access to the Tunnel Bus on weekends for cyclists;
- host a Windsor-Detroit open streets event, coupled with demonstrating a cross-border ferry; and
- organize bicycle events and races, once the Gordie Howe Bridge opens, that cross the border and showcase connectivity of greenways.

References

City of Detroit, 2018. Strategic plan for transportation. Detroit, Michigan, USA.

City of Windsor, 2019. Walk Wheel Windsor: Active Transportation Plan. Windsor, Ontario, Canada.

This page intentionally left blank.

7.46 Contaminated Sediment Remediation in the Canadian Portion of the Detroit River

Claire Sanders, Detroit River Canadian Cleanup, sanders@detroitriver.ca

Ken Drouillard, Great Lakes Institute for Environmental Research (GLIER), University of Windsor, kgd@uwindsor.ca

Jacqueline Serran, Detroit River Canadian Cleanup, serran@detroitriver.ca

Background

The Detroit River is a 51 km-long connecting channel that links Lake St. Clair to the western basin of Lake Erie. The river runs through two major urban areas (i.e., Detroit, MI and Windsor, ON) and has long been used for industrial and recreational purposes. Over the past 100 years, the shoreline and watershed of the river has experienced a large amount of urban, industrial, and agricultural development. As industry became more intensive, and the watershed more developed, water pollution, loss of habitat, and point and nonpoint source pollution became large issues, which led to the Detroit River being designated as a binational Great Lakes Area of Concern (AOC) through the Great Lakes Water Quality Board of the International Joint Commission in 1985 (Green et al., 2010).

Eight beneficial uses that were identified as impaired on the Canadian side of the Detroit River. The status of a number of them, such as Degradation of Benthos, Fish Tumors and Other Deformities, and Fish and Wildlife Consumption, depend on the quality of the sediment in the river. Contaminants such as heavy metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), which were released from factories or entered the river via runoff, have a negative effect on wildlife, benthos, and fish living within the system (e.g., by increasing tumour prevalence in fish) and in humans through the bioaccumulation of toxic substances through the food web. Over the past several decades, legislation has been introduced on both sides of the border to reduce the amount of contaminants entering the Detroit River; however, these legacy contaminants still exist in the sediment.

Status and Trends

Sediment Contamination on the Canadian side of the Detroit River

Elevated levels of contaminants have been found in sediments on both the Canadian and U.S. sides of the Detroit River. In 1993, the Ontario Ministry of the Environment established Provincial Sediment Quality Guidelines (Fletcher et al., 2008), which determined the thresholds above which adverse effects will be experienced by various sediment-dwelling organisms. The Lowest Effect Level (LEL) of contaminants of potential concern (COPCs) is the threshold of contaminants above which the most sensitive species may experience adverse effects and the Severe Effect Level (SEL) is the threshold above which ecological detriment to the majority species will begin to be observed.

Sediment samples were analyzed from the Detroit River AOC in 1999, 2001, 2009, and 2013 to determine whether contaminant levels exceeded SELs (Drouillard et al., 2010; 2014; 2015). There has been a general decline in SEL exceedances on both sides of the river and since 1999, only one SEL exceedance has been recorded in 2013 on the Canadian side of the river (Drouillard et al., 2014; McDougall, 2019; Table 1). The hot spots of contaminant accumulation were located along the American shoreline upstream of Belle Isle and downstream in the Trenton

Table 1: A summary of Severe Effect Level exceedances recorded in Canadian and American waters of the Detroit River, 1990-2013. Note: Excd. = exceedances.

Country	**1999**		**2001**		**2009**		**2013**	
	SEL Excd.	**Survey Sites**	**SEL Excd.**	**Survey Sites**	**SEL Excd.**	**Survey Sites**	**SEL Excd.**	**Survey Sites**
Canada	9	74	0	10	0	34	1	37
USA	14	73	2	6	6	39	3	37

Channel, which is consistent with previous studies (i.e., Thornley and Hamady, 1984). The one Canadian site that had SEL exceedances in 2013 for chromium, lead, and copper was located near the Ambassador Bridge, just inside of the Canadian border (Drouillard et al., 2014; 2015).

Though sediment COPCs continue to be above Great Lakes background levels on the Canadian site of the Detroit River, it is not expected that these contaminant levels will cause noticeable biological impairment (McDougall, 2019). The existing research indicates that sediment contamination on the Canadian side is localized, with the vast majority of sites sampled having concentrations below provincial SELs. As a result, no sediment remediation activities have been conducted in the Canadian waters of the Detroit River or are planned in the future, but continued monitoring of sediment contamination levels is recommended. With the increasing quality of the sediment in the Detroit River, two of the beneficial use impairments (BUIs) whose status is dependent on sediment quality (Fish Tumors and Other Deformities and Degradation of Benthos) have recently been recommended for a status change to not impaired for Canadian waters of the AOC.

There has been one sediment remediation project in a subwatershed of the Detroit River called Turkey Creek. From 2001 to 2008, a series of studies were undertaken to determine the extent of historical and ongoing sources of PCB contamination within the watershed. During the 2001 sampling campaign, PCB concentrations exceeded provincial water quality objectives in each water sample collected during a 28-day time-integrated period. Trace metals also exceeded provincial objectives, with both trace metal and PCB concentrations increasing in the upstream reaches of Turkey Creek, indicating a potential contaminant source upstream. In 2005, the upstream reaches of the Turkey Creek and the Grand Marais Drain were targeted to delineate areas of contamination and determine the bioavailability of PCBs. Water, sediment, soil, and young-of-year fish sampling was performed, and semi-permeable membrane devices were deployed from Walker Road to Central Avenue to track contaminants. Results showed that ongoing sediment transport and resuspension processes were maintaining an increased bioavailability of PCBs to organisms within the creek, that there were elevated PCB concentrations within the banks of the creek, and that just over 200 m of creek bed and banks were the likely contributors to the overall contamination in the Turkey Creek-Grand Marais drain. In 2008, 975 m^3 of sediments, contaminated with heavy metals and PCBs, were excavated to a target PCB concentration of less than 1ug/g in the Grand Marais Drain upstream of Walker Road. Reductions in PCB concentrations were observed in the Turkey Creek Grand Marais Drain in 2012 when a study was conducted to determine the success of the sediment remediation. Overall, contamination within the Turkey Creek watershed and at the mouth of the creek into the Detroit River have improved, although it is unclear as to whether this is a direct result of the remediation work.

Dredging for Navigational Purposes

While no locations have been identified for remedial dredging, dredging of sediments does take place in one area of the lower Canadian Detroit River for navigational purposes. The Canadian Coast Guard division of Fisheries and Oceans Canada currently assumes responsibility for these dredging projects. Today, routine maintenance dredging is conducted at least once every ten years to remove accumulated sediment to ensure that navigational channels are maintained at design depths (DFO, 2019). In the Detroit River, the Restrictions on Dredging Activities BUI was designated ‘impaired’ in the 1991 Stage 1 Remedial Action Plan Report because disposal of sediment on the Michigan side of the Detroit River and in the lower section of the Canadian side were not suitable for open water disposal because of heavy metals, PCBs, and contaminants.

The Ontario Provincial Sediment Quality Guidelines came into effect in the early 1990s after this BUI was identified in most AOCs and, as a result, the regulations and practices for management of dredged material have evolved and improved significantly. Sediment analyses of dredge spoils from 2002 and 2007 show that the sediment quality of the dredged material from the Canadian side of the Detroit River has remained consistent from year to year, with minor exceedances of Provincial Sediment Quality Guidelines Lowest Effect Levels (LEL) for arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc, total organic carbon, total Kjeldahl nitrogen, and total phosphorus. In 2002, six samples showed LEL exceedances for several PAHs, as well as trace amounts of PCBs. Due to these exceedances and the high silt content which limits upland beneficial reuse, the dredged sediment is disposed of in a conveniently located confined disposal facility. No contaminants approached the Severe Effect Levels.

Regulatory oversight in navigational dredging projects is achieved through the federal and/or provincial environmental protection legislation and approval process. Many jurisdictions now recognize that open water disposal is not without adverse environmental impacts, regardless of the contaminant level of the dredged material. In 2013, draft guidance from the Canada-Ontario Agreement federal and provincial remedial action plan management was produced. This guidance says:

> "Restrictions on Dredging Activities" BUI may be considered "not impaired" in AOCs where dredging for commercial navigation may be undertaken and the agency responsible for the dredging activities requires that the dredged material be disposed of in an existing, regulated management facility in accordance with provincial and/or federal guidelines and regulations."

Based on this guidance, the status of the Restrictions on Dredging Activities BUI on the Canadian side of the Detroit River was officially changed to unimpaired in April 2019.

Management Next Steps

Conclusions and Recommendations

Over the past several decades, legislation has been enacted on both the Canadian and American side of the Detroit River to reduce the amount of contaminants entering the Detroit River. As a result, on the Canadian side of the Detroit River, we are seeing an improvement in sediment quality. Where SEL contamination exists, it is localized in nature, indicating that severe biological impairment due to contaminated sediment on the Canadian side of the river is unlikely. Therefore, there have been no sediment remediation projects in the Detroit River itself to remove contaminated sediment. The only dredging of sediment that occurs in the Detroit River is to ensure that navigational channels are maintained at the required depth. The sediment quality of the dredged material remains consistent from year to year, with some exceedances of LEL and no exceedances of SEL.

There has been a concerted effort by both Canadian and American authorities and industries to reduce the amount of contaminants entering the Detroit River from both point and nonpoint sources. Further, infrastructure improvements at wastewater treatment plants and to sewer systems (i.e., the replacement of combined sewer systems) provide opportunity to further decrease contaminants entering the system. In addition, the continued regulation and education to ensure proper disposal of waste containing contaminants will help to ensure these chemicals do not inadvertently end up in river sediment.

References

Department of Fisheries and Oceans Canada, 2019. Interim code of practice: Routine maintenance dredging. Retrieved from https://www.dfo-mpo.gc.ca/pnw-ppe/codes/dredge-drageur-eng.html (accessed November 28, 2019).

Drouillard, K. D., 2010. Cause and Effect Linkages of Contamination and Delisting Criteria in the Detroit River Area of Concern. Great Lakes Sustainability Fund Project: 07-006. Great Lakes Institute for Environmental Research, University of Windsor. Windsor, Ontario, Canada.

Drouillard, K. D., Grgicek-Mannion, A., McPhedran, K. N. Lafontaine, J., 2015. Weight of Evidence for Assessing Toxicity and Recovery of Priority Pollutants in the Sediments of the Huron-Erie corridor. Great Lakes Institute for Environmental Research (GLIER). University of Windsor, Windsor, Ontario, Canada.

Drouillard, K. D., McPhedran, K. N., Grgicek-Mannion, A., Haffner, D., 2014. Report: Weight of Evidence Approach for Assessing Toxicity and Recovery of Priority Pollutants in Sediments of the Huron-Erie Corridor. Great Lakes Institute for Environmental Research (GLIER). University of Windsor, Windsor, Ontario, Canada.

Fletcher, R., Welsh, P., Fletcher, T., 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: an integrated approach. Ontario Ministry of the Environment. PIBS 6658e. May 2008. Toronto, Ontario, Canada.

Green, N.D., Cargnelli, L., Briggs, T., Drouin, R., Child, M., Esbjerg, J., Valiante, M., Henderson, T., McGregrod, D., Munro, D., 2010. Detroit River Canadian Remedial Action Plan: Stage 2 Report. Detroit River Canadian Cleanup, Publication No. 1, Essex, Ontario, Canada.

MacDougall, M.J., 2019. Detroit River Area of Concern Assessment of the Degradation of Benthos Beneficial Use Impairment in Canada Waters. RiverLabs (St. Lawrence River Institute). Cornwall, Ontario, Canada.

Thornley, S., Hamdy, Y., 1984. An Assessment of the Bottom Fauna and Sediments of the Detroit River. 1984, Her Majesty the Queen in Right of Ontario. ISBN. 0-7743-8474-3. Ontario Ministry of the Environment, Toronto, Ontario, Canada.

This page intentionally left blank.

7.47 Contaminated Sediment Remediation in the River Raisin Area of Concern

John H. Hartig, Great Lakes Institute for Environmental Research, University of Windsor, jhhartig@uwindsor.ca

Background

The River Raisin is located in the southeastern portion of Michigan's Lower Peninsula with the watershed extending into five Michigan counties and even dipping into a small portion of northern Ohio. Conversely, the boundary of the River Raisin Area of Concern (AOC), the area of the River Raisin most impacted by human-made contaminants, is located entirely within the City of Monroe. The boundary of the AOC is defined as the lower portion of the River Raisin (4.2 km or 2.6 miles), downstream from Dam No. 6 at Winchester Bridge in the City of Monroe, extending 0.8 km (one-half mile) out into Lake Erie following the Federal Navigation Channel and along the nearshore zone of Lake Erie, both north and south, for 1.6 km (one mile). Through the International Joint Commission, it was identified a Great Lakes AOC with impaired beneficial uses. In 1985, the Michigan Department of Natural Resources, in cooperation with U.S. Environmental Protection Agency, committed to developing a remedial action plan (RAP) to restore these impaired beneficial uses.

Status and Trends

Like many areas of the Great Lakes, industrial development, including paper mills and automotive manufacturing, left behind a legacy of pollution (Foose et al., 2018). The initial River Raisin RAP identified the following problems: heavy metals and polychlorinated biphenyl (PCB) contamination of the sediments and water column; sediment input from nonpoint sources outside of the AOC; and PCB contamination of fish (Michigan Department of Natural Resources, 1987). Because of PCB contamination, a fish consumption advisory had been issued by the Michigan Department of Public Health. The fish contamination and consumption advisory and the contamination of river sediments were identified as the primary impaired uses in the AOC and the 1987 RAP focused on these issues. In all, nine of the possible 14 BUIs were deemed to be impaired.

RAP Development in the Spirit of Adaptive Management

The Stage 1 RAP was developed to reach agreement on problem definition, including use impairments, and causes, and was completed in 1987. In the spirit of adaptive management, where assessments are made, priorities set, and action taken in an iterative fashion for continuous improvement, the RAP was updated periodically (Table 1). The RAP process placed a high priority on implementing concurrently both necessary studies and remedial and preventive actions. Actions to restore impaired beneficial uses have always been paramount. To ensure local ownership of the RAP, the Michigan Department of Natural Resources and the Michigan Department of Environmental Quality have organized many public meetings, helped organize a River Raisin Public Advisory Council, and worked with the River Raisin Watershed Council, the City of Monroe, and many others.

Contaminated Sediment Remediation

The River Raisin AOC was originally designated an AOC in 1985 because of PCB-contaminated sediments (Table 1). Scientific assessments were performed by Michigan Department of Environmental Quality (MDEQ) and the U.S. Environmental Protection Agency (USEPA) to quantify the severity and geographic

Table 1. A chronology of RAP activities to restore impaired beneficial uses in the River Raisin AOC.

Year	Activity
1985	Commitment by Michigan and U.S. EPA to develop and implement a RAP for River Raisin
1987	Stage 1 RAP Completed
1998	River assessment conducted
2002	RAP Update published
2003-2004	Michigan DEQ and U.S. EPA conduct post-navigational dredging study
2004	Coastal Zone Management grant awarded to Monroe for field assessment
2005-2006	PCB sludge excavated from Lagoon 1 and adjacent area, and properly disposed
2006	RAP Update published
2006	Monroe's Commission on the Environment and Water Quality established
2009	RAP Update published
2010	Michigan DEQ released updated guidance for delisting AOCs
2012	Stage 2 RAP published Degradation of aesthetics removed as an impaired use
2012	North River Raisin Wetland Enhancements
2012	Sterling Island Habitat Restoration
2012-2013	Low Head Dam Improvements
2013	Eutrophication or undesirable algae and beach closings removed as impaired uses
2015	Ford Marsh Restoration Project
2015	Loss of Fish and Wildlife Habitat and Degradation of Fish and Wildlife Populations beneficial uses restored
2016	PCB Contaminated Sediment Remediation Project Completed
2016	All remedial actions identified for use restoration in the RAP implemented

extent of sediment contamination. Quantitative cleanup targets were established based on: measured PCB uptake in fish and sediment dwelling organisms; PCB exposure reductions required to remove beneficial use impairments of restrictions on fish and wildlife consumption, bird or animal deformities or reproduction problems, and restrictions on dredging activities; and applicable laws like the U.S. Toxic Substance Control Act, the U.S. Clean Water Act, and the Michigan Toxic Substances Control Act.

In 1997, Ford Motor Company removed 20,000 m^3 of highly PCB-contaminated sediment from the AOC, under USEPA order at a cost of $6 million (Foose et al., 2018). From 1998-2002, the USEPA and MDEQ performed post-remediation sediment monitoring, finding that high levels of PCBs remained in both the sediments and in fish tissue. PCB contamination of the sediments is responsible for four of the beneficial use impairments: degradation of benthos, restrictions on fish and wildlife consumption, bird or animal deformities or reproductive problems, and restrictions on dredging activities.

In 2012, the U.S. Army Corps of Engineers performed a strategic navigational dredging project that removed 52,750 m^3 of PCB-contaminated sediment at a cost of $800,000. Additional sediment remediation took place in 2012-2013 and 2016 under the Great Lakes Legacy Act, in partnership with Ford Motor Company and the MDEQ (Figure 1). Methods employed included mechanical dredging hydraulic

Figure 1. Contaminated sediment remediation in the lower River Raisin (credit: U.S. Environmental Protection Agency).

dredging, and capping. In total, 95,350 m^3 of PCB-contaminated sediment were removed and disposed (completed in 2016) at a cost of $36.3 million (Foose et al., 2018). MDEQ and Ford provided cash and in-kind services of over $15.4 million under the Great Lakes Legacy Act cost-sharing agreement. The contaminated sediment was transported to a disposal facility certified to handle contaminated material in Wayne County, Michigan. Partners in the project included: USEPA, MDEQ, and Ford Motor Company.

Monitoring studies of the benthic conditions are now underway to determine the efficacy of the 2016 contaminated sediment remediation and the related ecosystem response.

Return of Bald Eagles in Monroe County

Bald eagles throughout the Great Lakes were impacted by persistent toxic substances, including the River Raisin watershed. U.S. Fish and Wildlife Service (USFWS) and Michigan Departments of Environment, Great Lakes, and Energy, and Natural Resources, have been monitoring bald eagles throughout the state for over 50 years. For 20 years, beginning in the late-1960s, no occupied bald eagle nests were reported in Monroe County (Figure 2a). Bald eagle nesting in Monroe County was again documented in 1987 and steadily increased thereafter to the point where 14 occupied nests have been found in recent years (2013, 2014 and 2015). Bald eagle fledging success in Monroe County has shown a similar improvement with 15 or more bald eagles fledging in recent years (2012, 2013, and 2015; Figure 2b). Other avian studies are underway to measure contaminant impacts and response to sediment remediation.

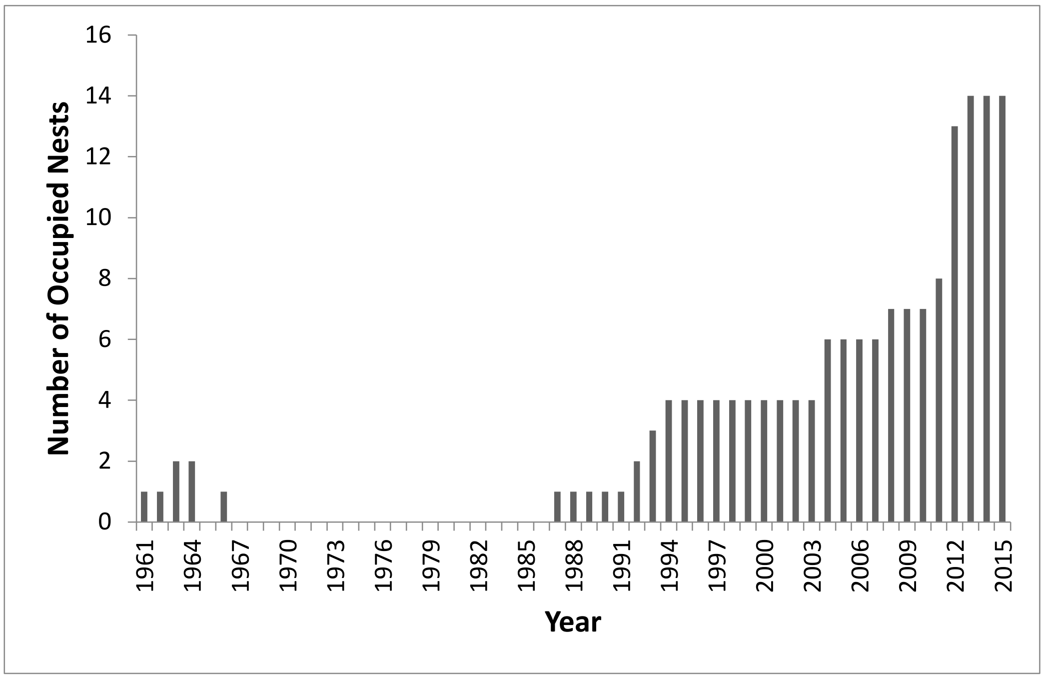


Figure 2a. Occupied bald eagle nests per breeding site in Monroe County, Michigan (source: USFWS and Michigan Departments of Environment, Great Lakes, and Energy, and Natural Resources).

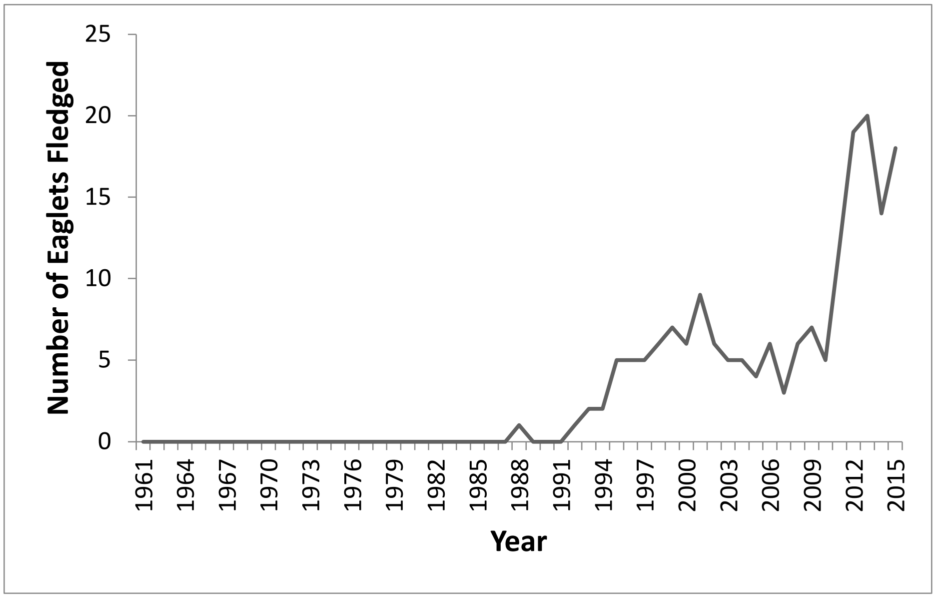


Figure 2b. Number of eaglets fledged per year in Monroe County, Michigan, 1961-2015 (data collected by USFWS and Michigan Departments of Environment, Great Lakes, and Energy, and Natural Resources).

Management Next Steps

All remedial actions identified for use restoration in the River Raisin RAP have now been implemented. Although these sediment remediation and habitat restoration projects have been completed, it will take time for the ecosystem to respond. Monitoring to track ecosystem response and ultimately use restoration is underway. This remediation and restoration accomplished were the result of collaborative partnerships.

Contaminated sediment remediation is often unpredictable (Foose et al., 2018). In the River Raisin AOC, a significant sediment remediation project was completed in 2012. Following that project, there was hope that all the contaminated sediments had been successfully remediated. However, upon further investigation and sampling, additional high levels of PCBs were found. In 2017, a second, large-scale sediment remediation project intended to get the last of the very high levels of PCBs in the sediments of the river was completed. Monitoring continues to determine if the PCBs were successfully remediated. The AOC program requires patience and dedication to keep working towards a goal of remediating all contaminated sediments, restoring habitat, and working with all public and private partners for a revitalized waterfront community.

Finally, it should be noted that Great Lakes Legacy Act and Great Lakes Restoration Initiative were essential is achieving the $36 million sediment remediation project completed in 2016. Great Lakes Legacy Act and Great Lakes Restoration Initiative were used to leverage cash and in-kind services from Michigan DEQ and Ford Motor Company as part of a cost-sharing agreement. This was a good example of a public-private partnership for significant sediment remediation.

References

Foose, M., Stefanski, D., Laroy, B., Micka, R., Hartig, J., Restoration of the River Raisin Area of Concern. International Association for Great Lakes Research, Ann Arbor, Michigan, USA.

Michigan Department of Natural Resources, 1987. Remedial Action Plan for the River Raisin Area of Concern. Lansing, Michigan, USA.

7.48 Contaminated Sediment Remediation in the U.S. Portion of the Detroit River

Rose Ellison, U.S. Environmental Protection Agency, Great Lakes National Program Office, ellison.rosanne@epa.gov

Sam Noffke, Michigan Department Environment, Great Lakes, and Energy, noffkes@michigan.gov

Ken G. Drouillard, University of Windsor, Great Lakes Institute for Environmental Research, kgd@uwindsor.ca

Alice Grgicak-Mannion, University of Windsor, Great Lakes Institute for Environmental Research, grgica3@uwindsor.ca

John H. Hartig, University of Windsor, Great Lakes Institute for Environmental Research, jhhartig@uwindsor.ca

Background

The Detroit River was designated as a Great Lakes Area of Concern (AOC) due to recognized impairments of at least nine beneficial uses (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991). The history of contamination of the Detroit River is complex as it receives inputs from upstream waters (Lake St. Clair and the St. Clair River) as well as point and nonpoint source inputs from two major urban centers (Detroit, Michigan and Windsor, Ontario) that include effluents from multiple industries, hazardous waste sites, wastewater treatment plants, combined sewer overflows, and urban runoff. Priority pollutants identified in the Detroit River include mercury and several other metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, dioxins, and furans (UGLCCS, 1988; Green et al., 2010).

Sediment Contamination

Several beneficial use impairments, including restrictions on fish and wildlife consumption, degraded fish and wildlife populations, fish tumors or other deformities, degradation of benthos, bird or animal deformities and reproductive problems, and restrictions on dredging activities, have direct cause-effect linkages with sediment contamination in the AOC (Green et al., 2010). The Detroit River is also identified as a main source of contamination to Lake Erie, especially during storm events which can resuspend and transport contaminated particles from accumulated contaminated sediment deposits (Zarull et al., 2001; Reitsma et al., 2003). As such, contaminated sediments are a main factor in the cleanup strategies recommended by the Stage II Remedial Action Plan for the Detroit River and the subject of past clean-up efforts (Hartig et al., 2009).

Studies to identify contaminated sediment repositories in the AOC began in 1985 as part of the binational Upper Great Lakes Connecting Channels Study (UGLCCS, 1988). Additional, sediment chemistry surveys and comprehensive geospatial mapping projects were conducted in 1999, 2008/2009, and 2013 that enabled the establishment of baseline conditions, mass inventories, and the identification of local contamination zones (Szalinska et al., 2006; Drouillard et al., 2006; Szalinska et al., 2013). Although there is evidence for declines in some priority pollutants including PAHs, PCBs, lead, mercury, and zinc between the 1980s and present, the rate of decline post-1999 has declined with most contaminants showing no change between 1999 and 2013.

To facilitate hazard assessment, sediment concentrations for thirteen priority pollutants collected from 1999-2013 were indexed to consensus-based sediment quality guidelines (MacDonald et al., 2000) to generate a multi-pollutant hazard score as described in McPhedran et al. (2017). Hazard scores less than 40 are considered non-troxic, values of 40-79 reflect some toxicity, values of 80-119 are likely toxic, values of 120-249 are toxic, and values 250 or greater are considered highly toxic (MacDougal, 2019). Figure 1 presents a map of hazard scores for priority pollutants in surficial sediments from monitoring stations in the Detroit River AOC. Areas with high hazard scores are found along much of the U.S. nearshore region commencing downstream of Belle Isle through to Mud Island located to the west of Fighting Island and throughout the Trenton Channel and downstream of Grosse Isle to the mouth of the river at Lake Erie.

History of Contaminated Sediment Remediation

Metropolitan Detroit's long history of human and industrial development has resulted in substantial sediment contamination along the U.S. shoreline. Between 1986 and 2020 there has been 396,800 m^3 of contaminated sediment remediated in the lower Rouge River at a cost of $62.75 million (Table 1). Between 1993 and 2020 there has been 287,570 m^3 of contaminated sediment remediated along the U.S. shoreline of the Detroit River at a cost of $56.3 million (Table 2). In addition, there are capping projects that will be undertaken in 2020-2022 along the Detroit River shoreline of the old Uniroyal site and the new Ralph C. Wilson, Jr. Centennial Park under development (Table 2).

All of these sediment remediation projects were the result of enforcement actions, with the exception of: the Lower Rouge River-Old Channel and the Black Lagoon, Uniroyal, and Wilson Park sites on the Detroit River that were or are being remediated through the Great Lakes Legacy Act; and Conner Creek that was remediated through a Supplemental Environmental Project (i.e., an environmentally beneficial project that is included as part of a settlement for environmental violations) with the Detroit Water and Sewerage Department.

Sediment Remediation Priority Setting

In 2012, a binational group of federal, state, local, nongovernmental, and university stakeholders worked together to compile data collected over last 30 years on sites of known sediment contamination in the Detroit River. From this preliminary exercise, six areas were targeted for further assessment:

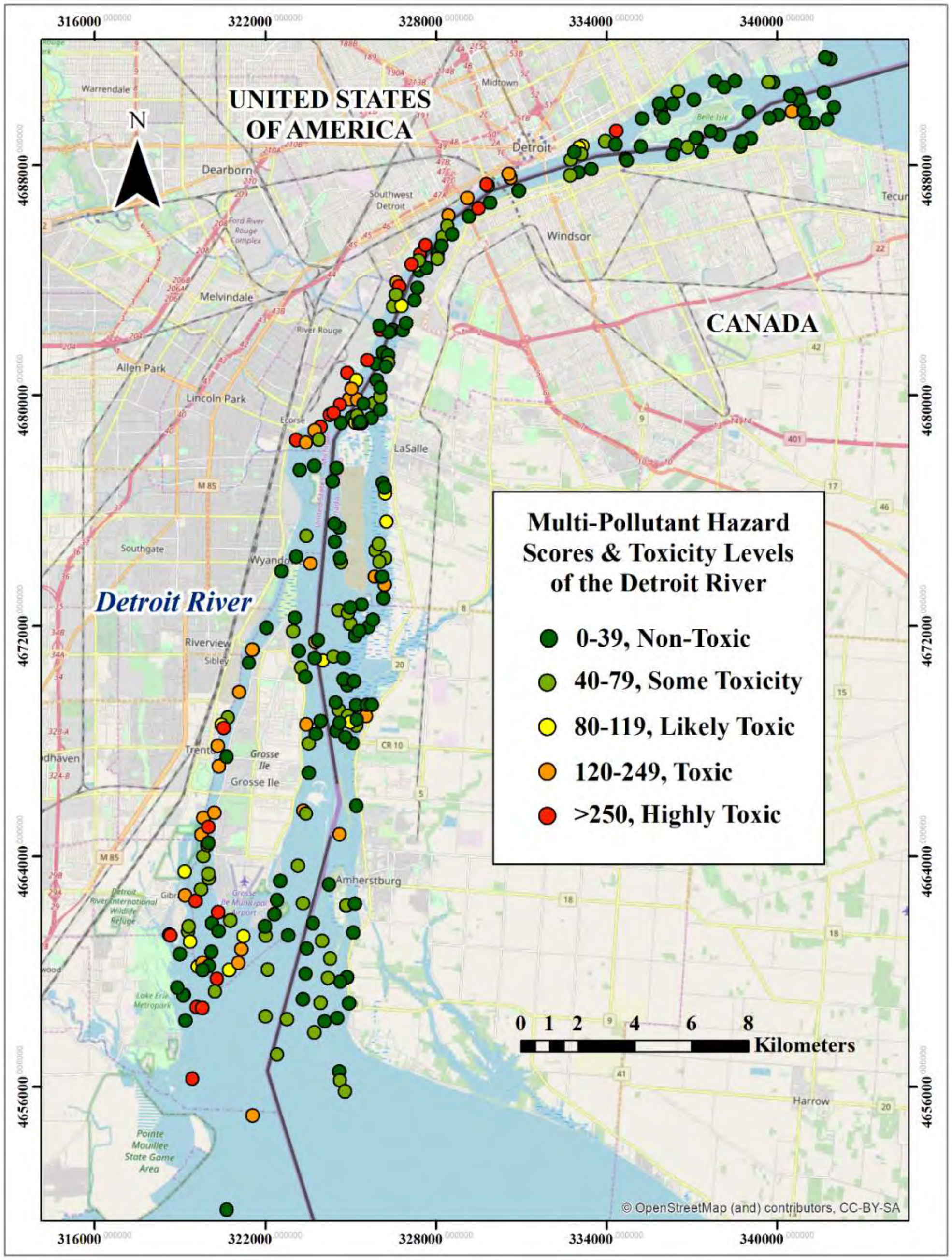


Figure 1. Multi-pollutant hazard scores for priority pollutants in surficial sediments from selected stations in the Detroit River AOC.

Table 1. Contaminated sediment remediation in the Rouge River, 1986-2020.

Location or Site	Nature of Project	Volume of Sediment	Year	Cost
Lower River near Double Eagle Steel	Dredging and disposal	30,000 m^3	1986	$1 million
Evans Products ditch	Dredging and disposal	7,300 m^3	1997	$750,000
Newburgh Lake	Dredging and disposal	306,000 m^3	1997-1998	$11 million
Lower River – Old Channel	Dredging and disposal	53,500 m^3	2019-2020	$50 million

Table 2. Contaminated sediment remediation in the U.S. portion of the Detroit River, 1993-2020.

Location or Site	Nature of Project	Volume of Sediment	Year	Estimated Cost
Carter Industrial Site	Removal of PCB-contaminated soils and disposal	35,100 m^3	1986-1987	$19.5 million
Elizabeth Park Marina	Dredging and disposal	3,100 m^3	1993	$1.3 million
Monguagon Creek	Dredging and disposal	19,300 m^3	1997	$3 million
Conner Creek	Dredging and disposal	111,630 m^3	2004	$4 million
Black Lagoon – Trenton Channel	Dredging and disposal	88,440 m^3	2004-2005	$9 million
BASF Riverview	Removal of contaminated soils, creation of an on-site disposal cell with an inward hydraulic gradient, removal and disposal of contaminated sediments, and creation of shoreline habitat and 0.4-ha of fish spawning	30,000 m^3	2007-2008	$19.5 million

Table 2. Contaminated sediment remediation in the U.S. portion of the Detroit River, 1993-2020.

Location or Site	Nature of Project	Volume of Sediment	Year	Estimated Cost
	habitat			
Old Uniroyal Site near MacArthur Bridge	Capping	Approximately 9,940 m^3 of sediment along 640 m of shoreline (isolate, stabilize, and cap with clean material)	2020	$2.9 million
Ralph C. Wilson, Jr. Centennial Park	Capping contaminated sediments and creation of shoreline habitat	Approximately 4,650 m^2 of river sediments, plus additional areas along the park shoreline	2021-2022	$5.5 million

- Harbortown Upstream
- Harbortown
- Riverbend
- River Rouge/Ecorse Shoreline
- Mid-Lower Trenton Channel
- Celeron Island Area

In 2013, U.S. Environmental Protection Agency and the State of Michigan initiated site characterization at these target areas. Characterization was completed in fall 2018. In total, 219 core samples and 191 ponar samples were collected generating 873 samples for analysis of toxic substances, including heavy metals and persistent organochlorine compounds. Data were compared to known standards and modeling was performed to further delineate contaminated areas.

In general, where sediments were present in the nearshore areas of the Detroit River on the U.S. side, they were contaminated. The enhanced monitoring survey was also able to get closer to the shore/river interface than previous river-wide sediment chemistry surveys, demonstrating much higher chemical gradients at the shoreline margins compared to deeper regions. Despite high water volume, flow rate, and time, contamination was highest near historical industrial and municipal outfalls.

From this exercise, nine areas have been targeted for contaminated sediment remediation along the U.S. shoreline of the Detroit River by U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes, and Energy (Figure 2 and Table 3). In total, an additional 5.1 million m^3 of contaminated sediment has been targeted for remediation to help meet long-term goals for restoring beneficial use impairments. These designated areas capture a large portion of the previously designated hazard score regions identified in Figure 1.

Management Next Steps

Following control of contaminants at their source, additional contaminated sediment remediation will be undertaken using sediment assessment and modeling techniques. U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes, and Energy will be undertaking further delineation of contaminated sediments, performing selected remedial investigations/feasibility studies to support sediment remediation, tracking sources of contamination, and initiating partner discussions. For example, U.S. Environmental Protection Agency

Figure 2. Targeted contaminated sediment remediation sites along the U.S. shoreline of the Detroit River identified by U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes, and Energy.

Table 3. Estimated volumes of contaminated sediment prioritized for remediation by U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes, and Energy.

Target Sites for Contaminated Sediment Remediation	Estimated Volume of Contaminated Sediments to be Remediated (m^3)
Harbortown Upstream	665,421
Harbortown Shoreline	565,770
Riverbend Shoreline	573,416
River Rouge/Ecorse Shoreline	1,682,021
Upper Trenton Channel	175,848
Monguagon Creek	30,582
McLouth Steel/Grosse Ile Shoreline	718,681
Elizabeth Park Canal	649,872
Gibraltar Canals	40,521
	Estimated Total: 5,102,132 m^3

entered into a partner agreement with the Detroit Riverfront Conservancy to provide the necessary 35% non-federal match on a Great Lakes Legacy Act capping project that will be undertaken in 2020 at the former Uniroyal site near Belle Isle and the new Ralph C. Wilson, Jr. Centennial Park. Similarly, additional partners will need to be recruited to provide non-federal match funding on any Great Lakes Legacy Act sediment remediation projects. An investigation for potential partners was finalized in February 2019 that brought to light industries that may be potential partners for future sediment remediation projects. In addition, a cooperative agreement has been signed between U.S. Environmental Protection Agency and Michigan Department of Environment, Great Lakes and Energy for the necessary remedial investigation work on both the Detroit and Rouge River AOCs.

There are several anticipated benefits associated with the above remediation activities. These include improvements to the number and degree of restrictiveness of fish consumption advisories, decrease in fish tumor prevalence, and generation of healthy benthic invertebrate communities. Indirectly, these successes are also expected to have positive impacts on fish and wildlife populations through reduction of toxic stress, in association with habitat improvements that coincide with sediment remediation efforts.

References

Drouillard, K.G., Tomczak, M., Reitsma, S., Haffner, G.D., 2006. A River-wide Survey of Polychlorinated Biphenyls (PCBs), Polycylic Aromatic Hydrocarbons (PAHs), and Selected Organochlorine Pesticide Residues in Sediments of the Detroit River—1999. J. Great Lakes Res. 32, 209-226.

Green, N, Cargnelli, L., Briggs, T., Drouin, R., Child, M., Esberg, J., Valiante, M., Henderson, T., McGregor, D., Munro, D., 2010. Detroit River Canadian Remedial Action Plan Stage 2 Report. Detroit River Canadian Cleanup, Publication No. 1, Essex, Ontario, Canada.

Hartig, J.H., Zarull, M.A., Ciborowski, J.J.H., Gannon, J.E., Wilke, E., Norwood, G., Vincent, A.N., 2009. Long-term ecosystem monitoring and assessment of the Detroit River and Western Lake Erie. Environ. Monit. Assess. 158, 87–104.

MacDonald, D., Ingersoll, C., Berger, T., 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Toxicol. Chem. 39, 20-31.

MacDougall, M., 2019. Detroit River Area of Concern Assessment of the Degradation of Benthos Beneficial Use Impairment in Canadian Waters. Final report submitted to Environment and Climate Change Canada and Canadian Detroit River Delisting Committee, Toronto, Ontario, Canada.

McPhedran, K.N., Grgicak-Mannion, A., Paterson, G., Briggs, T., Ciborowski, J.J.H., Haffner, G.D., Drouillard, K.G., 2017. Assessment of hazard metrics for predicting field benthic invertebrate toxicity in the Detroit River, Ontario, Canada. Integr. Assess. Environ. Manage. 13, 410-422.

Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991. Stage 1 Remedial Action Plan for the Detroit River Area of Concern. Lansing, Michigan, USA and Sarnia, Ontario, Canada.

Reitsma, S., Drouillard, K., Haffner, G.D., 2003. Simulation of sediment dynamics in Detroit River caused by wind-generated water level changes in Lake Erie and implications to PCB contamination (Appendix 21), in: Heidtke, T.M., Hartig, J., Yu, B., (Eds.), Evaluating Ecosystem Results of PCB Control Measures Within the Detroit River-Western Lake Erie Basin. EPA-905-R-03-001, Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, Illinois, USA.

Szalinska, E., Drouillard, K.G., Fryer, B., Haffner, G.D., 2006. Distribution of Heavy Metals in Sediments of the Detroit River. J. Great Lakes Res. 32, 442–454.

Szalinska, E., Drouillard, K.G., Anderson, E.J., Haffner, G.D., 2011. Factors influencing contaminant distribution in the Huron-Erie Corridor sediments. J. Great Lakes Res. 37, 132–139.

Upper Great Lakes Connecting Channels Study (UGLCCS), 1988. Upper Great Lakes Connecting Channels Study. A Rep. by Up. Gt. Lakes Connecting Channels Study Management Committee, U.S. Environmental Protection Agency, Department Environment. Canada. Michigan Department of Natural Resources Ontario Ministry of Environment. Toronto, Ontario, Canada.

Zarull, M.A., Hartig, J.H., Krantzberg, G., 2001. Contaminated Sediment Remediation in the Laurentian Great Lakes: An Overview. Water Qual. Res. J. Canada 36, 351–365.

7.49 Detroit's Leadership in Establishing Municipal Greenhouse Gas Reduction Targets and an Action Agenda to Address Climate Change

Joel Howrani Heeres, Detroit Office of Sustainability, howraniheeresj@detroitmi.gov

Nishaat Killeen, Detroit Office of Sustainability, killeenn@detroitmi.gov

Elizabeth Palazzola, Detroit Housing and Revitalization Department, epalazzola@detroitmi.gov

Background

In Detroit, climate change is projected to increase the intensity and frequency of storms that will test and overwhelm the city's infrastructure and threaten the health of residents in other ways. Flooding will continue to affect Detroit homes and streets due to projected increases in intense precipitation, seen as recently as summer 2019 in the Jefferson Chalmers neighborhood (City of Detroit, 2019). Detroit is also projected to see a significant increase in very hot days, with as many as 65 days above 32.2°C (90°F) by the end of this century, exacerbating the burden of heat and poor air quality on the city's most vulnerable residents (Figure 1).

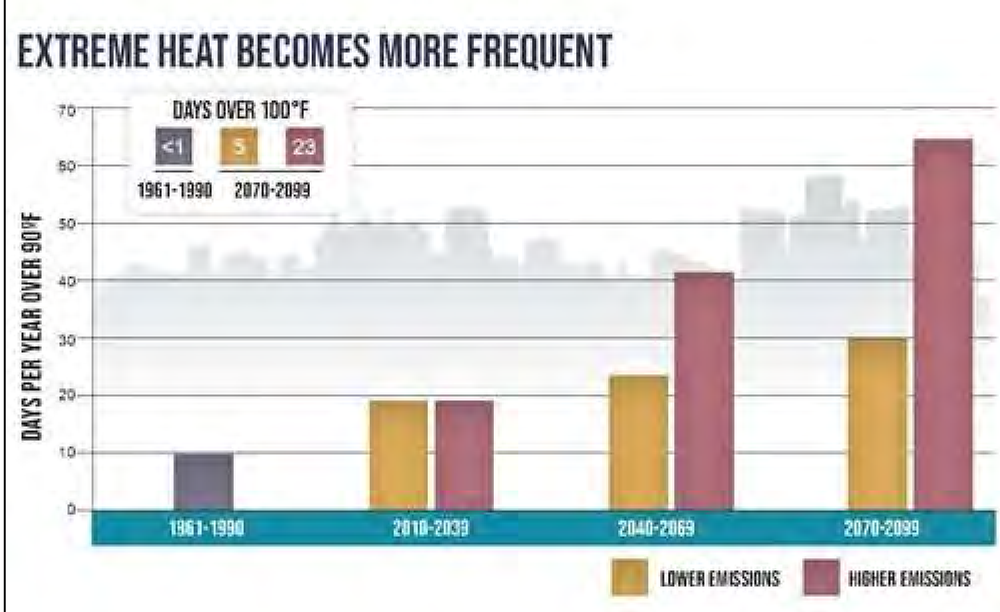


Figure 1. Trends in number of days per year with temperatures above 90°F in Detroit.

Status and Trends

Addressing the Climate Change Crisis

Greenhouse gas emissions are driving global climate change, and Detroit is committed to contributing its fair share to efforts led by cities around the world in mitigating the impacts of climate change. In June 2017, the United States pulled out of the Paris Climate Accord. Immediately following this announcement, mayors from throughout the United States started pledging to live up to the Paris Climate Accord and signed on as members of the Climate Mayors, a bipartisan, peer-to-peer network of mayors working to demonstrate leadership on climate change. Today, over 400 U.S. Mayors, representing 70 million Americans, have signed on, including Detroit Mayor Mike Duggan, to fight climate change and lower greenhouse gas emissions.

On July 24, 2019, Detroit City Council unanimously passed an ordinance to greatly and swiftly reduce greenhouse gas emissions from the city. The ordinance stipulates that greenhouse gas emissions from city sources will be reduced (from 2011 and 2012 baseline conditions as quantified by Carson et al., 2014) by 35% by 2024, 75% by 2043, and 100% by 2050. It will also work towards reducing citywide emissions by 30% by 2025. These carbon emission reduction targets, established in the ordinance, are based on the standards of the Paris Climate Agreement, which looks to prevent global temperatures from rising more than 2°C by the end of the century. For the U.S., this equates to a 26-28% reduction in greenhouse gas emissions by 2025 from a 2005 baseline.

A comprehensive greenhouse gas emission inventory was performed to quantify baseline annual CO_2 emissions in 2011-2012. This inventory showed that approximately 10.6 million metric tons of carbon dioxide (CO_2) equivalents were emitted in both 2011 and 2012 (Carson et al., 2014). The city has also committed to performing a greenhouse gas inventory assessment every four years, the first of which will be completed by August 1, 2020.

Management Next Steps

In June 2019, Detroit released a Sustainability Action Agenda that is a strategic roadmap to address key sustainability issues and create a city in which all Detroiters can thrive (City of Detroit, 2019). This Agenda focuses on achieving four outcomes:

- Healthy, thriving people;
- Affordable, quality homes;
- Clean, connected neighborhoods; and
- An equitable, green city.

This Sustainability Action Agenda builds on both the work the City has done since 2014 and community-led efforts like growing more food in the city, cleaning up and caring for vacant lots, and installing rain barrels. Over 6,800 Detroiters were involved in the development of the Agenda for a more equitable, prosperous, and environmentally sustainable city. It should be noted that climate change is only one of the issues addressed in the Sustainability Action Agenda.

Research/Monitoring Needs

Reducing Municipal and Citywide Greenhouse Gas Emissions

To become a truly green city, the City of Detroit must reduce its greenhouse gas emissions. This includes reducing emissions from city operations as well as emissions from Detroit's residents and businesses. To do this, the City will focus on consistent tracking of our greenhouse gas emissions, identifying targeted actions to address our largest emitting sectors, increasing the use of renewable energy, and ensuring efficient, green buildings operate and are constructed throughout the city.

As noted above, in 2012 Detroit's municipal greenhouse gas emissions were 1.18 million tons of carbon dioxide equivalent (CO_2) and community emissions were 10.6 million tons CO_2 (Carlson et al., 2014). The City's goal, as a signatory of the Chicago Climate Charter, is to reduce community-wide greenhouse gas emissions by 30% by 2025 from a 2012 baseline. For municipal emissions, Detroit has a goal to reduce greenhouse gas emissions by 35% by 2024 and 75% by 2034 from a 2012 baseline.

A sustainable Detroit means embracing the changing landscape of energy production towards more renewable options. Through the development of solar sites, Detroit can contribute to the local economy with green jobs and reduce greenhouse gas emissions and air pollution. As of April 2019, there was an estimated 3.3 MW of solar capacity in Detroit. Detroit aims to double the total solar generation capacity in the city by 2024 and triple it to 10 MW by 2029.

Industrial, institutional, and commercial buildings caused 40% of all greenhouse gas emissions in Detroit, making them prime candidates for impactful reductions. In 2016, industrial energy consumption was 110 thousand BTUs per square foot and commercial energy consumption was 42 thousand BTUs per square foot. As stated in the Detroit Sustainability Action Agenda, the City will work with the community to reduce average industrial and commercial energy consumption per square foot by 10% by 2024 and by 30% to 29 thousand BTU per square foot by 2029 (City of Detroit, 2019).

When 40% of Detroit's sodium streetlights were dark in 2014 and it resolved to switch to an entirely new system of 65,000 LED lights, safer, well-lit streets were not the only benefit. This major citywide project, done in partnership with the U.S Department of Energy, also slashed carbon emissions by 40,000 tons per year. That's the equivalent of taking 11,000 cars off the street. Improving lighting in our neighborhoods also had other benefits – when Detroiters feel safe biking or walking through their neighborhoods, the city becomes better connected and healthier.

As noted above, the City's most recent greenhouse gas inventory was completed in 2012 by the University of Michigan School of Environment and Sustainability (Carson et al., 2014). At that time, citywide emissions were 10.6 million metric tons CO_2. Municipal emissions were 11% of that total, or 1.18 million metric tons CO_2. While the City has taken a number of actions to reduce our emissions, such as the conversion of all of our 65,000 streetlights to LEDs and numerous actions in the Agenda that will result in lower carbon emissions, the City needs an overall strategy to achieve its carbon reduction goals. As a critical first step, we will conduct a new greenhouse gas inventory and Business-As-Usual (BAU) forecast of citywide greenhouse gas emissions. Based on the inventory, the City will develop a quantitative emissions reduction pathway analysis and climate action strategy.

Increasing Solar Generation

The city has over 3.3 MW of installed solar, with significant opportunities for an expansion of solar throughout the city. Solar installations have grown between 4% and 240% annually since 2012, without targeted marketing or promotion. In 2016, in partnership with DTE Energy, the City installed over 6,500 solar panels in O'Shea Park, constituting the largest urban solar installation in the country, generating 2 MW of power, enough to power 450 homes.

The City will develop a streamlined solar permitting process. The City will publicize existing finance and funding opportunities for integrating solar development into private projects and encourage developers to consider solar photovoltaic or other renewable energy technology in new housing and commercial projects. The City is also developing a solar potential map that will help property owners and developers quickly evaluate the opportunity to integrate solar into existing and new development projects. Finally, the City will evaluate opportunities to install solar systems on municipal buildings and facilities to lead by example.

Enhancing Energy and Water Efficiency at Municipal Facilities

The City of Detroit operates over 150 facilities, including police and fire stations, parking facilities, recreational centers, and office spaces. Currently, 88 facilities track and report their energy usage. These facilities spend approximately $7.2 million a year on energy. Energy consumption is concentrated heavily among the City's largest facilities, with ten buildings consuming more than half of this energy. The City estimates that energy efficiency measures could result in $2.1 million in annual savings at the ten largest facilities and an additional $860,000 in savings across the remaining facilities. Previous utility bill management efforts identified over $400,000 in savings from incorrect billing information which went directly back to the City. Energy audits have been conducted at 60 of the largest facilities to identify efficiency opportunities and potential capital upgrades. Recommendations are being integrated into capital improvement projects where feasible.

The City will implement both the large efficiency opportunities at the most energy-intensive facilities and the many no- or low-cost efficiency opportunities across all facilities. Beyond the 60 facilities that have already been evaluated, the City will collect energy and water data for all City buildings to understand our baseline energy use. For smaller facilities, the City will develop a set of standard measures and energy best practices, including LED lighting, low-flow hot water fixtures, and programmable thermostats, which can be implemented at a low cost. Finally, the City will implement a utility bill management system to monitor utility use and flag irregular usage and cost information for further investigation.

Launching the Mayor's Challenge Program for Commercial Buildings

Commercial and institutional buildings accounted for 33% of citywide greenhouse gas emissions in 2012. As the City invests in efficiency efforts in our own building stock, it will launch a challenge program to encourage private buildings to track their energy use, increase efficiency, and reduce their greenhouse gas emissions. Similar challenge programs in other cities such as Chicago, New York, and Atlanta have achieved significant energy savings in participating buildings.

The city will launch a challenge program for large commercial buildings to reduce their energy and water usage by 50% by 2030 and to measure these reductions. Together with the Detroit 2030 District, we will facilitate a peer-to-peer technical assistance group of building owners and managers to share proven and cost-effective energy reduction strategies.

Developing an Electric Vehicle Infrastructure Strategy

In 2018, the U.S. Environmental Protection Agency declared seven southeast Michigan counties in violation of ozone pollution standards, including Wayne County. Air pollution in Detroit is largely caused by emissions from industrial facilities and motor vehicles. Electric vehicles (EV) offer an opportunity to reduce harmful emissions from the transportation sector, which contribute to local asthma rates and other health issues and climate change. A collaborative project with DTE Energy has already resulted in pilot charging infrastructure and EV education in Capitol Park. The City convened government, local utility, and third-party stakeholders to identify the roles of each entity in the operation and maintenance of EV infrastructure in the city. The City will work with this group to develop a comprehensive electric vehicle strategy to support and accelerate widespread adoption of clean energy transportation. This will include identifying priority locations for new electric vehicle infrastructure; the necessary upgrades to existing infrastructure to support electric vehicles; and local policies, codes and incentives needed to support adoption.

Increasing Resilience

As Detroit begins to experience more extreme precipitation events, its wastewater infrastructure can become overwhelmed. However, by focusing on expanding the amount of and targeting the location of green stormwater infrastructure throughout the city, the City of Detroit can help reduce the impacts of these events. Likewise, informed and prepared communities will be more resilient to climate impacts. The City of Detroit will make information easier to access and provide emergency training to help to prepare communities for extreme events.

Reducing the Volume of Untreated Combined Sewer Overflows (CSOs)

Untreated CSOs are a result of overwhelming the city's system during rain events. In 2017, the regional sewer system recorded 77 CSO events into the Detroit and Rouge rivers. While over 96% of the sewage released into the Detroit waterways met regulatory requirements, 722 million gallons of untreated sewage were released into Detroit waterways during these events. These discharges create water quality impacts that could impact quality of life for residents, such as through beach closings. The City of Detroit will continue to take actions that reduce the volume of untreated discharges to local waterways.

Doubling the Acreage of Green Infrastructure

Green infrastructure is a key strategy for improved stormwater management, water quality, and neighborhood revitalization. As of 2018, Detroit managed approximately 900 acres through green stormwater infrastructure, direct discharge, and impervious removal (excluding demolitions). The City of Detroit aims to double the acres managed through green stormwater and related techniques citywide in 10 years, resulting in at least 1,800 acres managed by 2029.

Creating Neighborhood-Scale, Green Infrastructure Projects

CSO events are triggered when there is more precipitation than the sewage disposal system can handle, which may also cause neighborhood-level flooding. In the Sustainability Survey, 68% of the respondents indicated that they experience rainfall flooding in their neighborhood that disrupts their daily activity or damages property occasionally, often, or very often. Green stormwater infrastructure can create neighborhood amenities by adding green space to streets and adjacent properties and help manage stormwater by capturing and detaining rainwater, which keeps it out of the city's stormwater system.

In fiscal year 2017, Detroit Water and Sewerage Department invested over $6 million in green stormwater infrastructure activities. Four Water and Sewerage construction projects reached substantial completion, including Stoepel Park No. 1, Liuzzo Park, transportation corridor projects (joint with the Department of Public Works), and Tireman bioswales. Water and Sewerage also initiated two projects with Parks and Recreation (Crowell and O'Shea) which began construction in fall 2017.

The City of Detroit will work with private and public partners to develop neighborhood scale, distributed green stormwater infrastructure projects, focusing on neighborhoods that have high incidents of flooding and limited green space.

Incorporating Green Infrastructure in Street Redesign and Greenway Projects

Road surfaces are the largest area of impervious surface in the city and present an opportunity to capture and divert stormwater from the sewer system. Four of seven current bond streetscape projects integrate green infrastructure into their design, implementation, and maintenance. Building on this work, the City of Detroit will pilot green infrastructure on streetscape projects through incorporating street trees and vegetation into transportation projects whenever possible, with an emphasis on areas with high-flood risk. The City will also integrate stormwater best management practices into trail planning efforts. Green streets guidelines will be incorporated into the City's Transportation Master Plan of Policies to be completed in 2020.

Integrating Climate Change Impacts in Hazard Mitigation Planning

As Detroit faces a changing climate, natural disasters such as extreme heat and cold events and heavy rainfall are expected to happen more often and with higher intensity. The risks associated with these extreme weather events are not equally distributed across the city, as evidenced by the 2014 floods. The City updates its federally mandated Hazard Mitigation Plan every five years to identify actions that will reduce losses caused by disasters, including natural disasters. As part of the 2020 Hazard Mitigation Plan update, the City of Detroit will integrate information on climate change risks for residents and infrastructure and identify potential mitigation strategies. The City will work with all relevant city departments to help them identify the areas where local climate projections can result in substantive policy and programmatic shifts in how departments operate.

Concluding Remarks

Detroit is committed to upholding the Paris Accord and implementing the Sustainability Action Agenda. Detroit's Office of Sustainability developed the Action Agenda as part of an effort to make city operations more efficient by reducing energy costs and greenhouse gas emissions. The Action Agenda intentionally links quality of life with climate action. Responsibilities for each action item are given to specific city departments, as well as their partners in other offices, philanthropy, and the private sector. The Action Agenda also details timelines for carrying out actions and sources of funding currently available. Ultimate success will require broad-based resident buy-in and support.

References

Carlson, J., Cooper, J., Donahue, M., Neale, M., Ragland, A., 2014. City of Detroit Greenhouse Gas Inventory: An Analysis of Citywide and Municipal Emissions for 2011 and 2012. Master's Thesis, University of Michigan, Ann Arbor, Michigan, USA.

City of Detroit, 2019. Detroit Sustainability Action Agenda. Detroit, Michigan, USA.

This page intentionally left blank.

7.50 Detroit River-Western Lake Erie Cooperative Weed Management Area – The 7-Year Evolution of An Effective Partnership in Invasive Plant Surveys and Treatment

Jessie Fletcher, U.S. Fish and Wildlife Service, Detroit River International Wildlife Refuge, jessica_fletcher@fws.gov

Chris May, The Nature Conservancy, cmay@tnc.org

Susan White, U.S. Fish and Wildlife Service, Detroit River International Wildlife Refuge, susan_white@fws.gov

Background

Great Lakes coastal wetlands perform vital ecosystem services, including pollutant filtration, erosion prevention, and nutrient fixing, and serve as a home for a variety of plant and animal species. In southeastern Michigan, this important ecosystem has historically been filled to allow human development threatening these important ecosystem functions; over 87% if the shoreline along the U.S. side of the Detroit River has been artificially hardened (Herdendorf, 1992; Manny and Kenaga, 1991). Moreover, invasion of non-native plant species in Great Lakes coastal wetlands is especially damaging to this already imperiled ecosystem (Manny et al., 1988). Significant time and funding are allocated to survey and provide treatment to control invasive plant species in these coastal wetlands. In the past, progress was limited as natural resource managers in southeastern Michigan were only able to affect those properties within their direct ownership and treatments were not coordinated across ownership lines. This disconnect among those with the same goal of invasive plant species management was recognized and remedied by the establishment of the Detroit River-Western Lake Erie Cooperative Weed Management Area (DRWLE CWMA) in 2011.

The DRWLE CWMA began as a partnership of regional, state, and federal agencies, nongovernmental organizations, businesses, and universities to manage the spread of invasive *Phragmites australis* in Monroe and Wayne counties' coastal wetlands in southeastern Michigan. The DRWLE CWMA shares resources as well as survey and treatment information across over 4,046 ha of partner-owned land (Figure 1). Partners operate under a Memorandum of Understanding that outlines the goals, expectations, and responsibilities of CWMA members. Over the last seven years, this group expanded beyond *Phragmites* to combat a number of newly emerging and established invasive plant species that threaten coastal wetland ecosystems.

Status and Trends

Now eighteen members strong, the CWMA collaborates on "preventing the establishment and spread of species that are both non-native (not present on an evolutionary time-scale) and invasive (significantly reduce conservation values)" (Table 1). An emphasis on detection, inventory, monitoring, and information exchange between members functions as the backbone of a coordinated and integrated management strategy for invasive terrestrial and aquatic plant species. Members seek to prevent new invasive species from becoming established, but are also engaged in active invasive species removal.

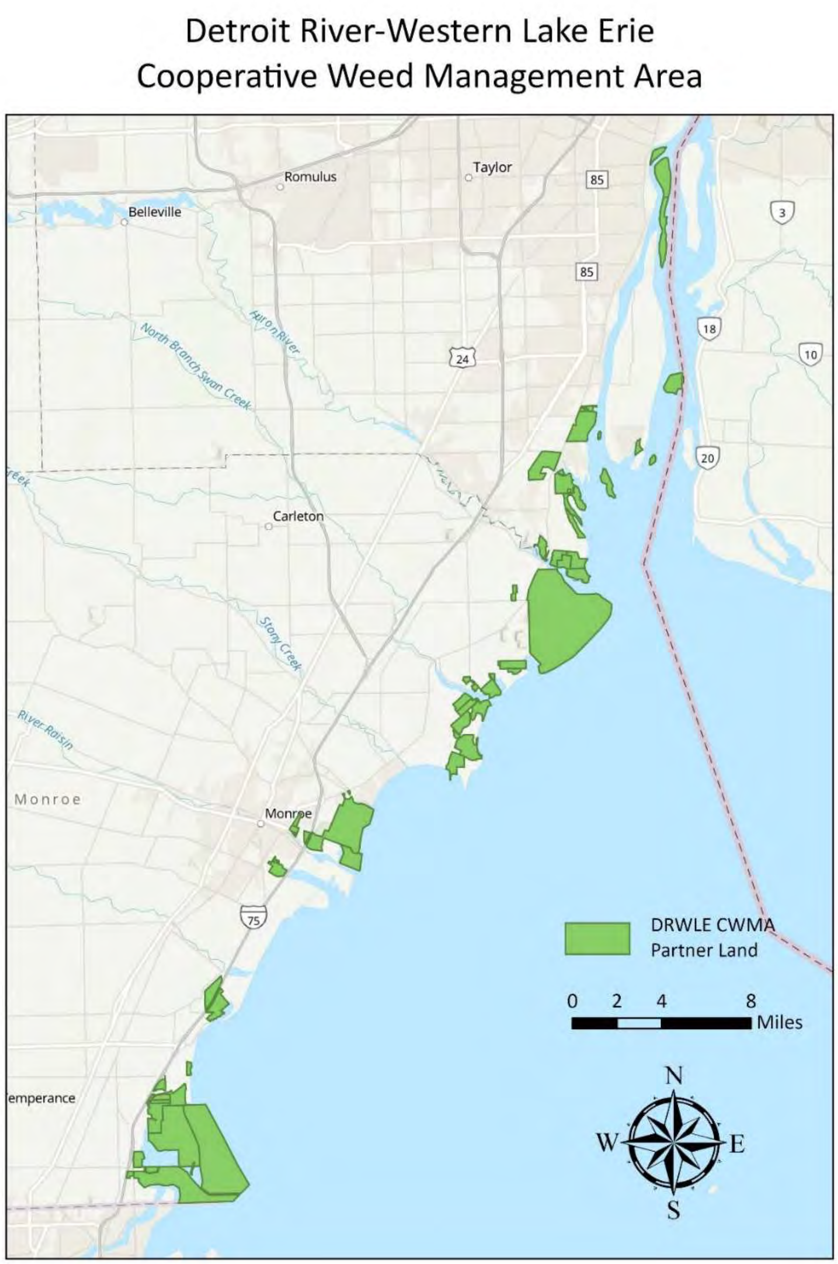


Figure 1. Detroit River-Western Lake Erie Cooperative Weed Management Area partner properties along the Detroit River and western Lake Erie.

Table 1. Members of the Detroit River-Western Lake Erie Cooperative Weed Management Area. Partners in bold are part of the core team that cooperatively manages the strike team and Marsh Master equipment for invasive species treatment.

- Alliance of Downriver Watersheds
- Bay Creek Hunt Club
- City of Monroe
- DTE Energy
- Ducks Unlimited, Inc.
- Eastern Michigan University
- **Huron-Clinton Metropolitan Authority**
- International Wildlife Refuge Alliance
- **Michigan Department of Natural Resources, Wildlife Division**
- Monroe Conservation District
- National Park Service, River Raisin National Battlefield Park
- Sisters, Servants Immaculate Heart of Mary
- Southeast Michigan Council of Governments
- Stewardship Network
- River Raisin Institute
- **The Nature Conservancy**
- **U.S. Fish & Wildlife Service, Detroit River International Wildlife Refuge**
- Wildlife Habitat Council

The DRWLE CWMA manages current and emerging invasive plant species by implementing species-specific best management practices. In 2015, a three-person strike team began conducting systematic surveys of all DRWLE CWMA partner lands for high-priority invasive wetland plant species. This was the first year of DRWLE CWMA-wide surveys based on rigorous protocols that lead to informed treatment decisions. Between 2015 and 2019, the strike team surveyed over 14,163 ha (with some acres surveyed multiple times) for invasive plant species (Table 2). During surveys, populations of invasive species within each property or subunit of a property are ranked based on size, density, treatment history, probability of expansion, and overall site quality. A level-of-concern ranking is assigned based on these metrics, which informs prioritization for treatment. All survey data are uploaded to the Midwest Invasive Species Information Network (MISIN; https://www.misin.msu.edu/) which serves as a region-wide spatial database for invasive plant and animal information.

Table 2. Number of DRWLE CWMA partner-owned hectares surveyed and the number of distinct invasive plant species populations identified during surveys between 2015 and 2019.

Year	Hectares Surveyed	Populations Identified
2015	3,180 ha (7,860 acres)	3,3361
2016	3,573 ha (8,831 acres)	3,943
2017	3,475 ha (8,588 acres)	2,593
2018	4,122 ha (10,188 acres)	3,473

During the 2018 and 2019 seasons, the CWMA created a three-tiered system for designating management importance and prioritized treatment of invasive species based on three criteria: 1) new or newly emerging invasive species are prioritized over well-established species; 2) invasive species that are more likely to rapidly take over habitat are prioritized over slowly invading species; and 3) treatment that may significantly benefit a site is prioritized over treatment with lower anticipated benefits. This new system reframed the focus on aquatic and terrestrial invasive species to better detect and target newly emerging and rapidly expanding invasive plant species (Table 3).

Table 3. Three-tiered grouping of all invasive plant species surveyed for the 2018 and 2019 season on DRWLE CWMA partner land. Group 1 invasive species are the highest priority for treatment.

Group 1		Group 2	
Black swallow wort	*Cynanchum louiseae*	European frog-bit	*Hydrocharis morsus-ranae*
Chinese yam	*Dioscorea polystachya*	Flowering rush	*Butomus umbellatus*
European black alder	*Alnus glutinosa*	Phragmites	*Phragmites australis*
Giant knotweed	*Fallopia sachalinensis*	Group 3	
Pale swallow wort	*Cynanchum rossicum*	Autumn olive	*Elaeagnus umbellata*
Parrot-feather milfoil	*Myriophyllum aquaticum*	Canada thistle	*Cirsium arvense*
Water hyacinth	*Eichhornia crassipes*	Common buckthorn	*Rhamnus cathartica*
Water lettuce	*Pistia stratiotes*	Garlic mustard	*Alliaria petiola*
White/Silver poplar	*Populus alba*	Glossy buckthorn	*Frangula alnus*
Yellow flag	*Iris pseudacorus*	Dame's rocket	*Hesperis matronalis*

In 2018, two hectares of Group 1 invasive species and over 66 ha of Group 2 species were identified and targeted for treatment by the DRWLE CWMA strike team. The strike team treated two hectares of Group 3 invasive plant species, but volunteer groups and CWMA partners treated many more hectares opportunistically by targeting buckthorn, autumn olive, and garlic mustard.

Management Next Steps

As of 2019, DRWLE CWMA is one of 21 cooperative invasive species management areas (CISMAs) in the state of Michigan. Together, this mosaic of partnerships covers all of Michigan's 83 counties and provides a variety of services to both public and private landowners. These services include education, outreach, and assistance in the identification and treatment of invasive plant species. Funding for continued operation of the survey and treatment strike team and maintenance of the DRWLE CWMA GIS database and website will be necessary to maintain the successful rehabilitation and protection of coastal wetlands in southeast Michigan. DRWLE CWMA will continue to evaluate effectiveness, adopt new techniques, modify existing processes, and engage partners to improve the detection and removal invasive plants.

Research/Monitoring Needs

The DRWLE CWMA is dedicated to the restoration, enhancement, and protection of coastal wetlands in the highly developed areas along the Detroit River and western Lake Erie. More than ever, it is imperative that natural resource and land managers connect with people who share the land managed. An important part of any successful CISMA is a comprehensive invasive species management plan that includes education and collaboration with surrounding landowners and members of the public. In 2020 and 2021, the DRWLE CWMA hopes to reach out and provide education and information to residents through an updated website and the launch of a social media presence. The CWMA encourages research and monitoring collaborations with universities and other partners to advance knowledge of restoration effectiveness and the impacts of invasive species on native species and ecosystem function. The International Wildlife Refuge Alliance has applied for the 2020 Michigan Invasive Species Grant Program on behalf of the DRWLE CWMA to fund the continued invasive species early detection and rapid response efforts by the strike team, as well as expanded outreach efforts.

References

Herdendorf, C.E., 1987. The ecology of the coastal marshes of Western Lake Erie: a community profile. U.S. Fish & Wildlife Service, Biological Report 85(7.9). Ann Arbor, Michigan, USA.

Herdendorf, C.E., 1992. Lake Erie coastal wetlands: an overview. Journal of Great Lakes Research 18, 553-551.

Manny, B.A., Edsall, T.A., Jaworski, E., 1988. The Detroit River, Michigan: an ecological profile. U.S. Fish & Wildlife Service, Biological Report 85(7.17). Ann Arbor, Michigan, USA.

Manny, B.A., Kenaga, K., 1991. The Detroit River: effects of contaminants and human activities on aquatic plants and animals and their habitats. Hydrobiologia, 219, 269-279.

Links for More Information:

Detroit River-Western Lake Erie Cooperative Weed Management Area: https://www.michiganinvasives.org/detroitlakeeriecwma/

Midwest Invasive Species Information Network (MISIN): https://www.misin.msu.edu/

Detroit River International Wildlife Refuge: https://www.fws.gov/refuge/detroit_river/

The Nature Conservancy: https://www.nature.org

This page intentionally left blank.

7.51 Green Infrastructure in Southeast Michigan

Southeast Michigan Council of Governments (SEMCOG)

Background

In Southeast Michigan, green infrastructure includes two broad categories: the natural and the built. The natural encompasses the undisturbed environment such as wetlands, trees, prairies, lakes, rivers, and streams. The second category includes built green infrastructure such as rain gardens, bioswales, community gardens, parks, and agricultural lands.

It is critical to evaluate both the natural and built elements of green infrastructure as an integrated system. Each green infrastructure element alone provides specific function and value, but as a system, the green infrastructure network provides benefits to our entire region. In addition to significant water quality benefits, green infrastructure provides tangible community, economic, and air quality benefits to Southeast Michigan. These benefits include:

- **Economic:** Using green infrastructure can reduce "grey" infrastructure costs and increase residential property values located near trails, parks, and waterways.
- **Green jobs:** Can promote economic growth and create green infrastructure construction and maintenance jobs.
- **Traffic calming:** Slows traffic visually and provides a buffer between the roadway and pedestrians.
- **Recreation:** Provides opportunities for hiking, hunting, fishing, and bird watching.
- **Habitat linkages:** Provides connections between habitat corridors to strengthen and support rare and important natural areas.
- **Health:** Encourages outdoor physical activity, which can have a positive impact in fighting obesity and chronic illnesses.
- **Energy and climate**: Shade trees reduce energy consumption and save money.
- **Air quality:** Removes air pollutants.
- **Water quality and flooding:** Reduces polluted stormwater runoff entering our rivers and lakes by absorbing the water into the ground.
- **Water supply:** Water absorbed into the soil renews groundwater supplies and increases flow into rivers.

Status and Trends

The Green Infrastructure Network Identified

Of the 1.17 million ha (2.9 million acres) of land in Southeast Michigan (i.e., Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties), 51 percent is categorized as open space. This includes more than 80,900 ha (200,000 acres) of parks, and over 404,680 ha (one million acres) on agricultural land (SEMCOG, 2014). In addition, the region has 33 percent tree canopy and 14 percent impervious surfaces. The region's impervious surfaces are equally divided between roads, buildings, and parking lots/driveways. The Center for Watershed Protection has established a target of less than 10 percent impervious surface to protect aquatic life (Center for Watershed Protection, 1998).

Percentage of Land Cover in Southeast Michigan

Figure 1 presents the percentage of land cover by five different categories within the seven-county region. These land cover data help identify potential targets of opportunity for strategically enhancing the region's green infrastructure. The following two examples ~ tree canopy and parks ~ provide a snapshot of the data benchmarked and the analysis undertaken that will improve Southeast Michigan's green infrastructure network.

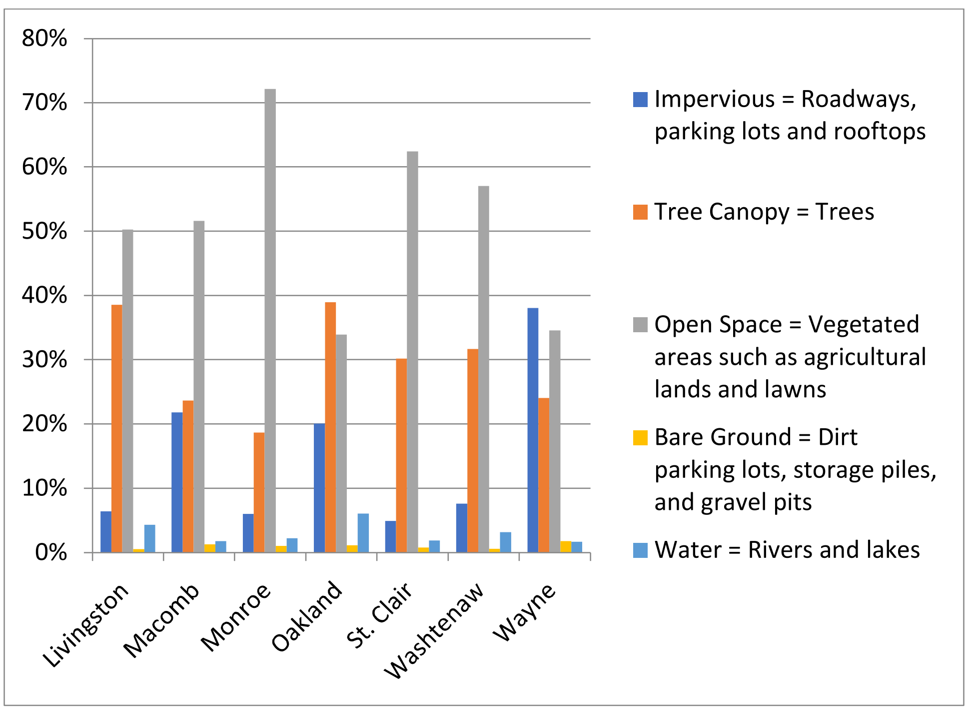


Figure 1. The percentage of land cover by five different categories within the seven-county SEMCOG region (source: SEMCOG).

Tree Canopy

Trees are integral to healthy communities and can provide a vast array of advantages, including wildlife habitat, aesthetics in downtown and pedestrian areas, water and air quality benefits, and even increase local property and commercial values.

Thirty-three percent of Southeast Michigan is covered in tree canopy, with individual counties ranging from a low of 20 percent to a high of 44 percent (Figure 2). SEMCOG's 2014 *Green Infrastructure Vision for Southeast Michigan* adopted a 40 percent tree canopy goal for the region. This canopy target will assist in identifying potential targets of opportunity for increasing green infrastructure and help create policy recommendations. Specific tree canopy policies include:

- Increases in tree canopy will be focused in urban areas with tree canopy currently below 20 percent.
- Specific land uses will be targeted for tree canopy increases, such as around industrial property, within riparian areas and central business districts, and along roadways and parking lots.

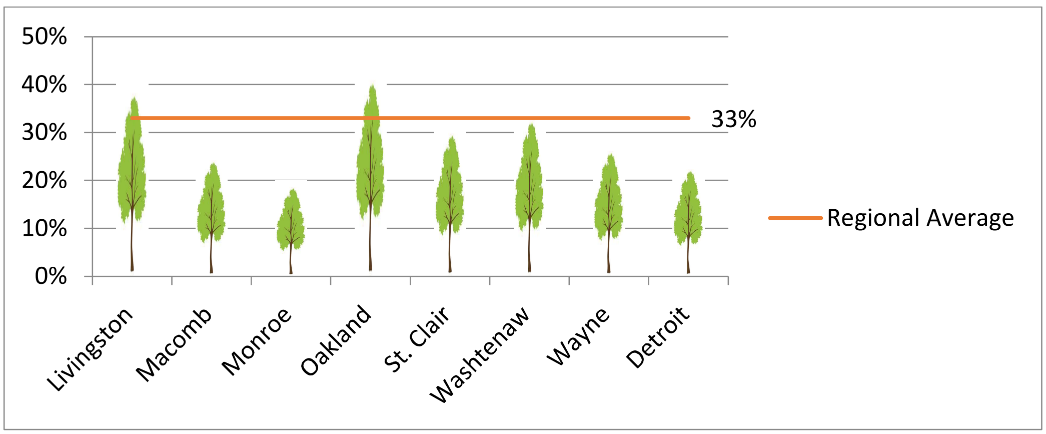


Figure 2. The percentage of tree cover within each of the seven counties within the SEMCOG region (source: SEMCOG).

Parks

Green infrastructure in parks can be effective in addressing urban stormwater problems. During public visioning sessions, parks were listed as the top green infrastructure element that stakeholders believe provide the highest economic value to their area. Southeast Michigan has an estimated 90,650 ha (224,000 acres) of public parkland with an estimated 16 park ha (40 park acres) per 1,000 residents (Figure 3). For comparison, urban counties in the State of Indiana range from 1-8 park ha (4-21 park acres) per 1,000 residents; the National Parks and Recreation Association (NPRA) has a median of 3 park ha (9.6 park acres) per 1,000 residents. While Southeast Michigan exceeds the national average, there are opportunities to strategically invest in improving green infrastructure in existing parks and even creating new parks.

Identifying Green Infrastructure Linkages

Once the region's green infrastructure was identified in SEMCOG's 2014 Green Infrastructure Vision for Southeast Michigan, areas of opportunity to link and enhance green infrastructure implementation were identified through further analysis.

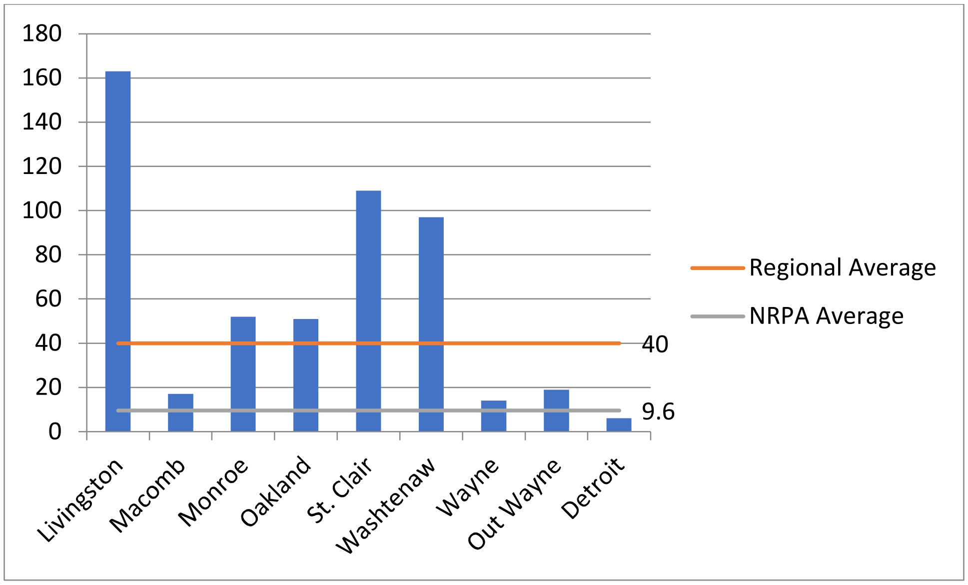


Figure 3. Acreage of parkland per 1,000 residents in each of the seven counties within the SEMCOG region (source: SEMCOG).

Water

Improving water quality in local waterways is a major focus for implementing green infrastructure in the region. SEMCOG conducted a public opinion survey of green infrastructure; results indicated that improving water quality was the top priority for implementing green infrastructure. This benefit is realized by planting vegetation that absorbs and filters stormwater runoff from urban areas. As water quality is improved, the economic value of adjacent areas is also enhanced.

Flooding

Green infrastructure can help mitigate the risk of flooding. This is particularly important as Southeast Michigan faces increasingly intense rainstorms.

Roadways

Roadways provide vital connections within our communities, transport goods, and provide an economic benefit to region. However, roadways are also significant contributors to stormwater runoff, which can negatively impact water quality. In Southeast Michigan, there are over 37,440 km (23,400 miles) of roadways generating approximately 2.65 billion liters (700 million gallons) of stormwater runoff. This stormwater carries more than 36.3 tonnes (40 tons) of phosphorus and 9,070 tonnes (10,000 tons) of sediment into local waterways, causing pollution. Traditionally, the focus of managing stormwater runoff from roads has been to remove it through the storm sewer pipes and send it directly to waterways. An alternative approach is to use trees and bioswales to infiltrate this runoff, thereby improving local water quality. Changing this traditional design standard to one that uses green infrastructure is critical for improved water quality.

Riparian Corridors

There are approximately 21,448 ha (53,000 acres) of riparian corridors – the land adjacent to a river or lake – in Southeast Michigan. Riparian corridors protect and enhance water quality, providing habitat corridors for wildlife, offering access to local waterways and walking and biking trails.

Trees, in particular along a riparian corridor, provide essential water quality benefits including preventing fertilizer and grass clippings from entering the water and shading (cooling) the river/lake, which improves fish habitat. They also prevent streambank erosion through their extensive root structure. There are opportunities along riparian corridors to increase tree canopy or provide public access to the waterway, especially if adjacent publicly owned parcels are vacant.

Vacant Land

Southeast Michigan is poised to "turn lemons into lemonade" as we address vacant abandoned parcels. Vacant property may provide a unique opportunity for connections and enhancements in the local green infrastructure network. As local governments evaluate the types of vacant parcels they have, green infrastructure strategies can be considered as either short-term or long-term improvements. Green infrastructure on vacant property can be used to increase recreational access to rivers and lakes, buffer ecologically sensitive areas such as wetlands, connect parks and trails together, and temporarily serve as community gardens or for native plantings to benefit the environment or the community. For example, in the City of Detroit, the Detroit Water and Sewerage Department is transforming vacant lots into green infrastructure to reduce stormwater from entering the sewer system.

Visioning Out: Implementing Green Infrastructure

The voices of key stakeholder groups and the general public have helped shape the direction for green infrastructure in Southeast Michigan. SEMCOG, with the help of each of the seven Southeast Michigan counties, conducted eight in-person visioning sessions and an online public poll to identify important green infrastructure elements and desired outcomes for a regional vision. The online poll garnered 854 responses, while the in-person visioning sessions saw over 250 people actively participate in mapping their green infrastructure priorities. The results of this intensive outreach revealed that the public highly values protecting and enhancing the following top three elements:

- Natural areas,
- Biking/hiking trails, and
- Trees along roads and in downtown areas.

In terms of specific targets of opportunity to increase green infrastructure (trees, bioswales, and other vegetation), the public indicated the following priority locations:

- Along rivers and lakes,
- On major roadways,
- Near parks, and
- On vacant property.

The region's green infrastructure network consists of many pieces, and many people have different roles in moving the regional vision forward. As a result, integrating green infrastructure planning into a local community structure requires collaboration across multiple municipal departments and agencies. Successful implementation incorporates elements from local government planning, engineering and public works, recreation, public outreach, and finance departments, in addition to numerous outside agencies. The following list of roles provides a sense of how these different pieces can begin to come together.

Local Government Roles

Governing Bodies/Councils

- Adopt policies that promote green infrastructure in the community and showcase its use and benefits to the public.
- Establish a community-wide policy that all publicly funded construction projects will consider green infrastructure at the concept stage.
- Establish funding incentives to implement rain gardens and bioswales strategically throughout the municipality/county.

Planning and Engineering

- Update zoning ordinances and land-use plans to encourage use of green infrastructure. At a minimum, include the use of green infrastructure in stormwater ordinances.

Community and Economic Development

- Evaluate vacant parcels for greening potential and/or opportunity to link or enhance parks.
- Partner with the business community to increase and/or maintain green infrastructure.
- Evaluate local natural assets to determine if ecotourism can be used or enhanced as an economic tool.
- Participate in state grant programs to increase tree canopy in residential neighborhoods.

Road Agencies/Department of Public Services

- Review road, water, and sewer infrastructure projects to identify potential opportunities to incorporate green infrastructure.
- Participate in infrastructure collaboration opportunities among road, water, sewer, and stormwater activities at a local, regional, and state level for efficient use of limited resources.
- Evaluate public service yards for green infrastructure opportunities, such as installing bioswales near aggregate storage piles.

Recreation

- Review the local park system to enhance or link park and recreational opportunities.
- Identify tree canopy coverage across the community and determine targets of opportunity for potential enhancements.
- Evaluate all community-owned properties, such as city hall, schools, and libraries for green infrastructure opportunities such as native plant grow zones and rain gardens/bioswales.
- Identify ways to enhance public access to parks and waterways.
- As local recreation plans are updated, identify specific goals for green infrastructure.
- Participate in regional parks and recreation planning.
- Provide a regional assessment of recreational needs in concert with park assessments.

Downtown Development Authority

- Plan and work with road agencies for integrated techniques, such as street trees, tree infiltration trenches, and bioswales that manage stormwater runoff.
- Educate businesses on the wide range of benefits of green infrastructure.

Historic District Commissions

- Consider using native plants that are historic to the region as a landscaping opportunity on historic sites.

State Government Roles

- Consider regional green infrastructure priorities when allocating grant resources.
- Prioritize green infrastructure implementation when making investments in state property.

- Emphasize the use of green infrastructure in state-regulated stormwater programs.
- Convene broader statewide and regional forums on green infrastructure.
- Encourage pervious surfaces and technologies.
- Encourage "blue/green" roofs to reduce urban heat island effects.

Academia Roles

- Increase research on performance levels, range of multiple benefits, and cost analyses of green infrastructure techniques.

Environmental Groups

- Organize volunteers to implement green infrastructure.
- Identify funding opportunities for implementing green infrastructure.

Business Community Roles

- Incorporate green infrastructure on commercial/industrial property, such as planting trees, bioswales, and rain gardens.
- Support community-based green infrastructure initiatives.

Public Roles

- Plant a tree, install rain gardens, or use rain barrels to reduce stormwater to local streams.
- Volunteer in local watershed activities, such as park cleanups, tree plantings, or water quality monitoring activities.

Green Infrastructure Progress

Green infrastructure is still in its infancy in southeast Michigan. However, measurable progress is being made. Table 1 presents selected examples of progress in implementing green infrastructure projects in southeast Michigan. Long-term commitments, sustained financial incentives and technical assistance, and continuous and vigorous oversight will be required to meet Southeast Michigan's long-term green infrastructure goals and targets.

Table 1. Examples of trends in green infrastructure indicators in southeast Michigan.

Organization	Green Infrastructure Indicator Trends	Reference
Michigan Natural Resources Trust Fund (MNRTF)	Between 1976 and 2012, MNRTF has invested $240 million in 415 projects dedicated to natural resource protection and public outdoor recreation development in Southeast Michigan	SEMCOG (2014)
Alliance of Rouge Communities (ARC)	Since 1985, ARC and its partners have installed over 24.3 ha of native plant grow zones throughout the watershed, planted over 15,000 native herbaceous plants and 3,500 trees/ shrubs, distributed over 8,600 tree seedlings, and removed over 7,646 m^3 of invasive plants	Ridgway et al., (2018)
Greening of Detroit	Since 1989, the Greening of Detroit has planted more than 100,000 trees in Detroit as part of green infrastructure in support of a healthy urban community	www.greeningofdetroit.com
Detroit Water and Sewerage Department (DWSD)	DWSD's National Pollutant Discharge Elimination System permit required an investment of $15 million in green stormwater infrastructure between 2013-2017 to reduce 10.6 million liters (2.8 million gallons) of stormwater flow. Detroit Water and Sewerage Department will invest $50 million by 2029. This permit identifies a number of specific green stormwater infrastructure project types, including downspout disconnections, demolition and removal of vacant structures, bioswales along roadways and parking lots, tree planting and other projects.	detroitmi.gov/how-do-i/find-information/green-infrastructure
Detroit Sustainability Action Agenda	In 2018, the City of Detroit spent $3 million on green stormwater infrastructure and requires private properties to control stormwater on site. Further, as of 2018, Detroit managed approximately 364 ha (900 acres) through green stormwater infrastructure, direct discharge, and impervious removal (excluding demolitions). The City aims to double	https://detroitmi.gov/government/mayors-office/office-sustainability/sustainability-action-agenda

Organization	Green Infrastructure Indicator Trends	Reference
	the acres managed through green stormwater and related techniques citywide in 10 years, resulting in at least 728 ha (1,800 acres) managed by 2029.	
Huron River Watershed Council (HRWC)	Throughout the watershed, the HRWC works with communities to protect and enhance green infrastructure. For example, on Norton Creek the Council is now enhancing green infrastructure by building rain gardens and bioswales, enhancing shoreline plantings, and installing rain barrels. The Council has also created partnerships with local and regional parks systems, land conservancies, and local governments to **protect over 4,047 ha (10,000 acres) in the watershed.**	hrwc.org/what-we-do/programs/green-infrastructure/
Clinton River Watershed Council (CRWC)	In 2014, CRWC partnered with the Great Lakes Stormwater Management Institute of Lawrence Tech University to enhance its existing WaterTowns community program by providing conceptual green infrastructure plans for public spaces in participating communities. The conceptual plans include specific green infrastructure improvements (such as rain gardens, porous pavement, bioswales, etc.) along with community placemaking suggestions (such as gathering spaces, trails, etc.). The green infrastructure plans were accompanied with estimates of volume of water retained on site. Between 2014 and 2018, 15 communities have made green infrastructure improvements.	www.crwc.org/watertowns/
Green Macomb Urban Forest Partnership	The Green Macomb initiative supports implementing green infrastructure in the county. Its first project, the Green Macomb Urban Forest Partnership, builds local capacity to manage and grow healthy urban forests in the county's most urbanized areas. In the more developed communities south of the Clinton River, tree loss has been intensified by urban development,	https://green.macombgov.org/Green-UrbanForestPartnership

Organization	Green Infrastructure Indicator Trends	Reference
	Dutch Elm Disease, and the Emerald Ash Borer. By prioritizing improvements in this area, the county is focusing on a watershed-based planning approach. To this extent, the Urban Forest Partnership is working to expand public awareness of the benefits that urban forests provide, develop technical tools and resources for sustainable local forestry programs, and advance creative partnerships to increase tree canopy.	

References

Center for Watershed Protection, 1998. Rapid Watershed Planning Handbook. Ellicott City, Maryland, USA.

Detroit Future City, 2012. Detroit Strategic Framework Plan. Detroit, Michigan, USA.

Detroit's Office of Sustainability, 2019. Detroit Sustainability Action Agenda. Detroit, Michigan, USA.

National Recreation and Park Association (NRPA), 2013. Parks and Recreation National Database Report. Ashburn, VA, USA.

Ridgway, J., Cave, K., DeMaria, A., O'Meara, J., Hartig, J.H., 2018. The Rouge River Area of Concern - A multi-year, multi-level successful approach to restoration of Impaired Beneficial Uses. Aquatic Ecosystem Health & Management. 21, 4, 398-408.

Southeast Michigan Council of Governments (SEMCOG), 2014. Green Infrastructure Vision for Southeast Michigan. Detroit, Michigan, USA.

This page intentionally left blank.

7.52 Greenway Trails in Windsor, Ontario

Lori Newton, Executive Director, Bike Windsor Essex, info@bikewindsoressex.com

Background

Greenways are linear open spaces, including habitats and trails, that link parks, nature areas, cultural features, or historic sites with each other, for recreation and conservation purposes. Based on experience throughout North America, greenways promote outdoor recreation, catalyze economic development, increase adjacent property values, celebrate historical and cultural assets, promote conservation and environmental education, and improve quality of life. Greenways can provide an exceptional outdoor recreational experience that reconnects children and families to natural resources that helps build a stewardship ethic. It should not be surprising that greenways are an enormous source of community pride.

Windsor has a long history of greenways dating back to the 1960s. Windsor's Department of Parks and Recreation maintains 12 km^2 of green space, 180 parks, and 64 km of trails. Beginning in the 1960s, Windsor started creating a shared-usage trail network, initially called the "Windsor Loop," that circumnavigates around the entire city and connects to neighboring communities (Table 1). The longest greenway trail in this network is the Roy A. Battagello River Walk (built in the late 1960s, and upgraded/widened several times), stretching from west of the Ambassador Bridge to the historical Hiram Walker Distillery, a distance of about 8 km.

This trail also connects to other trails leading to key natural areas and city parks, including Ojibway Park and Ojibway Prairie Provincial Nature Reserve, Malden Park, Spring Garden Area of Natural Scientific Interest, and others. Other key extensions of this greenway trail network include the Ganatchio Trail (built in 1971), its Little River Extension (built in 1996), the Devonwood Bike Trail (built between the mid-1980s and the early 1990s), and the Right Honourable Herb Gray Parkway, a 17-km network of bike and walking trails completed as part of a provincial project that improved traffic flow from the Ambassador Bridge to Highway 401 (opened in 2016).

Also completed as part of the County Wide Active Transportation System were the 50-km Chrysler Canada Greenway and the 22-km Cypher Systems Group Greenway completed in 1997 and 2017, respectively. However, much more needs to be done to connect all of these trails as part of an integrated trail network.

Table 1. History of greenway trails in Windsor and Essex County.

Time Period	Greenway Activities
1960s	Initial phase of the Roy A. Battagello River Walk constructed, stretching from west of the Ambassador Bridge to the historical Hiram Walker Distillery, a distance of about 8 km
1970s	Ganatchio Trail is a 5.3-km greenway constructed in 1971 through the Villages of Riverside, Little River, Greenway, and Tecumseh
1980s	Devonwood Bike Trail (built mostly between the mid- and late 1980s)
1990s	First phase of Little River Extension of the Ganatchio Trail built in 1996 The Chrysler Canada Greenway is a 42-km-long rail trail constructed in 1997 in Essex County, stretching from Oldcastle to Leamington
2000s	Second phase of Little River Extension of the Ganatchio Trail built in 2007
2010s	Right Honourable Herb Gray Parkway,17-km network of bike and walking trails, officially opened in 2016 Cypher Systems Group Greenway is a 22-km (13.7-mile) rail trail that was completed in 2017, connecting Essex to Amherstburg

Status and Trends

Master Plan

As set out in its Official Plan, the City of Windsor is committed to sustainability in all its forms and recognizes the importance of active transportation to enhance both community health and safety, as well as quality of life. The City is also committed to contributing to the reduction of air pollution by increasing opportunities for active modes of transportation, including walking, cycling and transit. The City's 20-year Strategic Vision further commits the City of Windsor to promoting active transportation as healthy and environmentally friendly modes of transportation.

The City has a history of recognizing the significance active transportation plays in shaping a sustainable, healthy, and robust community. The adoption of the recommendations made in the Bicycle Use Development Study in 1991 led to the construction of the marquee waterfront pathway network. The active transportation vision then took another step forward with the creation of the Bicycle Use Master Plan (BUMP) in 2001; however, the plan's recommendations were generally aspirational, with less than 5% of them being implemented over the subsequent 20 years. The BUMP shifted the view of bicycles for recreation to include commuter cycling and led to expanding the City's on- and off-road cycling network for both commuting and recreation. In 2019 the City recognized a need for a broader focus beyond cycling to other forms of active transportation. A new Active Transportation Master Plan (ATMP) called Walk Wheel Windsor (City of Windsor, 2019) was developed with a focus on community sustainability and meeting the City's Community Energy Plan goals.

The ATMP outlines a network that connects key existing trails and pathways, such as the recently completed Herb Gray Parkway Trail, and the downtown Waterfront Trail (Figure 1). Connecting these high-quality pathways to a developed on-street network will allow commuters, recreational users, and others to have safe, convenient, attractive, and fun options to travel by walking, cycling, or transit. The ATMP will guide Windsor's progress and investments in active transportation over the next 20 years.

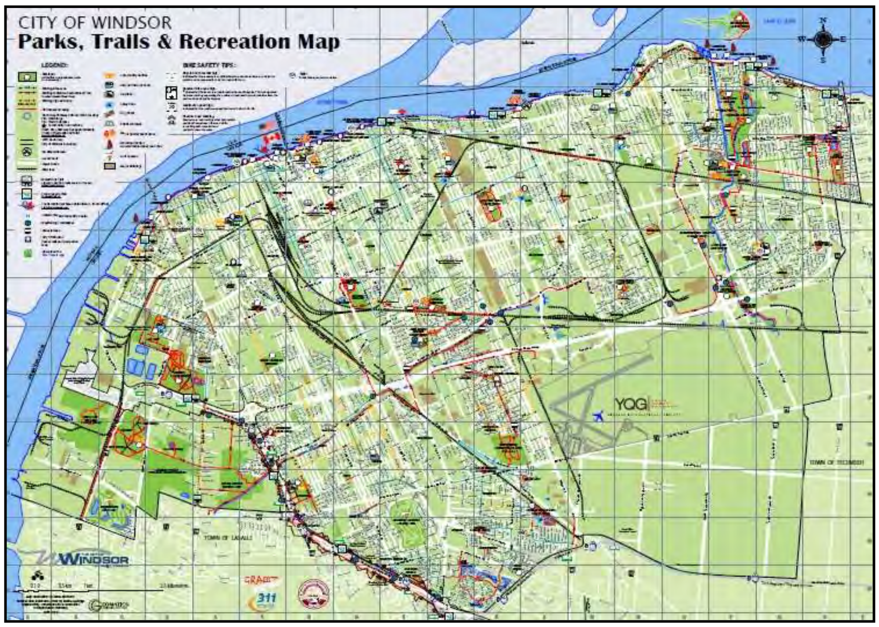


Figure 1. Parks, trails, and recreation map for Windsor, Ontario.

Management Next Steps

Future Directions

As part of the ATMP process, a vision, goals, and targets were developed to shape the overall future direction of the Plan and to serve as a basis from which actions, improvements, and investments are identified and prioritized. The ATMP vision is as follows:

> *By 2041, Windsor is a leader in active transportation. Walking, cycling, and transit are safe, convenient, and enjoyable mobility options for all residents and visitors, regardless of age, ability, trip purpose, or time of year. Active transportation connects Windsor's local and regional communities, contributing to a resilient, equitable, and healthy city with a high quality of life for Windsor residents.*

The five goals established in the Plan include:

- Develop a complete active transportation network that connects all neighborhoods
- Improve the safety and accessibility of vulnerable road users
- Support effective land-use planning to build an environment that makes walking, cycling, and transit convenient and enjoyable
- Ensure that the active transportation network is equitable and accessible for all residents
- Foster a culture for active transportation

Targets have been established in the Plan to support the goals, measure progress, and increase accountability. These include doubling the proportion of trips made by walking, cycling, and transit by 2031 and achieving 25% of all trips in Windsor made using sustainable transportation by 2041 (Table 2).

Table 2. Targets established in the Active Transportation Master Plan for the proportion of trips made by walking, cycling, and transit in Windsor.

Date	Percentage of Trips by Walking, Cycling, and Transit
Current (2019)	10%
2031	20%
2041	25%

Strategies and Actions

Greenways are important community assets and recreational cycling has many benefits; however, improvements to encourage commuter cycling and cycling as transportation will have significantly greater impacts on improving both environmental and health issues. The ATMP identifies five overarching themes: connecting communities, places for people, innovation and integration, culture shift, and quality of life. For each theme, the Plan includes several strategies and more detailed actions to improve active transportation. The implementation of these strategies and actions will help Windsor work towards achieving the vision, goals, and targets of the ATMP. The ATMP also includes an implementation and monitoring plan to prioritize investments and actions over the short, medium, and long-term and to monitor progress in achieving the Plan's goals.

Recommendations

- It is recommended that the City of Windsor become more proactive in providing safe, accessible, alternative transportation infrastructure (including signalized cycling crossings, striped bicycle lanes and bicycle/pedestrian crossings, and bicycle counters to measure success) within the city that encourages people to choose to bicycle or walk for distances less than 5 km. In 2016 and 2017 surveys, 85% of Windsor residents indicated that they would cycle more if there was safe, connected cycling infrastructure.
- It is recommended that the City of Windsor allocate and sustain adequate funding for greenway trail maintenance.
- It is recommended that the City of Windsor fill its Active Transportation Coordinator position identified in its Active Transportation Master Plan.
- It is recommended that the City of Windsor adopt specific targets for walking and cycling, separate from transit, to prioritize true active transportation.
- It is recommended that the City of Windsor work closely with cycling advocates to provide safer streets for vulnerable road users consistent with its vision and Active Transportation Master Plan.

References

City of Windsor, 2019. Walk Wheel Windsor: Active Transportation Plan. Windsor, Ontario, Canada.

This page intentionally left blank.

7.53 Growth of the Detroit River International Wildlife Refuge

John Hartig, University of Windsor, Great Lakes Institute for Environmental Research, jhhartig@uwindsor.ca

Collin Knauss, University of Michigan - School for Environment and Sustainability, crknauss@umich.edu

Background

The Detroit River has long served the United States and Canada as a critical transportation corridor and industrial hub that helped shape the economies of the shared metropolitan region (USFWS, 2005). By 1950, the city of Detroit became the fifth largest city in the U.S. and the river helped Detroit emerge as the nation's auto-manufacturing leader, a critical shipping channel, and industrial epicenter in the U.S. However, the ecosystems of the Detroit River and western Lake Erie suffered tremendously from the extensive human modifications, pollution, and development. The development led to urbanization, industrialization, and channelization of the river that resulted in severe pollution and ecological degradation. For decades, the connecting channels in the Great Lakes, including the Detroit River, received industrial and municipal effluents that deteriorated water quality and degraded the river's diverse habitats (Environment Canada and U.S. Environmental Protection Agency, 1988; Hartig and Thomas, 1988).

Detroit's industrial expansion and population growth reached a tipping point in the 1960s, when the Detroit River was considered one of the most polluted rivers in North America (Hartig and Wallace, 2015; Manny and Kenaga, 1991). Damaging environmental catastrophes, including the Rouge River (Detroit River's major tributary) catching fire in 1969 due to oil pollution, widespread waterfowl kills from oil, contamination by toxic substances like PCBs and DDT, and discharges of raw sewage, contributed to deteriorating ecosystem health and its designation as an international pollution hot spot or "Area of Concern" (Hartig and Wallace, 2015). Figure 1 shows an oil spill from the Rouge River entering the Detroit River in 1966.

The long-standing view of the Detroit River as a working river that primarily supported commerce, industry, and technological progress, began to shift after the 1960s with the public becoming increasingly engaged in addressing the river's health (Hartig and Wallace, 2015). Spurred by legislative and public engagement initiatives, 40 years of pollution prevention and control resulted in substantial environmental progress since the 1960s (Hartig, 2014). This remarkable turnaround for the Detroit River continues today, with increased ecological recovery, economic revival, and community pride for the river (Hartig et al., 2010). These recent successes also prepared the region for the creation of the Detroit River International Wildlife Refuge (DRIWR), the first and thus far only international wildlife refuge in North America (Hartig and Wallace, 2015).

In 2000, a group of U.S. and Canadian conservationists and scientists developed a conservation vision for the lower Detroit River ecosystem, promoting the establishment of an international wildlife refuge. Soon after in 2001, the refuge was established on the U.S. side by Public Law 107-91, with primary management and oversight by the U.S. Fish and Wildlife Service (USFWS). Canada later created the Western Lake Erie Watersheds Priority Natural Area, overseen by the Essex Region Conservation Authority (ERCA), to coordinate among

Figure 1. Water pollution of the Detroit River, 1966 (photo credit: Michigan Department of Natural Resources).

Canadian federal, provincial, local, and nongovernmental organizations, and work with U.S. partners in fulfillment of the international wildlife refuge (Hartig and Wallace, 2015). The boundaries of these two complementary and reinforcing initiatives were designed to fulfil the spirit and intent of the DRIWR and are presented in Figure 2. The region's exceptional biodiversity is recognized in the North American Waterfowl Management Plan, the Western Hemispheric Shorebird Reserve Network, and the Canada-U.S. Biodiversity Investment Area Program (Hartig and Wallace, 2015). In addition, the DRIWR's location is unique because it is one of only a few refuges to exist within a major metropolitan area (Hartig et al., 2010).

Status and Trends

Protecting and conserving the remaining critical wildlife habitats in and around the DRIWR represents a high priority for the USFWS and its many partners. In 2005, after several years of coordinated public-private planning, the USFWS completed the Comprehensive Conservation Plan (CCP) for the DRIWR. The CCP initially defined the DRIWR's strategies for fulfilling its legal purpose, management goals for a 15-year period up to 2020, and specific objectives needed to accomplish the goals. To accomplish the management goals, agencies and other stakeholders engaged in cooperative management. This enabled the DRIWR to develop robust partnerships and expand its conservation area through agreements with industries, government agencies, and other organizations (Hartig et al., 2010).

The DRIWR's long-term goal is to protect and restore sufficient habitat for a healthy ecosystem that can support desired fish and wildlife populations and diversity. In the short-term, coordinated efforts have aimed to protect the remaining relatively healthy headwaters, biotic refugia, riparian habitat, and floodplains (Hartig et al., 2010). Once protected, agencies have recognized the importance of restoring connecting corridors between healthy habitats to link them together (Hartig et al., 2010). Often, these complex restoration projects have required cooperation at many levels. The primary leadership for expanding and managing the DRIWR on the U.S. and Canadian sites has been the USFWS, under the National Wildlife Refuge System, and ERCA, respectively. The conservation efforts have involved more than 200 community, governmental, NGO, and business partners (Hartig et al., 2010).

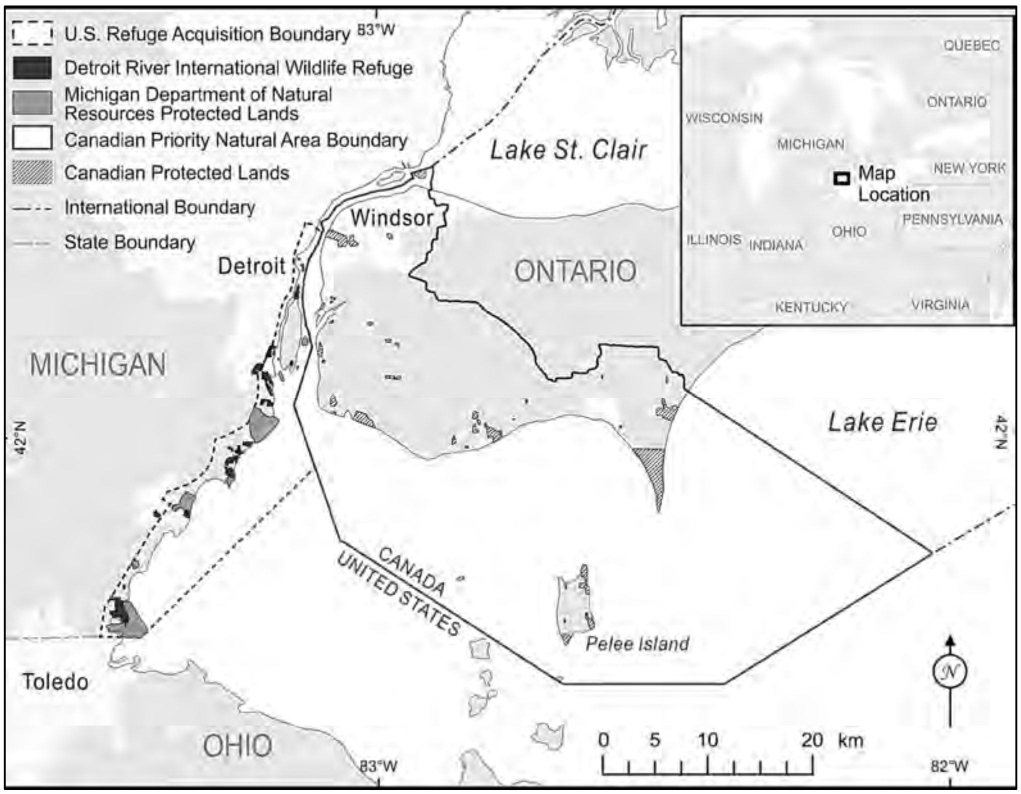


Figure 2. U.S. Refuge Acquisition Boundary and Canadian Western Lake Erie Watersheds Priority Natural Area (Hartig and Wallace, 2015).

The DRIWR's binational goal is to achieve a cumulative 10,117.1 ha (25,000 acres) of conserved lands, wetlands, and waters that are devoted to conservation and outdoor recreation by 2025. Nearly seven million people live within a 45-minute drive of the refuge (Hartig and Wallace, 2015). As seen in Figure 3, to date, 1,536.6 ha (3,797 acres) of Essex Region Conservation Authority lands and 397 ha (981 acres) of City of Windsor lands have been added to a Canadian registry of lands for the refuge, and 3,195.8 ha (7,897 acres) of Michigan Department of Natural Resources lands have been added to a U.S. registry of lands that already includes 2,471.4 ha (6,107 acres) of lands owned and/or cooperatively managed by USFWS. Together, the U.S. and Canada have 7,600.8 ha (18,782 acres) of land in southwest Ontario and southeast Michigan being managed collaboratively under the DRIWR.

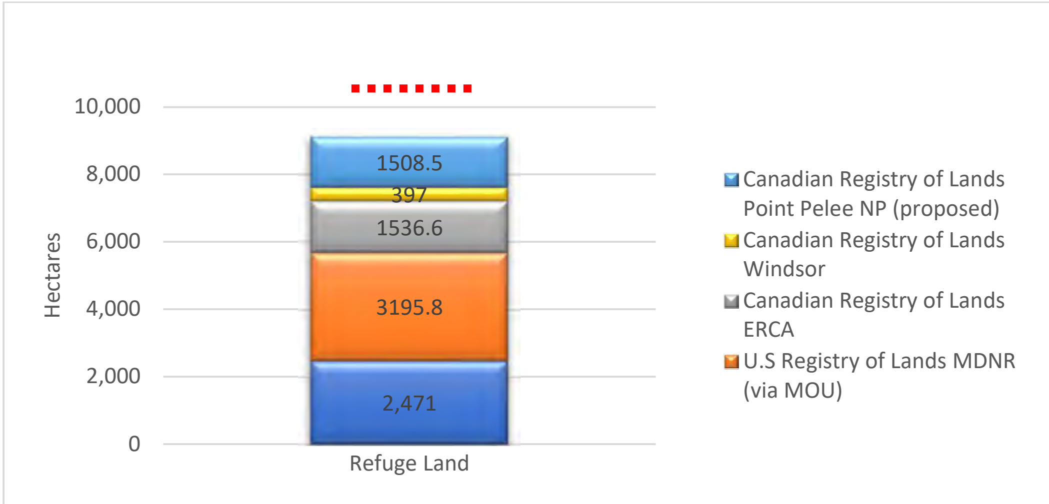


Figure 3. Growth of the DRIWR from 2001 to present.

Notes: The red-dotted line indicates the binational goal of conserving 10,117 ha (25,000 acres) by 2025. Note that the 1,508 ha (3,727.6 acres) conserved through the Canadian Registry of Lands at Point Pelee National Park is proposed. Approximately 2,509 ha (6,200 acres) will have to be added to reach the binational goal of 10,117.1 ha by 2025.

Management Next Steps

To achieve the binational goal of conserving 10,117.1 ha (25,000 acres) as part of the DRIWR by 2025, it will be important for managers to collaborate on transboundary conservation and invest time and resources into building effective public-private partnerships. On the Canadian side a priority should be placed on adding Point Pelee National Park and The Nature Conservancy of Canada lands on Pelee Island to the Canadian registry of lands. Other Canadian lands to be explored for possible addition to the Canadian registry of lands include Mans Marsh, Fighting Island, and Jack Miner Bird Sanctuary. Possible cooperative agreements or acquisitions on the U.S. side include the West Marsh located adjacent to the Refuge's Ford Marsh in Monroe County and the Promedica property on the lower River Raisin in Monroe. Conservation easements should also be explored to build these registries of lands.

The DRIWR is still relatively new and has limited staff, so resources should be aimed at expanding the organizational capacity through the International Wildlife Refuge Alliance, the official Friends group of the DRIWR. Managers on both sides should continue to strengthen relationships with nongovernmental organizations like SEMI Wild, the two hawk watches, Essex County Field Naturalists, etc.

Research/Monitoring needs

Partners in the DRIWR understand that in order to sustain effective transboundary conservation, sound science must continue to be a priority (Hartig et al., 2010). Monitoring programs should be strengthened. Investments in citizen science initiatives that inform, and guide management should be increased. Continued emphasis must be placed on adaptive management processes that analyze problems, seeks opportunities, outlines priorities, and engages actions in an iterative manner for continuous improvement (Hartig et al., 2010, Hartig, 1997).

Good examples of integrating monitoring and research programs with management include fish spawning reef construction in the Detroit River, Detroit River-Western Lake Erie Cooperative Weed Management Area, Detroit River Area of Concern habitat restoration projects on both sides of the border, common tern habitat restoration, and wetland restoration efforts in both southwest Ontario and southeast Michigan. Continued priority should be placed on such efforts that strengthen the science-policy linkages. Finally, DRIWR monitoring and management must co-evolve with the Lake Erie Millennium Network, the Lake Erie Lakewide Management Plan, biennial State of the Strait Conferences, the Detroit River, Rouge River, and River Raisin Remedial Action Plans, the Lake Erie Committee of the Great Lakes Fishery Commission, and others.

References

Essex Region Conservation Authority, 2014. Detroit River Canadian Shoreline Environment Canada and U.S. Environmental Protection Agency, 1988. Upper Great Lakes connecting channels study. Final report, Volume II. U.S. Env. Protect Agency, Chicago, Illinois, USA.

Hartig, J. H., Thomas, R. L., 1988. Development of plans to restore degraded areas in the Great Lakes. Environmental Management. 12, 327-347.

Hartig, J.H., Robinson, R.S., Zarull, M.A., 2010. Designing a sustainable future through creation of North America's only International Wildlife Refuge. Sustainability. 2, 3110–3128.

Hartig, J.H., 2014. Bringing Conservation to Cities: Lessons from Building the Detroit River International Wildlife Refuge. Ecovision World Monograph Series, Aquatic Ecosystem Health & Management Society, Burlington, Ontario, Canada.

Hartig, J.H., Wallace, M.C., 2015. Creating world-class gathering places for people and wildlife along the Detroit riverfront, Michigan, USA. Sustainability. 7, 15073–15098.

Manny, B.A., Kenaga, D., 1991. The Detroit River – Effects of contaminants and human activities on aquatic plants and animals and their habitats. Hydrobiologia, 219, 269–279.

U.S. Fish and Wildlife Service (U.S. FWS), 2005. Detroit River International Wildlife Refuge Comprehensive Conservation Plan and Environmental Assessment. Grosse Ile, Michigan, USA.

This page intentionally left blank.

7.54 PHOSPHORUS DISCHARGES FROM GREAT LAKES WATER AUTHORITY'S WATER RESOURCE RECOVERY FACILITY

Majid Khan, Great Lakes Water Authority, Majid.Khan@glwater.org

Ed Hogan, Wade Trim, ehogan@wadetrim.com

Imad Salim, Wade Trim, isalim@wadetrim.com

Background

Figure 1. An aerial photograph of GLWA's Water Resource Recovery Facility - one of the largest in North America (credit: GLWA).

1Lake Erie has a long history of accelerated eutrophication. During the 1960s, Lake Erie was on the front cover of several national magazines because phosphorus-induced algal blooms and oxygen depletion of deeper waters caused fish kills. In general, phosphorus is the scarcest and readily controllable nutrient relative to plant needs. Therefore, the United States and Canadian governments worked through the Great Lakes Water Quality Agreement to set phosphorus target loads to control water quality problems associated with phosphorus enrichment. This phosphorus control program called for controlling inputs from municipal wastewater treatment plants, controlling inputs from agricultural and urban runoff, and restricting the phosphorus content of cleaning agents and laundry detergents. The Great Lakes Water Authority's (GLWA) Water Resource Recovery Facility (WRRF), formerly known as the Detroit Wastewater Treatment Plant, was the single largest point source contributor of phosphorus to Lake Erie. This regional wastewater treatment plant was constructed in 1940, subsequently expanded to accommodate growth, and currently serves over three million people in 78 communities. This facility provides both primary and secondary treatment to 2,461 million liters (650 million gallons per day (MGD)) of wastewater on an average day but has the sustained peak capacity of 1,700 MGD of primary treatment, and 930 MGD of secondary treatment (Figure 1).

Status and Trends

In 1970, the Detroit Wastewater Treatment Plant began removing phosphorus from its effluent using pickle liquor (ferrous chloride) and polymer to meet the 1 mg/L phosphorus effluent standard for all major plants (3.8 million liters; one million gallons per day or greater). Pickle liquor was obtained from local steel mills and pumped or fed by gravity into plant headworks, while polymer was injected into channels leading to the primary clarifiers. Aeration facilities for secondary biological treatment were constructed during 1973-1976 (Panek et al., 2003). Through this process, ferrous chloride is converted to ferric chloride, which has been found to more effectively precipitate phosphorus. During 1979-1980, staff at the plant implemented an alternative sludge removal process which increased sludge handling capability and indirectly increased the plant's ability to remove phosphorus.

Two statewide phosphorus control initiatives were also implemented. In 1971, Michigan enacted a phosphorus limitation of 8.7 percent by weight on all cleaning agents. Michigan's phosphorus detergent ban was implemented in 1977, restricting the phosphorus content of household laundry detergents to no greater than 0.5 percent by weight (Panek et al., 2003).

The combined influence of these phosphorus control efforts can be seen in Figure 2a and 2b below. The result was a greater than 90 percent reduction in phosphorus concentration and loading from the Detroit Wastewater Treatment Plant. Similar reductions occurred in other wastewater treatment plants; however, because of the Detroit plant's 2,461 million liters (650 million gallons) per day flow, the impact on Lake Erie was substantial. Phosphorous reductions at the Detroit Wastewater Treatment Plant would become the single largest cause of the reversal of cultural eutrophication of Lake Erie during the 1970s and 1980s. Lake Erie responded with dramatic improvements in water quality.

With the passing of the Clean Water Act in 1972, and the issuance of the first National Pollutant Discharge Elimination System (NPDES) permit, there were a number of problems with consistent and adequate operation of the plant. These problems climaxed in a 1977 Federal Consent Judgment, which outlined the specific deficiencies, areas requiring improvement, and target dates for achieving compliance. A full-scale evaluation of the plant was performed in 1979 to identify the treatment capacity and capability, and additional capital improvements, and to help ensure adequate operation of the plant. It was not until 1981, when the construction and modification of secondary settling tanks were completed, that the plant would achieve consistent operation sufficient for secondary treatment standards.

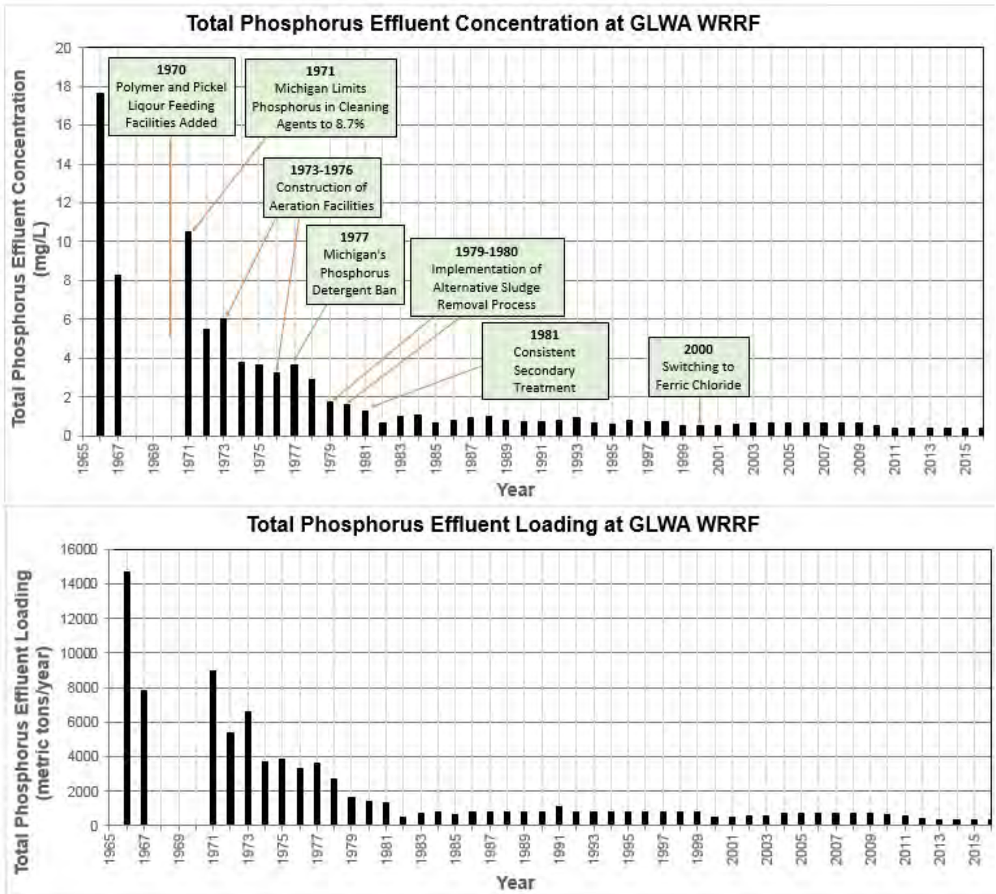


Figure 2a and 2b. Total phosphorus effluent concentration (a) and effluent loading (b) from Great Lakes Water Recovery Facility, 1966-2016.

The story of reductions in phosphorus loadings and the subsequent reversal of cultural eutrophication of Lake Erie is one of the greatest success stories of water resource management. Indeed, the U.S.-Canada phosphorus control program is heralded as an international model.

By the early 1990s, zebra and quagga mussels invaded Lake Erie causing major changes in the food web and lake ecosystem. Additionally, farming practices changed over a similar time frame, with the advent of no-till farming and increased use of drain tiles. In recent years, blooms of blue-green algae have occurred in the western basin of Lake Erie, particularly in the mouth of the Maumee River, raising new concerns. The exact reasons for these blooms are uncertain. Did increased discharge of nutrients occur? Did zebra mussels change the water quality and favor productivity of blue-green algae? Will this lead to more taste and odor problems in drinking water supplies? Research needs to be focused on answering such questions.

In the meantime, Michigan implemented a statewide residential fertilizer phosphorous ban in 2012. Concurrently, GLWA has moved forward with a set of treatment process measures to further mitigate phosphorus impact on the Detroit River. These measures include refinements in the ferric chloride dosing and secondary treatment processes including:

1. Maintaining a minimum of 0.5 mg/L phosphorus in the influent to secondary treatment to maintain a healthy level of nutrients for the secondary biological process that results in a better overall phosphorus removal;
2. Maintaining solids inventory below 500 dry tons;
3. Maintaining solids retention time close to 24 hours; and,
4. Keeping dissolved oxygen levels between 2.0 and 4.0 mg/L in the last bay of aeration basins.

Since 2006, phosphorus discharge concentrations have been reduced by an additional 40 to 50 percent (on average from approximately 0.8 to 0.4 mg/L). This average concentration approaches the lower limit of phosphorus reduction that can be achieved through technology-based treatment. Figure 3a and 3b better illustrate the effectiveness of these measures over the last 10 years.

Reflecting the success of the WRRF in reducing phosphorus discharge limits, the NPDES permit issued March 2013 was modified to reduce the phosphorus discharge limits from 1.0 mg/L to 0.7 mg/L effective in 2015. In 2016, the permit further reduced the phosphorus discharge limits to 0.6 mg/L during the growing season.

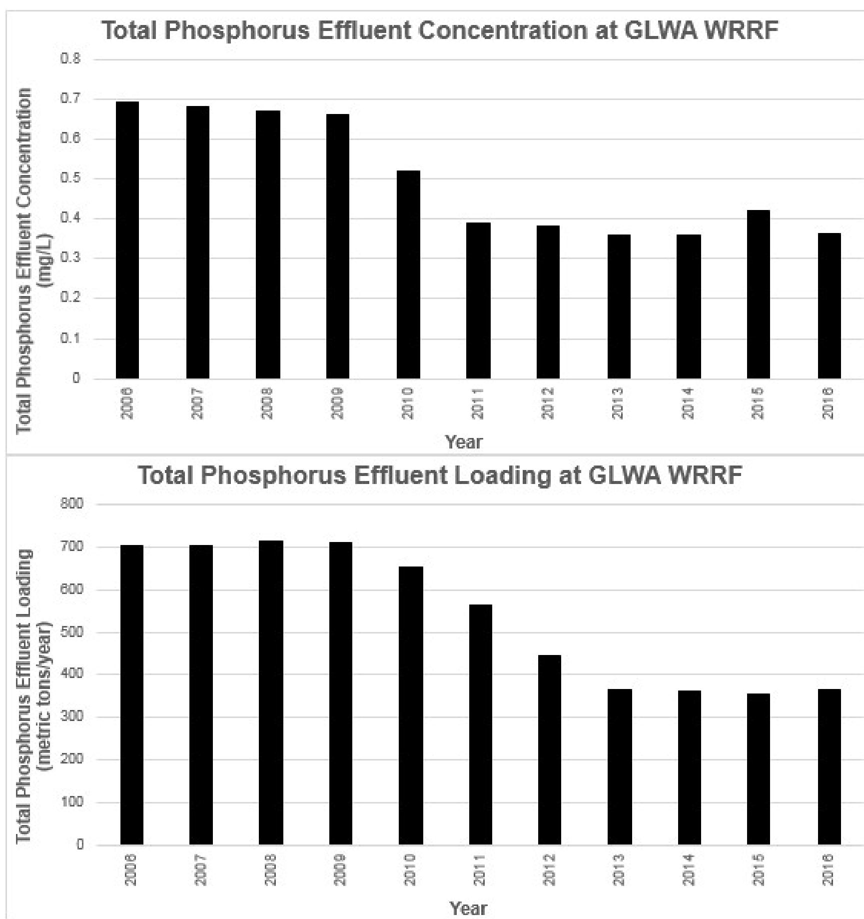


Figure 3a and 3b. Total phosphorus effluent concentration (a) and effluent loading (b) from Great Lakes Water Recovery Facility, 2006-2016.

Management Next Steps

In June 2015, the states of Michigan and Ohio, together with the Province of Ontario, entered into the Western Basin of Lake Erie Collaborative Agreement (Agreement). This Agreement established a collaborative initiative with a defined goal of achieving a 40 percent load reduction in total and dissolved reactive phosphorus entering the Western Basin by year 2025, and an interim goal of a 20 percent reduction by 2020. Each state and province has committed to developing, with stakeholder involvement, a plan identifying their proposed actions and timelines toward achieving this phosphorus reduction goal, including measuring progress through established and defined benchmarks and reporting.

Current management efforts are focused on farming practices along major tributaries to western Lake Erie, as well as maintaining the significant phosphorous reductions from the GLWA WRRF. The major changes that have occurred in Lake Erie in recent years are not well understood. However, it is clear that management programs, research, and monitoring must be sustained and closely coupled in order to achieve management goals for the Detroit River and Lake Erie. The Lake Erie Committee of the Great Lakes Fishery Commission has recommended a "hold-the-line on phosphorus levels" until there is clear scientific evidence that suggests otherwise.

Research/Monitoring Needs

Phosphorous reduction goals identified in the Western Lake Erie Basin Collaborative are specifically designed to reduce nuisance algae blooms (Michigan Department of Environmental Quality, 2016). This is different than the harmful algal blooms which are associated with the presence of algal toxins at unacceptable levels. It is hoped that by reducing the nuisance algae blooms, that a reduction in harmful algal blooms will also occur.

Under a 2012 amendment to the Great Lakes Water Quality Agreement, a multi-modeling program was developed and implemented. A final report was completed on August 31, 2016 under the Nutrient Annex 4 Objectives and Targets Development Task Force (Battelle, 2016). Significantly, the report concludes that achieving cyanobacteria biomass reduction in the Wester Basin requires a focus on reducing total phosphorous loading from the Maumee River, with emphasis on high-flow event loads in the period from March through July. The results further state that the phosphorous load from the Detroit River is not a driver of cyanobacteria blooms.

Monitoring and research must be sustained for calculating reliable loading estimates, evaluating impacts of remedial efforts, understanding short- and long-term ecosystem trends, and refining modeling frameworks applied for management and decision making. Coordinated, comprehensive research will be needed to understand cause-and-effect relationships relative to the recent changes in Lake Erie and to ensure ecosystem-based management.

References

Battelle, 2016. Great Lakes Water Quality Agreement, Nutrient Annex 4 Objectives and Targets Development Task Team, Multi-Modeling Report – Final. Columbus, Ohio, USA.

Michigan Department of Environmental Quality, 2016. Michigan Implementation Plan, Western Lake Erie Basin Collaborative. Lansing, Michigan, USA.

Panek, J., Dolan, D.M., Hartig, J.H., 2003. Detroit's role in reversing cultural eutrophication of Lake Erie, in: Hartig, J.H., (Ed.), Honoring Our Detroit River: Caring for Our Home, Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 79-90.

Links for More Information

Great Lakes Water Authority: www.glwater.org

7.55 Soft Shoreline Along the Canadian Side of the Detroit River

C. Sanders, Detroit River Canadian Cleanup, csanders@erca.org

Background

The Detroit River, a 51-km connecting channel, flows south from Lake St. Clair to Lake Erie, and is part of the international boundary that separates Canada from the United States. The river drains all or part of six municipalities in Canada and flows past the City of Windsor, the Town of LaSalle, and the Town of Amherstburg. Historically, the abundant natural resources within the Detroit River watershed provided an oasis for fish and wildlife. Over the last century, the river and its watersheds became a prime settlement site and an active transportation, industrial, and recreational corridor. The Detroit River has experienced remarkable industrial development over the last 100 years. With this development came widespread pollution and a significant loss of coastal wetlands, as well as degradation of habitat and water quality. As the communities in the river's watershed grew on both sides of the border, this degradation continued without responsible environmental management. Intensive urban and industrial development along the shoreline led to shoreline hardening and other alterations that affect fish habitat, shoreline processes, and water quality (Nodwell et al., 2007). This contributed to the designation of the Detroit River as an Area of Concern (AOC) in the revision of the Great Lakes Water Quality Agreement by Protocol in 1987.

Status and Trends

Loss of fish and wildlife habitat is one of the 14 impaired uses identified in the Detroit River remedial action plan (RAP). The Stage 1 report noted that "a significant loss of fish and wildlife habitat and, in particular, wetlands in the Detroit River AOC has occurred as a result of a number of factors, including poor substrate quality, diking, dredging, the construction of bulkheads, and filling" (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991).

Delisting criteria for the Canadian side of the Detroit River for the loss of habitat beneficial use impairment was identified in the Stage 2 report under the following four categories: aquatic and riparian habitat, shoreline softening, terrestrial habitat, and coastal wetlands. The delisting criteria for shoreline softening and coastal wetlands in the RAP Stage 2 document states: develop and begin to implement a shoreline management strategy to soften and naturalize Detroit River Canadian shoreline, whenever opportunities arise.

Hard shorelines, characterized by concrete breakwaters or steel sheet piling, were commonly engineered along both the U.S. and Canadian side of the Detroit River in the early 20th century to protect from erosion and flooding, and to accommodate industry and ship navigation (Hartig and Bennion, 2017). Previous shoreline assessments suggest that more than 80% of the entire Canadian and U.S. shoreline combined is developed and artificially hardened as a result of urbanization and industrialization which has degraded habitat for many fish species.

Since the establishment of the RAP, soft shoreline engineering, which is the process of using rocks, vegetation, and other materials to improve the ecological features in the land-water interface, has been championed as a remedial action under the loss of fish and wildlife beneficial use impairment. Unlike a steel breakwater and other 'hard' structures, which impede the growth of plants, soft shorelines, also known as living or green shorelines, grow over time. These more natural infrastructure solutions provide wildlife habitat, as well as protection and resilience to communities near the waterfront. It has proven to be an innovative and cost-effective technique for shoreline management (ERCA, 2014). To date, a total of 53 soft shoreline engineering projects have taken place along the Canadian and American Detroit River and western Lake Erie shorelines (Hartig et al., 2018). Most of these projects were opportunistic and based on erosion control priorities. The Detroit River Canadian Cleanup Stage 2 report recognized that a strategic approach is required to identify areas that can be softened on a proactive basis.

The 2012 Detroit River Shoreline Assessment revealed the primary land uses along the river as: commercial (5%), park (19%), natural (21%), industrial (12%), residential (38%), and other (5%). Since public funding availability and support for habitat creation varies for each of these land uses, different communications' strategies are required to engage residential landowners vs. municipal or industrial landowners. Furthermore, a long-term strategy to support Detroit River municipalities in adopting this infrastructure technique will be required to ensure long-term sustainability.

The DRCC Stage 2 also notes that a management strategy should follow an ecosystem approach to habitat conservation and recommends that shoreline softening projects should be integrated with habitat enhancements on the land and in the water (i.e. in conjunction with possible wetland creation and riparian buffers). Therefore, this strategy must also consider what opportunities have already been identified for enhancing or creating hydrologically connected wetlands and riparian buffer areas around coastal wetlands through the Essex Region Natural Heritage Systems Strategy (ERNHSS).

2012 Shoreline Assessment

The Detroit River Canadian shoreline includes approximately 1,000 public and private mainland properties (ERCA, 2012). As part of the Detroit River Shoreline Assessment Project, each property along the Canadian side of the Detroit River was visited and details related to the site's biological and structural characteristics (e.g., natural, sheet steel wall, etc.) were collected. This information was analyzed and mapped. Opportunities for restoration were classified to identify and prioritize areas for shoreline restoration or enhancement. Site specific restoration opportunities are now being developed.

Shoreline Changes Over Time

The Lake Erie Biodiversity Conservation Strategy (LEBCS; Pearsall et al., 2012), funded by U.S. Environmental Protection Agency's Great Lakes Restoration Initiative and Environment Canada, aims to facilitate coordination of actions among partners, providing a common vision for conservation of Lake Erie. The LEBCS endeavors to set ecosystem objectives and establish targets, including targets for Lake Erie connecting channels (Huron-Erie Corridor and Upper Niagara River). While the LEBCS was never officially adopted by the Lake Erie Lakewide Management Plan, the Lake Erie Partnership Management Committee officially endorsed the critical threats identified in the LEBCS (Luca Cargnelli, pers. comm. 2018).

The LEBCS establishes soft shoreline habitat quality targets for the Lake Erie connecting channels (Detroit River, St Clair River, and Upper Niagara River), which are recommended to provide critical habitat for the full diversity of native species. These targets are:

- Less than 60% soft shoreline = poor quality
- 60%-70% soft shoreline = fair quality
- 70-80% soft shoreline = good quality
- Greater than 80% soft shoreline = very good quality

The LEBCS also establishes targets for 2030 to assure long-term viability for connecting channels. The target established for soft shoreline is: shoreline hardening is below 50% along both shores by 2030, so that Lake Erie Connecting Channels continue to improve as critical habitat for the full diversity of native species.

An evaluation and summary of the historical loss and current shoreline rehabilitation efforts along the Canadian side of the Detroit River outlines the current state of efforts in the AOC and provide trends of shoreline rehabilitation against quantitative targets. This evaluation was done using a comparison of the 1931, 1988, and 2017 georeferenced aerial imagery, and is based on the Hartig and Bennion (2017) study. For the entire Canadian shoreline of the Detroit River, currently 39% of the shoreline was identified as 'hard' (Figure 1). The 61% soft shoreline places it just inside the LEBCS 'fair' indicator category noted above. In order to reach a 'good' rating, an additional 5.04 km of shoreline would need to be softened. To reach a 'very good' rating, an additional 10.96 km needs to be 'softened' along the length of the river. In addition, despite the on-going effort of the RAP and the ten projects undertaken along the shoreline, this analysis shows that the trend towards shoreline hardening has not been reversed since the establishment of the RAP. If the trend continues, losing less than a kilometer of soft shoreline will place it in the 'poor' habitat quality category as established by the LEBCS.

Figure 1. Percentage of Hard vs. Soft Shoreline in 1931, 1988, and 2017.

It should also be noted that a strict assessment of hard vs. soft shoreline does not take into consideration habitat quality and values associated with linked substrate and vegetation. In several of the priority restoration opportunities noted below, the shoreline is technically 'soft' with rubble, concrete, or limestone rip-rap. As noted in Hartig and Bennion (2017), while this incidental habitat and rip-rap are superior to sheet steel piling, opportunities may still exist to remove the rubble, and pull back to the shoreline to create more gradual slopes with undulating shorelines. Pre- and post-monitoring of emergent and submerged vegetation, fish assemblages, invertebrates, and amphibians at these sites can help to fully document ecological results and allow adjustments to management actions.

Conclusions and Recommendations

Over the past 32 years, considerable habitat restoration has occurred in and along the Detroit River. Despite this progress, more work is needed to meet long-term ecological goals. This is emphasized by the knowledge that, despite intentional effort and 10 shoreline projects undertaken through the remedial action plan, the 'hardening' trend has not been reversed along the Canadian side of the Detroit River. For long-term sustainability, the habitat priorities of the RAP need to be reflected in Official Plans and other regional policies and funding made available to support landowners who choose more ecologically friendly shoreline options. To make further gains in natural shoreline, implementing a program that provides funding to private landowners to support up to 50% of the project costs should be considered. As with other landowner stewardship programs, the Conservation Authority would be able to administer this type of program, but federal and/or provincial funding would be required to implement it.

There has been progress in reversing the loss of coastal wetlands in the corridor since the start of the RAP. Policy and long-term ecological goals for improving wetland function in the AOC should align with the ERNHSS and the strategic directions outlined in the Ontario Ministry of Natural Resources and Forestry's guiding document (A Wetland Conservation Strategy 2017 - 17 2030). Developing targets for improving wetland function, particularly for the Canard River complex, should continue to be a priority for the RAP.

After the completion of the new bridges, and as management tools become available for *Phragmites* and urban waterfront redevelopment progresses, it will be important to be opportunistic in ensuring landowners and municipalities understand the benefits of shoreline and wetland restoration. Finally, additional pre- and post-monitoring at these sites would be useful to fully document ecological results and allow adjustments to management actions (Hartig et al., 2011).

References

Essex Region Conservation Authority, 2012. Detroit River Shoreline Assessment Report. Essex, Ontario, Canada.

Essex Region Conservation Authority, 2014. Detroit River Canadian Shoreline Restoration Alternatives Selection Manual. Essex, Ontario, Canada.

Hartig, J.H., Zarull, M.A., Cook, A., 2011. Soft shoreline engineering survey of ecological effectiveness. Ecological Engineering. 37, 1231-1238.

Hartig, J.H., Bennion, D., 2017. Historical loss and current rehabilitation of shoreline habitat along an urban-industrial river – Detroit River, Michigan, USA. Sustainability. 9, 5, 828-848.

Hartig, J.H., Sanders, C.E., Wyma, R.J.H., Boase, J.C., Roseman, E.F., 2018. Habitat rehabilitation in the Detroit River Area of Concern. Aquatic Ecosystem Health & Management Society. 21, 4, 458-469.

Manny, B.A., 2003. Setting priorities for conserving and rehabilitating Detroit River habitats, in: Hartig, J.H. (Ed.), Honoring Our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 79-90.

Michigan Department of Natural Resources (MDNR) and Ontario Ministry of the Environment (OMOE). 1991. Stage 1 Remedial Action Plan for Detroit River Area of Concern. Lansing, Michigan, USA and Toronto, Ontario, Canada.

Nodwell, A., Kyba, S., Loewen M., 2007. St Clair River Restoration Assessment Project Report. St. Clair Region Conservation Authority. Strathroy, Ontario, Canada.

Pearsall, D., Carton de Grammont, P., Cavalieri, C., Chu, C., Doran, P., Elbing, L., Ewert, D., Hall, K., Herbert, M., Khoury, M., Kraus, D., Mysorekar, S., Paskus, J., Sasson, A., 2012. Returning to a Healthy Lake: Lake Erie Biodiversity Conservation Strategy. Technical Report. A joint publication of The Nature Conservancy, Nature Conservancy of Canada, and Michigan Natural Features Inventory. Lansing, Michigan, USA.

This page intentionally left blank.

7.56 SOFT SHORELINE ALONG THE U.S. DETROIT RIVER SHORELINE

John Hartig, University of Windsor, Great Lakes Institute for Environmental Research, jhhartig@uwindsor.ca

Collin Knauss, University of Michigan - School for Environment and Sustainability, crknauss@umich.edu

Background

The Detroit River is a 51-km international connecting channel that sits in the middle of the Great Lakes and serves as a vital connection between the upper Great Lakes to the lower Great Lakes (Hartig and Bennion, 2017). The Detroit River has been a critical international shipping route since the early 1820s and today remains one of the busiest navigational channels in the United States (Bennion and Manny, 2011, U.S. Army Corps of Engineers, 2004). Human population densities in U.S. and Canadian portions of the Detroit River watershed are nearly 4,000,000 and 390,000, respectively (Hartig and Bennion, 2017).

To support industry and commerce, shipping channels were created as part of the Great Lakes-St. Lawrence Seaway System. The creation of these shipping channels and expansion of industry and commerce resulted in considerable loss and degradation of aquatic habitats. For example, since 1874 a variety of anthropogenic activities, including urbanization, industrialization, dredging, dredge spoils disposal, channelization, and shoreline hardening, have transformed the channel morphology, altered the natural river flow, and degraded habitats (Bennion and Manny, 2011; Caulk et al., 2000). Between 1874 to 1968, nearly 100 km of navigational channels were created by removing more than 46,200,000 m^3 of rock and sediment from over 40.5 km^2 of river bottom (Bennion and Manny, 2011). To support shipping, industry, and commerce, hard shoreline engineering became a common practice. Hard shoreline engineering utilizes concrete breakwaters or steel sheet piling to: (1) stabilize shorelines for protection from flooding and erosion, (2) provide greater human safety, and/or (3) enhance commercial navigation or industrial development (Caulk et al., 2000; Hartig and Bennion, 2017).

As one of the most biologically rich and diverse areas in the Great Lakes region, the Detroit River provides critical habitat for numerous fish and wildlife species (Bull and Craves, 2003). Hard shoreline engineering, while beneficial for commercial, navigational, and industrial uses, typically has negative ecological value, often providing no fish and wildlife habitat (Caulk et al., 2000). In addition to habitat loss, shoreline hardening alters sediment transport processes, including the interchange between accretion and erosion, which then influences down river deposition (Patrick et al., 2016). As seen in Figure 1, human development, industrialization, and shoreline hardening along the Detroit River have contributed to a 97% loss of coastal wetland habitat (Manny, 2003).

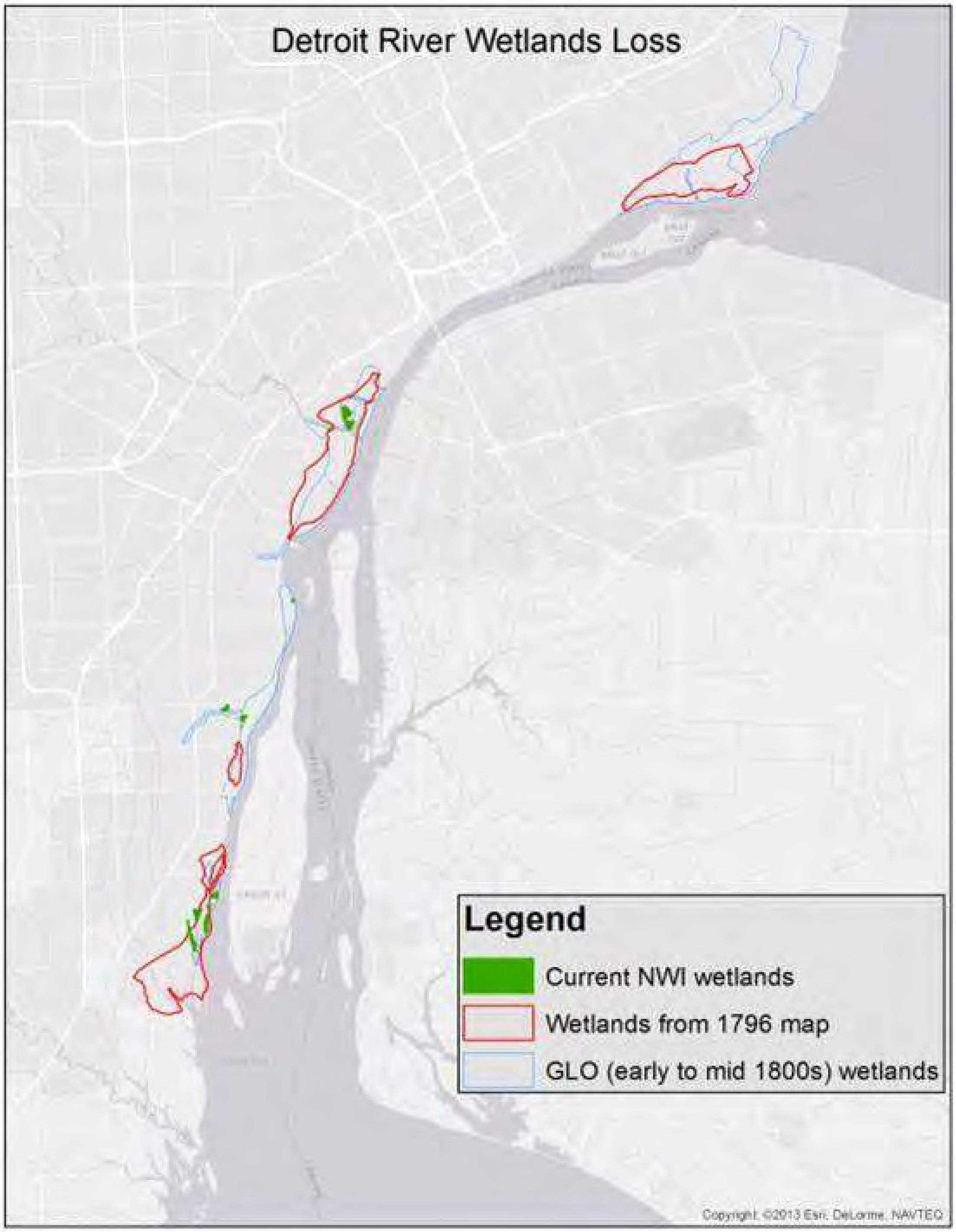


Figure 1. Extent of wetlands loss along the U.S. mainland of the Detroit River (Base map credit: map created using ArcGIS® software by Esri - ArcMap 10.4.1) (Hartig and Bennion, 2017).

To address the negative impacts of shoreline hardening on the Detroit River's ecological health, there has been growing interest in the practice of soft shoreline engineering, which utilizes ecological principles and practices to reduce erosion, improve shoreline stability, enhance habitat quality, and improve aesthetics (Hartig et al., 2001; Caulk et al., 2000). Soft shoreline engineering is accomplished using a variety of materials and vegetation to restore the land-water interface by strengthening ecological elements without sacrificing engineered shoreline integrity (Hartig and Bennion, 2017). Figure 2 shows before and after photos of the Rouge Power Plant in River Rouge, Michigan, as an example of soft shoreline engineering along the Detroit River.

Figure 2. Before (left) and after (right) photos of the Rouge Power Plant in River Rouge, Michigan (credit: Nativescape) (Hartig and Bennion, 2017).

Status and Trends

In July of 1998, the Detroit River was designated as an American Heritage River by Presidential Executive Order. Under the Greater Detroit American Heritage River Initiative, a group of U.S. and Canadian researchers and resource managers convened a conference on soft shoreline engineering in 1999 (Hartig and Bennion, 2017). Out of this conference, a Best Management Practices for Soft Engineering of Shorelines manual emerged that encouraged and galvanized support for using soft shoreline engineering techniques (Caulk et al., 2000).

Between 1995 and 2016, 19 shoreline habitat modification projects were completed along the U.S. portion of the Detroit River (Hartig and Bennion, 2017). These projects involved either soft shoreline engineering, incidental habitat, or switching from steel sheet piling or concrete breakwaters to a limestone rip-rap with some minimal habitat features. Eight of the 19 projects involved soft shoreline engineering, seven represented shoreline conversion to limestone rip-rap, and four provided incidental habitat to structures.

Following the 2012 amendments to the Great Lakes Water Quality Agreement, the Lake Erie Biodiversity Conservation Strategy was developed as a binational initiative intended to support assessments of the lake's biodiversity and challenges (Pearsall et al., 2012; Hartig and Bennion, 2017). Additionally, the strategy created specific plans and actions to promote native biodiversity of Lake Erie, which included the lake itself, connecting channels (i.e., Detroit River), and adjacent watersheds (Hartig and Bennion, 2017). Through this effort, several science-based targets were developed to support biodiversity conservation, including the following soft shoreline targets to sustain critical habitats for native species in the Detroit River (Hartig and Bennion 2017, Pearsall et al. 2012):

- less than 60% soft shoreline—poor quality
- 60–70% soft shoreline—fair quality
- 70–80% soft shoreline—good quality
- >80% soft shoreline—very good quality.

The 19 shoreline habitat modification projects resulted in improving 4.93 km of shoreline habitat. However, a comparison between 1985 and 2015 georeferenced aerial imagery showed that 2.32 km of soft shoreline changed to hard shoreline. It is important to note that 11 of the 19 shoreline habitat modification projects on the Detroit River were already georeferenced as "soft" in 1985 (Hartig and Bennion, 2017). Three of the projects covering 360 m changed the shoreline from "hard" to "soft", while the five remaining projects added 1.22 km of incidental habitat to hardened shoreline. Surprisingly, even with the addition of 1.58 km of soft shoreline and incidental habitat, there was an overall decline of 0.74 km of soft shoreline from 1985 to 2015 (Figure 3). In order for the Detroit River to attain a good state of at least 70% soft shoreline, an additional 12.1 km of soft shoreline will have to be added (Hartig and Bennion, 2017).

Management Next Steps

Despite current management efforts by resource managers and conservation organizations, shoreline hardening continues to outpace soft shoreline engineering along the Detroit River. Potential reasons for this overall loss include insufficient training among planners and designers, absence of "habitat champions" at the design stage of urban waterfront redevelopment projects, and perceived risks accompanying soft engineering alternatives (Hartig and Bennion, 2017). For long-term shoreline habitat goals to be realized, continuous and vigorous oversight of soft shoreline engineering projects will be necessary.

Going forward, resource managers should focus efforts on moving beyond opportunistic habitat enhancement/improvement project goals towards more holistic ecosystem-based management goals. Greater emphasis should be placed on identification, quantification, and understanding of critical habitats needed for target species management within an ecosystem framework. While restoration of the shoreline habitat along the Detroit River will be a long-term process, urban waterfront redevelopment projects should engage habitat experts early in the design stages, when key decisions are often made. Projects should further establish broad-based objectives for soft shoreline engineering, with measurable targets for success and integrated technical support.

Specific recommendations for management organizations to help further adopt soft shoreline engineering techniques include (Hartig and Bennion, 2017):

- Work with state and federal regulatory agencies to integrate soft shoreline engineering into permitting processes and if hard engineering is needed for port operations, marina development, or residential development, state and federal agencies should promote incidental habitat engineering;

- Ensure habitat projects recruit many partners to leverage resources;
- Start with demonstration projects;
- Undertake habitat modification projects that support learning and education, where hypotheses are created and tested using scientific rigor and rationale;
- Engage citizen scientists, volunteers, university students, and/or researchers in monitoring and post-project monitoring;
- Measure environmental and social benefits from projects and communicate successes; and
- Advocate for public education and outreach, especially events that highlight project successes and benefits.

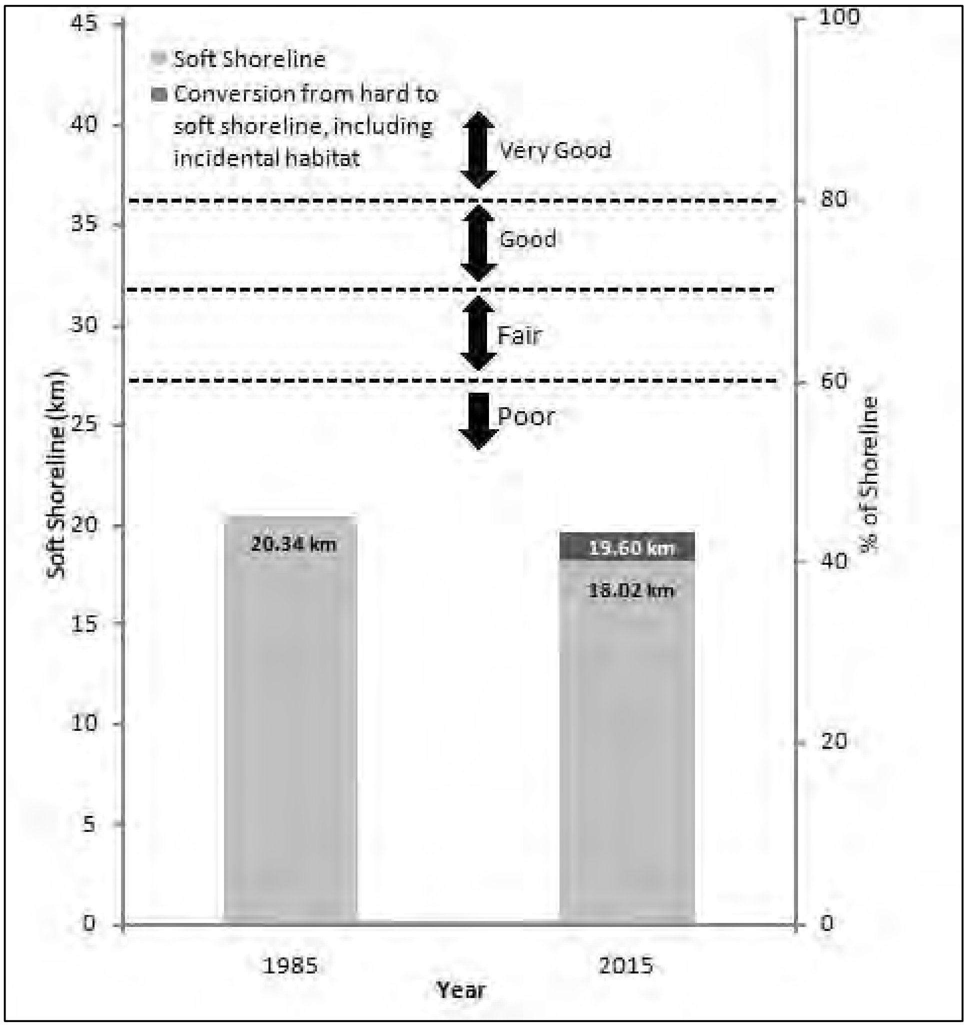


Figure 3. The extent of soft shoreline along the U.S. mainland of the Detroit River as measured by georeferenced aerial imagery, 1985 and 2015 (Hartig and Bennion, 2017).

Research/Monitoring Needs

Post-project monitoring of soft shoreline projects is often lacking. This could be rectified by: incorporating pre- and post-project monitoring of effectiveness into all federal and state permits for habitat modification; ensuring that any shoreline restoration grants include post-project monitoring; and working with conservation partners to sign a Memorandum of Understanding or a non-binding partnership agreement to perform pre- and post-project monitoring to measure project effectiveness.

Greater emphasis needs to be placed on strengthening science-management linkages. Scientists and resource managers need to reach agreement on target species and quantitative goals for restoration. Once this is accomplished, scientists and resource managers need to identify, understand, and quantify the factors affecting these target species. If habitat is a limiting factor, resource managers should quantify the amount and quality of habitat that is needed to support the desired species by life history stage. Once measurable habitat targets are established, resource managers can review and evaluate habitat modification options, identify preferred actions, implement habitat modification/enhancement actions, and then track effectiveness. Ideally, monitoring should be conducted for at least five years to ensure that measurable habitat targets are achieved and that the restored habitat remains protected and successful. Further, long-term monitoring should be performed in the spirit of adaptive management, where assessments are made, priorities set, and actions taken in and iterative fashion for continuous improvement.

References

Bennion, D.H., Manny, B.A., 2011. Construction of shipping channels in the Detroit River-history and environmental consequences. Scientific Investigations Report 2011–5122, U.S. Geological Survey, Reston, Virginia, USA.

Bull, J.N., Craves, J., 2003. Biodiversity of the Detroit River and environs - Past, present, and future prospects, in: Hartig, J.H. (ed.), Honoring our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 141–169.

Caulk, A.D., Gannon, J.E., Shaw, J.R., Hartig, J.H., 2000. Best Management Practices for Soft Engineering of Shorelines. Greater Detroit American Heritage River Initiative: Detroit, Michigan, USA.

Hartig, J.H., Bennion, D., 2017. Historical Loss and Current Rehabilitation of Shoreline Habitat along an Urban-Industrial River – Detroit River, Michigan, USA. Sustainability 9, 5, 828-848.

Hartig, J.H., Kerr, J.K., Breederland, M., 2001. Promoting soft engineering along Detroit River shorelines. Land and Water-The Magazine of Natural Resource Management and Restoration. 45, 6, 24-27.

Manny, B.A., 2003. Setting priorities for conserving and rehabilitating Detroit River habitats, in: Hartig, J.H. (Ed.), Honoring Our Detroit River: Caring for Our Home. Cranbrook Institute of Science, Bloomfield Hills, Michigan, pp. 79-90.

Patrick, C.J., Weller, D.E., Ryder, M., 2016. The relationship between shoreline armoring and adjacent submerged aquatic vegetation in Chesapeake Bay and nearby Atlantic coastal bays. Estuaries Coasts 39, 158–170.

Pearsall, D., Carton de Grammont, P., Cavalieri, C., Chu, C., Doran, P., Elbing, L., Ewert, D., Hall, K., Herbert, M., Khoury, M., Kraus, D., Mysorekar, S., Paskus, J., Sasson, A., 2012. Returning to a Healthy Lake: Lake Erie Biodiversity Conservation Strategy. Technical Report. A joint publication of The Nature Conservancy, Nature Conservancy of Canada, and Michigan Natural Features Inventory. Lansing, Michigan, USA.

U.S. Army Corps of Engineers, 2004, Waterborne commerce of the United States, calendar year 2004. Part 3 – Waterways and harbors, Great Lakes. Waterborne Commerce Statistics Center, New Orleans, Louisiana, USA.

This page intentionally left blank.

7.57 The Legacy of Bicycles in Detroit, Michigan: A Look at Greenways Through Time

Todd Scott, Detroit Greenways Coalition, todd@detroitgreenways.org

Gwen Gell, Taubman College of Architecture and Urban Planning, University of Michigan, ggell@umich.edu

Background

Greenways are constantly evolving and changing infrastructure. Greenways are trails accessible to non-motorized forms of movement which provide ecological, transportation, and connective functions within an urban area. For the purposes of this indicator report, the term "greenways" also includes bicycle infrastructure on roadways. As a city's land uses change, new administrations come into power, and the economy fluctuates and greenways and bicycle routes can shift. This report highlights the change in greenways overtime in an effort to illustrate the story of non-motorized transportation in the City of Detroit.

Status and Trends

Detroit's topography is favorable to bicycles. The expansive flat land makes for a pleasant experience biking though the city. While there has been an increase in ridership and bicycle infrastructure in recent years, the known legacy of bicycles began prior to the automobile and contributed to the development of the Motor City.

Timeline

Pre-1700 Established Native American networks throughout the region were the first greenways in Southeast Michigan (Sewick, 2016; Mason, 1959; Hinsdale, 1931). Early surveyors map the trails created and used by the Anishinaabe, Wyandot, Iroquois, Fox, Miami, and Sauk tribes (Herberg, 2017). The present-day grid patterns of the region follow these original Native American pathways.

1701 Cadillac establishes Fort Pontchartrain du Détroit - this is considered the 'founding' of the modern City of Detroit

1851 The first velocipede is for sale in Detroit

1868 On December 18th, on Jefferson Avenue, the Detroit Journal reports the first velocipede ride in Detroit.

1879 The first bicycle club in Detroit is formed

1880 The Good Roads Movement Begins in the United States, started by cyclists, to advocate for improved roads

1884 The Detroit Free Press publishes an expose on an international cycle tour, titled *The Great Canada Bicycle Tour* (Bates, 1884). Written by President Bates of the Detroit

Bicycle Club, the piece highlights the journey starting in Detroit, Michigan on July 2, 1883, crossing Ontario, and ending in Buffalo, New York on July 12, 1883.

Cycling, at this time, was an activity engaged primarily by upper-class men and was considered a gentleman's sport. From the drawings in the article, we can infer these men were crossing the country on bicycles with a very large front wheel, or Penny Farthing. Cyclists, or wheelmen, were likely riding on gravel, wood, and dirt road conditions.

The article highlights not only Detroit's bicycle legacy, but the beginnings of an international bicycle relationship.

1893 Mayor Pingree's unrealized initiatives included developing the riverfront as a public space and expanding the inner greenspace of the city for citizens of Detroit - part of his expanding welfare platform (Stark, 1943).

1896 In April, the Detroit Free Press publishes an insert called *Outside Runs: Guide Map of City of Detroit for Bicyclists, Showing Pavement* (Calvert Lithographic & Engineering Company, 1896). This map indicates the material of roads for cyclists including, wood, asphalt, brick, macadam, and granite. In addition to materials, the map also highlights longer day trips outside of the city.

(Charles Brady King drove the first automobile in Detroit the month prior to the bicycle map being made)

1906 Ed Hines, an avid cyclist and leader of the Detroit Wheelmen, is elected as Wayne County Road Commissioner. He is a passionate supporter of the Good Roads Movement and is influenced by creating safe roads for all users. He begins implementing the median line on roads in Southeast Michigan.

"I can remember in the early '90s when it seemed as if every man in Detroit rode a bike. Now it seems as if every other man you know owns an automobile and the 'bikes' have been relegated to the rear for use by messengers and errand boys."
– Wayne County Road Commissioner Ed Hines, 1914 (Detroit News, 1896)

1929 The Ambassador Bridge opens between Detroit and Windsor, for cars, bicycles and pedestrians.

1936 The Detroit News Hiking Club is formed. This club was active up until WWII.

1970 Bicycle interest and funding stagnates for nearly 80 years - between the 1890s and the 1970s. Automobiles provide personal freedom to travel, but lead to auto-dominant roadways. Building a city which accommodates the automobile becomes the top priority for Detroit, the Motor City. Industrialization and urban sprawl, amongst many other factors, creates roadways hostile non-motorized forms of transportation.

In the 1970s, due to national oil shortages and the environmental movement, cities across the nation became a platform for bicycle activism and insurgence. The Bike Boom brought bicycles to the attention of decision makers. City leadership across the country completed feasibility studies, but little action was taken.

1972 The State of Michigan road funding changes to require a minimum of 1% to be spent on non-motorized uses. The legislator who led that effort, Dick Allen, suggests Detroit use its funding to build a protected bike lane network.

1976 The publication of a report titled *The Land & The River* by the Interagency Task Force for Detroit/Wayne County Riverfront Development. This study inventories riverfront lands and takes stock of future possibilities beyond an industrial waterfront.

1977 City administration completes an exploratory study of linking the riverfront, *Policies and Possible Futures for the Riverfront, 1977* (DeVito et al., 1977). This conceptual plan examines the feasibility of non-traditional uses of the riverfront, including providing accessibility to bicycles, access for pedestrians, and building dense housing along the Detroit River.

1979 *Linked Riverfront Park Projects* is a report of recommendations for the Detroit Riverfront created for the City of Detroit Parks and Recreation Department.

1980 *Marina/Canal Feasibility* is developed out of the *Linked Riverfront Park Projects* (Schervish, Vogel, and Merz, 1980).

1981 *West Riverfront Bicycle/Pedestrian Route* is an analysis of the riverfront which identifies different possible routes, designs, and implementation (Krichbaum, et al., 1981). This is prepared by the City of Detroit's Recreation Department and developed out of the larger *Linked Riverfront Parks Project*.

Mt. Elliott Interpretive Center: an adaptive reuse plan (Schervish, Vogel, and Merz, 1981) reports on the possibilities on how to reuse the U.S. Coast Guard Group/Base between Heart Plaza and Belle Isle

1982 *Detroit's East Riverfront: the people and places of yesterday* is a historical report identifying recreational opportunities on the east riverfront for the City of Detroit's Recreation Department (Kozora,1982).

Detroit East Riverfront Bikeway Construction Project is a report containing details about implementing a bicycle path along the riverfront. This was prepared for the City of Detroit's Recreation Department (Detroit Recreation Department, 1982).

1985 *Know Your Riverfront: a historical information brochure* is published by the Detroit Recreation Department (Detroit Recreation Department, 1985).

1986 In 1986, the Rails to Trails Conservancy is established. This organization spurs greenway development and efforts across the country.

1989 The Michigan Rails-to-Trails Conservancy is founded. It coordinates the construction and transition of old rail lines to greenways across the state.

1990 Throughout the 1990s, southeast Michigan and Detroit sees an increase in organizing and planning for greenway and bicycle infrastructure.

Southeast Michigan Greenways Initiative is established to champion greenways

1994 City of Detroit Land Use plan includes greenways as one of their 5 keys to city redevelopment

Southeast Michigan Greenways: Wayne County Report

1997 Rail to Trails publishes Southeast Michigan Greenways: A regional overview – Vision, Tools, Process (Deck et al., 1998).

1998 Rails to Trails Conservancy and National Park Service releases: *A Vision for Southeast Michigan Greenways* (Deck et al., 1998).

Detroit River selected as 1 of 14 American Heritage Rivers, established under the Metropolitan Affairs Coalition. Creating linked greenways is identified as 1 of 5 top priorities.

1999 Southwest Detroit Riverfront Greenway Project Publishes: *Detroit's New Front Porch* (The Greenways Collaborative, 1999).

Downriver Linked Greenways Initiative establishes linked greenways between 21 Downriver Communities

2000 As the City's agency and momentum for greenway projects begin to wane, smaller neighborhood level community development organizations begin to plan their own communities. Planning and implementation are made possible through matching grants from the Southeast Michigan Greenways Initiative, spearheaded by the Community Foundation of Southeast Michigan.

2001 Community Foundation of Southeast Michigan launches its Greenway's Initiative to build a regional network of greenway trails. Over $33million is awarded and $125 million is leveraged to build over 160 km (100 miles) of greenways in Southeast Michigan, including Detroit.

The Ambassador bridge closes bicycle and pedestrian access in 2001.

2002 City of Detroit creates a riverfront vision.

Abandoned Rail Corridor and Inventory Assessment is published by Rails-to-Trails Conservancy for the Greenways Initiative. This proves to be the future foundation for successful greenway projects throughout the city (Rails to Trails Conservancy, 2002). The development of the Inner Circle Greenway, known as the Joe Louis Greenway, is a result of this report.

2003 The Detroit Riverfront Conservancy is established.

2006 Detroit hosts Super Bowl XL, significant efforts towards beautification are implemented throughout the city, including investment in the Conner Creek Greenway near Detroit City Airport.

Detroit develops a non-motorized plan (Patel, 2006). The plan is adopted by City Council in 2008.

2007 Ribbon Cutting ceremony for the first two completed miles of the Detroit RiverWalk.

The Detroit Greenways Coalition is formed.

2009 Community Foundation funds several construction grants throughout the city, including Southwest Detroit Greenlink.

Ribbon cutting on the Dequindre Cut.

A concept is developed for the River Rouge Greenway.

Detroit Greenways Coalition develops *Detroit Greenway Network Plan*.

2010 In the 2010s, community organization plans are realized. Construction is funded and underway. The City of Detroit goes into austerity measures during the bankruptcy. Post-bankruptcy the city begins to comprehensively plan greenways on a city-wide scale.

2013 City of Detroit files for Bankruptcy.

2014 City of Detroit emerges from Bankruptcy.

Southeast Michigan Council of Governments (2014) publishes: *Nonmotorized Plan for Southeast Michigan*.

2015 Iron Belle Trail is announced linking the Upper Peninsula to Detroit on a 3,520-km (2,200-mile) greenway.

2016 Dequindre Cut Extension Opens.

Envisioning Detroit as the World's Greenway Capital: A 50-year vision of the Detroit Greenways Coalition is published.

A U.S.-Canada Greenways Vision was created in 2014 calling for a bicycle/pedestrian lane on the Gordie Howe Bridge, improvements to the tunnel bus system, and re-establishment of a cross border ferry (Detroit Greenways Coalition, 2014).

2017 Joe Louis Greenway named as a 41.6-km (26-mile) greenway that will eventually encircle the city and connect neighborhoods.

2018 Detroit sees an expansion of bicycle infrastructure along Jefferson Avenue and the Lower-Eastside Neighborhoods, intended to create a comprehensive greenway network (Detroit Transportation Department, 2018).

2019 Construction of the Joseph Campau Corridor (City of Detroit, 2019).

Detroit Greenways Coalition publishes Bike & Walk Detroit City: 2019 Route Map and Safety Guide.

2022 Expected date of completion for the first phase of the Joe Louis Greenway.

Expected date of completion of the Ralph C. Wilson, Jr. Centennial Park on the Detroit RiverWalk.

2024 Expected completion of the Gordie Howe Bridge, uniting Canada and the United States through a multi-modal byway.

Management Next Steps

The City of Detroit is in the midst of implementing new greenways, specifically the Joe Louis Greenway, extending into the neighborhoods on the Westside of the city. The first phase is expected to be completed in 2022. The City also intends to extend the Dequindre Cut to the north. The Conner Creek Greenway is under negotiation to be rerouted in order to accommodate an expected increase in truck traffic due to the new Fiat Chrysler plant.

The new international Gordie Howe Bridge, expected completion in 2024, incorporates plans for a non-motorized lane creating a formal bicycle/pedestrian connection between the United States and Canada. The bridge will result in international connections to greenways in both countries, ranging from a small local loop to larger cross-country paths.

Continued priority should be placed on identifying creative financing options for greenways, as well as a provision for long-term maintenance and security. Research should address these issues to work toward collaborative solutions to financing, construction, long-term operation and maintenance, and security.

Greenways are constantly evolving to rise to the spatial opportunities and meet the needs of users. Detroit's legacy of bicycle usage within the city began prior to the automobile and continues today. The rise of bicycle related infrastructure – including greenways – is evidence of the City's bicycle tradition. The future holds many opportunities to expand and connect Detroiter's to their neighborhood, city, and nearby towns and countries.

References

Bates, L.J., 1884. The Great Canada Bicycle Tour. The Detroit Free Press (May), Detroit, Michigan, USA.

Calvert Lithographic & Engineering Company, 1896. Outside Map of the City of Detroit and Bicyclists, Showing Pavements. Library of Congress, Washington, D.C., USA.

City of Detroit, 2019. Joseph Campau Streetscape Project. Detroit, Michigan, USA. https://detroitmi.gov/departments/department-public-works/complete-streets/streetscape-program/jos-campau-streetscape-project (accessed August 7, 2019).

Deck, L., Cox, N., Nelson-Jameson, B., 1998. Southeast Michigan Greenways: Vision, Tools, Process. Report. Ann Arbor, Michigan, USA.

Detroit Greenways Coalition, 2014. U.S.-Canada Greenways Vision Map. Detroit, Michigan, USA.

Detroit Recreation Department, 1982. Detroit East Riverfront Bikeway Construction Project. Detroit, Michigan, USA.

Detroit Recreation Department, 1985. Know Your Riverfront Parks: A Historical and Informational Brochure. Detroit, Michigan, USA.

Detroit Transportation Department, 2018. Strategic Plan for Transportation. Detroit, Michigan, USA.

Detroit News, 1896. March 1 Edition. NewsBank: Access World News, University of Michigan Library, Ann Arbor, Michigan, USA.

Detroit News, 1996. The Detroit News Hiking Club. Detroit, Michigan, USA. http://blogs.detroitnews.com/history/1996/12/15/the-detroit-news-hiking-club/ (accessed August 13, 2019).

DeVito, A.P., Jones, L.L., Knack, J.H., Hoffman, R.G., Stearns, J.L., 1977. USA. City of Detroit. Planning Department. Policies and Possible Futures For The Riverfront. Planning Department, City of Detroit, Detroit, Michigan, USA.

Herberg, L., 2017. Who Were the Natives in Detroit? WDET, Detroit, Michigan, USA. https://wdet.org/posts/2017/04/30/85115-curiosid-who-were-the-natives-in-detroit/ (accessed August 7, 2019).

Hinsdale, W. B., 1931. Archaeological Atlas of Michigan. University of Michigan Press, Ann Arbor, Michigan, USA.

Kozora. K., 1982. Detroit's East Riverfront: People and Places. City of Detroit, Recreation Department, Detroit, Michigan, USA.

Krichbaum, D., Jordan, T., Saperstein, H., Viail, E., Reich, B., 1981. West Riverfront Bicycle/Pedestrian Route. City of Detroit, Recreation Department, Detroit, Michigan, USA.

Louie, B.G., 2001. Northville Michigan. Arcadia Publishing, Charlestown, South Carolina, USA.

Mason, P.P., 1959. Michigan Highways from Indian Trails to Expressways. Michigan Historical Commission, Lansing, Michigan, USA.

Patel, A., 2006. Non-Motorized Urban Transportation Master Plan. USA. City of Detroit, Department of Public Works, Detroit, Michigan, USA.

Rails to Trails Conservancy, 2002. GreenWays Initiative: Planning for Detroit's Rails to Trails. Detroit, Michigan, USA.

Schervish, Vogel, and Merz, 1980. Chene/St. Aubin Park Marina/Canal Feasibility. City of Detroit, Recreation Department, Detroit, Michigan, USA.

Schervish, Vogel, and Merz, 1981. Mt. Elliott Interpretive Center. City of Detroit, Recreation Department, Detroit, Michigan, USA.

Sewick, P., 2016. Detroit Urbanism: Retracing Detroit's Native American Trails. http://detroiturbanism.blogspot.com/2016/01/retracing-detroits-native-american.html (accessed August 7, 2019).

Sisson, P., 2017. 'Bike Boom': Lessons from the '70s Cycling Craze That Swept the U.S. Curbed. https://www.curbed.com/2017/6/28/15886810/bike-transportation-cycling-urban-design-bike-boom (accessed August 21, 2019).

Southeast Michigan Council of Governments, 2014. Nonmotorized Plan for Southeast Michigan: A Plan for SEMCOG and MDOT's Southeast Michigan Regions. Detroit, Michigan, USA.

Stark, G.W., 1943. City of Destiny: The Story of Detroit. Arnold-Powers, Detroit, Michigan, USA.

The Greenways Collaborative, 1999. The Southwest Detroit Riverfront Greenway Project. Ann Arbor, Michigan, USA.

7.58 The Need for a Multinational Climate Change Adaptation Plan

Patricia Galvao-Ferreira, Faculty of Law, University of Windsor, patricia.galvao@uwindsor.ca

Kevin Berk, Faculty of Law and Great Lakes Institute of Environmental Research, University of Windsor, berkk@uwindsor.ca

Antonia Hristova, Faculty of Law, University of Windsor, hristova@uwindsor.ca

Background

Climate change is a global problem with local sources and local impacts. The Detroit River-Western Lake Erie Basin is already experiencing impacts of climate change. Indicator reports prepared for this project provide a clear base of evidence for this reality.

Recent trend data show an increase in annual average atmospheric temperature in the Western Lake Erie Climate Division that has “had and will continue to have various impacts on the region, such as changes in local ecosystems and amplified extremes in regional temperature” (Maher and Channell, this report: 7.11). Similarly, an overall increase in annual precipitation has been observed in the Western Lake Erie division since 1951. As indicated by Maher and Channell (this report: 7.37), “such changing trends in precipitation have had and will continue to have various impacts on the region, such as increased runoff and flooding.” Precipitation is also a key driver of Great Lakes water level fluctuations, together with evaporation and runoff. More importantly, it is crucial to note that “high water levels can cause flooding, property inundation, and coastal erosion, while low water levels can lead to negative impacts on shipping and navigation, seasonal recreation, and coastal wetland habitats for birds and fish” (Maher and Channell, this report: 7.27). Additionally, changes in ice cover can lead to changes in evaporation rates, which in turn have implications for lake levels and precipitation amounts. Ice cover also affects shipping and navigation, as well as seasonal recreational activities on the lakes. Data from the Great Lakes Environmental Research Laboratory (GLERL) demonstrate a downward trend in ice coverage on Lake Erie since the 1990s (Maher and Channell, this report: 7.14).

These changes are not expected to slow down or be reversed in the immediate future either. Richter’s report on Climate Change Adaptation in Windsor, Ontario indicates that by 2050 the average annual temperature in Ontario will increase by 2.5°C to 3.7°C, from the 1961-1990 baseline (Richters, this report: 7.43). In the face of these trends, the cities of Windsor and Detroit have each committed to take action to both mitigate and adapt to the threat that climate change poses to their citizens.

Windsor was one of the first municipalities in Canada to embrace climate adaptation planning, with City Council and the City administration approving the 2012 Climate Change Adaptation Plan. The Plan established both short-term and long-term adaptation actions. The City of Windsor has successfully implemented their Climate Change Adaptation Plan with almost all actions completed or underway. On 19 November 2019, the City of Windsor joined hundreds of municipalities across Canada approving a climate change emergency declaration (Garton, 2019). In addition to steps to adapting to climate change, "the City of Windsor is taking steps to help the global effort to reduce greenhouse gas emissions" evidenced through actions such as tracking corporate and community emissions and establishing the City of Windsor's Community Energy Plan (2017) which aims to contribute to climate change mitigation efforts, create economic advantage, and improve energy performance by reducing per capita use and per capita $C0_2$ emissions by 40% by 2041 (Richters, 2019).

Similarly, Detroit has created a municipal action agenda to fulfill its commitments to mitigate emissions and to adapt to the impacts of climate change. Detroit is a member of the Climate Mayors – a bipartisan, peer-to-peer network of mayors working to demonstrate leadership on climate change, with standards based on the Paris Climate Agreement (Heeres et. al., this report: 7.49). In June 2019, Detroit released a Sustainability Action Agenda – "a strategic roadmap to address key sustainability issues to create a city where all Detroiters can thrive" focusing on the outcomes of healthy, thriving people; affordable, quality, homes; clean, connected neighborhoods; and an equitable, green city (Heeres et. al., this report: 7.49). The City is a signatory to the Chicago Climate Chapter and aims to reduce community-wide greenhouse gas emissions by 30% by 2025 from a 2012 baseline. To adapt, Detroit has committed to reducing the volume of untreated combined sewer overflows (CSOs); doubling the acreage of green infrastructure; creating neighborhood-scale, green infrastructure projects; incorporating green infrastructure in street redesign and greenway projects; and integrating climate change impacts in hazard mitigation planning (Heeres et. al., this report: 7.49).

Although individual cities in the Detroit River-Western Lake Erie Basin have demonstrated leadership on climate adaptation, for the most part this action has been done unilaterally. Yet the transboundary nature of climate change poses a threat to the basin's ecosystem health that requires a more coordinated effort between the various regulatory and policy systems on both sides of the border, with a shared vision and strategy.

Such a shared vision for transboundary climate adaptation plans in river basins is exemplified by the European Union's Climate Adaptation Platform, Climate-ADAPT, a partnership between the European Commission and the European Environment Agency (EEA). Climate-Adapt supports European countries in adapting to climate change by helping users to access and share data and information on i) expected climate change in Europe; ii) current and future vulnerability of regions and sectors; iii) EU, national, and transnational adaptation strategies and actions; iv) adaptation case studies and potential adaptation options; and v) tools and support for adaptation planning (Climate-ADAPT, 2019).

Climate-Adapt has recognized the cross-border nature of most direct and indirect impacts of climate change in European river basins, with associated hydrological, social, and economic interdependencies. In response, Climate-Adapt recommends that countries with shared basins should "establish contact with neighboring countries to inform about the adaptation process and areas of concern with regard to cross-border impacts and identify approaches for coordination over different political, legal, and institutional settings" (ClimateAdapt, 2019).

A study of lessons learned and good practices of climate adaptation strategies in transboundary basins, conducted by United Nations Economic Commission for Europe (UNECE) and the International Network of Basin Organizations, has underscored how transboundary cooperation helps to share costs and benefits of adaptation and to ensure synergies and linkages between various adaptation strategies at local, regional, and national levels. Transboundary climate adaptation cooperation thus increases the efficiency and effectiveness of climate adaptation in a basin (United Nations, 2015). Some examples of transboundary climate adaptation plans in Europe are BaltAdapt, a transnational climate adaptation plan for the Baltic Sea Region, and the Danube River Basin Climate Adaptation Strategy. A similar transboundary initiative is needed for the Detroit River and western Lake Erie.

Status and Trends

The lack of a transnational climate adaptation plan in the Great Lakes Basin or in other basins like Detroit and western Lake Erie is not due to lack of recommendations. Since at least 2003, the International Joint Commission's (IJC) Great Lakes Water Quality Board (WQB) has been publicly stressing the need for climate change plans in the Great Lakes Basin (see WQB, 2003). This example is particularly notable because the IJC is an independent advisory body to both the Canadian and American governments, created by the Boundary Waters Treaty signed by each country in 1909 (Boundary Waters Treaty). The IJC thus represents a crucial starting point for binational environmental action in the Great Lakes Basin. In 2003 the WQB published a report stating the risks posed by global warming in the Great Lakes:

> *A change in climate could lead to alterations and impacts on environmental quality (air, water, soil, sediment); surface and ground water quantity; ecosystem health and functioning; human health; the "built" environment (sewer and treatment plant capacity); and socio-economic systems, including agriculture, forestry, fisheries, recreation, tourism, energy, transportation, and manufacturing* (WQB, 2003).

Following from this acknowledgement, the WQB went on to recommend that the Canadian and American governments invest in creating binational adaptation measures to assist with the Great Lakes Basin's resilience to climate change (WQB, 2003). Unfortunately, no comprehensive plan was agreed upon coming out of this report, with only *ad hoc* measures being adopted under existing IJC programs.

As scientific evidence of climate impacts in the Great Lakes Basin became more available, the WQB emphasized the need for a comprehensive binational climate adaptation strategy again in 2017, when the WQB's "Emerging Issues Working Group" released the following recommendation:

> *The Federal Governments of Canada and the United States should demonstrate global leadership by jointly developing, in cooperation with other governments and organizations across the Great Lakes basin, a Binational Approach to Climate*

> *Change Adaptation and Resilience in the Great Lakes. Such an approach would include a shared vision, coordinated action, creation of a network to share science, information and knowledge, including Métis, First Nations and Tribal traditional ecological knowledge if offered, and the commitment of adequate funding to carry out these objectives* (WQB, 2017).

The recommendation from the WQB further stated that the United States and Canada should "negotiate and develop a Binational Approach to coordinate and advance strategies that support climate change adaptation and increase ecological resilience in the Great Lakes ecosystem region, with a particular emphasis on safeguarding Great Lakes water quality" (WQB, 2017). However, despite this strong recommendation, once again no concrete binational climate change plans have been put into place in the Great Lakes Basin.

Management Next Steps

Although the recommendations of the WQB have not been followed, they represent a concrete starting point for the implementation of a multinational climate change plan in the Great Lakes Basin, or in some of the ecosystems in the region. Perhaps the greatest strength of the recommendations is in how they set out what such an arrangement should look like in the region. In dissecting the quote above from the WQB's 2017 recommendation, one can determine that such an agreement would require four elements:

1. A shared vision
2. Coordinated action
3. Creation of a network to share science, information and knowledge, including Metis, First Nations and Tribal traditional ecological knowledge if offered
4. Commitment of adequate funding to carry out these objectives (WQB, 2017)

These recommendations are especially useful in the context of this indicator report project. First and foremost, this project, which includes cooperation from both sides of the border, has in itself established a network to share science, information, and knowledge on a transboundary level. Additionally, the network of partners that this indicator project has created can be said to demonstrate a shared vision for environmental protection of the region. Our hope is that this project will stand as an example of the possibility and necessity of continuing such a network on an even larger scale. Additionally, we hope the indicator project demonstrates the existence of an emerging shared vision for coordinated climate adaptation work across borders which has been contemplated as necessary to achieve the goals of the WQB recommendation. The UN study noted, based on successful initiatives, that transboundary cooperation on adaptation usually starts at a technical or expert level, while later positively influencing broader cooperation, including at a political level.

Although this indicator can provide guidance and evidence for the feasibility of implementing the WQB's recommendations, the recommendations themselves also provide great context regarding the next steps following completion of the project. Establishing a multinational plan goes beyond having a shared vision or sharing information and knowledge. As the WQB's proposed plan stated, coordinated action and commitment of adequate funding will also be necessary to create such a plan. From a policy perspective coordinated action could take a number of shapes – be it at the municipal, state/provincial, or nation to nation levels.

The municipal level is a particularly promising avenue to begin this multinational work. As described above both the City of Windsor, Ontario, and the City of Detroit, Michigan, are independently working on climate change adaptation plans. Additionally, other cities in the region, particularly the City of Toledo, Ohio, have demonstrated a willingness to take strong steps to protect the lands and waters of the region. The Federation of Canadian Municipalities have funded a project to support regional-scale action and collaborative learning in the Columbia Basin Boundary Region in April 2019, showing the potential of this coordination on one side of the border. Cooperation and coordination of the individual climate change plans of these cities could be a strong avenue by which to begin a multinational climate change adaptation regime in the region.

Beyond the municipal level, the obvious avenue for the implementation of a multinational plan would be through the cooperation and coordination of the federal governments of Canada and the United States, along with the Indigenous Nations in the region, under the IJC guidance. This possibility seems unlikely at the moment, however, as the United States federal policy currently does not make climate change a priority, as evidenced by their withdrawal from the Paris Agreement. Although this might make a federal agreement unlikely in the near future, a great possibility exists at the state/provincial level. This possibility manifests itself in The Conference of Great Lakes St. Lawrence Governors & Premiers ("GSGP"), which includes the ten governing bodies around the Great Lakes including the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, as well as the provinces of Ontario, and Quebec. The purpose of the GSGP is to protect the economic and environmental interests of the Great Lakes Basin. Despite this organizing purpose, the GSGP is not currently implementing any coordinated plan to address the threat of climate change to the Great Lakes. This organization then, presents a strong opportunity as a binational body which could facilitate a multinational climate change plan.

Research/Monitoring Needs

This current project thus represents proof that there is a network of groups in our region with the experience and willingness to work cooperatively to tackle the threat of climate change. However, additional work needs to be done to assist and ensure that the partners to this project can coordinate and synthesize their work on climate change. In this way, the documenting of ecosystem health and community organizing done by this project can serve as a starting point to coordinated action on a climate change plan in the region.

It is additionally essential that the recommendation of the WQB is not lost for many years as the 2003 recommendation was. We must monitor how the Parties respond to this IJC recommendation and what steps are taken to implement it.

References

Climate-ADAPT, 2019. https://climate-adapt.eea.europa.eu (accessed 7 February 2020).

Dasgupta, A., IPCC 1.5° Report: We Need to Build and Live Differently in Cities. https://www.wri.org/blog/2018/10/ipcc-15-report-we-need-build-and-live-differently-cities (accessed 7 February 2020).

Detroit River-Western Lake Erie Basin Indicator Project, 2019. http://web2.uwindsor.ca/softs/keyindicators/index.htm (accessed 7 February 2020).

Great Lakes Water Quality Board, 2003. Climate Change and Water Quality in the Great Lakes Basin. https://legacyfiles.ijc.org/publications/C210.pdf (accessed 7 February 2020).

Great Lakes Water Quality Board Emerging Issues Work Group, 2017. Climate Change and Adaptation in the Great Lakes. https://www.ijc.org/sites/default/files/WQB_CCAdaptation_ProjectSummary_20170110.pdf (accessed 7 February 2020).

Garton, R., 2019. Windsor Declares Climate Change Emergency. CTV News Windsor. https://windsor.ctvnews.ca/windsor-declares-climate-change-emergency-1.4692487 (accessed 7 February 2020).

Prieur-Richard, A., Walsh, B., Craig, M., Melamed, M.L., Colbert, M., Pathak, M., Connors, S., Bai, X., Barau, A., Bulkeley, H., Cleugh, H., Cohen, M., Colenbrander, S., Dodman, D., Dhakal, S., Dawson, R., Espey, J., Greenwalt, J., Kurian, P., Lee, B., Leonardsen, L., Masson-Delmotte, V., Munshi, D., Okem, A., Delgado Ramos, G.C., Rodriguez, R.S., Roberts, D., Rosenzweig, C., Schultz, S., Seto, K., Solecki, W., van Staden, M., Ürge-Vorsatz, D., 2019. Global Research and Action Agenda on Cities and Climate Change Science. https://citiesipcc.org/wp-content/uploads/2018/09/Research-Agenda-Aug-10_Final_Short-version.pdf (accessed 7 February 2020).

United Nations, 2015. Water and Climate Change: Adaptation in Transboundary Basins: Lessons Learned and Good Practices. https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_Good_practices/ece.mp.wat.45.pdf (accessed 7 February 2020).

7.59 Transboundary Conservation in the Detroit River-Western Lake Erie Region

Muhammad Khan, Faculty of Law, University of Windsor, khan1e1@uwindsor.ca

Background

The watersheds of the Detroit River and western Lake Erie are home to a rich diversity of flora and fauna. For example, Essex County is located within the extreme southwest quadrant of the Carolinian Canada forest zone (Lebedyk et al., 2013). Its unique habitats and relatively moderate temperatures create the conditions for one of the most unique areas of biodiversity in Canada, with an estimated 2,200 herbaceous plants species as well as over 400 bird species (Lebedyk et al., 2013). It is also well recognized for more than 240 federally or provincially classified rare species (Essex Region Conservation, 2019). Moreover, the Detroit River is designated as both an American Heritage and Canadian Heritage River, and the only river system in North America to achieve such dual designations (Citywindsor.ca, 2019). The region is also home to the only international wildlife refuge in North America – Detroit River International Wildlife Refuge (DRIWR).

After initial settlement of Detroit in 1701, this region slowly developed into an industrial hub; principally after the growth of the automobile sector in Detroit (Lebedyk et al., 2013). As a result, both Essex County and the City of Detroit have undergone substantial industrialization and urbanization in the past few decades. According to Statistics Canada, the population of the county has continued to rise significantly from 1987 and it remains one of the fastest growing counties in the country (Statistics Canada, 2019). However, this development has negatively impacted the environment of the region, causing significant loss of wetlands and natural habitats, and undermining water quality (Lebedyk et al., 2013). It is estimated that there has been an overall loss of approximately 97% of the original wetland area and 95% of the original forest area (Lebedyk et al., 2013). As a result, habitat conservation has become a top priority.

Environmental stressors in this region do not respect national boundaries and they affect both sides of the border. This indicator outlines transboundary actions/initiatives taken to rehabilitate and conserve habitats to protect fish and wildlife and options to expand and improve transboundary conservation efforts.

Transboundary conservation initiatives require highly complex arrangements as these areas include and affect a wide variety of stakeholders, ranging from governmental agencies, nongovernmental organizations, local communities, the private sector, and Indigenous peoples. Shared governance, often called cooperative management, is "a partnership in which government agencies, local communities and resource users, nongovernmental organizations, and other stakeholders negotiate, as appropriate to each context, the authority and responsibility for management of a specific area or set of resources" (International Union for onservation of Nature, World Commission on Protected Areas, 1997). One useful way of looking at the level of cooperation on transboundary conservation is to utilize a numerical scale first developed by Zbicz (1999) and adapted by Sandwith et al. (2001), that ranks the level of conservation cooperation from none (Level 0) to full cooperation (Level 5; Table 1).

Table 1. Levels of cooperation between internationally adjoining conservation areas (Zbicz, 1999; Sandwith et al., 2001)

Level of Cooperation	**Characteristics**
Level 0 – No Cooperation	Staff from two conservation areas never communicate or meet. There is no sharing of information or cooperation on any specific issues.
Level 1 – Communication	There is some two-way communication between conservation areas. Meetings/communication takes place at least once a year. Information is sometimes shared. Notification of actions which may affect the other conservation area will sometimes take place.
Level 2 – Consultation	Communication is more frequent (at least two times per year). Cooperation occurs on at least two different activities. The two sides usually share information. Notification of actions affecting the adjoining conservation area usually occurs.
Level 3 – Collaboration	Communication is frequent (at least every two months). Meetings occur at least three times per year. The two conservation areas actively cooperate on at least four activities, sometimes coordinating their planning and consulting with the other conservation area before taking action.
Level 4 – Coordination of planning	The two conservation areas communicate often and coordinate actions in some areas, especially planning. The two conservation areas work together on at least five activities, holding regular meetings and notifying each other in case of emergency. Conservation areas usually coordinate their planning, often treating the whole area as a single ecological unit.
Level 5 – Full cooperation	Planning for the two conservation areas is fully integrated, and, if appropriate, ecosystem-based, with implied joint decision-making and common goals. Joint planning occurs, and, if the two share an ecosystem, this planning usually treats the two conservations areas as a whole. Joint management sometimes occurs, with cooperation on at least six activities. A joint committee exists for advising on transboundary cooperation.

Status and Trends

Using this numerical scale, the current state of transboundary cooperation for the DRIWR is estimated to be Level 4 (coordination of planning). U.S. and Canadian stakeholders have cooperated on more than ten projects/activities that involve convening regular meetings, sharing information, coordinating planning, setting priorities, notification of emergencies, and, in some cases, undertaking shared projects from an ecosystem perspective (Table 2).

Table 2. Examples of transboundary conservation activities carried out under the Detroit River International Wildlife Refuge, 2000-2019.

Date	Transboundary Conservation Activity
2000	Conservation Vision workshop in Windsor, Ontario
2001	Conservation Vision signed on behalf of Canada by then Canadian Deputy Prime Minister Herb Gray and then Canadian Member of Parliament Susan Whelan, and on behalf of the United States by Congressman John Dingell and then Greater Detroit American Heritage River Initiative Chairman Peter Stroh
2001	Detroit River International Wildlife Refuge Establishment Act signed into law in the U.S. (Public Law 107-91)
2002	Canada responded to the U.S. Establishment Act by using a number of existing Canadian laws to work in a similar fashion
2004	Canada-U.S. State of the Strait Conference convened that focused on monitoring for sound management
2005	U.S. Fish and Wildlife Service drafts the U.S. Comprehensive Conservation Plan and Environmental Assessment for the Detroit River International Wildlife Refuge with input from Environment and Climate Change Canada
2006	Canada-U.S. State of the Strait Conference convened that focused on status and trends of key indicators of ecosystem health in the Detroit River and western Lake Erie
2007	U.S. and Canada develop ByWay to FlyWays Bird Driving Tour Map that highlights 27 exceptional birding locations in southeast Michigan and southwest Ontario
2007	Canada and the U.S. celebrate International Migratory Bird Day
2008	Sturgeon spawning reef constructed of Fighting Island that represented the first fish habitat restoration project in the Great Lakes funded by both Canada and the U.S.
2009	Canada-U.S. State of the Strait Conference convened that focused on ecological benefits of habitat modification
2011	Common tern roundtable convened to set a quantitative restoration target and coordinate monitoring and management actions
2011	Canada-U.S. State of the Strait Conference convened that focused on use of remote sensing and GIS to better manage the Huron-Erie Corridor
2012	Memorandum of Collaboration Agreement for the Western Lake Erie Watersheds Priority Natural Area signed that provided the mechanism for federal, provincial, and local partners to work with U.S. partners on the Detroit River International Wildlife Refuge (expired after five years)
2013	Essex Region Conservation Authority, serving as the lead organization for the Priority Natural Area, signed a Memorandum of Understanding with

Date	Transboundary Conservation Activity
	U.S. Fish and Wildlife Service to work collaboratively on transboundary conservation and outdoor recreational initiatives in the spirit of the international wildlife refuge
2013	Canada-U.S. State of the Strait Conference convened that focused on setting ecological endpoints and restoration targets
2014	Fighting Island fish spawning reef expanded
2015	Canada-U.S. State of the Strait Conference convened that focused on coordinating conservation in the St. Clair-Detroit River system
2016	U.S.-Canada Greenways Vision Map developed
2017	Canada-U.S. State of the Strait Conference and SEMI WILD co-sponsor an Urban Bird Summit
2019	Canada-U.S. State of the Strait Conference convened that focused on status and trends of key indicators of ecosystem health

One of the initial collaborative activities between Canada and the United States which remains relevant today is the Canada-U.S. Conservation Vision for the Lower Detroit River Ecosystem that was laid out in 2001. Its objectives included ensuring (Fws.gov, 2019):

- Clean and safe environment for all wildlife and other biota including humans
- Fish and wildlife communities are healthy diverse and self-sustaining
- Levels of toxic substances do not threaten wildlife, fish, or human health
- Remaining marshes, coastal wetlands, islands, and natural shorelines be protected in perpetuity
- Degraded marshes, wetland, island, and shoreline habitats be rehabilitated when possible and be protected in perpetuity

To address these objectives the U.S. Fish and Wildlife Service developed a Comprehensive Conservation Plan for the DRIWR, with input from Canada (Hartig et al., 2010). The refuge was established in 2001 and covered an area of only 49.1 ha at the time. It has grown rapidly since then and now occupies 2,306.7 ha on the U.S. side. Pollution prevention and control efforts, and enhancements of habitats, have resulted in ecological recovery over the past few decades including "an increase in the populations of sentinel indicator species like bald eagles, peregrine falcons, osprey, lake sturgeon, lake whitefish, walleye, and burrowing mayflies" (Hartig et al., 2010).

In September 2012, the Western Lake Erie Watersheds Priority Natural Area (PNA) was established in Canada to better coordinate efforts among different levels of government and the nongovernmental and private sectors, and to foster transboundary conservation in the spirit and intent of the 2001 Conservation Vision (Figure 1) (U.S. Fish and Wildlife Service, 2019). The Canadian partners involved in this effort included Environment and Climate Change Canada, Fisheries and Oceans Canada, the Ontario Ministry of Natural Resources, the Nature Conservancy of Canada, Ducks Unlimited Canada, and the Essex Region

Conservation Authority (ERCA) (U.S. Fish and Wildlife Service, 2019). The aim was to provide these organizations with a mechanism to increase wildlife protection and to "work more closely with our U.S. neighbors and to complement progress being made in the U.S. on the Detroit River International Wildlife Refuge, and other related initiatives" (Hill, 2019). The PNA initiative aims to involve the local community through education and outreach projects. It also promotes research and more stringent monitoring of the wildlife in the area to build a community which "recognizes the relationships between healthy environment, healthy people, and healthy economy" (U.S. Fish and Wildlife Service, 2019). This was followed by a signing of a Memorandum of Understanding between ERCA and U.S. Fish and Wildlife Services in August 2013 to clarify the collaborative relationship between them regarding cooperative conservation and ecosystem-based management (Citywindsor.ca, 2019).

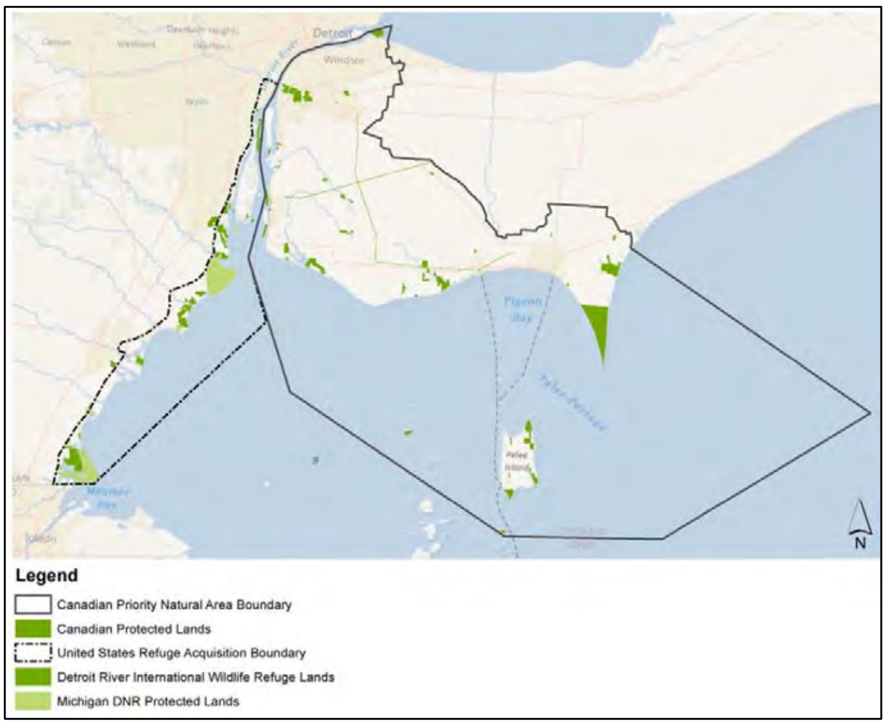


Figure 1. Map of the Canadian Priority Natural Area Boundary and the U.S. Refuge Acquisition Boundary.

ERCA estimates that only about 3% of the land in the Windsor-Essex region is set aside for conservation and parks and that this is the lowest proportion of any region in Ontario (Figure 2) (Lebedyk et al., 2013). The natural cover of the county is 6.89%, of which 4.92% is terrestrial and 1.97% is wetlands (Table 3). According to the standards of Lake Erie Biodiversity Conservation Strategy, the shoreline of the Lake Erie connecting channels on the Canadian side is of fair quality (with approximately 61% soft shoreline).

In Canada, environmental issues do not decisively fall under any federal or provincial head of power since it was not a matter considered during the formulation of the constitution (Jung, 2019). This has resulted in fragmented legislation between the provinces and federal government regarding the environment (Jung, 2019). Many environmental statutes come with enforcement mechanisms, but enforcement is not always a priority of governmental agencies. There is a strong reliance on voluntary initiatives and non-binding policies (Jung, 2019). Habitat conservation falls under this area of law and is also subject to a "patchwork framework of environmental protection" (Jung, 2019)

Figure 2. Land Use Plan for the County of Essex (Countyofessex.ca, 2019).

Table 3. Existing land use in Essex County (Lebedyk et al., 2013).

Land Use	Ha	%
Terrestrial Habitat	8,223.0	4.92
Wetland Habitat	3,287.6	1.97
Total Natural Area	11,555.2	6.89
Total Anthropogenic	155,614.8	93.11
Total Land Area	167,170.0	100.00

Federal legislation that directly relates to conservation of wildlife in the Essex County is the Species at Risk Act 2002 (SARA). The purpose of the Act is "to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity, and to manage species of special concern to prevent them from becoming endangered or threatened." This Act relies on a "stewardship first" approach which only provides mandatory protection of endangered species in federal lands and allows discretionary protection in private lands (Olive, 2011). It does not provide any regulatory power in non-federal land (Olive, 2011).

Ontario passed the Ontario Endangered Species Act (OESA) in 2007. This statute also applies to private property and works in tandem with SARA to protect species at risk (Olive, 2011). However, this Act assumes compliance by private landowners and is rarely enforced by the Ontario Ministry of Natural Resources and Forestry (OMNRF). The law assumes that these landowners are aware of which species at risk are present on their properties, as well as the appropriate steps needed to protect them (Olive, 2011). Further, the government often expects landowners to bear the costs of conservation and the majority do not have the requisite knowledge to apply for stewardship funds (Olive, 2011). A case study in Pelee Island within western Lake Erie found that the OESA was not being complied with and that there was no enforcement by the OMNRF (Olive, 2011). Additionally, though both SARA and OESA rely on stewardship, neither Act defines the meaning of this word (Olive, 2011).

Ojibway Park

The Ojibway Prairie complex is one of the major conservation areas on the Canadian side of the border and provides habitat for several endangered species on the OESA list. The complex consists of five natural areas (i.e., Black Oak Park, Tall grass Prairie Heritage Park, Spring Garden natural area, Ojibway park, and Ojibway Prairie Provincial Reserve (Figure 3) (Ojibway.ca, 2019a). It covers approximately 350.1 ha and fosters conservation of the savanna ecosystem which was present before settlement in the region (Ojibway.ca, 2019a). Examples of threatened species include the Butler's Garter snake, Eastern Fox snake, Red-headed Woodpecker, and the Eastern Meadowlark (Ojibway.ca, 2019b). The complex has a relatively high biodiversity and provides habitat for several species not found in other parks or conservation centers in Ontario (Ojibway.ca, 2019b).

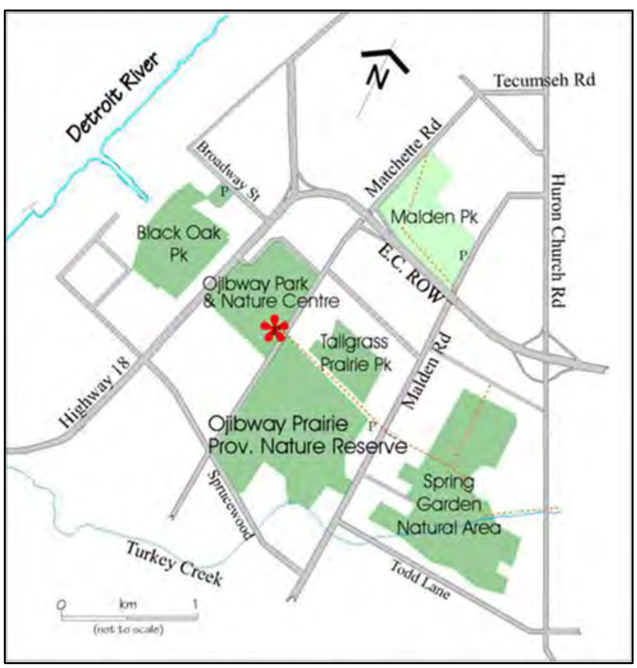


Figure 3. Map of Ojibway Prairie Complex (Ojibway.ca, 2019)

Targeted conservation is especially important in the Windsor-Essex region due to the fragmented landscape. The ERCA has followed the Natural Heritage System Approach that identifies core natural areas which provide habitats for a wide variety of animals and plants (Lebedyk et al., 2013). The system lays out 10 principles for evaluating the ecological importance of location (Lebedyk et al., 2013). The Ojibway Shores tract has been identified as a possible addition to the Ojibway Complex and it meets 9 out of 10 of these principles (Gardner-Costa et al., 2019). Addition of this land to the park would create a corridor with the Detroit River and connect to the DRIWR. Such corridors are essential to allow migration of wildlife and to foster biodiversity of natural communities and genetic pools. Further, ecosystems existing in isolation are much more vulnerable to adverse natural events or human activities than those connected to other natural areas (Lebedyk et al., 2013).

Options to Improve Transboundary Conservation

Options to improve transboundary conservation include:

- Re-energize the PNA under ERCA and ensure participation of all key stakeholders, especially federal and provincial partners. Ensure that U.S. Fish and Wildlife Service is invited to at least one meeting per year to foster transboundary conservation.

- Designate either Parks Canada, Bird Studies Canada, or Environment and Climate Change Canada to be the lead agency for working with the U.S. Fish and Wildlife Service on the DRIWR. These Canadian and U.S. federal agencies could then meet at least once per year with the other conservation partners to review progress, set priorities, and agree to cooperative conservation actions/initiatives. One advantage of this option would be that the lead responsibilities would fall to Canadian and U.S. federal agencies.

- Through existing or new legislation establish a National Wildlife Area in Canada to work closely with the U.S. Fish and Wildlife Service on the DRIWR. As part of this option, either Parks Canada, Bird Studies Canada, or Environment and Climate Change Canada should be designated as the lead federal agency in working with the U.S. Fish and Wildlife Service on the DRIWR. These two Canadian and U.S. federal agencies could then meet with the other conservation partners at least once per year to review progress, set priorities, and agree to cooperative conservation actions/initiatives. This option would also have the advantage of assigning the lead responsibility to Canadian and U.S. federal agencies and would charge them with working with other conservation partners.

- Work with local interests to establish Ojibway Urban National Park in Canada with an emphasis on bringing conservation to cities. This would be a comparable mission of that of the U.S. Fish and Wildlife Service for the DRIWR. The two federal parties (i.e., Parks Canada and U.S. Fish and Wildlife Service) could then meet at least once per year to review progress, set priorities, and agree to cooperative conservation actions/initiatives. This too would have the advantage of assigning the lead responsibility to Canadian and U.S. federal agencies and would charge them with working with other conservation partners.

All of these options would be a step toward improving transboundary conservation consistent with a long-term goal of achieving Level 5 (Full Cooperation) identified in Table 1.

Establishing Ojibway Urban National Park, similar to the Rouge National Park in Toronto, is an exciting potential development. The Rouge Urban Park was established by the Rouge National Urban Park Act in 2015 and is currently operated by Parks Canada to conserve wildlife and reclaim lost habitats. This legislation outlined the lands the park occupied, made it compulsory for the government to protect wildlife in the park, and also allowed the appointment of wardens to patrol it.

Member of Parliament Brian Masse of Windsor-West held a townhall meeting in August 2019 regarding the addition of Ojibway shores and the potential establishment of an urban national park (Charlton, 2019). Some of the benefits of creating Ojibway Urban National Park include greater recognition and awareness, access to federal funds, easier land acquisition, and the expertise of federal organizations such as Parks Canada (Charlton, 2019). Being under federal jurisdiction would also subject the area to the laws under SARA to protect endangered species. An important role of the national park could be to coordinate transboundary conservation activities with U.S. efforts under the DRIWR. Such a federal mandate and input from federal agencies like the Canadian Wildlife Service and Parks Canada could elevate the priority of transboundary conservation initiatives. Although the area of the proposed park is relatively small (3.64 km^2) compared to Rouge National Park (50 km^2) in Toronto, its ecological impact could be great through a partnership with the U.S. and the DRIWR.

With an urban national park designation, conservation mechanisms currently in place could be utilized to a greater extent, including collaboration with OMNRF for stricter enforcement of the OESA and SARA. It should be noted that the PNA designation is still in effect in the western Lake Erie watersheds and provides a mechanism for federal and local organizations to connect and direct conservation activities in synchrony with the DRIWR.

References

Charlton, L., 2019. Turning Ojibway lands into national urban park touted at town hall. Windsor Star. Available at: https://windsorstar.com/news/local-news/turning-ojibway-lands-into-national-urban-park-touted-at-town-hall (accessed 27 Nov. 2019).

Citywindsor.ca, 2019. Western Lake Erie Watersheds Priority Natural Area Registry of Lands. Available at: https://citywindsor.ca/cityhall/City-Council-Meetings/CouncilReports/Documents/Western%20Lake%20Erie%20Watersheds%20Priority%20Natural%20Area%20Registry%20of%20Lands.pdf (accessed 28 Nov. 2019).

Countyofessex.ca, 2019. Official Plan Schedule Maps. Available at: https://www.countyofessex.ca/en/official-plan-schedule-maps.aspx (accessed 27 Nov. 2019).

Detroit River International Wildlife Refuge Establishment Act (United States), Essex Region Conservation Authority, 2019. Species at Risk. Available at: https://essexregionconservation.ca/watershed-health/species-at-risk/ (accessed 27 Nov. 2019).

Essex Region Conservation Authority, 2019. Species at Risk. Available at: https://essexregionconservation.ca/watershed-health/species-at-risk/ (accessed 27 Nov. 2019).

Foran, M., 2018. The Subjugation of Canadian wildlife: Failure of Principles and Policies. McGill-Queen's University Press, Montreal, Quebec, Canada.

Fws.gov, 2001. A Conservation Vision for the Lower Detroit River Ecosystem. Available at: https://www.fws.gov/uploadedFiles/a%20conservation%20vision%20for%20the%20lower%20detroit%20river%20ecosystem.pdf (accessed 25 Nov. 2019).

Gardner-Costa J., Lebedyk D., Preney T., Sanders C., Waldron W., 2017. Ojibway Shores Natural Heritage Inventory/Evaluation. Report prepared for the Windsor Port Authority, Windsor, Ontario, Canada.

Hartig, J., Robinson, R., Zarull, M., 2010. Designing a Sustainable Future Through Creation of North America's Only International Wildlife Refuge. Sustainability, 2, 9, 3110-3128.

Hill, S., 2019. Canada's First Priority Natural Area is in Essex County. Windsor Star. Available at: https://windsorstar.com/news/64147 (accessed 25 Nov. 2019).

International Union for Conservation of Nature, World Commission on Protected Areas, 1997. Transboundary Protected Areas as a Vehicle for International Co-operation. Proceedings of the Parks for Peace Conference. Somerset West, South Africa.

Jung, D., 2019. Canada's Patchwork Environmentalism. Journal of Parliamentary and Political Law, 12, 797-832.

Lebedyk, D., Belanger, R., Dufour, T., Nelson, M., 2013. Essex Region Natural Heritage System Strategy - An Update to the Essex Region Biodiversity Conservation Strategy. Essex Region Conservation Authority, Essex, Ontario, Canada.

Ojibway.ca, 2019a. Ojibway Prairie Complex - Parks & Recreation - City of Windsor. Available at: http://www.ojibway.ca/complex.htm (accessed 27 Nov. 2019).

Ojibway.ca, 2019b. Rare, Threatened and Endangered Species of the Ojibway Prairie, Ontario. Available at: http://www.ojibway.ca/raresp.htm (accessed 27 Nov. 2019).

Olive, A., 2011. Can Stewardship Work for Species at Risk? A Pelee Island Case Study. Journal of Environmental Law and Practice. 22, 223-239.

Sandwith, T., Shine, C., Hamilton, L., Sheppard, D., 2001. Transboundary protected areas for peace and cooperation. International Union for Conservation of Nature. Gland, Switzerland and Cambridge, United Kingdom.

Statistics Canada, 2019. Focus on Geography Series, 2016 Census. Species at

Risk Act 2002 (Canada). Ottawa, Ontario, Canada.

U.S. Fish and Wildlife Service, 2019. Western Lake Erie Watersheds Identified as a Priority Natural Area. Grosse Ile, Michigan, USA.

Zbicz, D., 1999. Transboundary Cooperation Between Internationally Adjoining Protected Areas, in: Harmon, D. (Ed.), On the Frontiers of Conservation. George Wright Society, Hancock, Michigan, USA, pp. 199-204.

This page intentionally left blank.

7.60 Treaty Responsibilities Between Settler and Indigenous Nations in the Western Lake Erie-Detroit River Ecosystem

Kevin Berk, Faculty of Law and Great Lakes Institute of Environmental Research, University of Windsor, kevinberk@osgoode.yorku.ca

Background

The ecosystem that includes the Detroit River and western Lake Erie is Indigenous land. These lands and waters are both the historical and current home of the Three Fires Confederacy (the Odawa, Ojibwe, and Potawatomi Nations) and the Wyandot. Additionally, the health of this ecosystem has profound impacts on nearby Indigenous nations (i.e. the Aamjiwnaang First Nation) who are impacted by the water and air which flows through this ecosystem.

As today's residents are living and working on Indigenous land, any legitimacy for their presence, and the presence of the states of Canada and the United States of America, must be rooted in the treaties executed between Indigenous nations, to whom the land belongs, and European settler colonial states. It is thus essential that work done in relation to the land and waters by settlers be conducted in accordance with not only the laws of the settler states and the state's obligations under treaties, but also the laws of the Indigenous nations to whom the land belongs.

Status and Trends

History and Status

The Foundational Treaties

In 1613 as Dutch settlers moved up the Hudson River and into Mohawk territory, the Haudenosaunee met with the settlers and presented them with a treaty in the form of a Wampum Belt (Figure 1). In Canada's Indigenous Constitution John Borrows describes this Wampum Belt as such:

> *The belt consists of two rows of purple wampum beads on a white background. Three rows of white beads symbolizing peace, friendship, and respect separate the two purple rows. The two purple rows symbolize two paths or two vessels travelling down the same river. One row symbolizes the Haudenosaunee people with their law and customs, while the other row symbolizes European laws and customs. As nations move together side-by-side on the River of Life, they are to avoid overlapping or interfering with one another* (Borrows, 2010).

The Wampum Belt, commonly referred to as the Two Row Wampum Belt today, formed the basis of all future treaties between the Haudenosaunee and European settlers as it was extended to the relationship with each of the British, French, and

American governments (Borrows, 2010). The Haudenosaunee intended for the principles in the treaty to last "as long as the grass is green, as long as the water flows downhill, and as long as the sun rises in the east and sets in the west" (Keefer, 2014).

Figure 1. Two Row Wampum Belt (Source: https://www.onondaganation.org/culture/wampum/two-row-wampum-belt-guswenta/).

As the treaty formed the basis of all future treaties between the Haudenosaunee and European settlers, it is the foundation of the modern day Canadian and American law. In the Canadian context this foundational nature was reaffirmed in the Treaty of Niagara, 1764, between the British Crown and two thousand chiefs from over twenty-four Indigenous nations (Borrows, 1997). The Treaty of Niagara included the British Crown presenting the Royal Proclamation, 1763, to the Indigenous nations, who in turn presented the Crown with the Two Row Wampum Belt to demonstrate each party's understanding of the treaty and the Royal Proclamation (Borrows, 1997). As a result, the Royal Proclamation, which in the Canadian state's law is the legal basis for all future treaties, must be read in accordance with the obligations of the Treaty of Niagara and the Two Row Wampum Belt (Borrows, 1997). According to John Borrows this means that:

> *The contents of each treaty signed after the Royal Proclamation/Treaty of Niagara have more to them than appears on their face. The parties negotiated subsequent treaties against a background of Canadian Proclamation/Niagara usage (extending from the Maritimes to the foothills of the Rocky Mountains), the implications of which both parties can be tacitly assumed to accept. The implied conditions each party would assume in subsequent treaties would be the promises spelled out in 1764, or those similar to them renewed at later meetings. As will be recalled, these were promises of a preservation of sovereignty, alliance, trade, consent to land surrender, and affirmations of peace, friendship, and respect* (Borrows, 1997*).*

Treaties in the Detroit River/Western Lake Erie Region

The land surrounding western Lake Erie and the Detroit River was the specific subject of treaties over a century after the Two Row Wampum treaty was formed, and a decade after the Royal Proclamation and Treaty of Niagara came into effect. In 1790 the British government entered a treaty (called Treaty 2 by the Canadian government) with representatives of the Odawa, Ojibwe, Potawatomi, and Wyandot nations for the purchase of a tract of land spanning from the Detroit River, along Lake Erie, to just south of modern-day London, Ontario (Figure 2). In this treaty the Wyandot retained a tract of land along the Detroit River which encompasses modern day Amherstburg. This land was later the subject of "Treaty 35" in 1833 between the British government and the Wyandot alone (Figure 2). Treaty 2 also did not include Walpole Island, located at the North of Lake St. Clair, which remains unceded land.

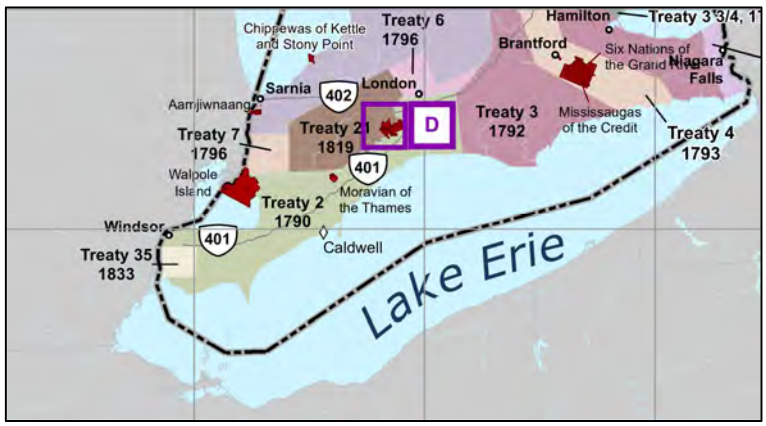


Figure 2. Map of Southwestern Ontario Treaties (Adapted from: https://files.ontario.ca/treaties_map_english.pdf).

The American government executed a similar treaty with the Odawa, Ojibwe, Potawatomi, and Wyandot nations in 1807, called the Treaty of Detroit, which included much of southeast Michigan as well as northwest Ohio, including the Maumee River (Figure 3).

Figure 3. Treaty of Detroit, highlighted in olive on the map of Michigan and bright yellow on the map of Ohio (Source: https://blogs.lib.msu.edu/red-tape/2017/nov/november-17-1807-treaty-detroit-signed/*).*

Adherence to Treaties

Unfortunately, both the Canadian and American governments have not upheld the relationship of peace, friendship, respect, and non-interference to which they are bound by the Two Row Wampum treaty. There are numerous examples of why this is the case. A prominent and explicit example from the Canadian side is the residential school system. Recently the Canadian government formed the Truth and Reconciliation Commission (TRC) to investigate the depth of the harm caused by the residential school system, its ongoing legacy, and what needs to be done to reconcile these past harms. The TRC's final report unequivocally identified the residential school system as an act of cultural genocide perpetrated against the Indigenous peoples of Canada by the Canadian Government (TRC, 2015). This is not merely a historical issue, as there is currently a crisis in Canada with a vastly disproportionate number of Indigenous children being taken away from their families and placed into foster care compared to the rest of Canadian society (Figure 4). Additionally, this is not a uniquely Canadian issue as there was a long history of equivalent programs in the United States (Adams, 1995).

Figure 4. Indigenous children in foster care in Canada (Source: https://www.sac-isc.gc.ca/eng/1541187352297/1541187392851).

The lack of adherence to the Two Row Wampum relationship also often manifests in the form of environmental harm. Prominent examples of this include pipeline projects which are planned to move through Indigenous land without consent or proper consultation. The projects constitute a clear breach of the doctrine of non-interference from the Two Row Wampum treaty. Multiple projects have led Indigenous peoples to protect their lands in recent years including at Standing Rock in 2016, and in Wet'suwet'en territory from 2019 to the present day. Another common form of environmental harm is the development of highly polluting industry around Indigenous reserves. This type of development results in negative health income for those living on reserve. This has been found amongst residents of

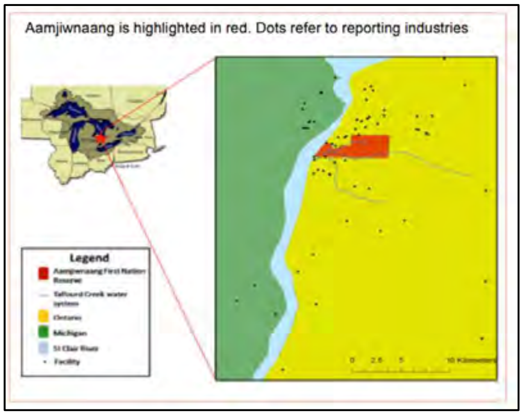


Figure 5. Aamjiwnaang First Nation in relation to industry (Source: Basu and Cyderman, 2013).

the Aamjiwnaang First Nation Reserve in Sarnia, Ontario, who are surrounded by Sarnia's "Chemical Valley" (Figure 5; Basu and Cyderman, 2013). Similar results have been found amongst the population of Awkesasne First Nation on the Saint Lawrence River who are similarly surrounded by industrial facilities (Jacobs, 2018). Environmental impacts do not only relate to land use, but also to clean drinking water for many Indigenous nations in Canada. Insufficient progress is being made to remedy this reality (David Suzuki Foundation, 2018).

These environmental issues are of particular importance due to the centrality of the lands and waters to Indigenous life, culture, and laws. For example, the Akwesasronon judge the health of the people in a holistic interconnected manner with the health of the Earth Mother, waters, fish life, food plants, animals, and trees (Jacobs, 2018). Thus, harm done to the environment by the Canadian state greatly impacts the meaning of the health for the Akwesasne people. A further example is how the laws of the Anishinaabe (which includes the Three Fires Confederacy of the Odawa, Ojibwe, and Potawatomi nations) are in part derived from nature. This means that Anishinaabe rely on observing and learning from the natural order of the world around them to seek guidance and inspiration for their laws (Borrows, 2010). Thus, harm done to the environment, be it from climate change, invasive species, pollution, or land use, interferes with the law that Anishinaabe nations are built upon. This interference with the health and the laws of Indigenous peoples is once again a clear example of contravention of the Two Row Wampum treaty.

In summary, the treaties which form the basis of the settler states' existence and legitimacy for occupying the land are not being followed. This is clear in the amount of interference by the settler states in the lives of Indigenous peoples. This then becomes further relevant at the local level with regard to the treaties conveying land, such as the treaties in the Western Lake Erie-Detroit River Basin which were outlined earlier. As described above, the Two Row Wampum belt is the foundation of all future treaties between the Settlers and Indigenous peoples (Borrows, 2010). Furthermore, Canadian treaties, such as the ones signed in the Essex region, are enabled by the Royal Proclamation and the Treaty of Niagara. As the relationships and promises that are identified in the Two Row Wampum Belt and the Treaty of Niagara are not being followed, the legitimacy of the treaties, which enable settlers to occupy the lands which are the subject of the treaties (including the entirety of the Western Lake Erie-Detroit River Basin), is questionable.

Management Next Steps

The treaties between settler states and Indigenous peoples, including the relationship of the Two Row Wampum Belt, must be followed. Work being done on the health of ecosystems in Canada and the USA can be a catalyst for this action. As degraded ecosystem health is in effect interference in the lives and laws of Indigenous peoples, greater collaborative efforts are warranted to eliminate this interference. It is important to note that this work on restoring ecosystem health must not be oriented solely to the standard of the settler states, but also conducted in a spirit of partnership in accordance with the standards of the laws and customs of the Indigenous peoples whose lands they occupy. In "Earth-Bound: Indigenous Resurgence and Environmental Reconciliation" John Borrows argues that:

> *Reconciliation between Indigenous peoples and the [Canadian] Crown requires our collective reconciliation with the earth. Practices and partnerships of resurgence and reconciliation must sustain the living earth and our more-than-human relatives for future generations. This will not occur without the simultaneous resurgence of Indigenous laws, governments, economies, education, relations to the living earth, ways of knowing and being, and treaty relationships (*Borrows, 2018*).*

As a result of this reality, environmental work in this region inexorably engages with Indigenous peoples and the process of reconciliation. It is our responsibility to ensure that our environmental work engages with, and promotes, the process of reconciliation, rather than hindering it.

It is thus recommended that all Canadian-U.S. initiatives to clean up, restore, and sustain the Detroit River and western Lake Erie, recognize that this ecosystem is comprised of Indigenous lands and waters. As such, environmental initiatives must not be simply binational but rather multinational. Goals for the region must be the result of partnership with Indigenous nations and must be consistent with the laws and customs of the Three Fires Confederacy (the Ojibwe, Odawa, and Potawatomi Nations) and the Wyandot with whom the treaties in this region were signed.

Research/Monitoring Needs

All future assessments of the health of this ecosystem should be done in partnership with Indigenous nations. Considerable monitoring and research data on ecosystem health are available from Indigenous nations. Therefore, greater collaboration is necessary on monitoring, research, and ecosystem health assessments for the corridor.

As noted above, the Akwesasronon judge the health of the people in a holistic interconnected manner with the health of the Earth Mother, waters, fish life, food plants, animals, and trees (Jacobs, 2018). Through the Great Lakes Water Quality Agreement, the Canadian and U.S. governments have adopted an ecosystem approach to restoring and maintaining the health of the Great Lakes. An ecosystem approach accounts for the interrelationships among, land, air, water, and all living things, including humans. Therefore, all nations view humans as part of nature and ascribe to more comprehensive, ecosystem-based management. It is recommended that a conference or workshop be convened with Indigenous nations to explore the current state of ecosystem-based management and what improvements could be made to achieve common goals.

References

Adams, D.W., 1995. Education for Extinction: American Indians and the Boarding School Experience, 1875-1926. University Press of Kansas, Lawrence, Kansas, USA.

Basu, N., Cyderman, D., 2013. Multiple Chemical Exposure Assessment at Aamjiwnaang. McGill Environmental Health Sciences Lab Occasional Report 2013-1, Montreal, Quebec, Canada.

Borrows, J., 1997. Wampum at Niagara: The Royal Proclamation, Canadian Legal History, and Self-Government, In: Asch, M., Aboriginal and Treaty Rights in Canada: Essays on Law, Equity, and Respect for Difference. UBC Press, Vancouver, BC, Canada.

Borrows, J., 2010. Canada's Indigenous Constitution. University of Toronto Press, Toronto, Ontario, Canada.

Borrows, J., 2018. Earth-Bound: Indigenous Resurgence and Environmental Reconciliation, In: Asch, M., Borrows, J., Tully, J., (Eds.), Resurgence and Reconciliation: Indigenous-Settler Relations and Earth Teachings. University of Toronto Press, Scholarly Publishing Division, Toronto, Ontario, Canada.

David Suzuki Foundation, 2018. Reconciling Promises and Reality: Clean Drinking Water for First Nations, Vancouver, BC, Canada.

Harrison, J., 2017. November 17, 1807: Treaty of Detroit Signed. Michigan State University Libraries, East Lansing, Michigan, USA.

Government of Canada, June 2019. Reducing the Number of Indigenous Children in Care. Ottawa, Ontario, Canada.

Government of Ontario, 2017. First Nations and Treaties. Ottawa, Ontario, Canada.

Jacobs, B., 2018. Impacts of Industrial and Resource Development on the Holistic Health of Akwesasronon: A Human Responsibility/Rights Solution. University of Calgary, Calgary, Alberta, Canada.

Keefer, T., March 2014. A Short Introduction to the Two Row Wampum. Briarpatch. Regina, SK, Canada.

Truth and Reconciliation Commission of Canada, 2015. Honouring the Truth, Reconciling for the Future: Summary of the Final Report of the Truth and Reconciliation Commission of Canada. Ottawa, Ontario, Canada.

This page intentionally left blank.

7.61 U.S. Habitat Restoration Under the Detroit River Remedial Action Plan

Bob Burns, Friends of the Detroit River, rlb315@comcast.net

Sam Lovall, Friends of the Detroit River, sam.lovall@gmail.com

Background

The Detroit River is a 51-km connecting channel through which the entire upper Great Lakes (i.e., Lakes Superior, Michigan, and Huron) flow to the lower Great Lakes (i.e., Lakes Erie and Ontario). In 1985, the Detroit River was identified as a Great Lakes Area of Concern (AOC) by the International Joint Commission's Great Lakes Water Quality Board where Canada-U.S. Great Lakes Water Quality Agreement objectives or jurisdictional standards, criteria, or guidelines, established to protect beneficial uses, were exceeded and remedial actions were necessary to restore beneficial uses (International Joint Commission,1985).

Following a Great Lakes Water Quality Board recommendation, the eight Great Lakes states and the Province of Ontario, in cooperation with the federal governments of Canada and the United States, committed in 1985 to developing and implementing a remedial action plan (RAP) to restore beneficial uses in each AOC within their political boundaries. Each RAP was to identify the specific measures necessary to control existing sources of pollution, abate existing contamination (e.g., contaminated sediments), and restore all impaired uses.

A RAP for the Detroit River began in 1986 with the establishment of a team of representatives from the federal, state, and provincial governments (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991). Loss of fish and wildlife habitat and degradation of fish and wildlife populations are long-standing issues in the Detroit River and represent two of eleven identified use impairments. The Detroit River RAP noted that a significant loss of fish and wildlife habitat, including a 97% loss in coastal wetlands, occurred as a result of human activities like diking, dredging, construction of bulkheads, and filling (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991).

Status and Trends

U.S. Habitat Restoration Through the RAP

Early efforts focused on quantifying the severity and geographic extent of habitat loss and degradation, followed by efforts to set habitat restoration goals and objectives (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991). Initially, lack of a clear habitat problem definition and scientifically-sound restoration options, along with lack of funding, were obstacles to realizing habitat improvements. However, in the late 1990s habitat rehabilitation projects started to receive funding.

On the Detroit River's U.S. side, Michigan Department of Environmental Quality (MDEQ) and the Detroit River Public Advisory Council (PAC) went through a multi-stakeholder input process to reach agreement on a habitat problem definition (MDEQ and Ontario Ministry of the Environment, 1991), including identifying geographic extent, evaluating habitat restoration options, and prioritizing projects (Manny, 2002, 2003; Esman, 2008). Initially, habitat work under the RAP was largely aspirational and made little tangible progress. In 2005, in an effort to re-energize the Detroit River PAC, the Friends of the Detroit River (FDR) took over fiduciary responsibilities to move the process beyond aspiration and into the realm of implementation. Shortly thereafter, in 2009, the Great Lakes Restoration Initiative (GLRI) was established as a funding mechanism to protect and restore the Great Lakes. FDR successfully submitted three proposals to GLRI, launching the beginning of large-scale U.S. restoration projects.

In 2014, as part of developing a "guidance plan" to remove fish and wildlife related beneficial use impairments (BUIs), the Detroit River PAC identified 14 projects which, when completed, would constitute removal of "loss of fish and wildlife habitat" and "degradation of fish and wildlife populations" as impaired beneficial uses (Table 1). These diverse projects involved existing shoal, nearshore, and wetland habitat restorations, in addition to creating new reproductive habitats for birds and fishes. The planning work done to identify these projects helped advance concepts into reality. Very little funding would have been allocated to the Detroit River if the strategic planning and guidance plan for removal of fish and wildlife related BUIs had not been in place.

GLRI funding for the first several large-scale restoration projects came through competitive grants from the U.S. Environmental Protection Agency. The National Oceanic and Atmospheric Administration also provided consistent support for FDR to obtain GLRI grant funding and technical support, providing over $25 million to date. It is important to note that the GLRI provided over $2 billion to accelerate restoration efforts over ten years in all Great Lakes states, particularly in AOCs.

Table 1. Fourteen projects identified by the U.S. Detroit River Public Advisory Council, which when completed, would constitute removal of "loss of fish and wildlife habitat" and "degradation of fish and wildlife populations" as impaired beneficial uses on the U.S. side of the Detroit River (Detroit River Public Advisory Council, 2014).

Delisting Project	**Brief Description**	**Status**
Detroit River Reefs	Construct four fish spawning reefs: (NE of Belle Isle, NE of Grassy Island, Fort Wayne, and Fort Wayne Expansion)	Completed in 2017
Detroit Upper Riverfront Parks	Restore shoreline and upland habitat at Lakewood East Park, and A.B. Ford Park, targeting fish, birds, pollinators, reptiles and amphibians	Design phase complete; Construction could begin in 2020 pending existing high water and flooding conditions
Belle Isle Hydrological Analysis and Pre-	Investigate the internal waterways and surface drainage patterns of Belle Isle in order to effectively design habitat restoration projects in	Completed in 2016

Delisting Project	Brief Description	Status
Design	the wet-mesic flatwoods forest and Lake Okonoka	
Belle Isle Flatwoods Forest	Implement a variety of surface drainage improvements to restore degraded hydrology associated with 80.9 ha of wet-mesic flatwoods forest complex; enhancing conditions for the forest's rich diversity of plants, which is unique and globally rare, will restore habitat for diverse wildlife populations.	Design phase complete; Construction to begin in fall of 2020
Lake Okonoka	Enhance water quality and restore habitat for fish, birds, amphibians, and reptiles by making hydrologic connections between the Blue Heron Lagoon and the lake, and between the lake and the Detroit River, allowing flow of Great Lakes water and fish into and through the lake	Construction is underway
Milliken State Park	Restore 0.4 ha of urban upland along the Detroit River to a wet meadow and prairie complex including native shrubs and trees, targeting pollinators (with emphasis on monarch butterflies), birds, reptiles, and amphibians	Completed in 2018
Hennepin Marsh	Protect and enhance two areas of existing submergent wetlands for fish spawning and nursery habitat by restoring and newly constructing a series of stone shoals, offering diverse habitat structure and protection to 16 ha of calm backwater area	In design phase
Stony Island Shoal	Restore 185 m of existing shoal and create over 850 m of new shoals to protect the island from further loss of coastal wetlands and to create conditions for new wetland habitat evolution, further enhancing 20 ha of fish nursery and spawning area (Figure 1; Figure 2a and b)	Completed in 2018
Sugar Island	Restore and enhance wildlife habitat to create up to 12 ha of calm fish spawning and nursery habitat on the island's south end and stabilize it from severe erosion	In design phase
Celeron Island	Stabilize coastal wetlands at the island's south end and north bay by constructing 1,200 m of protective, wildlife habitat shoals, enhancing fish and wildlife habitat (Figure 3; Figure 2a and b)	Completed in 2019
Blue Heron Lagoon	Reconnect the Blue Heron Lagoon to the Detroit River, restoring fish access to 15.6 ha of existing wetlands and other wildlife habitats within the lagoon along with the eventual connection to 3.5 km of canal habitat, including coastal wetlands in Lake Okonoka designed for spawning and nursery habitat (Figure 4)	Completed in 2013

Delisting Project	Brief Description	Status
Belle Isle South Fishing Pier	Provide connectivity between fish spawning and nursery areas by creating 1 ha of protected coastal wetlands downstream of new and existing spawning reefs and creating deep and shallow water habitats in the flat bottomland between the pier and shoreline	Completed in 2013
U. S. Steel Shoreline	Restored 335 m of riparian shoreline habitat and 1.9 ha of upland habitat adjacent to the shoreline with native forbs, shrubs, trees and habitat structures, targeting birds, reptiles and amphibians	Completed in 2013
Wayne County's Refuge Gateway	Stabilized 365 m of shoreline using soft engineering and restored 4.2 ha of emergent marsh, 1.7 ha of submergent marsh, and 4.8 ha of upland buffer habitats, targeting a diversity of wildlife populations	Completed in 2010

Figure 1. A new habitat shoal off the south shore of Stony Island protects a fragile coastal wetland from further erosion and creates over 20 ha of calm backwater for fish spawning and nursery (credit: Friends of the Detroit River).

Figure 2a and b. Diverse bird populations make use of new habitat shoals created at Stony and Celeron Islands, including gulls, terns, eagles, and herons (credit: Friends of the Detroit River).

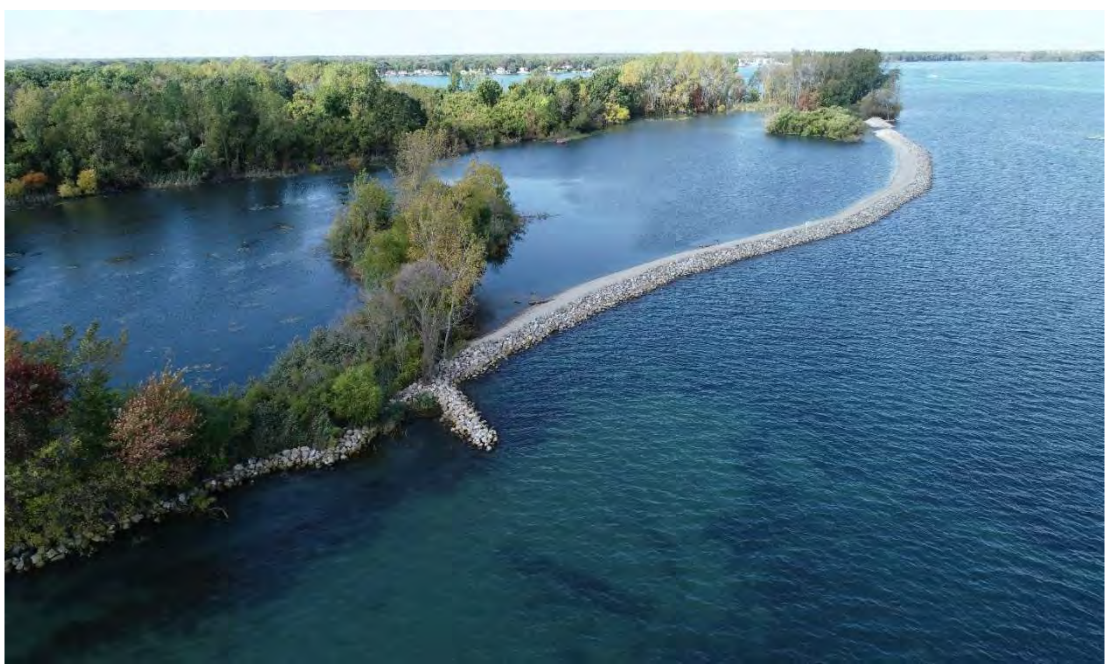


Figure 3. A new habitat shoal protects fragile coastal wetlands at Celeron Island's north bay from further erosion and enhances this backwater area for fish spawning and nursery activity (credit: Friends of the Detroit River).

Figure 4. The Blue Heron Lagoon was opened to the Detroit River, allowing Great Lakes water and fish to pass into a calm spawning and nursery area (credit: Friends of the Detroit River). A connection to Lake Okonoka is in the far background.

Management Next Steps

FDR and partners have made significant progress to address the loss of fish and wildlife habitat and populations in and along the Detroit River since the development of the Detroit River RAP. However, the reversal of impacts from decades of unregulated discharges of industrial and municipal wastes, the disposition of tens of thousands of cubic meters of contaminated legacy sediment along the bottom of the Detroit River, and the destruction of 97% of the river's historical coastal wetlands have brought significant challenges to the habitat restoration process.

A constant and reliable source of funding is one of the primary reasons for recent, successful implementation of habitat restoration projects, since the approval of the Great Lakes Restoration Initiative in 2010. The long-term success of completed work and future efforts will need some form of long-term dedicated funding.

Many of the habitat restoration projects implemented to date were on public properties owned by local, state, or federal entities. However, large blocks of property along the Detroit River, owned by private concerns and individuals, present a great opportunity to expand the habitat restoration process. Strategies to engage these private property owners should be developed in the future.

Along with continued funding for long-term support of habitat restoration work in the Detroit River, funding for monitoring efforts will be essential to understand how the river's fish and wildlife populations utilize newly restored areas as these sites continue to mature. Long-term monitoring will influence what additional improvements can be implemented at these sites to make them even more productive in the future.

Important lessons learned from the habitat restoration projects completed so far include the need to use an adaptive management approach in design and implementation and to establish strong working relationships with project partners.

FDR and our project teams have fortunately adapted to new conditions brought about by climate change in recent years, but the future is very unpredictable. If water elevations continue to rise, a new emphasis on saving existing infrastructure might become a priority. If this occurs, it will be our responsibility, in working with our partners, to conduct this work in a manner that benefits the needs of wildlife as well.

References

Detroit River Public Advisory Council, 2014. Targets for Removal of "Loss of Fish and Wildlife Habitat" and "Degradation of Fish and Wildlife Populations" Beneficial Use Impairments of the Detroit River Area of Concern. Submitted to Michigan Department of Environmental Quality, Office of the Great Lakes. Taylor, Michigan, USA.

Esman, L.A., 2008. The Michigan Department of Environmental Quality Biennial Remedial Action Plan Update for the Detroit River Area of Concern. Michigan Department of Environmental Quality, Lansing, Michigan, USA.

International Joint Commission, 1985. Report on Great Lakes Water Quality. Great Lakes Water Quality Board, Windsor, Ontario, Canada.

Manny, B.A., 2002. Habitat Protection and Remediation, Detroit River. U.S. Geological Survey, Great Lakes Science Center, Ann Arbor, Michigan, USA.

Manny, B.A., 2003. Setting Priorities for Conserving and Rehabilitating Detroit River Habitats, in: Hartig, J.H., (Ed.), Honoring Our Detroit River: Caring for Our Home, Cranbrook Institute of Science: Bloomfield Hills, Michigan, pp. 79–90.

Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991. Stage 1 Remedial Action Plan for the Detroit River Area of Concern. Lansing, Michigan, USA and Sarnia, Ontario, Canada.

This page intentionally left blank.

8.0 State of the Strait Conference Abstracts of Posters

<u>State of native mussels in the Detroit River</u>

Shay S. Allred[1], Daelyn A. Woolnough[1], Todd J. Morris[2], and David T. Zanatta[1]

[1] Central Michigan University, Dept. of Biology; [2] Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences

There is concern for native freshwater mussels (Bivalvia: Unionidae) in the Great Lakes region after populations were severely reduced following the introduction of dreissenids in the mid-1980s. Several unionid refuges, or areas with relatively low dreissenid impact and surviving unionids, have been found in coastal areas of the lower Great Lakes; however, the connecting Detroit River had not been surveyed since 1998. For this study, 56 sites were surveyed in the Detroit River in 2019. Sites selected were a mixture of historical, potential refuge, and stratified randomized sites. All sites were surveyed for unionid mussels using SCUBA for 1 person-hour. Living unionids and shells were identified to species and quantified. Divers qualitatively estimated a variety of biotic and abiotic habitat characteristics at each site. Six PONAR grabs were taken at each site and used to estimate dreissenid densities and sediment particle sizes. Of the 56 sites surveyed, only five sites had living unionids totaling 220 live animals of 11 species. 96% of the live unionids found (212/220) were at two sites downstream from the River Canard. The most common live species were Mapleleaf (*Quadrula quadrula*) and Fragile Papershell (*Leptodea fragilis*). Other regionally imperiled unionids found alive were Threehorn Wartyback (*Obliquaria reflexa*) and Round Pigtoe (*Pleurobema sintoxia*). Over 2,000 unionid shells of 31 species were collected from 39 sites, confirming the large and diverse unionid assemblage that existed prior to the dreissenid invasion. Numerous shells of endangered Northern Riffleshell (*Epioblasma rangiana*) were found at 18 sites along the entire length river and a single valve of the endangered Clubshell (*Pleurobema clava*) was found in U.S. waters near Belle Isle. Next steps are to use the 2019 data to build a model to predict where unionids remain that can be used to assist with site selection for a similar survey on the St. Clair River in 2020.

<u>Spatial extent of contemporary lake whitefish spanning in western Lake Erie</u>

Zachary J. Amidon[1], Robin L. DeBruyne[1], Edward F. Roseman[2], and Christine M. Mayer[1]

[1] University of Toledo, Cooperative Ecosystem Studies Unit; [2] USGS Great Lakes Science Center

Degradation of lake whitefish spawning areas in the Detroit River, Maumee Bay, and western basin reefs and shoals has been identified as a contributing factor to Lake Erie's population collapse in the 1950s. This decline prompted the United States and Canada to take steps to improve the aquatic ecosystem of Lake Erie. A recent increase in commercial fish harvest and catch of early-life history stages of lake whitefish in the western basin of Lake Erie provide evidence that lake whitefish

are once again spawning in some of their historical spawning areas, however the extent of use is unknown. To investigate the contemporary distribution of lake whitefish spawning within western Lake Erie, 31 potential spawning locations were sampled for eggs in 2016 and 2017. A subset of sites within Maumee Bay and an open lake reef complex were sampled repeatedly each year to determine the onset of spawning and 17 sites outside these two areas were each sampled once to describe the spatial extent of spawning. Spawned eggs were first detected on November 22 in 2016 and on November 18 in 2017. Viable eggs were collected at 27 of 31 sampled locations, verifying that lake whitefish spawned in Maumee Bay, on the mid-lake reefs, and other locations in 2016 and 2017. These findings confirm that lake whitefish are using historical spawning areas and available spawning habitat in western Lake Erie. The expanded use of available spawning habitat adds spawning stock diversity that is vital for generating population stability and resilience.

Detection of endocrine disrupting chemicals and pharmaceuticals and personal care products in environmental waters using online concentration LC-MS/MS

Johnna Birbeck[1], Diana McKenzie[2], Cassandra Ward[1], and Judy Westrick[1]

[1] Wayne State University, Dept. of Chemistry; [2] Bay Mills Community College, Dept. of Science

Endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) are two groups of compounds that have been detected at low levels in source waters and are of emerging concern. U.S. Environmental Protection Agency methods 539 (EDCs) and 1694 (PPCPs) are LC-MS/MS methods for detection in water with three rate-limiting steps; laborious solid phase extraction (SPE) step for clean-up and concentration, long chromatography runs, and in Method 1694's case, multiple methods for detection of the different classes of compounds. Two separate online concentration LC-MS/MS methods for EDCs and PPCPs were developed which removed SPE step, and reduced sample volume, solvent, instrumentation time, while having detection limits in the ppt levels. An online LC-MS/MS method using a Thermo Scientific EQuan MAX Plus™ with a TSQ Altis triple quadrupole was created for both EDCs and PPCPs that can concentrate and clean-up source water samples with sample run time < 15 minutes. The EDC method detects 13 different EDCs and metformin using an ammonium hydroxide in water and methanol gradient. The PPCP method detects 10 different PPCPs using an ammonium formate in water and methanol gradient. One mL of sample was loaded onto the concentration column using 0.1% formic acid in water for PPCPs and water for EDCs. Seven compounds (erythromycin, estradiol, estriol, estrone, ethinyl estradiol, equilin, and nonylphenol) from both methods are currently on the US EPAs Contaminate Candidate List 4 (CCL4). Each method was validated using the US EPA procedures for the initial demonstration of capability outlined. These validation procedures include demonstration of precision and accuracy, low system background, minimum reporting level confirmation, quality control samples and detection limit determination. Each method was able to meet qualifications set by US EPA methods. The Bay Mills Indian Communities reservation is located along the Waishkey Bay and the Great Lakes basin along the

northern border of Michigan's upper peninsula. This community depends on the local tribal community college, tourism, and subsistence and commercial fishing. Anthropogenic chemical contamination through sewage lagoons and aging septic tanks is a concern, as contamination along the waterway would be economically detrimental for this community. This study focuses on the determining the impact of the sewage lagoons and septic tanks by determining the concentrations of PPCPs and EDCs. Sampling sites were located along Waishkey Bay and the northern Great Lakes Basin. Preliminary data from the sampling sites showed presence of four PPCPs (acetaminophen, caffeine, sulfamethoxazole, and carbamazepine) at 10 ppt or less, and four EDCs (bisphenyl-A (BPA), estrone, ethinyl estradiol, and iso-nonylphenol) ranging between 0.5-325 ppt. Of those detected, three are present on CCL4 (estrone, ethinyl estradiol, and nonylphenol). These methods are advantageous because they remove the need for SPE which is a laborious step that has the ability to introduce sample mishandling, reduces the sample size that is needed to be collected as only 1mL is concentrated onto the system, reduces the chromatography run time which also reduces solvent use and increases sample throughput. Furthermore, these methods make rapid assessment sampling and analyzing in emergency situations feasible. Advantages of emerging contaminant online LC-MS/MS methods are reduced sample handling and solvent use while increasing sample throughput and sensitivity.

Evidence of immediate and continued use of constructed reefs by spawning Lake Sturgeon

Taaja R. Tucker[1], Edward F. Roseman[2], Robert D. Hunter[2], Robin L. DeBruyne[1], Dustin A. Bowser[2], Stacey Ireland[2], and Gregory W. Kennedy[2]

[1] University of Toledo, Cooperative Ecosystem Studies Unit; [2] USGS Great Lakes Science Center

Pollution, channelization, dredging, and development in the St. Clair-Detroit River System (SCDRS) reduced water quality and decreased the availability of natural spawning substrate for fishes and declines in fish populations including lake sturgeon *Acipenser fulvescens*. These losses resulted in designation of portions of the rivers as a Great Lakes Area of Concern with Beneficial Use Impairments related to fish habitat and populations. Improvements to water quality since the 1970s provided opportunities for habitat and population restoration with wide-spread positive response by lake sturgeon. Toward this end, artificial reefs are being constructed and monitored through a collaborative multi-agency partnership. This poster provides a summary of research and monitoring of lake sturgeon use of reefs constructed 2004-2018 in the SCDRS.

Demonstration of agent-based modelling in aquatic ecosystem research

Elisa Q. Ward

Academie Ste Cecile International School

Agent-Based Modelling (ABM) is an approach to modeling systems that focuses on simulating individuals, or "agents", that has been used in modeling all sorts of different applications in different fields of study, showing to be very promising in the simulating of aquatic ecosystems. Three separate example models have been developed using the Netlogo ABM programming language, each focusing on a separate application. Such applications include predator-prey dynamics and evolutionary adaptive responses, the effectiveness of environmental interventions, and the exploration of the effectiveness of preventive measures. When considering the usage of ABM, there were a set of proposed criteria when it would be the most effective. The proposed criteria are based off the goal of the study, specifically whether it involves evolution, or what the outcome of the model relies on, specifically the interactions between agents or based on individual learning and behavior. However, the criteria aren't mutually exclusive, and multiple can be applied to the same model. Despite the promising signs, ABM has limitations and areas that need to be improved. One such limitation is difficulty dealing with multiple time scales, as both short-term and long-term events were happening simultaneously. Another limitation is the number of individual agents in the system, as it is computationally infeasible to model large numbers of agents and requires some sort of limit. There is a solution to this however, which is to utilize a hybrid approach, where different populations were modelled as agents or continuous variables. While ABM has its flaws, it is a very promising method of research in aquatic ecosystems when used appropriately.

A rapid, robust microcystin online concentration LC/MS/MS method

Judy A. Westrick and Johnna A. Birbeck

Wayne State University, Dept. of Chemistry, Lumigen Instrument Center

In the summer of 2015, U.S. Environmental Protection Agency (EPA) announced an age-dependent drinking water Health Advisory (HA) for the natural freshwater toxins, microcystins (MCs). For children pre-school age and adults, the MCs the drinking water HA values are 0.3 μg/L and 1.6 μg/L, respectively. Although the HA values are non-regulatory values that serve as informal technical guidance to federal, state, and local drinking water practitioners, this announcement does provide compelling health information that cannot be ignored. In parallel, the U.S. EPA released a solid phase extraction/liquid chromatography tandem mass spectrometry (LC/MS/MS) method that quantifies seven MCs (EPA Method 544). Our goal was to create an online concentration LC/MS/MS method with 12 MCs that meets the EPA's quality assurance/quality control (QA/QC) criteria. Microcystin concentrations were measured in samples from freshwater lakes and drinking water. Samples were prepared by three freeze/thaw cycles, centrifuging, and filtering through a 0.25 μm polycarbonate filter. Our LC/MS/MS platform included a

Thermo Scientific EQuan MAX (online sample concentrator) and ThermoFisher's UltiMate 3000 (UHPLC) system and a TSQ Quantiva (MS/MS). The microcystin on-line concentration method included 12 microcystins with calibration curves from 0.5 – 500 ppt with good linearity (R2 values greater than 0.996). The microcystins eluted between 2.2 – 5.2 minutes allowing for the total analyses time to be less than 12 minutes. Over 150 MCs have been reported. The current U.S. EPA method quantifies for seven MCs, whereas our method quantities 12 MCs. Of the twelve MCs quantified, MC-RR has the lowest limit of detection (LOD) at 0.5 ng/L, and MC-WR has the highest of the LOD at 4.26 ng/L. These limits of detection compare very closely to if not lower than EPA method 544. The total run time for the online concentration LC/MS/MS method is 12 minutes as compared to an 8-hour day for solid phase extraction and a 26 minute per sample analysis for the EPA Method 544. This method provides rapid, high-throughput, and sensitive workflow on a LC/MS/MS platform for research scientist, drinking water practitioners, and health departments for recreational monitoring. We have started evaluating many source water samples and approximately 30% of the samples have MCs other than the seven MCs in the EPA method. These samples contained [Asp3] MC-RR, [Asp3] MC- LR, MC-HilR, and MC-WR at concentrations above the low health reference level of 21 ng/L. Recent investigations suggest that [Asp3] MC-RR and [Asp3] MC-LR are more toxic and pose a greater health risk. By not including these MCs in Method 544, the true risk potential of exposure to MCs in drinking and recreational waters will be underestimated greatly. The cost-effective online concentration LC/MS/MS method reduces sample preparation, chemical usage, and instrument time while meeting all EPA criteria.

This page intentionally left blank.

International Joint Commission • Commission Mixte Internationale 1909

Canada

SEMCOG
Southeast Michigan Council of Governments

Ontario
Ministry of Natural Resources and Forestry

Community Foundation
FOR SOUTHEAST MICHIGAN

CIGLR
Great Lakes Science for Society

DETROIT RIVER CANADIAN CLEANUP
www.DetroitRiver.ca

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

DETROIT ZOOLOGICAL SOCIETY
DETROIT ZOO • BELLE ISLE NATURE CENTER

FRIENDS of the DETROIT RIVER

The Nature Conservancy

DTE Energy

Essex Region Conservation Authority

GLWA
Great Lakes Water Authority

friends of ojibway prairie

INTERNATIONAL WILDLIFE REFUGE ALLIANCE

BASF
We create chemistry

GLIER
GREAT LAKES INSTITUTE FOR ENVIRONMENTAL RESEARCH
at the University of Windsor

OGL

University of Windsor

Windsor Law
University of Windsor

ECT Environmental Consulting & Technology, Inc.

EASTERN MICHIGAN UNIVERSITY

IAGLR

GLISA
A NOAA RISA TEAM

Sea Grant
Michigan

NATURE CONSERVANCY CANADA
CONSERVATION DE LA NATURE

Environmental Interpretive Center

M DEARBORN
OFFICE OF METROPOLITAN IMPACT

SEMI WILD

RACKHAM GRADUATE SCHOOL
UNIVERSITY OF MICHIGAN

CDM Smith