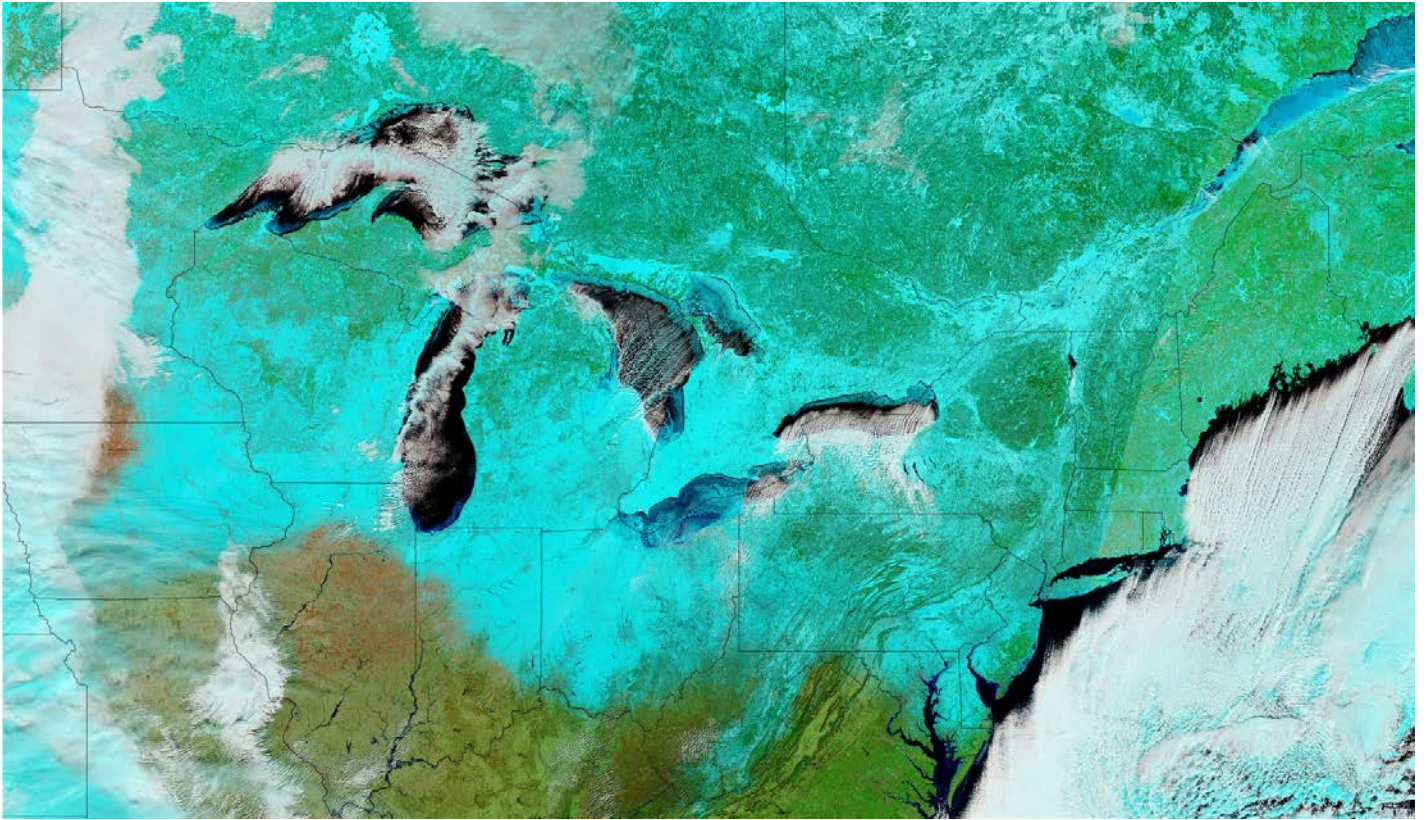**2014-2015**

G. Allen Burton, Director
Thomas H. Johengen, Associate
Director
G110 Dana Building
440 Church Street
Ann Arbor, MI 48109-1041
734 -763-3010
www.ciler.snre.umich.edu

ANNUAL REPORT:
COOPERATIVE INSTITUTE FOR
LIMNOLOGY & ECOSYSTEMS
RESEARCH
CILER

NA12OAR4320071 – Year Three |

Cooperative Institute for Limnology and Ecosystems Research – CILER

G. Allen Burton, Director
Thomas H. Johengen, Associate Director
University of Michigan
Ann Arbor, Michigan

Annual Report for NA12OAR4320071

Year Three (12 months): July 1, 2014 – June 30, 2015

Table of Contents

From the Director

As we come to the close of the third year of CILER's current cooperative agreement, it is gratifying to see the productivity in our core research areas and expansion into new ones. While the former efforts demonstrate CILER's continued commitment to NOAA's Great Lakes mission, the output from these new initiatives will help generate information important for understanding emerging and ongoing threats to the lakes.

CILER continues to support key, core research programs in direct support of NOAA's mission with $3 million of project funding in 33 grants addressing our 5 focus areas, during the past year, and nearly $10.7 million since the beginning of this agreement in July 2012. CILER continues to rely heavily on its regional partners and 21 units outside of the University of Michigan received funding during the past year.

We received excellent input from our Executive Board, Management Council and Council of Fellows representing our Consortium member universities, the University of Michigan and NOAA. Our many research projects are described in this Annual Report, but I want to highlight a few of those efforts below.

CILER continues to support the Harmful Algal Blooms (HABs), Bacteria and Beach Quality Forecasting for the Great Lakes. This program focuses on developing improved Lake Erie HAB forecasts to determine the timing, extent, and distribution of the HABS bloom, along with direct monitoring to determine actual toxin concentrations and relationship to environmental drivers. Through these activities, CILER supports NOAA's efforts to improve decision support tools related to bacterial loading and toxicity as well as helping to improve ecological forecasting of harmful algal blooms. Key accomplishments for this year include increased field monitoring and improved HABS modeling and data analysis.

Our ice modeling study uses a combination of high-resolution models and forecasts to improve our understanding of ocean and sea ice circulation in the Bering-Chukchi-Beaufort Seas. This year's accomplishments include setting up a 3D physical-biological model to validate the simulations involving the seasonal phytoplankton variations in the Bering Sea.

The Great Lakes SOAR project is a key component in the protection and restoration of ecosystem resources research theme with its up to date information on ecosystem health

related data. The data provided by the continuation of this project has helped in the development of decision support tools. We have been able to significantly expand our realtime observing network witin Lake Erie and have operationalized the dissementatoin of the conitnuous monitroing results through the project's website.

Once again we had an excellent student Summer Fellows Program as well as the GLERL CILER Long-term Fellows Program. We advertised for 15 separate positions and received more than 100 applications. Most of these summer fellows were placed at the NOAA-GLERL facility; although we had three student fellows work at remote locations (NOAA-Lake Michigan Field Station, the University of Wisconsin – Milwaukee, and State University of New York College of Environmental Science and Forestry in Syracuse NY). We awarded two Long Term fellowships - one to Purdue University and one to the University of Wisconsin – Milwaukee. The student positioned at Purdue University will focus on characterizing the spatial variation in condition and trophic connections of larval fish as part of the 2015 Coordinated Science and Monitoring Initiative (CSMI) in Lake Michigan. The student working at UW-Milwaukee will be conducting research that evaluates the metabolism and biogeochemical cycling in benthic ecosystems of the Great Lakes.

CILER also launched three new outreach and education initiatives this year. The first of these initiatives is collaboration among CILER, NOAA-GLERL, and NOAA-Michigan Sea Grant (MISG) to support a communications summer student fellow. Mentors from each of these institutes have worked with a student to develop communications material to highlight the scientific effort behind the 2015 CSMI – Lake Michigan and to develop content that demonstrates the way in which CILER, NOAA-GLERL, and MISG partner to advance research in the Great Lakes region.

Another new CILER initiative was to fund a workshop and retreat that brought researchers from around the Great Lakes region together to plan ways to expand research capacity on Great Lakes hydrometerological processes.

Finally, we have the lead organization role in hosting the 23rd International Association for Hydro-Environment Engineering and Research - International Symposium on Ice. This conference will be held at the University of Michigan in 2016.

In terms of new and emerging efforts, CILER continues to promote truly interdisciplinary research projects, and with important results. We have begun organizing three "Mini-Summits" for Fall 2015 through Spring 2016 bringing together experts to identify key research gaps and action plans on three topic areas selected by our Management Council. The findings of these summits will be presented to NOAA for their consideration.

In addition, CILER researchers continued activities on three ongoing collaborative projects with funding from the University of Michigan Water Center and the Water Environment Research Foundation. One of these projects focuses on characterizing the distribution and potential ecological effects of microplastics in the Great Lakes. The interdisciplinary research team is advancing the science of microplastic research by coupling hydrodynamic models with field sampling efforts and with source identification of microplastic material. A second project is focused on developing a world-classes microbial genomics effort at the University of Michigan, by partnering with CILER and NOAA-GLERL researchers. Through this effort the project team will create massive new omics datasets that will be used to mine genome sequences from cyanobacteria, bacteria, and viruses and will be used to advance our understanding of the conditions that impact HABs formation in the western basin of Lake Erie. Finally, a third project is investigating the ecological significance of trace organic chemicals, including endocrine disrupters, discharged from wastewater treatment plants and combined sewer overflows – whose inputs into the Great Lakes are in the billions of gallons per year.

Thanks to the dedication of a top-notch group of CILER, NOAA-GLERL researchers and our many partners at other universities, we have made much progress this year in observing, understanding, and forecasting conditions in North America's Great Lakes. We look forward to the opportunity to continue to capitalize on the strong partnerships that have been an essential hallmark of CILER from its inception.

G. Allen Burton

Director – Cooperative Institute for Limnology and Ecosystems Research

Introduction

The Cooperative Institute for Limnology and Ecosystems Research (CILER) was first established in 1989, with the objective of fostering University and NOAA partnerships in the Great Lakes region. As a Center of Excellence at the School of Natural Resources and Environment (SNRE) at the University of Michigan, CILER brings together this expertise in Great Lakes science and outreach.

The establishment of the latest CILER Cooperative Agreement went into effect in July of 2012. This agreement was awarded to the University of Michigan (host institution) and nine partner universities (Grand Valley State University, Michigan State University, Michigan Technological University, Penn State University, State University of New York at Stony Brook, University of Illinois at Urbana Champaign, University of Minnesota-Duluth, University of Toledo and University of Wisconsin). Since the current Cooperative Agreement has been in effect, CILER has supported approximately 100 research projects that total over $19 million in funding. Extramural funding has increased each year over the five-year period. The Great Lakes Restoration Initiative (GLRI) resulted in a significant increase in proposal submissions both to NOAA and the U.S. Environmental Protection Agency for NOAA and EPA directed monies.

CILER's Vision

To enhance the quality of the Great Lakes and its related ecosystem services, through a partnership of universities, NOAA scientists, and other stakeholders.

CILER's Mission

- Advance our understanding of, and ability to predict, complex ecosystem processes, responses, and dynamics in the Great Lakes.

- Identify and characterize emerging areas of concern for the Great Lakes ecosystem, with applications to all coastal ecosystems.

- Provide a forum for better linking ecosystem responses, sustainable ecosystem services, and decision-making in the Great Lakes.

- Translate research into productive outcomes for stakeholders in the region through outreach and education.
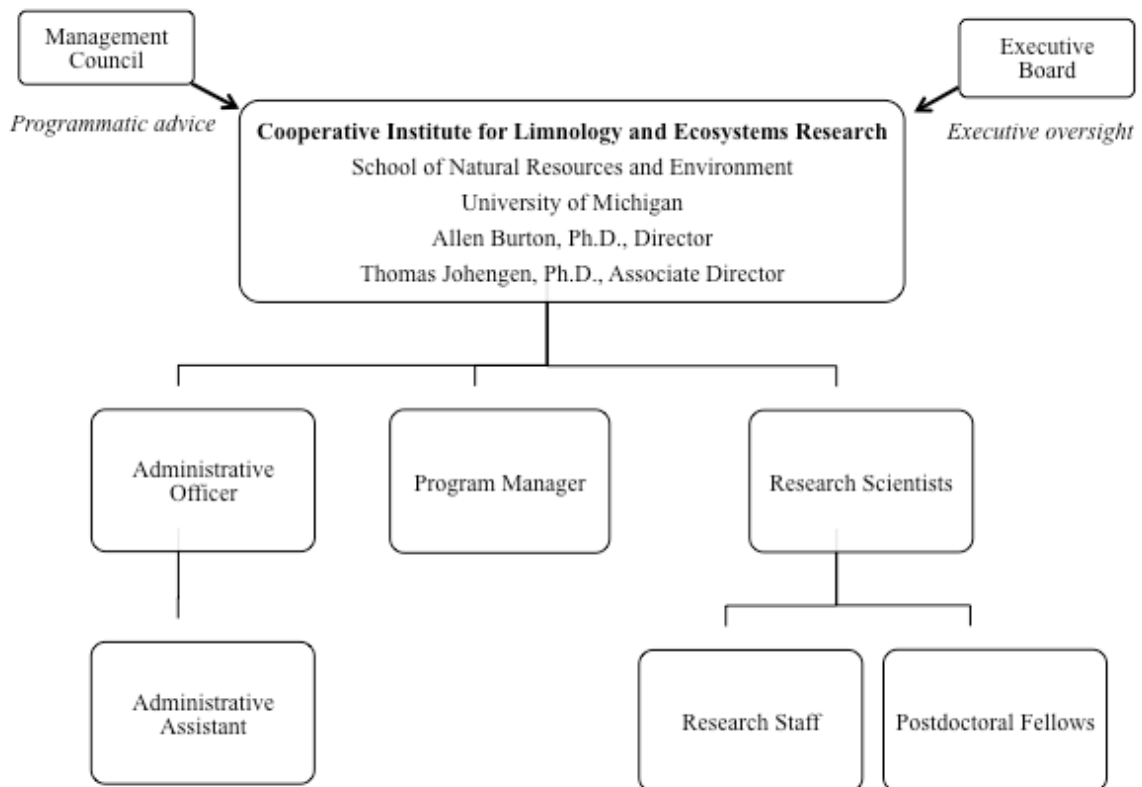
- Improve effectiveness of education and expand research training opportunities for students and postdoctoral fellows.

CILER's Goals

- Advance the science of Great Lakes ecosystem forecasting by integrating physical, chemical, and biological components to allow for more effective responses and management of invasive species, climate change, habitat alteration, and contaminants.
- Facilitate the translation of research into more effective decision-making and public education.
- Support NOAA's mission and strategic goals.
- Facilitate research in the Great Lakes region.
- Mentor and train the next generation of scientists through research and educational opportunities.

CILER Organizational Chart

Management Council

Programmatic advice

Cooperative Institute for Limnology and Ecosystems Research
School of Natural Resources and Environment
University of Michigan
Allen Burton, Ph.D., Director
Thomas Johengen, Ph.D., Associate Director

Executive Board

Executive oversight

Administrative Officer

Program Manager

Research Scientists

Administrative Assistant

Research Staff

Postdoctoral Fellows

Education and Outreach Activities

The two primary goals of CILER's Education and Outreach efforts are to communicate the research that CILER does to a broad audience (including stakeholders and policy makers) and to provide research and training opportunities for undergraduate and graduate students. CILER supports many of these activities through Task 1 funds, such as the Great Lakes Summer Student Fellows Program, the Long-term Fellows program, the CILER postdoctoral program, and the CILER-GLERL Great Lakes Seminar series. In addition, several of the funded research projects that CILER supports have an outreach or educational component.

One of the keystones of CILER's education efforts is the annual Great Lakes Summer Student Fellows Program. CILER has been co-hosting this program with NOAA-GLERL since 1989. Each year this program attracts highly qualified undergraduate and graduate students to NOAA and university facilities to work with Federal mentors on research related to Great Lakes issues. The objective of this program is to train promising young scientists under the mentorship of a Great Lakes researcher. In turn, the program provides students the opportunity to work on a substantive research issue in the Great lakes that supports CILER's and NOAA's research missions in the region.

CILER also receives Task I funding to support a GLERL CILER Long-Term Fellowship Program. The goals of this program are to: 1) increase training and educational opportunities for students in Great Lakes research; 2) enhance academic and NOAA collaborations to improve research effectiveness; and 3) increase student retention within the freshwater aquatic sciences. The Fellowships are available to faculty researchers throughout the Great Lakes region who are, or would like to, collaborate with a NOAA-GLERL researcher in supporting a student on a joint research project. These fellowships provide up to $25,000 for one year of support for a student.

In addition to supporting postdoctoral positions through research projects, CILER also administers a competitive Postdoctoral Fellowship Program. This program provides salary and research support for a post-doctoral fellow who will work closely with a CILER Management Council or Council of Fellows member on a project of mutual interest. The program is administered as a Task IC activity, because it will be a competitively awarded position based on funds that are not associated with a specific research project.

CILER sponsors and coordinates a joint CILER-GLERL Seminar Series. This series continues to bring in regional, national and international researchers to talk about pertinent new and emerging scientific issues to GLERL, the University of Michigan and other universities and sites within the Great Lakes region. The series facilitates collaborations between researchers, provides educational opportunities for NOAA and university scientists and serves as an outreach forum for stakeholders and the general public to attend.

Executive Summary

The activities from the third year of the current Cooperative Agreement reflect CILER's continued commitment to its core research activities as well as the launch of several new initiatives. In terms of research activities, CILER funded $3 million dollars in research grants during the reporting period. Some of the bigger projects include multi-institutional projects that allow researchers from across the Great Lakes region to collaborate on research focused on examining lake wide processes. Some of the key activities and results from these efforts are detailed below.

Research Highlights

Harmful Algal Bloom Forecasting

CILER continues to support the Harmful Algal Blooms (HABs), Bacteria and Beach Quality Forecasting for the Great Lakes. This program focuses on the development of improved Lake Erie HAB forecasts of bloom timing, intensity, and distribution. IN addition, direct weekly monitoring occurs to determine actual microcystin concentration and other important environmental drivers of the bloom, which are reported directly to regional stakeholders. . Through these activities, CILER supports NOAA's efforts to improve decision support tools related to bacterial loading and toxicity as well as helping to improve ecological forecasting of harmful algal blooms.

Key accomplishments for this year include increased field monitoring and improved HABS modeling and data analysis. Field sampling programs were extended to western Lake Erie to include two additional stations further east: One near the Toledo water intake and one near West Sister Island, which provides an early warning for blooms that might be advected towards the Bass Island region.

Other parts of the project have developed a linkage between the watershed model, Huron to Erie connecting waterways forecasting system and a bacteria particle model for automated forecast capability. The overall goal of this work is to develop, calibrate and confirm a watershed-scale fecal indicator bacteria (FIB) fate and transport model to provide flow and loading estimated to hydrodynamic nearshore plume models.

Modeling Sea Ice - Great Lakes Ice Modeling, Measurement and Climate Change

The ice modeling study uses the combination of high-resolution models and forecasts to improve our understanding of ocean and sea ice circulation in the Bering-Chukchi-Beaufort Seas. This year's accomplishments include setting up a 3D physical-biological

model to validate the simulations involving the seasonal phytoplankton variations in the Bering Sea with a focus on physical and biochemical mechanisms related to the formation of the Bering Sea Green Belt and Subsurface Chlorophyll Maxima in the summer.

SOAR - Great Lakes Synthesis, Observations and Response System

The Great Lakes SOAR project is a key component in the protection and restoration of ecosystem resources research theme with its up to date information on ecosystem health related data. The data provided by the continuation of this project had helped in the development of decision support tools. New sites where instrumentation was deployed allowed for the operation of real-time mode for the first time and the results were made available through the project's website.

Outreach and Education Highlights

During FY2015, CILER was again able to administer both the Great Lakes Summer Fellows Program as well as the GLERL CILER Long-term Fellows Program. In terms of the former, we advertised for 15 separate positions and received more than 100 applications. Most of these summer fellows were placed at the NOAA-GLERL facility; although we had three student fellows work at remote locations (NOAA-Lake Michigan Field Station, the University of Wisconsin – Milwaukee, and State University of New York College of Environmental Science and Forestry in Syracuse NY).

In terms of the Longterm Fellows Program we were able to award two fellowships this year - one to Purdue University and one to the University of Wisconsin – Milwaukee. The student positioned at Purdue University will focus on characterizing the spatial variation in condition and trophic connections of larval fish as part of the 2015 Coordinated Science and Monitoring Initiative (CSMI) in Lake Michigan. The student working at UW-Milwaukee will be conducting research that evaluates the metabolism and biogeochemical cycling in benthic ecosystems of the Great Lakes.

CILER also launched three new outreach and education initiatives this year. The first of these initiatives is collaboration among CILER, NOAA-GLERL, and NOAA-Michigan Sea Grant (MISG) to support a communications summer student fellow. Mentors from each of these institutes have worked with a student to develop communications material to highlight the scientific effort behind the 2015 CSMI – Lake Michigan and to

develop content that demonstrates the way in which CILER, NOAA-GLERL, and MISG partner to advance research in the Great Lakes region.

Another new CILER initiative was to fund a workshop and retreat that brought researchers from around the Great Lakes region together to plan ways to expand research capacity on Great Lakes hydrometerological processes. CILER piloted this effort to assess the utility in this approach to helping research teams develop proposals for future potential RFP opportunities.

CILER has also been asked to organize and host the 23rd International Association for Hydro-Environment Engineering and Research - International Symposium on Ice. This conference will be held at the University of Michigan in 2016, and CILER is taking a lead planning this event, including developing a schedule, arranging facilities, and covering logistical support.

Finally, CILER has devoted additional effort and time this year to improving and updating our outreach material. We have revamped the CILER website so that it contains more content appropriate for both stakeholders and the general audience. We have reorganized the way in which information is categorized and the navigation menus, so that visitors can locate information more easily. Our web statistics for the past year indicate that we had approximately 6,700 users, 28,000 pageviews, and an average session duration of 2:22 minutes. We also had 67% of visitors classified as "new visitors." Along with these website improvements, CILER has updated much of its outreach material, including developing a new factsheet about the Cooperative Institute, that highlights key outcomes and metrics (see http://ciler.snre.umich.edu/sites/ciler.snre.umich.edu/files/factsheets/CILER201504.pdf).

Administrative Summary

The primary role of CILER administration is to support research carried out under the auspices of the Cooperative Institute. Two of the most important administrative tasks are to facilitate financial elements of the consortium and to support the development, implementation, and coordination of our multi-university, regional research programs.

There have been two significant changes for CILER in terms of administrative processes during this fiscal year. The first is the departure of CILER's Administrative Officer, Heather Hazzard, who left to take a position at Michigan State University.

The second notable event was the change in the way that NOAA releases Task 1 funding to the Cooperative Institutes.   This was the first year that funding for all of the administrative tasks came in parcels of funding, and at different times. From a financial operations perspective, this created many challenges in terms of supporting full-time employees from funds that in some cases had not arrived in time to pay salary, fringe, etc. for that month.

Executive Board - Management Council - Council of Fellows

The Executive Board makes recommendations concerning CILER's administration, budget, future cooperative agreements, and Management Council members.   The members of the Executive Board changed this year (aligned with CILER's original proposal for the cooperative institute). We appreciated the effort and service of Russell Callender and Al Powell. CILER has two new NOAA members on its Executive Board: Allison Allen (NOAA-NOS) and Richard Wagenmaker (NOAA-NWS). In addition, the previous SNRE Dean, Marie Lynn Miranda left the University of Michigan in June 2015. The current interim Dean of the school, Dan Brown, is serving on the Executive Board in her place.

The Executive Board last met 03-January 2013. The Board did not meet in 2014. We had originally schedule a meeting for May 2015, which has since been re-scheduled for 21-August 2015 due to summer research and other scheduling conflicts.

The members of the Executive Board include:

Allison Allen (Portfolio Manager, NOAA Ecological Forecasting Roadmap, NOAA-NOS)
Dan Brown (Interim Dean, UM-SNRE)
Allen Burton (CILER Director, Ex-Officio)
Deborah Lee (Director, NOAA-GLERL, Ex-Officio)
Volker Sick (Associate Vice-President for Research, UM)
Richard Wagenmaker (Meteorologist in Charge, NOAA – National Weather Service)

CILER Management Council

The Management Council provides reviews and recommendations of the scientific direction of the CI, and includes directors of the Great Lakes Sea Grant programs, with additional representation by NOAA and university scientists.

Similar to the Executive Board, the members of the Management Council were updated in Spring 2015, with some members leaving, some returning and some new members being added.

This Council last met in May 2015.

The current members of the Management Council are:

Jay Austin, Assistant Professor, Department of Physics and the Large Lakes Observatory, University of Minnesota-Duluth

Jim Diana, Director, Michigan Sea Grant Program, University of Michigan

Andrew Gronewold, Physical Scientist, NOAA-GLERL

Tomas Hook, Associate Director of Research, Illinois-Indiana Sea Grant

Donna Kashian, Assistant Professor, Department of Biological Science, Wayne State University

Val Klump, Director, Great Lakes Water Institute, University of Wisconsin – Milwaukee

Stu Ludsin, Associate Professor, Evolution, Ecology & Organismal Biology, The Ohio State University

Doran Mason, Research Ecologist & CILER Program Manager, NOAA-GLERL

Peter McIntyre, Assistant Professor, Department of Zoology, University of Wisconsin-Madison

Cheryl Murphy, Assistant Professor, Department of Fisheries & Wildlife, Michigan State University

Steve Ruberg, Group Leader, Marine Instrumentation Lab, NOAA-GLERL

Al Steinman, Director, Annis Water Resources Institute, Grand Valley State University

Carol Stepien, Director, Lake Erie Center, The University of Toledo

Craig Stow, Aquatic Ecosystem Modeler, NOAA-GLERL

Donald Uzarski, Director, Biological Station and Institute for Great Lakes Research, Central Michigan University

William Wise, Interim Director, New York Sea Grant, Stony Brook, NY

Additional information about the members of the Management Council can be found at
http://ciler.snre.umich.edu/content/management-council

Council of Fellows

The new Council of Fellows include over 30 Great Lakes academic and federal researchers willing to engage in CILER research activities, including mentoring of graduate and postdoctoral fellows.

James Ammerman, Director, New York Sea Grant

Joe Atkinson, Professor, State University of New York - University at Buffalo

Jay Austin, Asst. Professor, Univ. of Minnesota-Duluth's Large Lakes Observatory

Stuart Batterman, Professor, University of Michigan's School of Public Health

Dima Beletsky, Research Professor, CILER

Bopi Biddanda, Research Scientist, Grand Valley State University, Annis Water
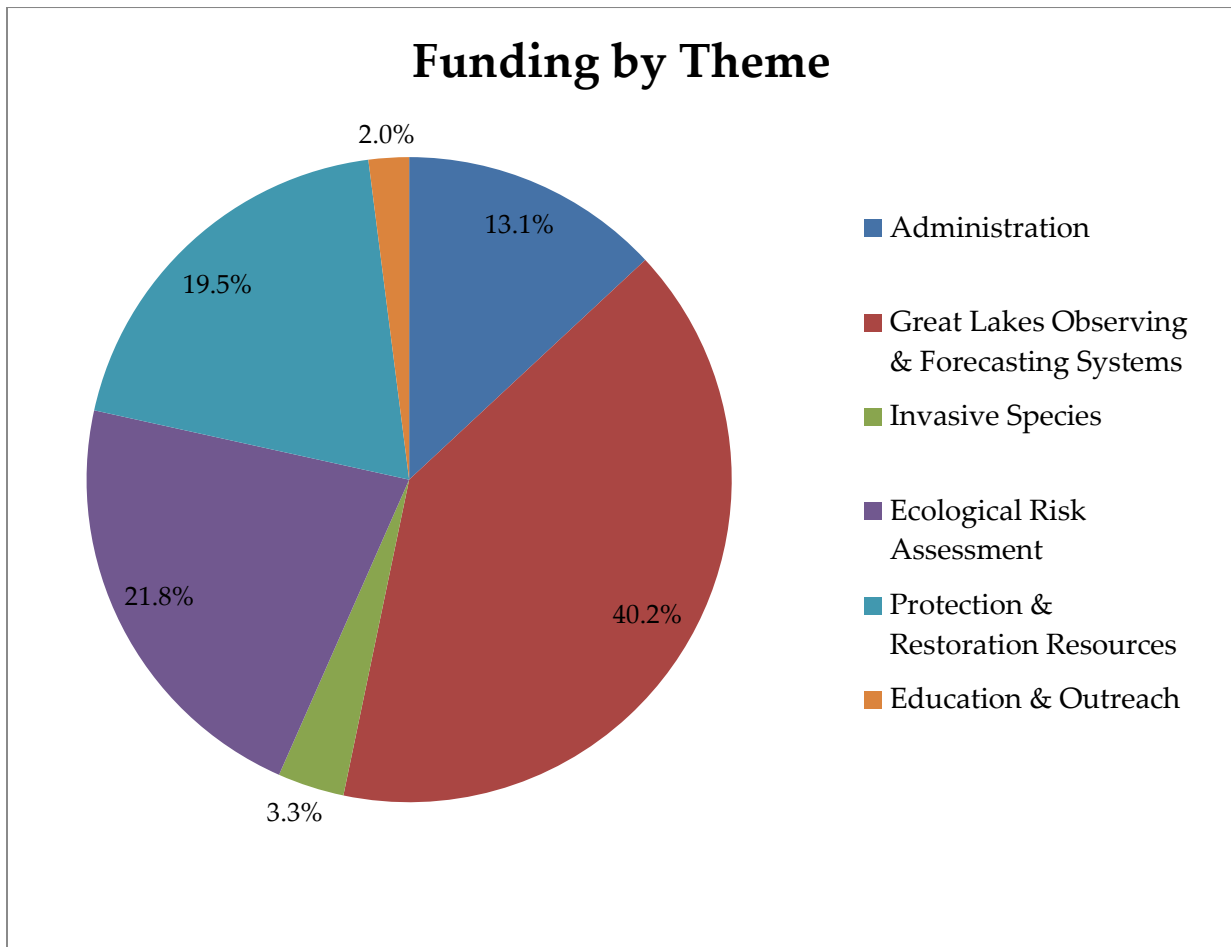
Resources Institute
Harvey Bootsma, Associate Professor, University of Wisconsin - Milwaukee
Greg Boyer, Professor, SUNY – College of Environmental Science and Forestry
Thomas Bridgeman, Associate Professor, The University of Toledo
Rose Cory, Assistant Professor, EES, Univesity of Michigan
Greg Dick, Associate Professor, EES, University of Michigan
Brad Cardinale, Professor, SNRE, University of Michigan
Hunter Carrick, Professor, Central Michigan University
Steve Colman, Professor, Univ. of Minnesota-Duluth's Large Lakes Observatory
Jim Cotner, Professor, University of Minnesota
Vincent Denef, Assistant Professor, EEB, University of Michigan
Melissa Duhaime, Assistant Research Scientist, EEB, University of Michigan
Mark Flanner, Assistant Professor, AOSS, University of Michigan
Joseph Johnson, Assistant Professor, University of Minnesota-Duluth
Branko Kerkez, Assistant Professor, CEE, University of Michigan
George Kling, Professor, EEB, University of Michigan
Peter Lavrentyev, Professor, University of Akron
Brent Lofgren, Physical Scientist, GLERL
Nancy Love, Professor, University of Michigan
Rex Lowe, Professor, Bowling Green State University
Phanikumar Mantha, Associate Professor, Michigan State University
Guy Meadows, Professor Michigan Technological University
Brian Miller, Director, Illinois-Indiana Sea Grant
Cheryl Murphy, Asst. Professor, Michigan State University
Scott Peacor, Associate Professor, Michigan State University
Lutgarde Raskin, Professor, University of Michigan
Jennifer Read, Director, University of Michigan Water Center
Richard Rood, Professor, AOSS, University of Michigans
Carl Ruetz III, Associate Professor, Grand Valley State University
Ed Rutherford, Research Fishery Biologist, GLERL
David Schwab, Research Scientist, Water Center
Paul Seelbach, Eco. Hlth. & Restor. Branch Chief, USGS-Great Lakes Science Center
Bob Shuchman, Co-Director, Michigan Tech Research Institute, MTU
Allison Steiner, Associate Professor, AOSS, University of Michigan
Robert Sterner, Professor, University of Minnesota
R. Jan Stevenson, Professor, Michigan State University
Henry Vanderploeg, Research Ecologist, GLERL
Mike Wiley, Professor, SNRE, University of Michigan
Chin Wu, Professor, University of Wisconsin-Madison

For information on individual Fellows can be found on CILER's website: http://ciler.snre.umich.edu/content/council-fellows, with a link to their online profiles, which includes their affiliations, contact information, and research interests.

Funding Distribution

This funding distribution report details project funding from the beginning of the cooperative agreement through June 30, 2015.

The total funding level from July 1, 2012 through June 30, 2015 is $10,667,437.

Funding by Theme

- Administration — 13.1%
- Great Lakes Observing & Forecasting Systems — 40.2%
- Invasive Species — 3.3%
- Ecological Risk Assessment — 21.8%
- Protection & Restoration Resources — 19.5%
- Education & Outreach — 2.0%

Figure 1. Funding distribution for CILER by theme through the current Cooperative Agreement, through 06/30/15

The Task I Activities Funding from July 1, 2012 through June 30, 2015 is $796,493 received through the Cooperative Agreement to support these activities to date.

The University of Michigan and UM-SNRE have provided additional funds to support Task I activities by supplying >$500,000 to date in support of CI activities.
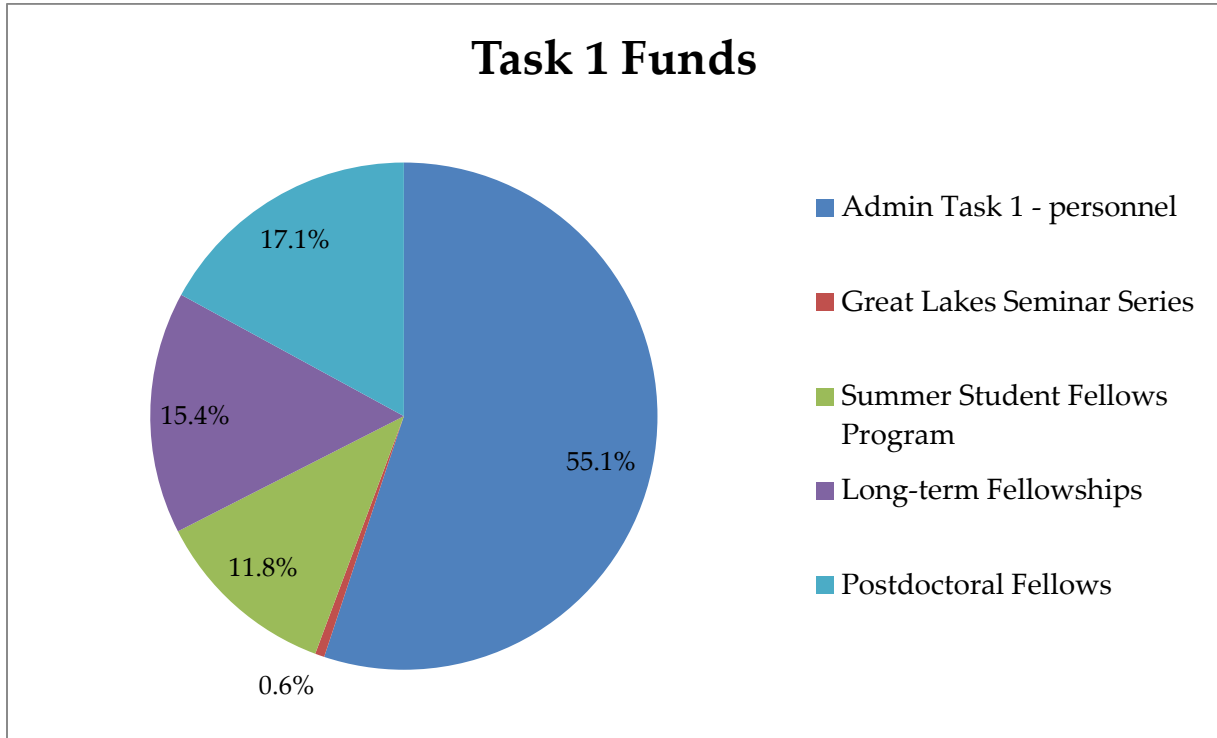
Figure 2. Funding distribution for CILER Task I Funds, from 07/01/12 through 06/30/15, based on total funds received to date.

Table 1. Breakdown of funding by Theme awarded to CILER for the current Cooperative Agreement, NA12OAR4320071, through June 30, 2015.

Task	Research Theme	Funding (%)	Funding ($)
I	Administration	13.1%	1,394,387
II	Theme I: Great Lakes Observing and Forecasting Systems	40.2%	4,288,064
II	Theme II: Invasive Species	3.3%	356,330
II	Theme III: Ecological Risk Assessment	21.8%	2,329,841
II	Theme IV: Protection and Restoration of Ecosystem Resources: Linking to Human Dimensions	19.5%	2,083,225
II	Theme V: Education and Outreach	2.0%	215,591
Totals		100%	10,667,437

Table 2: List of all project numbers relating to projects found in the report

Theme	Project Grant #	General Title
	F031364	PARENT
		COST SHARE (10000 FUND)
4		*SUBK Univ. of Wisconsin (Post Doc)*
	F031561	CILER CA ADMIN (728,969.00)
4	F031743	NOAA Emergency Response/Habitat Blueprint
2	F031749	Asian Carp
1	F031751	Improving runoff GL Basin
3	F031752	Lake Ontario Benthic
5	F031753	Summerfellows (176,591.00)
2		*SUBK Long Term Summerfellow (U.Toledo)*
1		*SUBK Long Term Summerfellow(UW-Madison)*
2	*F035919*	*Long Term Fellow - Kerkez*
2	*F035920*	*Long Term Fellow - Dick*
1	F031754	GIP - Climate Modeling
5	*F031755*	*SUBK PSU SeaBASS 2012 closed*
5		*SUBK PSU SeaBASS 2014*
1	F031757	Climate Change
1		*SUBK University of Wisconsin*
		SUBK - MSU
4	F031758	Tipping Points
4	*CLOSE*	*SUBK MSU - Tipping pts.*
4	*CLOSE*	*SUBK MSU - Tipping pts*
4		*SUBK Univ. Illinois - Tipping pts.*
4	*CLOSE*	*SUBK Purdue - Tipping pts.*
4	*F033822*	*SUBK SNRE Adlerstein - Tipping pts*
1	F031760	HMO -Hydrodynamic Modeling and Observ
1	F031761	Coastwatch
1	F031762	Modeling Sea Ice

1	F031767	GLRI Climate Project
4	F031769	SOAR
4		*SUBK MTRI*
4		*SUBK University of Toledo*
		SUBK GVSU
1	F031770	Larval Dispersal
3	F031773	LM-LH-LTR
3	CLOSE	*SUBK Wayne State Univ.*
3	CLOSE	*SUBK to Palm Island Environmentals*
1	F031806	GLOS
1		*SUBK SUNY ESF*
1		*SUBK Wisc-Milwaukee*
1		*SUBK Minn-Duluth*
1		*SUBK MTU*
3	F031807	NGOMEX - Impacts of hypoxia
5	F032078	CILER/GLERL seminar series
	F032506	CILER Director Oversight
3	F032629	OHH-HABS
3	CLOSE	*SUBK - Palm Island*
3	CLOSE	*SUBK - Grand Valley State*
3		*SUBK - MSU*
1	F033117	Manistique River
1		*SUBK UW-Madison*
4	F033695	Weather Ready Nation
4		*SUBK - Minnesota Sea Grant*
4		*SUBK - MSU Sea Grant*
4		*SUBK - Wisconsin Sea Grant*
4	CLOSE	*SUBK - Indiana-Illinois Sea Grant*
4	CLOSE	*SUBK - New York Sea Grant (Cornell)*
	F036968	S. Florida Coral Reefs
		SUBK - Univ. of Minnesota

	F037036	Western L. Erie Phosphorus
	F037110	FATE: Yellowtail Flounder
		SUBK - Stonybrook
	F037313	Coastal Storms
	F038477	*Coastal Storms*

Table 3. Breakdown of subcontract funding by institution:

Grand Valley State	$70,000
Indiana-Illinois Sea Grant	$5,264
Michigan State University	$312,441
Michigan State University Sea Grant	$2,731
Michigan Tech University	$504,549
MTRI (Michigan Tech University)	$125,000
Minnesota Sea Grant	$4,171
New York Sea Grant (Cornell)	$5,829
Palm Island Environmental	$128,240
Penn State University	$35,000
Purdue University	$60,000
State University of New York	$301,500
Stonybrook	$91,343
University of Illinois	$131,971
University of Minnesota-Duluth	$333,782
University of Toledo	$118,000
University of Wisconsin	$352,443
University of Wisconsin - Madison	$100,312
University of Wisconsin - Milwaukee	$229,049
Wayne State University	$30,000
Wisconsin Sea Grant	$22,479
Grand Total	$2,872,761

THEME I: Great Lakes Observing and Forecasting Systems

PROJECT TITLE: IMPROVING RUNOFF ESTIMATES IN THE GREAT LAKES BASIN

Principal Investigators: Allen Burton (CILER), Lauren Fry (CILER)
NOAA Technical Contacts: Andrew Gronewold (NOAA-GLERL)

NOAA Strategic Goal 3: Climate Adaptation and Mitigation

Overview and Objectives:
GLERL and CILER will be providing support to the International Joint Commission (IJC) during the final phases of the International Upper Great Lakes Study (IUGLS) on calculating historical Great Lakes basin runoff estimates, and for establishing a cornerstone for future (post-IUGLS) research on improving those estimates. In addition to serving as an integral component of the Great Lakes water balance, runoff estimates serve as the backbone for regional ecosystems research.

Specific Aims/Milestones: Characterize the relationship between landscape features, geomorphology, and hydrologic response across the Great Lakes basin using historical flow gauge records and GIS data.

Relationship to NOAA/CILER Goals:
- The proposed research is being conducted in collaboration with academic partners at Michigan State University.
- Runoff constitutes roughly one-third of the water balance for the Great Lakes; improving our understating of runoff variability and uncertainty propagates directly into an improved understanding of physical system and ecosystem dynamics.

We expect this research to lead to updated historical runoff estimates that will be disseminated through the (under development) Great Lakes water level data and forecasting dashboard.

Accomplishments:

The accomplishments for FY2014 are identical to those from FY2013, as the major research activities were completed in the previous year. The accomplishments from this project are detailed below.

Several activities are underway or completed to improve runoff estimates in the Great Lakes basin. The first phase of the Great Lakes Runoff Intercomparison Project (GRIP) involved an interagency binational collaboration to investigate the differences in runoff simulated by the hydrological models that are either already employed for Great Lakes basin runoff estimation or could be readily adapted. These models included NOAA GLERL's Area Ratio Method (ARM) and Large Basin Runoff Model (LBRM), NOAA National Weather Service's Sacramento Soil Moister Accounting Model (Sac-SMA), the USGS Assessment of Flows In Networks of Channels model (AFINCH), and three configurations of Environment Canada's *Modélisation Environmentale* - Surface Hydrology (MESH). Results from this study will be published in Journal of Hydrology (Fry et al., 2014). Additionally, continued collaboration with former CILER summer fellow, Jonathan Kult, on research to identify the influences of temporal scales of analysis for regionalization approaches to hydrological modeling is in review with Journal of Hydrology (Kult et al., 2014). Finally, in summer of 2013, Drew Gronewold and Lauren Fry hosted a CILER summer fellow, Nathan Kelly, who worked to configure the NWS Community Hydrologic Prediction System for application to basin-scale runoff modeling at GLERL. This involved collaborating with NWS River Forecasting Center counterparts to replicate the Sac-SMA model simulations that were conducted for the Lake Michigan GRIP project as a learning process for the GLERL hydrology team.

Publications:

Fry, L. M., Gronewold, A. D., Fortin, V., Buan, S., Clites, A., Luukkonen, C., Holtschlag, D., Diamond, L., Hunter, T., Seglenieks, F., Durnford, D., Dimitrijevic, M., Subich, Ch., Klyszejko, E., Kea, K., and Restrepo, P. (2014). The Great Lakes Runoff Intercomparison Project Phase 1: Lake Michigan (GRIP-M). *Journal of Hydrology*, In Press.

Kult, J. M., Fry, L. M., Gronewold, A. D., and Choi, W. (2014). Regionalization of hydrologic response in the Great Lakes basin: Considerations of temporal scales of analysis. *Journal of Hydrology*, In Review.

Presentations: None to report.

Outreach Activities: None to report.

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: GREAT LAKES COASTWATCH RESEARCH ASSISTANT FOR NOAA COASTWATCH PROGRAM ELEMENT

Principal Investigators: Tom Johengen (CILER)
NOAA Technical contacts: George Leshkevich (NOAA-GLERL)

NOAA Strategic Goal 5: NOAA Enterprise-wide Capabilities

Overview and Objectives:

To address critical coastal environmental problems, the National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service has established the NOAA Ocean Remote Sensing (NSORS) Program. Within NSORS, CoastWatch is a NOAA-wide program designed to provide a rapid supply of up-to-date, coordinated, environmental (remotely sensed, chemical, biological, and physical) information to support Federal, state, and local decision makers and researchers, who are responsible for managing the Nation's living marine resources and ecosystems. NOAA CoastWatch focuses on specific regional priorities, such as unusual environmental events (e.g. harmful algal blooms), accumulating algal biomass, mapping wetland change (e.g. change detection), and mapping ice cover/ice thickness (e.g. hazard mitigation).

This project focuses on research and applications development utilizing CoastWatch imagery and imagery from new satellite sensors such as synthetic aperture radar (SAR) for ice classification and mapping and ocean color sensors such as the Sea Viewing Wide Field-of-View Sensor (SeaWiFS), MODIS, and VIIRS for ocean color (chlorophyll) products. These products will enhance the CoastWatch Great Lakes product suite by developing regional products and applications for the Great Lakes, and will contribute to the operational responsibilities of sister agencies such as the U.S. Coast Guard and National Weather Service.

Regional products delivered in an untimely fashion or in a unusable format, whether to land or ship-based users, defeats the objectives and goals of the program. Therefore, the development of tools to effectively and efficiently deliver these products to regional users in near real-time and in a useable format is of great importance. This will foster additional research applications by regional data users employing the processed satellite data such as, detection and tracking of thermal fronts and analysis of

circulation patterns and upwelling (fish recruitment studies) and modeling and forecasting Great Lakes parameters (Great Lakes Forecasting System).

The goal of the CoastWatch Great Lakes program is to develop and deliver environmental data and products for near real-time monitoring of the Great Lakes to support environmental science and decision making. One of the objectives of the continuing CoastWatch program is to provide access to near real-time and retrospective satellite observations and derived products of the Great Lakes for Federal, state and local decision making and supporting research. Communications requirements and data distribution are accomplished electronically via the Internet (CoastWatch Great Lakes web site).

Additional (future) products include turbidity, ocean color (chlorophyll, DOC, SM), and ice mapping. Additional activities to be performed include participation in field data collection, research on new algorithm development of the remotely sensed data, assist in development of project reports and scientific presentations, and provide the necessary computer system and software support to facilitate these activities

Accomplishments:

A. Monitor, develop and/or improve the operational program to receive, process, analyze, and archive the CoastWatch data:

1. Wrote the idl and unix programs on CW new server (CWOPS) to produce GLSEA (dat, asc, png) using night time AVHRR image only.

2. Reorganized the file system on CWOPS to match the new GLERL network requirement:
   a. Moved all the web page and ftp files to new folders.
   b. Changed the path for all operational programs and php programs.
   c. Modified the script to download goes sst image from DDS server.
   d. Wrote the unix script to download (curl) the ice files from ice center (NIC).
   e. Wrote the unix script to download NPP VIIRS image from DDS server to CWOPS.

3. Developed the programs to download and process the Sentinel 1A SAR imagery.
4. Wrote the unix script to clean the CWOPS (reduce the used space from 87% to 79%)
5. Finished CW new server (CWO) operation system installation.

B. Maintain and improve the CoastWatch Great Lakes Node web server, design and develop the web site:

1. Installed THRDDS Server in CoastWach web server.
2. Updated the operational program and wrote a php program to show the RADARSAT image in CoastWatch web site.
3. Wrote php script for modis image in CoastWatch webpage gallery section.
4. Wrote php script to show Sentinel 1A SAR Image in CW web site.
5. Wrote the IDL and unix program to process the ice charts. Provide the graph and data for Great Lakes Long term average ice concentration (1973 - 2015) compared to current year on CW web site.
6. Wrote program to auto update modis gallery on CW web page.

C. Design, modify, and develop the software to analyze and process the CoastWatch data:

1. Wrote the IDL program to compare the NPP image and AVHRR image.

D. Participate in CoastWatch related research and prepare presentations for meetings:

2. Wrote the IDL programs to make the chart that shows the three month (Sept-Nov, 2014) departures of surface water temperatures on the Great lakes compared to the long-term average from 1995-2013. The image has showed on "Great Lakes Region Quarterly Climate Impacts and Outlook"
3. Wrote the IDL programs to make the Great Lakes ice cover anomaly chart, that shows the current 2014 (March - May) Great Lakes average ice concentration minus the long-term average concentration (1973-2013) for March, April, May. The chart has showed on "Great Lakes Region Quarterly Climate Impacts and Outlook".
4. Wrote the IDL program to make the Great Lakes ice cover anomaly chart, that shows the current 2015 (March - May) Great Lakes average ice concentration minus the long-term average concentration (1973-2014) for March, April, May. The chart will be showed on "Great Lakes Environmental research Laboratory Facebook".
5. Wrote the IDL program to process the RADARSAT 2 images for Great Lakes ice classification project.

E. Assist in the mentorship of a Great Lakes summer fellow:

1. Assist a summer student in 2014 for upwelling research.

Publications
None this reporting period - CoastWatch Update planned this year

Presentations
Presentation to NOAA Chief Scientist Rick Spinrad, OAR AA Craig McLean, and NWS AA Louis Uccellini on CoastWatch and CoastWatch related activities, February 20, 2015.

Leshkevich, G. and S.V. Nghiem, Preliminary Assessment of Sentinel-1 SAR Data for Great Lakes Ice Type Classification and Mapping. 58th Annual Conference of the International Association for Great Lakes Research, University of Vermont, Burlington, VT, May 25-29, 2015.

Outreach Activities:
None

Relevant Website:
http://coastwatch.glerl.noaa.gov

Significant Interactions/Collaborations
We developed CoastWatch-related collaborative research projects with other Federal agencies, universities, and research organizations such as NASA JPL, Michigan Tech Research Institute (MTRI), and Upstate Freshwater Institute.

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: LARVAL DISPERSAL, HABITAT CLASSIFICATION, AND FOOD WEB MODELING

Principal Investigators: Allen Burton (CILER), Dmitry Beletsky (CILER)
NOAA Technical contacts: Ed Rutherford (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

Invasive species are one of five key NOAA-identified stressors of native biodiversity and ecosystem function in the Laurentian Great lakes. In the context of on-going management and policy discussions, it is thus critical to forecast species invasions and their costs, and to predict the effectiveness and costs of potential management responses to these invasions. By integrating ecology and economics at a landscape scale, we will be able to communicate forecasts in terms of introduction pathways, which are the most appropriate targets for cost effective management, especially where preventing new invasions is the goal. We thus propose to use ecological models and GIS databases to support a NOAA CSCOR proposal (D. Lodge, PI) entitled "Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes."

To forecast what portions of the Great lakes are most vulnerable to invasions, we will use abiotic data layers to develop an environmental classification that groups areas of environmental similarity as a surrogate descriptor of biotic patterns, because abiotic data are available with more extensive spatial coverage than biological data. All GIS variables and classifications will be freely available as an output of the project and will provide a new spatial framework for a variety of applications of management interest.

We will hold an expert workshop to elicit information on model input and uncertainties and to report preliminary results of simulations for Lakes Michigan and Erie. We will revise and report simulations for lakes Michigan and Erie, and run simulations for Superior, Ontario, and Huron, while incorporating uncertainty in model parameters and under different invasion and management scenarios.

Products will include: maps and predictions of invasive species larval dispersal in four of five Great Lakes; developed databases and eco-regional habitat classifications for

environmental niche modeling; Ecopath/Ecosim food web models and predictions of invasive species impacts on Great Lakes food webs and fisheries.

<u>Accomplishments:</u>
Modeling Natural Dispersal of Invasive Species:
Dispersal of hydrilla (aquatic invasive plant) in Lake Huron and Lake Ontario has been studied with a particle transport model. The model is developed by David Schwab (University of Michigan) and is described more fully in Michalak et al. (2013) and further modified to restrict particle movement to lake surface only. Advection fields for the particle transport model are obtained from the hydrodynamic model developed by Beletsky and Schwab (2001) and ran for select years in Lake Huron on a 2 km grid and Lake Ontario on on a 1 km grid. We are predicting hydrilla transport in 2008-2010 from ports, major tributaries and boat ramps. Release times are from mid-July through November (by hydrilla turions or fragments). We targeted hydrilla settlement in nearshore waters: less than 8 m deep. Dispersal was much stronger in Lake Ontario compared with Lake Huron and we are analyzing differences in lake-average current speed as possible explanation. We are also currently finalizing two journal publications on larval transport modeling in Lakes Michigan and Erie.

Bioeconomic Models of Invasive Species Impacts on Food Webs:
The manuscript of potential impacts of Asian carp on food web of Lake Erie is submitted to Transactions of the American Fisheries Society after second revision. We used this Lake Erie EwE to investigate the potential impacts of three future invasive species, golden mussel, killer shrimp and ruffe on Lake Erie food web. Lake Michigan EwE model has been finalized and used to estimate impacts of invasive species, including Asian carps, ruffe, killer shrimp, golden mussel, and northern snakehead. We are using the models to predict the ecological services portfolio following invasive species management in both Lake Erie and Lake Michigan. The results were presented at IAGLR 2015 and a manuscript is under preparation targeting to PNAS. EwEs for Saginaw Bay and main basin of Lake Huron are developed and calibrated. The impacts on fish production of *Dreissena*, alewife and nutrient loading on Lake Huron food webs were estimated individually and combined. The results have been presented at the IAGLR 2013, 2014 meetings. We are working on manuscripts to predict Asian carp impacts on food webs in Lake Erie and Lake Michigan, Saginaw Bay and Lake Huron main basin. We continue to communicate with Drs. Tom Stewart (Ontario Ministry of Natural Resources) and Lars Rudstam (Cornell University) and colleagues on collaborative modeling of invasive species impacts on the Lake Ontario food web using EwE.

Habitat Classification and GIS data layers:

We have developed environmental data layers for Great Lakes coastal, nearshore and offshore areas to support a Great Lakes habitat classification and environmental niche models of invasive species distribution and relative abundance. Some of the habitat layers were derived from existing models of lake ice, waves, water temperature, bathymetry, circulation, while other layers (chlorophyll a, Cladophora) were produced by collaborators at Ontario Ministry of Environment, Canada's Dept. of Environment, Michigan Tech Research Institute and University of Michigan. The completed habitat data layers will be posted at the Great Lakes Aquatic habitat Framework web site (http://ifr.snre.umich.edu/projects/glahf), a collaborative habitat database and mapping project led by Drs. Catherine Riseng (University of Michigan) and Kevin Wehrly (Michigan DNR) on a server hosted by University of Michigan. Our core partners for habitat classification are at University of Michigan SNRE (Catherine Riseng, Lacey Mason, Beth-Sparks Jackson), Michigan DNR (Kevin Wehrly), Nature Conservancy (Scott Sowa, Lindsay Chadderton, Gust Annis, Mary Khoury), USGS-GGLSC (Jim McKenna and Chris Castiglione), and elsewhere (Lizhu Wang, IJC; Lucinda Johnson University of Minnesota; Dana Infante Michigan State University). This group has held webinar meetings for habitat classification each month, and a classification workshop at NOAA GLERL in Dec. 2012. We anticipate finishing the habitat classification and a technical report by September 2015.

Publications:

Beletsky, D., N. Hawley, Y.R. Rao. 2013. Modeling summer circulation and thermal structure of Lake Erie. *J. Geophys. Res. Oceans, 118, doi: 10.1002/2013JC008854*

Cleary, P., N. Fuhrman, L. Schulz, J. Schafer, J. Fillingham, H. Bootsma, E.J. Williams, S.S. Brown. Ozone distributions over southern Lake Michigan: Comparisons between ferry-based and shoreline observations, and air quality forecast models. In review Atmospheric Chemistry and Physics

Kao Y-C, Adlerstein S, Rutherford E. 2014. The relative impacts of nutrient loads and invasive species on a Great Lakes food web: An Ecopath with Ecosim analysis. Journal of Great Lakes Research 40, Supplement 1: 35-52.

Presentations:

Beletsky, D., R. Beletsky, J. L. Sieracki, J.M., Bossenbroek, W.L. Chadderton, and E., Rutherford. Modeling Larval Dispersal of Invasive Species in Lake Michigan 38th Annual Larval Fish Conference. August 17-21, Quebec City, Canada

Beletsky, D., R. Beletsky, J. L. Sieracki, J.M., Bossenbroek, W.L. Chadderton, and E., Rutherford. Modeling spread of invasive species in Lake Michigan. IAGLR, May 26-30, 2014, Hamilton, ON.

Beletsky, R. D. Beletsky, J. Sieracki, J. Bossenbroek, L. Chadderton, and E. Rutherford. Modeling spread of invasive species by Lake Currents.16th Workshop on Physical Processes in Natural Waters, Queensland, Australia, 8-11 July 2013.

Beletsky, D. Modeling thermal structure and circulation in the Great Lakes. GIS Day 2011 Modeling Symposium, University of Notre Dame, December 2, 2011, South Bend, IN.

Bootsma, H.A. Nearshore trophic structure and ecosystem dynamics in Sleeping Bear Dunes National Lakeshore. Avian Botulism in Distressed Great Lakes Environments. Ann Arbor, MI, January 7-8, 2014.

Bootsma, H.A. , B.A. Turschak, E.H. Tyner, C.M. Mosley, and Z.G. Driscoll. Temporal and spatial shifts in Lake Michigan carbon and nutrient dynamics as revealed by stable C and N isotopes. American Society for the Sciences of Limnology and Oceanography. Honolulu, HI, Feb. 23-28, 2014.

Bootsma, H.A. Lower food web dynamics in Lake Michigan. Invited presentation. Great Lakes Regional Research Information Network (GLRRIN). Ann Arbor, MI. April 1-2, 2014.

Bootsma, H.A. Regulation of nuisance algae by phosphorus and trace metals in Lake Michigan. Presentation given to Wisconsin Department of Natural Resources. Feb. 11, 2014.

Bootsma, H.A., and B. Turschak. Factors regulating avian botulism outbreaks in Lake Michigan. Avian Botulism in Distressed Great Lakes Environments. Jan. 7-8, 2014. Ann Arbor, MI.

Bravo, H.R., S.A. Hamidi, J.T. Waples, and J.V. Klump. (in press).   Modeling multiple physical drivers of the circulation and thermal regimes impacting seasonal hypoxia in Green Bay, Lake Michigan. In Modeling Coastal Hypoxia – Numerical Simulations of Patterns, Controls and Effects of Dissolved Oxygen Dynamics. Springer.

Chadderton, W.L., Jerde, C.J., Mahon A.M., Wittmann, M.E., Tucker, A.J., D.L. Lodge., J. Bossenbroeck, J. Seracki,and D. Beletsky. Eurasian ruffe –implications of recent eDNA surveillance efforts in the Laurentian Great Lakes. 18th International Conference on Aquatic Invasive Species, April 21-25, 2013, Niagara Falls, Ontario, Canada.

Fillingham, J.H., and H.A. Bootsma. Modeling carbon and phosphorus cycles in the nearshore zone of Lake Michigan. International Association for Great Lakes Research. Hamilton, Ontario, Canada. May 26-30, 2014.

Grunert, Brice, Val Klump, Colleen Mouw. 2014. The role of meteorological forcing on the persistence and mixing of distinct water masses in Green Bay, Lake Michigan. AGU Ocean Sciences Meeting, Honolulu HI Feb. 23-28, 2014.

Kao, Y.C., Adlerstein-Gonzalez, S., *Rutherford, E.S., Zhang, H. Identifying ecological tipping points for a Great lakes food web: An Ecopath with Ecosim analysis Joint Aquatic Sciences Meeting (JASM) 2014, Portland, Oregon, May 18-23, 2014

Klump, J.V., Hector Bravo, James T Waples, Shelby Labuhn, Tracy Valenta, John Kennedy, David Lorenz, Kevin Fermanich, Paul Baumgart, Sajad A. Hamidi. 2014. Multiple drivers of temporal and spatial trends in the biogeochemistry of hypoxia in Green Bay, Lake Michigan. AGU Ocean Sciences Meeting, Honolulu HI Feb. 23-28, 2014

Klump, J.V., K. Fermanich, J. Kennedy, S. LaBuhn, T. Valenta, J. Waples and M. Zorn. 2014. Dolan, Data and Green Bay (David Dolan Memorial session), IAGLR Conf. Hamilton Ont, May 26-30, 2014.

Klump, J.V., Briefing on Hypoxia & Research in Green Bay, Green Bay Metropolitan Sewerage District Board of Commissioners, March 26, 2014, NEW Water, Green Bay WI

Klump, J.V., South Shore Yacht Club, March 26, 2014, Milwaukee, WI

Klump, J.V., "*Dead zones* in Green Bay – what's the deal?"   Baird Creek Preservation Foundation, April 7, 2014, Green Bay WI

Klump, J.V., League of Women Voters, April 12, 2014, Milwaukee WI

Klump, J.V.,   Wingspread Conference on Climate Change and the Great Lakes, April 15-17, 2014

Klump, J.V., "Green Bay: Dead zones, climate and its future." 17th Biennial Seminar on Water Resources and Environmental Management, June 17, 2014. U. Wisconsin-Green Bay, WI

Phillips, J.C., G.A. McKinley, V. Bennington, H.A. Bootsma, D.J. Pilcher, R.W. Sterner, and N.R. Urban. CO_2-induced acidification of the Laurentian Great Lakes. American

Society for the Sciences of Limnology and Oceanography. Honolulu, HI, Feb. 23-28, 2014.

Pilcher, D., G. McKinley, H. Bootsma, and V. Bennington. Physical drivers of Lake Michigan biogeochemistry. American Society for the Sciences of Limnology and Oceanography. Honolulu, HI, Feb. 23-28, 2014.

Rutherford, E.S., Zhang, H., Breck, J., Mason, D., Zhu, X., Johnson,T., Cooke, R., Wittman, M., Lodge, D., Rothlisberger, J., Finnoff, D. Quantifying uncertainty of Asian carp impacts on Lake Erie's food web and fisheries. The 142nd Annual Meeting of the American Fisheries Society, Minneapolis– St Paul, MN, August 19-23, 2012.

Rutherford, E.S., Zhang, H., Breck, J., Mason, D., Zhu, X., Johnson,T., Cooke, R., Wittman, M., Lodge, D., Rothlisberger, J., Finnoff, D. Quantifying uncertainty of Asian carp impacts on Lake Erie's food web and fisheries. ICAIS 2013. Niagara Falls, Ontario. April 21-24, 2013.

Rutherford E.S., Zhang, H., Mason, D. M., Lodge, D. M., Wittmann, M.E., Cooke, R.M., Breck, J.T., Vanderploeg, H.A. Relative Importance of Timing, Life History, and Habitat of Non-Indigenous Species for Predicting Invasion Success and Impact in Great Lakes Ecosystems. Joint Aquatic Sciences Meeting (JASM) 2014, Portland, Oregon, May 18-23, 2014

Rutherford, E.S., Zhang, H., Barnes, M.A., Chadderton, W.L., Finnoff, D.C., Shakoor, A., Mason, D.M., Wittmann, M.E., Lodge, D.M., Apriesnig, J. And Warziniack, T. Run DMC! Forecasting Ecological Impacts of Dreissenid Mussel Control on Great Lakes Food Webs. IAGLR 58th Annual Conference on Great Lakes Research, New Views New Tools, Burlington, Vermont, May 25-29, 2015.

Turschak, B.A., and H.A. Bootsma. Spatial variability in the trophic structure of Lake Michigan fishes as revealed by stable C and N isotopes. International Association for Great Lakes Research. Hamilton, Ontario, Canada. May 26-30, 2014.

Wittmann, M.E., Cooke, R. M., Rothlisberger, J.D., Rutherford, E.S., Zhang, H., Mason, D.M., Lodge, D.M. Structured expert judgment forecasts bighead and silver carp in Lake Erie with little effect on sport and commercial fish populations. Joint Aquatic Sciences Meeting (JASM) 2014, Portland, Oregon, May 18-23, 2014

Zhang, H., Rutherford, E, Mason, D., Ivan, L., Lodge, D., Wittmann, M., Cooke, R., Rothlisberger, J., Breck, J., Zhu, X., Johnson, J. Forecasting impacts of Asian Carp on the Lake Erie food web. NMFS-OAR Modeling Uncertainty Workshop, April 13-15. 2015. Ann Arbor MI,

Zorn, M.E.; Waples, J.T.; Valenta, T.; Kennedy, J.; Klump, J.V. High temporal resolution determination of dissolved phosphate and nitrate in Green Bay, Lake Michigan using continuous monitoring, in situ sensors. Green Bay Hypoxia Workshop: Biogeochemical Dynamics, Watershed Inputs and Climate Change. May 2, 2014. Green Bay, WI.

Zorn, M.E.; Waples, J.T.; Valenta, T.; Kennedy, J.; Klump, J.V. Determination of phosphate, nitrate, dissolved oxygen and temperature in Green Bay, Lake Michigan using high temporal resolution in situ sensors. 17th Seminar on Water Resources and Environmental Management. June 19-20, 2014. Green Bay, WI.

Outreach Activities:

Webinar entitled "Modeling risk and potential impacts of silver and bighead carp invasion on Great Lakes food webs." Research results from this project were presented to an audience of 22 people. Mar 12, 2015.

E. Rutherford, H. Zhang, L. Ivan, Y-C. Kao, S. Adlerstein, A. Shakoor, D. Mason, D. Lodge, M. Wittmann, R. Cooke, J. Rothlisberger, and J. Breck. Modeling Risk and Effects of Bighead and Silver Carp on Great Lakes Food Webs.

Relevant websites

CSCOR Great Lakes Aquatic Habitat
Classification: http://ifr.snre.umich.edu/projects/glahf

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: GREAT LAKES RESTORATION INITIATIVE CLIMATE PROJECT

Principal Investigators: Allen Burton (CILER); Michael Notaro (University of Wisconsin Center for Climate Research)
NOAA Technical Contacts: Jia Wang (NOAA-GLERL); Andrew Gronewold (NOAA-GLERL); Brent Lofgren (NOAA-GLERL)

NOAA Strategic Goal 3: Climate Adaptation and Mitigation

Accomplishments:
- Four Coupled Model Intercomparison Project Phase Five (CMIP5) global climate models (GCMs), namely MIROC5, CNRM-CM5, IPSL-CM5-MR, and MRI-CGCM3, have been dynamically downscaling using the International Centre for Theoretical Physics (ICTP) Regional Climate Model Version Four (RegCM4), interactively coupled to a one-dimensional lake model to represent the Laurentian Great Lakes. The downscaling includes the Great Lakes Basin, applies a horizontal grid spacing of 25-km, and covers the time periods of the late 20th, mid-21st, and late 21st centuries. Two additional CMIP5 GCMs, namely ACCESS1-0 and GFDL-ESM2M, are in the process of being dynamically downscaled with RegCM4 in order to expand the pool of downscaled models to six.
- The RegCM4-based dynamical downscaling data is being applied for a diverse range of applications.
  (1) Using the GLERL channel model, future water levels of the Laurentian Great Lakes have been estimated based on MIROC5-RegCM4 and CNRM-RegCM4, with ongoing efforts to product additional water level estimates based on IPSL-RegCM4, MRI-RegCM4, ACCESS-RegCM4, and GFDL-RegCM4. Results from the MIROC5-RegCM4 and CNRM-RegCM4-based projections of lake levels, water temperatures, ice cover, and evaporation were summarized in a publication, which is now in revision. The study found that, while the downscaling of both GCMs led to consistent (in terms of sign) projections of increases in annual air temperature, precipitation, and all net basin supply (NBS) components, the resulting projected water level trends are opposite in sign. It was clear that it is not sufficient to correctly simulate the signs of the projected change in each NBS component but also their relative magnitudes.
  (2) Future changes in lake-effect snow within the Great Lakes Basin were analyzed in the MIROC5-RegCM4 and CNRM-RegCM4 simulations and published.

According to the study, Great Lakes' ice cover is projected to dramatically decline and, by the end of the century, become confined to the northern shallow lakeshores during mid-to-late winter. Projected reductions in ice cover and greater dynamically induced wind fetch lead to enhanced lake evaporation and resulting total lake-effect precipitation, although with increased rainfall at the expense of snowfall. A general reduction in the frequency of heavy lake-effect snowstorms is simulated during the 21st century, except with increases around Lake Superior by the mid-century when local air temperatures still remain low enough for wintertime precipitation to largely fall in the form of snow.

(3) In collaboration with the State University of New York at Oswego and Ducks Unlimited, cumulative winter severity indices, based on air temperature and snow depth, are being computed to estimate projected changes in dabbling duck populations and migration timing for eastern North America, including the Great Lakes region.

(4) In collaboration with the Michigan Department of Natural Resources and University of Wisconsin-Extension, climate change projections have been developed for the state of Michigan. Impacts of projected changes in temperature and snow depth on white-tailed deer abundance across the Midwest and Great Lakes Basin are being investigated.

(5) In collaboration with the Great Lakes Indian Fish and Wildlife Commission, dynamically downscaled climate change projections for Minnesota, Wisconsin, and Michigan are being applied to investigate climate change implications for wildlife on tribal lands.

(6) The Ontario Climate Consortium is using the dynamically downscaled climate data in a series of hydrologic modeling and risk assessment studies of small watersheds in Ontario, Canada.

Publications:

Notaro, M., V. Bennington, and B. Lofgren, 2015: Dynamical downscaling-based projections of Great Lakes' water levels. *J. Climate*, in revision.

Notaro, M., V. Bennington, and S. Vavrus, 2015: Dynamically downscaled projections of lake-effect snow in the Great Lakes Basin. *Journal of Climate*, 28, 1661-1684.

Bennington, V., M. Notaro, and K.D. Holman, 2014: Improving climate sensitivity of deep lakes within a regional climate model and its impact on simulated climate. *Journal of Climate*, 27, 2886-2911.

Notaro, M., A. Zarrin, S. Vavrus, and V. Bennington, 2013: Simulation of heavy lake effect snowstorms across the Great Lakes Basin by RegCM4: Synoptic climatology and variability. *Monthly Weather Review*, 141, 1990-2014.

Notaro, M., K. Holman, A. Zarrin, E. Fluck, S. Vavrus, and V. Bennington, 2013: Influence of the Laurentian Great Lakes on regional climate. *Journal of Climate*, 26, 789-804.

Holman, K.D., A. Gronewold, M. Notaro, and A. Zarrin, 2012: Improving historical precipitation estimates over the Lake Superior basin. *Geophysical Research Letters*, 39, L03405, doi:10.1029/2011GL050468.

Presentations:
Dynamically downscaled projections of lake-effect snow in the Great Lakes Basin, May 2015, American Geophysical Union Joint Assembly, Montreal, Canada.

Dynamical downscaling-based projections of Great Lakes' water levels, May 2015, University of Wisconsin-Madison Water Symposium, Madison, Wisconsin.

Application of dynamical downscaling to generate projections of winter severity, with implications for waterfowl migration and deer survival, March 2015, Joint webinar of the Northeast Climate Science Center and Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative, Madison, Wisconsin.

Development of climate projections for the Great Lakes region, November 2014, Webinar presentation to the Great Lakes Water Quality Agreement Climate Annex Subcommittee, Madison, Wisconsin.

MET-606 Historic and projected Wisconsin climate change, impacts, and adaptation, October 2014, University of Wisconsin-Madison, Molecular and Environmental Toxicology (MET-606) class, Madison, Wisconsin.

Overview of relevant research on climate change projections/adaptation and dust storms, August 2014, Meeting with Iranian visitors through the World Learning Initiative, Madison, Wisconsin.

Climate change 101, July 2014, AINL G-WOW (Gikinoo'wizhiwe Onji Waaban) Changing Climate, Changing Culture Institute, Ashland, Wisconsin.

Outreach Activities:
Taught three sessions, "Climate change 101", "Tips and tools for educating about climate change and taking action", and "Addressing the climate change controversy" at the Apostle Islands National Lakeshore (AINL)Gikinoo'wizhiwe Onji Waaban GWOW) Changing Climate, Changing Culture Institute, Ashland, Wisconsin, July 2014.

Interviews and Press Releases:
The Why Files (whyfiles.org), "Climate change: Who is a climate scientist?", 2015.
Syracuse Post-Standard, "Study: Less lake effect snow, more rain near Great Lakes as climate changes", 2014.

Wisconsin Center for Academically Talented Youth (WCATY) Summer Transitional Enrichment Program (STEP) Summer Sentinel, "The beginning of the end: Impact of global warming will be felt throughout the 21st century", 2014.

Wisconsin Public Radio, "Despite record lake ice this winter, climate forecasts still say trend is warming," 2014.

Nelson Institute news release, "Climate research shows changes in Midwestern winters," 2014.

Public News Service article, "Research shows big changes coming in Wisconsin winters," 2014.

Madison.com, "UW researcher: Good chance for less snow but more rain in winter later this century," 2014.

Related website:
Interactive mapping website for the dynamically downscaled climate projections
http://ccr.aos.wisc.edu/resources/data_scripts/dyndown/

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: HYDRODYNAMIC MODELING AND CONTAMINATED SEDIMENT IN MANISTIQUE RIVER, MI

Principal Investigators: Chin H. Wu (University of Wisconsin-Madison)
NOAA Technical Contacts: Eric Anderson (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

The Manistique River Area of Concern covers the last 1.7 miles of the Manistique River. The contamination legacy comes from industrial waste (oils and combined sewer overflows) as well as debris and sawdust from more than a century of logging and milling. Currently, there still remains two beneficial use impairments that include a restriction on dredging and on fish consumption. A multi-agency and multidisciplinary effort is underway in order to understand and remediate the Manistique River. The Cooperative Institute for Limnology and Ecosystems Research (CILER), US-EPA, Great Lakes Environmental Research Laboratory (GLERL), US Geological Survey Water Resources of Michigan, National Marine Fisheries Service and the University of Wisconsin-Madison are working together with the ultimate goal of delisting Manistique River from being an Area of Concern. Extensive field measurements have been conducted by the University of Wisconsin-Madison in order to assess effective remediation actions plans (RAP). In particular, detailed atmospheric, flow, and sediment parameters are employed to further reveal the role of the physical processes on the fate and transport of contaminated sediments. Additionally, the hydrodynamics and sediments data

Figure 1. Location of measurements
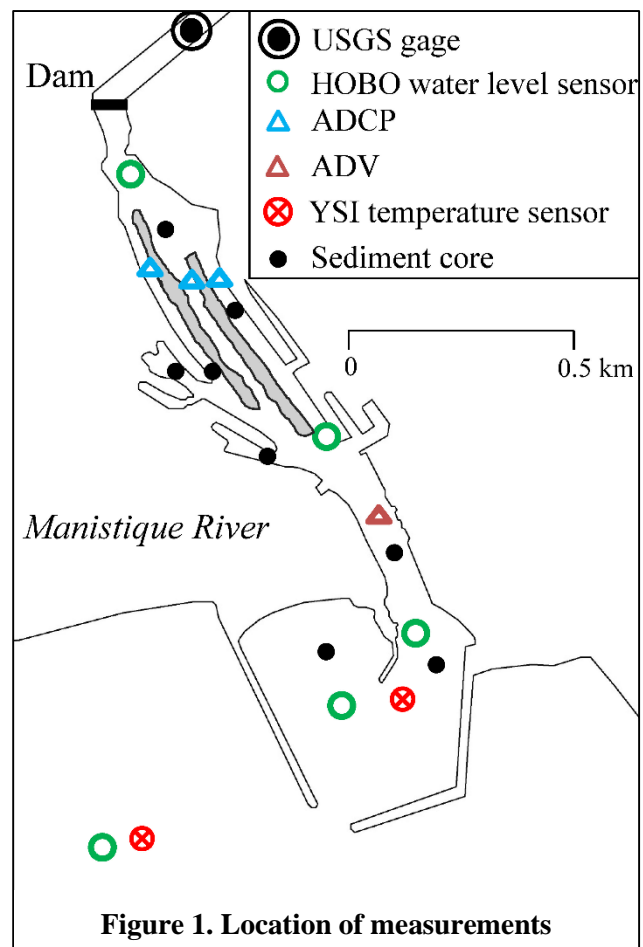
would be used to estimate contaminated sediment residence time, and help identify potential contaminant sources in Manistique River, MI.

The specific objectives of the project are:

- Conduct an extensive fieldwork campaign in the Manistique River to collect observations of water velocities, water levels, temperature, turbidity, discharge, conductivity, and bottom sediment samples for hydrodynamic model calibration. In addition side-scan sonar (SSS) mapping inside the harbor and along Manistique River would be performed.
- Sediment material types, critical shear stress, and erosion potential would be obtain for determining bottom sediment characteristics necessary for sediment modeling. Furthermore, field observations would be compiled and prepared for the input of a 3D hydrodynamic model of the Manistique River. Subsequently, the bottom sediment properties and the 3D hydrodynamic model outputs are used as input to a novel sediment particle tracking model.

Accomplishments:

The field work campaign in the Manistique River conducted in 2012 provided essential information for the data analysis and numerical modeling efforts that have been carried out during 2014 and 2015. Figure 1 shows the locations of water level, water velocity profile, water quality, temperature, and sediment samples. The hydrodynamic monitoring and sediment sample locations were distributed to cover both inside and outside Manistique River, starting from upstream Dam, Paper Mill, Upstream and Downstream of the Islands, Route 2, River Mouth, and inside and outside Harbor. High resolution sampling frequency (at least every 10 minutes) was employed for the whole monitoring period (June - November, 2012).

Furthermore we measured velocity and turbulence using an acoustic Doppler velocimeter (ADV) for examining bottom shear stress. Using SSS, the bottom stratigraphy mapping was

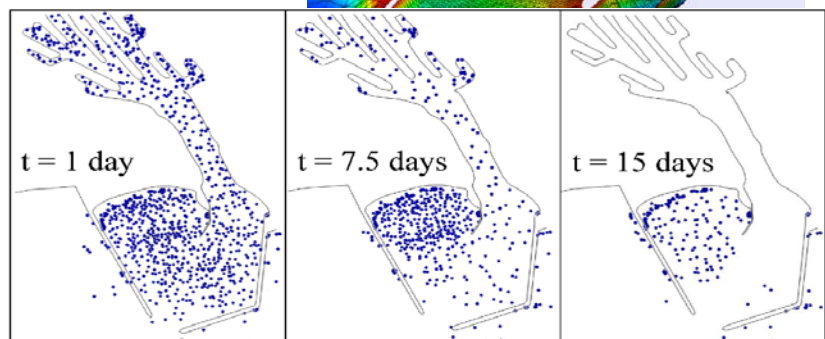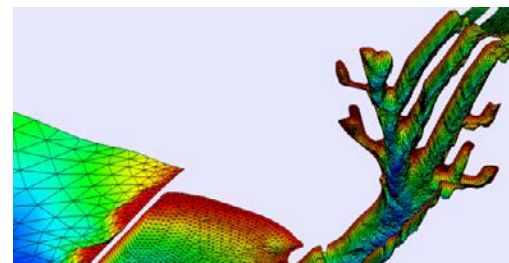

Figure 2. Bottom sediment softness.

Figure 4. Snapshots of sediment particle distribution under seiche motion

43

obtained (see Figure 2 with hard/soft bottom in bright/dark color). Multiple sediment erosion tests were conducted in the Water Resources laboratory of the University of Wisconsin-Madison in order to obtain the erosion rates and critical shear stress of the sediment samples. Since July, 2014, we have focused on the development of a novel particle tracking modeling approach to investigate sediment transport processes. The particle tracking model relies on the output of a hydrodynamic model. Hydrodynamic and sediment data were compiled and formatted to be the input for the FVCOM hydrodynamic model. A high-resolution unstructured mesh with more 500,000 elements was developed to accurately resolve the complex geometry of Manistique River (Fig. 3). Subsequently, the particle tracking model uses as input the hydrodynamic outputs of FVCOM and the sediment properties obtained from the laboratory tests of the sediment samples. We aim to reveal the role of the "normal" streamflow, flood flows, water level oscillations (seiches/high frequency), and temperature gradients in the transport of contaminated sediments. In particular, the particle tracking model is used to estimate how long does it take for the contaminated sediments to be flushed out of Manistique River under different hydrodynamic conditions. Figure 4 shows the temporal variation of bed sediment particles location under one of our seiches numerical experiments.

We have reached the following conclusions: (i) During the summer low flow condition, erosion and sediment transport are relatively small; (ii) seiches caused by storm events can play an important role in flushing out contaminated sediments; (iii) During the spring high flow, contaminated sediments are highly mobilized; and (iv) The combined high flow and seiches can resuspend and rapidly flush out contaminated sediments from the AOC to Lake Michigan.

CILER and UW-Madison scientists have collaborated in modeling the sediment transport and conducting the field campaign. During the project period, we had several meetings with Dr. Eric Anderson at the NOAA Great Lake Environmental Research Laboratory, and at the International Association of Great Lakes Conference. Weekly discussions via email and phone conversations have led to the success of the development of a novel sediment transport modeling approach.

Publications:
Linares, A., Wu, C.H., Anderson E.J., Role of High-Frequency Water Level Oscillations and Flood Flows on contaminated sediment transport in the Manistique River, Michigan, to be submitted to *Journal of Great Lakes Research*.

Linares, A., Wu, C.H, Anderson E.J., Bechle, A.J., Meteorologically induced high-frequency water level oscillations in northern Lake Michigan, to be submitted to *Journal of Geophysical Research*.

Presentations:

Linares, A., Anderson, J.D., Anderson E.J., Wu, C.H., Role of High-Frequency Water Level Oscillations and Flood Flows on contaminated sediment transport in the Manistique River, Michigan, IAGLR, Burlington, May 25-29, 2015.

Wu, C.H., Linares, A., Meteorologically induced high-frequency water level oscillations in northern Lake Michigan, IAGLR, Burlington, May 25-29, 2015.

Outreach Activities:

Throughout the project, we further collaborated with Dr. Eric Anderson and Dr. David Schwab for developing novel numerical modeling approaches to investigate the transport of contaminated sediments.

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: A HIGH-RESOLUTION ATMOSPHERIC, WAVE AND CIRCULATION MODEL GUIDANCE SYSTEM FOR THE GREAT LAKES REGION

Principal Investigators: Allen Burton (CILER), Ayumi Manome (CILER)
NOAA Technical contacts: Eric Anderson (NOAA-GLERL), Jia Wang (NOAA-GLERL)

NOAA Strategic Goal 3: Climate Adaptation and Mitigation

Overview and Objectives:

The Great Lakes region currently has no model guidance capacity regarding the combined wind- and wave-induced coastal surge events, including meteotsunamis/seiches. This is an important omission, since waves can significantly impact surge levels, and conversely currents can steepen waves, causing dangerous nearshore conditions. This project addresses these shortcomings by developing a combined circulation, ice and wave model, run on an unstructured grid and a high-resolution atmospheric model. The work will be achieved through a close collaboration within NOAA-wide integrated team that includes GLERL, National Centers for Environmental Prediction (NCEP), National Weather Service (NWS), and National Ocean Service (NOS), as well as the researchers at CILER.

Specific Aims/Milestones:

The four main goals are listed as below. In FY 2015, the milestones 1, 2, and part of 3 are targeted. This work represents the next generation in operation wave and circulation modeling in the Great Lakes, and will extend the NWS/NOS's present forecast capability to high-risk areas in the nearshore.

1. Develop a prototype unstructured wave modeling system to better resolve the transition from deeper water, through the nearshore, and into the surf zone.
2. Add high-resolution atmospheric forcing to drive the coastal hydrodynamic processes at the proper level of detail.
3. Integrate the unstructured grid wave model with the FVCOM-based unstructured grid circulation models currently being developed at GLERL.
4. Combine all these elements and transit the modeling system to operations.

Achievements:

Related to Milestone 1

- A number of high-risk coastal field sites were identified (e.g.
- Saginaw Bay, Lake St. Clair, Green Bay, and Grand Traverse Bay , southern shore of Lake Michigan, Cleveland).
- The unstructured grids for the hydrodynamic and wave models were developed.

Related to Milestone 2

- A high-resolution WRF atmospheric model was set up. Several spatial resolutions were selected (12 km, 4 km, 1 km).
- A number of hindcasts of the hydrodynamic model and the wave model were conducted for historic storms across the Great Lakes (e.g. 2012 super storm Sandy, 2014 Halloween event that caused a severe surge in the southern shore of Lake Michigan). The hydrodynamic and wave models are forced by the WRF outputs, as well as the interpolated meteorology that is based on the observations over the Great Lakes from the National Data Buoy Center and the Coastal Marine Automated Network. (Also related to Milestone 3)
- The hindcasts results were assessed by comparing with observations of water level, temperature, and significant wave height.
- The meteotsunamis and wind wave events from the new unstructured grid models to results from a high resolution Cartesian grid. The results are similar, increasing confidence in the new models.
- The high-resolution WRF atmospheric model outputs were evaluated in comparison with the available observations at Great Lakes NOAAPORT. A summer fellow under the GLERL-CILER summer fellowship program participated in the work, developing the python program to compare the WRF model outputs with the various observations.

Publications:

Anderson, E.J., A.J. Becgle, C.H. Wu, D.J. Schwab, G.E. Mann, K.A. Lombardy, Reconstruction of a Meteotsunami in Lake Erie and the Effects of Enclosed Basins on Hydrodynamic Response, in preparation.

Manome, A., and J. Wang, Simulating hydrodynamics and ice cover in Lake Erie using an unstructured grid model, in preparation.

Presentations:

Anderson, E.J., Lake Erie FVCOM performance and comparison to GLCFS/POM, 2014 NOAA FVCOM Workshop, Silver Spring, MD, September 9-10, 2014.

Anderson, E.J., A.J. Bechle, C.H. Wu, G.E. Mann, D.J. Schwab, and K. Lombardy, Detection and Reconstruction of a Meteotsunami on Lake Erie, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Van der Westhuysen, A., E.J. Anderson, G. Mann, H. Alves, J.G.W. Kelley, E. Myers, A. Manome, and D.J. Schwab, A High-Resolution Atmospheric, Wave and Circulation Forecast System for the Great Lakes Region, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Kelley, J.G.W., E.J. Anderson, Y. Chen, G. Lang, and J. Xu, Upgrade of NOAA/NOS' Lake Erie Operational Forecast System to FVCOM: Skill Assessment, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Wang, J., Application of a modified version of FVCOM to Great Lakes hydrodynamic-ice modeling, 2014 NOAA FVCOM Workshop, Silver Spring, MD, September 9-10, 2014.

Outreach Activities: None to date

Relevant Web content:
- Great Lakes Coastal Forecasting System: http://www.glerl.noaa.gov/res/glcfs/
- Great Lakes NOAAPORT : http://coastwatch.glerl.noaa.gov/marobs/

Supplemental Material: None to date

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: GREAT LAKES OBSERVING PROGRAM

Principal Investigators: Thomas Johengen (CILER), Guy Meadows (Great Lakes Research Center, Michigan Technological University), Jay Austin (Large Lakes Observatory, University of Minnesota – Duluth), Gregory L. Boyer (Great Lakes Research Consortium, SUNY-ESF), J. Val Klump (Great Lakes WATER Institute, University of Wisconsin-Milwaukee), B. Shuchman (Michigan Technological Research Institute) and W. Charles Kerfoot (Lake Superior Ecosystem Center, Michigan Technological University)

NOAA Technical Contacts: Dave Schwab (NOAA-GLERL), Steve Ruberg (NOAA-GLERL)

NOAA Strategic Goal 5: NOAA Enterprise-wide Capabilities

Overview and Objectives:

The GLOS-RA proposed to implement key observing system and modeling improvements over the 2012-17 period that focus on critical needs of the Great Lakes region as identified through an extensive needs assessment process. The overall focus of the program is to develop new products for four priority issue areas that affect the health, well-being and economic viability of the region, these being: climate change impacts; ecosystem and food web dynamics; protection of public health; and navigation safety and efficiency. Critical information needs for these priority areas are being addressed by implementation of an array of integrated observations including new moorings and additional sensors to measure temperature and current profiles. AUV/glider technologies are being initiated to collect critical transect information. Cross-lake ferries and other vessels of opportunity are being instrumented to collect repetitive observations of surface chemistry. Satellite remote sensing products are being derived to begin daily monitoring of lake surface loadings of nutrients and sediments. CILER and associated partners within the nearshore observing team have helped establish, maintain, and develop operational capabilities for the proposed observing system components including data collection and output and new products to serve identified users and managers within the Great Lakes.

The work proposed under this project will significantly advance implementation of the rapidly evolving GLOS-RCOOS conceptual design. Data and information needs of the four priority issues addressed under this proposal will satisfy the following specific objectives:

- Increase nearshore observations to improve wind/wave forecasting and circulation modeling;
- Improve monitoring of lake heat and water balances;
- Advance nearshore ecological forecasting procedures;
- Develop continuous running high resolution hydrodynamic models of the interconnecting waterways; and
- Integrate information and deliver customized products that meet specific user needs.

This project addresses NOAA Strategic Plan Goal(s):
 1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;
2) Understand climate variability and change to enhance society's ability to plan and respond;
3) Serve society's needs for weather and water information;
4) Support the nation's commerce with information for safe, efficient, and environmentally sound transportation

<u>Accomplishments:</u>
<u>University of Michigan</u>
The University of Michigan CILER deployed one S2 coastal monitoring buoy for the 2014 Great Lakes navigational season off the coast of Ludington, Michigan. The buoy contains an inertial wave sensor (IWS) as well as a met package and a thermistor string. The buoy transmits all data real-time in ten minute intervals to the GLOS website, the UGLOS website and the NDBC. The buoy was retrieved for the winter season in November 2014. During the winter the buoy was maintained and readied for the 2015 deployment. The buoy was deployed May 18, 2015 for this navigational season, it continues to transmit all data to GLOS, UGLOS and the NDBC. CILER also continues to maintain the S2 buoy that is deployed in Douglas Lake in partnership with University of Michigan's Biological Station. It was maintained over the winter and deployed on April 30, 2015.

In addition to the buoy observations, the glider was deployed 3 times during the 2014 navigational season. The first deployment was May 19th through June 19th in Lake Michigan. During this 31 day deployment, the glider sailed 4 lake crossings covering 679 km of lakebed and collecting 2950 water column profiles. The glider sailed two more missions in Lake Michigan during the navigational season, the second mission ran for 32 days, from July 25th through August 28th with the third mission running 30 days from September 18th through October 17th. The glider flew 784 km during the second deployment, collecting 2800 profiles and it flew 660 km on the third mission collecting

3600 profiles. This full water column data will be used to compliment the Lake Express Ferry Box surface observations.

This winter, the glider was returned to Slocum for CTD calibration and was outfitted with a new hull extension to support the addition of a Bio-Spherical PAR sensor. The PAR will be used for verification of remote sensing in Lake Michigan. A new lithium battery pack was also purchased, allowing the glider to be deployed for a total of 180 days per pack in comparison to the 30 days if it were run on the alkaline battery pack.

The AUV's flew one mission together so that the newly refitted YSI AUV could be verified against the existing YSI AUV. The AUV's were maintained and calibrated over the winter season. A new technician has been training on the deployment and use of the AUV's to help support the existing technician in deployments this summer.

In partnership with GLERL, four restoration sites located in Muskegon Lake were mapped using side scan sonar during the first week of May.

All data from 2013 missions have been processed using the IOOS Toolbox and is ready to be sent to IOOS. Data collected in 2012 is currently being used by IOOS for testing the second generation glider Data Assembly Center (DAC.) The Lake Ontario Cooperative Science and Monitoring Initiative (CSMI) data from 2013 has been disseminated.

University of Wisconsin- Milwaukee
Between May and November 2014, the UW-Milwaukee School of Freshwater Sciences at the Great Lakes WATER Institute operated several observing systems as part of GLOS, including two nearshore buoys at depths of 10 m and 20 m (NOAA 45013) north of Milwaukee, a buoy in Green Bay (13 m, NOAA 45014) and a monitoring system on the high speed Lake Express ferry that operates between Milwaukee WI and Muskegon MI. In addition, SFS has been helping to coordinate the collection and dissemination of data from two other nearshore locations on Lake Michigan – one at Kewaunee, operated by the Wisconsin DNR, and one at Sleeping Bear Dunes National Lakeshore, operated by the National Park Service. With the exception of some minor problems, these systems were fully operational during the reporting period

Problems with the temperature string reliability resulted in replacement of the existing strings with RST thermistor strings (www.rstinstruments.com), and additional support was received to assist in this replacement. These strings required some changes in the interface hardware (accomplished at sea), but   proved to be robust and provided an excellent record following interface repairs. As reported previously the pressure based wave gage sensor system proved problematic and was not deployed on either buoy in

2014. We are investigating other options. For the 2014 season, systems were operable during the following times (percentage of season): <u>Milwaukee 45013</u>: Met station 5/05/14 to 11/21/14 (98%); Sondes 5/05/14 to 11/21/1413 (88%); Aquadopp current meter 5/05/14 to 11/21/14 (96%); Temperature string 5/05/14 to 11/21/14 (80%). In addition to the above measurements, this buoy was augmented by several bottom sensors, including a light logger, a bottom sonde, and a time lapse camera. The data from these sensors have been used, to calibrate and validate a nearshore ecosystem model that will be used by managers to predict the severity of nuisance algal blooms and to develop nutrient management criteria for the Lake Michigan nearshore zone.

The Green Bay Met station (45014) operated from 5/30/14 to 10/08/14 (100%); Sondes from 5/30/14 to 10/08/14 (100%); Aquadopp current meter from 5/30/14 to 10/08/14 (99%); Temperature string from 5/30/14 to 10/08/14 (74%).

The Green Bay buoy was deployed from late May to early October, 2014. Oxygen sensor data from the surface water combined with meteorological data are producing the first continuous estimates of oxygen exchange across the air-water interface, water column gross primary production (GPP), and net ecosystem production (NEP). These data are contributing to a larger effort to understand the drivers of hypoxic and anoxic conditions in Green Bay.

The Lake Express High-Speed Ferry monitoring system was reinstalled in May 20th and monitoring began immediately. The system worked well throughout the 2014 ferry operating season (May – Oct). All data collected since 2007 have been analyzed. Some of these data are currently being used in the calibration and validation of a Lake Michigan carbon model, which was initiated in the fall of 2011. In addition, these data are being used to test and improve models of ozone distribution, which is influenced to a large degree by chemical reactions in the above-lake atmosphere. A publication with these data is currently in review in Atmospheric Chemistry and Physics.

In addition to the above activities, we collaborated with colleagues at the Cooperative Institute for Limnology and Ecosystems Research (CILER, University of Michigan) and the NOAA Great Lakes Environmental Research Laboratory to conduct glider transects across Lake Michigan along the path followed by the high-speed ferry. These data were augmented by nearshore CTD transects conducted by our lab. These data will be used to better understand water column processes that drive the surface dynamics of chlorophyll, temperature and CO_2 that are observed with the ferry system.

Both monitoring buoys have been deployed for the 2015 navigational season, Buoy 45013 was redeployed on 5/13/15 and buoy 45014 was redeployed 6/2/2015 all data is currently

being transmitted to NDBC. The Lake Express High-Speed Ferry monitoring system was reinstalled in May 2015 for the current navigational system

State University of New York
A 1.5m TIDAS buoy was deployed in Lake Ontario off of the City of Oswego during the summer of 2014. The buoy was retrieved in September 2014 after breaking free from its mooring on September 20th during an early season storm.   It was retrieved without damage on September 23rd after traveling approximately 40 miles to the northeast. Fortunately we had installed GPS tracking devices on the TIDAS buoys last year allowing us to monitor its movements.

The meteorological station had a greater than 99% data transfer success rate. Wave height and direction had a 98.7% transfer rate though we questioned the accuracy of wave direction. The internal compass was recalibrated for 2015.   The thermistor string worked flawlessly this year with 100% surface to bottom data.   This thermistor string is was the first deployment of the new TS2010 string provided by NexSens. We were less successful with deployment of the YSI sonde and experienced numerous failures (33-45% data transfer) over the course of the summer. Over the winter, we did a full review of that water quality information for Quality Control and Quality Assurance.

The failure of the TIDAS buoy interface with the YSI sonde remains a major issue as this is our primary sensor for chlorophyll and algal pigments.   The systems were fully evaluated by engineers from NexSens to determine the cause of instrument failure. They replaced the old thermistor string with a new thermistor string that worked flawlessly.   Unfortunately similar efforts to patch the sonde connections were less successful. The YSI sonde worked for the first half of the season then failed for most of the remainder of the season.

In summer of 2014, we deployed three MB300 Bay buoys in Sodus Bay Lake Ontario specifically to monitor for harmful algal blooms.   This effort was jointed funded by the Great Lakes Restoration Initiative. Over the winter, changes were made to all 3 MB300 to allow better flow around the submerged C6 sensor. This consisted of drilling a series of holes in the ballast tube above and below the area in which sits the C6. In addition, stand-alone temperature loggers were purchased with the intent of being deployed in the hypolimnetic waters of Sodus Bay.   All three buoys worked well with the meteorological data from the center buoy and the thermistor string approaching 100% successful data transfer.   Interface with the C6 sondes approached 80% with the bulk of the missing 20% correlated with when we needed to remove the sondes from the water for calibration and cleaning.

Winter efforts were focused on fine tuning the C6 and sonde calibration protocols for all 5 buoys. This included additional tank testing to look at calibration protocols and secondary standards. All the sondes were taken apart, cleaned, reassembled and recalibrated as needed. Sensors on both the C6 units and YSI 6600 series sondes that failed our QAQC checks were replaced as needed.   New pH probes were installed on all 6600 series sondes in 2014.

We also received approval from EPA region 2 of the QAPP for our buoy and boat deployments in Sodus Bay.   This approval has been a two year effort. It required additional tank work over the winter with our C6 sondes to determine their linearity and representativeness as required by the Sodus Bay QAPP.

We moved and fixed our shore based weather station located in Sodus Bay at LeRoy Island. This was to repair the wind sensor and corresponding data logger to eliminate aesthetic complaints from the homeowner that was hosting the installation. That system continued to function over the winter through the ice season and to provide important year round information.

University of Minnesota-Duluth

The Meteorological buoys 45027 and 45028 were scheduled to be deployed on 20 May but deployment had to be postponed due to persistent ice on Lake Superior. Deployment was delayed until 13 June and the buoys were recovered on 13 November 2014. The buoys carried standard instrumentation (as in previous years). All data was ported to GLOS and NDBC. An upgrade to the shoreside server led to much better data reliability. 45027 stopped transmitting on 15 September; upon recovery we determined that this was due to a failed cell-phone modem, all data was collected by the logger for the 15 September-13 November time frame. A replacement modem was purchased and configured for use for the 2015 season. A small mooring was placed at 45028 position upon the buoys retrieval to monitor ice over winter.

Over the winter all meteorological equipment on the buoys were returned for calibration. The GPS was replaced on 45027, and the thermistor string was sent in for maintenance. The firmware was updated on both loggers to improve communications ability and our web presence was improved. UMD's two meteorological buoys (NDBC 45027 and 45028) were deployed on 15 May 2015 from the R/V Blue Heron. These buoys are reporting the same parameters as in previous years; in addition, 45027 now has a precipitation sensor on it, which uses radar to measure the amount and type of precipitation. To our knowledge this is the only open water precipitation measurement anywhere on the Great Lakes. Both buoys are operating normally, and are transmitting data directly to NDBC and GLOS on a 10-minute schedule.   We are currently

contracting with a local web design firm to develop a smart-phone friendly website, focusing on providing information immediately useful to commercial and recreational boaters in the western arm of Superior.

The UMD glider team worked with the local EPA lab to commission their new glider Nokomis. Three Keweenaw to Isle Royal transects were accomplished, two with UMD's Gichigami and one with EPA's Nokomis. Two extensive shelf surveys were completed with Nokomis on the Wisconsin Shelf to the west of the Apostles.

The gliders were deployed for a total of 45 deployed days and recorded over 1250km of surveys. Gichigami developed a leak in its fore hull section on second of these and had to be taken out of service. It was returned to TWR for servicing, and the WetLABS triplet sensor was replaced since it has been identified as a potential source of leaks in other gliders.

The Harbor Superior entry equipment was deployed, the ADCP was deployed in non-real-time mode to collect data that we can work with over the winter to improve our ability to measure exchange with the lake.

Michigan Technological University
Michigan Tech deployed two buoys in Lake Superior near the north and south entrances to the Keweenaw Waterway, one buoy in Little Traverse Bay of Northern Lake Michigan, and deployed a temperature profiling array on both entrances to the Keweenaw Waterway during the 2014 navigational season. These buoys were all redeployed for the 2015 navigational season.

Additionally Michigan Tech supported supplemental GLOS projects: a full meteorological station operating at the Great Lakes Research Center on the Keweenaw waterway in conjunction with three live web cameras (supported internally by Michigan Tech) documenting year-around conditions on the waterway which connects western Lake Superior with Keweenaw Bay and joint operations support of three glider missions between North Entry and Isle Royale. MTU launched, recovered and transported the UMD Gichigami glider in cooperation with Dr. Jay Austin of UMD.

To support the reporting of the real-time buoy observations, an interactive web portal site (www.uglos.mtu.edu) has been developed. This website not only supports the Michigan Tech real-time assets but also those of other GLOS participants. UGLOS nominally provides rapid response, ten-minute data from all buoys to more fully capture the dynamics of the coastal zone and to augment the hourly observations

provided by NDBC.   The data collected by Michigan Tech is shared with GLOS and the NDBC.

All buoy data was transmitted to the GLOS, NDBC, and U-GLOS websites as well as MTU's Web portal site: www.lakesuperiormichigantech.org. The little Traverse Bay (LTB) Buoy in northern Lake Michigan was deployed in partnership with the local communities of Harbor Springs and Petoskey. This buoy also contained the standard GLOS met-ocean package, with directional waves and thermistor string to the bottom. All MTU buoys were converted to the new, commercially available thermistor strings.

Michigan Tech Research Institute
The overall goal of the GLOS remote sensing activity is to further advance the use of ocean color satellites to map water quality in the Great Lakes. The water quality parameters that are retrieved from the satellite data include chl, doc, sm, HABs, optical properties (Kd 490 (clarity), KdPAR, and photic depth) sediment plumes, primary productivity (PP), and Lake Bottom mapping.

To support the further development of remote sensing algorithms and derived products an extensive database of *in situ* optical water properties and coincident chemistry has been constructed to provide this data to the broader user community. This Great Lakes Optical Properties Geospatial Database can be found at www.glopgd.org. Additional in situ water optical properties are being measured this summer in Lakes Michigan, Huron and Erie in collaboration with NOAA/GLERL. The following four tasks are being performed under this

GLOS remote sensing initiative:
  1. Clean–up, document, and distribute through a web based distribution system the Great Lakes Optical Properties Geospatial Database (GLOPGD).
  2. Generate satellite derived time series products of the Great Lakes to support the GLOS mission.
  3. Transition the CPA-A algorithm to NOAA for use operationally within the Great Lakes Coast Watch System.
  4. Document in reports, journal articles, and conference presentations the algorithms description (CPA-A, HABs, lake bottom mapping), their initial performance and recommendations for additional work. Provide the algorithms and share our findings with NOAA and other Great Lakes scientists.

Publications:
Fiorentino, L. and J. Austin, Spatial and temporal structure of the benthic nepheloid layer in Lake Superior. (In prep)

Austin, J.A. and J. Brethauer, Observations of radiatively driven convection in a deep, dimictic lake. International Association of Great Lakes Research annual meeting, Hamilton, ON. May 2014.

Presentations:

Brooks, C.N., R.A. Shuchman, M.J. Sayers, N. Jessee, K.A. Endsley, R. Sawtell, N. Molen "Extending Great Lakes Remote Sensing Products to Stakeholders through GLOS, Coastwatch, and custom portals" 57th International Conference on Great Lakes Research, IAGLR , Hamilton, ON Canada, May 26-30, 2014 (presentation).

Endsley, K.A., M.J. Sayers, R.A. Shuchman, C. Brooks, and G. Leshkevich. "The Great Lakes Optical Properties Geospatial Database (GLOPGD)" 57th International Conference on Great Lakes Research, IAGLR , Hamilton, ON Canada, May 26-30, 2014 (presentation).

Sayers, M.J., Z. Raymer, R.A. Shuchman, G. Fahnenstiel, G. Leshkevich, and C. Brooks. "Harmful Algal Bloom Mapping for the Great Lakes Using MODIS Satellite Data" 57th International Conference on Great Lakes Research, IAGLR , Hamilton, ON Canada, May 26-30, 2014 (presentation).

Sayers, M.J., R.A. Shuchman, G. Leshkevich and J. Traub. "Long Term Chlorophyll Observations in the Great Lakes from Oceancolor Satellite Data Using Multiple Retrieval Approaches." 57th International Conference on Great Lakes Research, IAGLR, Hamilton, ON Canada, May 26-30, 2014 (presentation).

Outreach Activities:

UMD continues their collaboration with the Great Lakes Aquarium, with a display showing data from the meteorological buoys. With support from Minnesota Sea Grant, it was overhauled this winter and an interactive display was added as well. UMD also works closely with the National Weather Service office in Duluth.

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: HYDRODYNAMIC MODELING AND OBSERVATION IN SUPPORT OF GLRI DECISION SUPPORT TOOLS

Principal Investigators: Allen Burton (CILER); Chin Wu (University of Wisconsin-Madison)
NOAA Technical Contact: Eric Anderson (NOAA-GLERL), Steve Ruberg (NOAA-GLERL)

NOAA Strategic Goal 5: NOAA Enterprise-wide Capabilities

Overview and Objectives:
The Finite Volume Coastal Ocean Model (FVCOM) has been adapted and implemented successfully in the Great Lakes Huron-Erie Corridor as part of GLERL's real-time forecasting systems. Building on this initial work, CILER and GLERL researchers have developed an FVCOM model of the Upper St. Lawrence River and are in the midst of implementing the model as part of the GLERL real-time operations. Through success in connecting channel predictions using FVCOM and initial tests on open-lake modeling (e.g. Lake Erie), FVCOM has been chosen to replace the Princeton Ocean Model (POM) hydrodynamic models currently in place for the Great Lakes. In order to upgrade the current hydrodynamic forecasting models in the Great Lakes, models will be developed and tested for Lake Erie and a combined Lake Michigan-Huron, including nested areas such as Green Bay. These models form the basis for integration of Great Lakes coastal observational data into practical decision support tools for GLRI. GLERL and CILER personnel will work closely with GLOS and other GLRI participants to identify specific user needs and develop appropriate decision support tools.

1. We will continue implementation of the Upper St. Lawrence River forecasting model. Through collaboration with GLOS, we will respond to user feedback from the summer 2012 testing period and improve the model function and output based on user needs. After the user-testing phase and GLOS-driven workshops, we will make the necessary model changes and recalibration to improve model accuracy and address specific user needs for recreational boating and hydrodynamic forecasting.

2. We will operationalize a Lake Erie FVCOM model, integrating it into the GLERL real-time operations. Model calibration for water levels, currents, and temperatures will be carried out for a range of years (e.g. 2004, 2005, 2011) and then implemented into a nowcast/forecast automated operation.

3. We will develop a Lake Michigan-Huron FVCOM model for real-time hydrodynamic forecasting. The combined lake model will provide boundary conditions for two nested models, Green Bay and Saginaw Bay. Each model and sub-model will be tested and calibrated for a range of years (e.g. 2008, 2010, 2011, 2012). Upon successful calibration for water levels, currents, and temperatures, the combined-lake model will be implemented into real-time operations along with real-time simulations for Green Bay and Saginaw Bay. The nested bay models will provide river plume conditions and simulations for the Fox River and Saginaw River, respectively.

Accomplishments

The accomplishments for FY2014 are identical to those from FY2013, as the major research activities were completed in the previous year. To date, the accomplishments from this project include:

- Watershed model predicting *E. coli* loading (nowcast) from the Clinton River watershed is running in real-time.
- Watershed model has been linked with hydrodynamics model (HECWFS) via a particle model, and we are in the process of sensitivity analysis of the linked modeling system.
- Completed second year of nearshore sampling, adding off-shore sampling and high frequency sampling events in the nearshore zone using an automated sampler.
- Developed a storm response approach based on observed watershed response to precipitation in order to better capture storm loads during the 2014 season.
- Conducted analysis comparing laboratory analysis methods for enumerating *E. coli* that formed the basis for using one method (IDEXX Colilert Quantitray) that is more efficient, allowing for increased sampling.
- Improved project website
- Implementation of Upper St. Lawrence River model for nowcast/forecast
- Lake Erie FVCOM model implementation into real-time nowcast/forecast at GLERL
- Lake Michigan-Huron FVCOM model developed (in process for real-time modeling)

Publications: None to date

Presentations:

- Fry, L. M., Anderson, E. J., Kramer, E., & Ritzenthaler, A. (2014). Linking hydrological and hydrodynamics models to determine the impacts of rivers on beach water quality. In *International Association for Great Lakes Research Annual Meeting*. Hamilton, ON.
- Fry, L. M., Anderson, E. J., Kramer, E., & Ritzenthaler, A. (2014). Application of a new integrative process-based nearshore water quality modeling system to evaluate the contribution of river discharge to observed E. coli concentrations. In *University of North Carolina Water Microbiology Conference*. Chapel Hill, NC.
- Anderson, E. J., Fry, L. M., Kramer, E., Campbell, K., & Ritzenthaler, A. (2014). A linked hydrologic-hydrodynamic-bacteria model framework for beach water quality forecasting. In *Ocean Sciences Meeting*. Honolulu, HI.
- Fry, L. M., Anderson, E. J., Ritzenthaler, A., Campbell, K., Kramer, E., & Gronewald, A. D. (2013). Representation of Spatial and Temporal Variability in Beach Water Quality Using a Bacteria-Hydrology-Hydrodynamics Modeling Framework. In *Great Lakes Beach Association Annual Meeting*. Sheboygan, WI.
- Fry, L. M., Ritzenthaler, A., Anderson, E. J., Campbell, K., & Gronewald, A. D. (2013). Development of a multimodel framework linking a pathogen loading model to a hydrodynamics model for beach water quality forecasting. In *International Association for Great Lakes Research Annual Meeting*. West Lafayette, IN.

Outreach Activities:

- Meeting at the Marina: Public Meeting on NOAA's Work in the Clinton River and Lake St. Clair Water Quality
- Hosted two CILER summer fellows, 4 students from the University of Michigan's Future Public Health Leaders Program, and two students from the University of Michigan's Undergraduate Research Opportunities Program.
- Participated at public meetings
- Presented at an environmental engineering graduate seminar at Michigan Technological University
- Regularly gave tours of the bacterial analysis laboratory

THEME I: GREAT LAKES OBSERVING AND FORECASTING SYSTEMS

PROJECT TITLE: MODELING SEA ICE-OCEAN-ECOSYSTEM CHANGES, AND GREAT LAKES ICE MODELING, MEASUREMENT, AND CLIMATE CHANGE

Principal Investigators: Allen Burton (CILER); Hongyan Zhang (CILER)
NOAA Technical contacts: Jia Wang (NOAA-GLERL)

NOAA Strategic Goal 3: Climate Adaptation and Mitigation

Overview and Objectives:

This study is to use the combination of a high-resolution Coupled Ice-Ocean Model (CIOM) and Princeton Regional Ocean Forecast (and Hindcast) System's data-assimilation methodologies to improve our understanding of ocean and sea ice circulation in the Bering-Chukchi-Beaufort seas. A 3-D, 9-compartment, Physical-Ecosystem Model, coupled to CIOM, will be used to study the ice-ocean-ecosystem dynamics in the same region. This study will have a broad impact on 1) the ice-ocean-ecosystem dynamics that explains the high primary productivity region, along the Green Belt (i.e., along the Bering Slope), seasonal blooms and the interannual variability and 2) ice edge variability due to climate changes and the impacts on primary and secondary productivity.

Continue to develop an ice-circulation model based on the FVCOM for the whole Great Lakes. Conduct model simulations of Great Lakes ice in response to climate change, and develop FVCOM-ecosystem coupled model for Lake Michigan. Measure lake ice thickness by deploying and recovering the instruments, ice profilers and current meters.

Specific Aims/Milestones:
1) Synthesis studies using CIOM/PhEcoM/PROFS system for the period of 1990-present. Reconstruction of the realistic circulation and plankton dynamics in the Bering-Chukchi-Beaufort seas will be accomplished.

2) Assimilation of RUSALCA observed biogeochemical data into PhEcoM. Bai and Hu will conduct simulations covering the same RUSALCA surveys. Mizobata and Hu will prepare and process the data assimilation of SIC, SSH, and RUSALCA moorings. Our synthesis goal is to compare the simulation and assimilation results using the CIOM/PhEcoM/PROFS system with the RUSALCA and other observations in terms of reconstruction of ocean circulation and ecosystem dynamics in the RUSALCA.

3) Dr. Mizobata will participate in Mirai and Oshoro-maru cruises. Wang will send Hu or Bai to Oshoro-maru cruise.

4) Conduct simulation of Great Lakes ice using the updated version of FVCOM coupled with an ice model in response to climate change, using a modified numerical scheme and ice model

5) Update Great Lakes ice atlas

Accomplishments:
- A three dimensional physical-biological model was set up and validating to simulate the seasonal phytoplankton variations in the Bering Sea, especially, focus on the physical and biochemical mechanisms of forming the Bering Sea Green Belt, and Subsurface Chlorophyll Maxima in summer. (Hu and Wang, in preparation)
- The updated version of FVCOM coupled with an ice model was validated in the hindcast for Lake Erie, from 2002 to 2013. The results are compared with the observed ice extent, ice thickness, water temperature, and current speed. (Manome and Wang, in preparation)
- The application of the updated version of FVCOM coupled with an ice model to the entire Great Lakes with relatively low resolution (~5 km) was initiated.
- Investigated storm impacts on sea ice, oceanic dynamics, and surface heat flux in the Chukchi–Beaufort Seas using the CIOM (coupled ice–ocean model). The CIOM successfully reproduced the storm impacts. Simulated sea ice movements are comparable to the satellite observations. Storms have some significant impacts: such as, alter pathways of the Pacific inflow water; induce upwelling and slope current reversal; increase heat loss to the atmosphere. (Bai et al. 2015)
- The Great Lakes ice atlas was updated. A summer fellow under the GLERL-CILER summer fellowship program participated in updating the atlas, as well as upgrading the current separate codes that process the ice data at multiple steps into an integrated IDL code.

Publications:
Bai, X. H. Hu, J. Wang, Y. Yu, E. Cassano, J. Maslanik, 2015: Responses of surface heat flux, sea ice and ocean dynamics in the Chukchi- Beaufort Sea to storm passages during winter 2006/2007: A numerical study. Deep-Sea Research Part I, 102, 101-117. Doi:10.1016/j.dsr.2015.04.00

Hu, H., and J. Wang, Simulation of Phytoplankton Distributions and Variations in the Bering-Chukchi Sea with a 3-D Physical Biological Model, in preparation.

Manome, A., and J. Wang, Simulating hydrodynamics and ice cover in Lake Erie using an unstructured grid model, in preparation.

Presentations:
Bai X. and Wang, J., Great Lakes ice surface heat budget analysis: 1979-2012, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Manome, A., Wang, and Hall, D., Ice-Hydrodynamic Simulation with Data Assimilation of Satellite-Derived Ice Surface Temperature, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Hu, H., Wang, J., Manome, A., and Bai, X., Simulation of Lake Erie ice and thermodynamics, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Wang, J., and Bai, X., Seasonal Prediction of Great Lakes Ice cover using indices of interannual; & decadal teleconnections, *Conf of Int'l Association for Great Lakes Research*, Burlington, VT, May 25-29, 2015.

Outreach Activities: None to date

Relevant Web content: None to date

Supplemental Material: None to date

THEME II: INVASIVE SPECIES

PROJECT TITLE: ASSESSING THE RISK OF ASIAN CARP INVASION AND IMPACTS ON GREAT LAKES FOOD WEBS AND FISHERIES

Principal Investigators: Allen Burton (CILER), Hongyan Zhang (CILER) and Dmitry Beletsky (CILER)
NOAA Technical Contacts: Edward Rutherford and Doran Mason (GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

Bighead (*Hypophthalmichthys nobili*) and silver (*H. molitrix*) carp (Asian carps) threaten to invade the Great Lakes and disrupt aquatic food webs and fisheries through their consumption of lower trophic levels. In river and lake ecosystems in North American, Asia and Europe, the introductions of Asian carps have resulted in the decline of many native fish species, with planktivorous fish and fish with planktivorous stages being particularly affected (e.g Arthur et al. 2010; Pegg et al. 2009).

Preliminary studies suggest that Asian carps will have limited distribution and impacts on Great Lakes ecosystems. Cooke et al. (2009) conducted feeding studies on bighead carp at a range of temperatures and zooplankton densities, and found carp grew only at higher zooplankton densities that are found only in limited areas of the Great Lakes. Cooke and Hill (2010) used a bioenergetics model to predict growth of Asian carps in up to 6 areas within each Great Lake given site-specific data on water temperature, and zooplankton and phytoplankton densities. Cooke and Hill (2010) found that silver and bighead carp would be unable to grow in most open-water regions, but would likely be able to grow in many of the embayments and wetlands along the edges of the Great Lakes. Herborg et al. (2007) used environmental niche modeling to predict invasion routes and distributions of Asian carps, and identified near shore environments of Lake Ontario as suitable habitats.

While we generally agree with the approach taken by Cooke and Hill (2010) and Herborg et al. (2007), we believe it is important to take a much more detailed look at the potential for Asian carps to survive, grow and impact other fish species and food webs at additional locations throughout the Great Lakes Basin. For example, water temperatures and the densities of phytoplankton and zooplankton are known to vary substantially throughout the water column and across space and time. Using a single set of numbers to represent environmental conditions at a location will miss many of

those details, and may result in a region being incorrectly identified as uninhabitable by Asian carps. Moreover, very few studies have been conducted to document Asian carp impacts on other fishes or fisheries (Sampson et al. 2009). Impacts of Asian carps on aquatic food webs are potentially complex, and require spatially-explicit models of trophic interactions to assess direct and indirect influences. A spatially-explicit modeling approach such as those we propose below allows a more detailed look at the effects of Asian carps on key members of the food web, and allows for the inclusion of density-dependent feedbacks (e.g., lower survival of age-0 fish, but higher growth and reproductive output by older survivors) which may help species compensate for the effects of an Asian carp invasion.

Our objectives are to:
1. Predict in which Great Lakes habitats Asian carps can successfully grow, survive and reproduce.
2. Predict Asian carp's impacts on food webs, key fish species and fisheries in different Great Lakes environments.
3. Survey the Chinese literature for relevant information on Asian carps' energetics, vital rates and ecology

Outcomes

At the end of the two-year project, this work will expand on the results of Cooke and Hill (2010) and help identify regions in Lakes Huron, Michigan and Erie that could support Asian carps. Our individual-based model and food web model will identify the species and fisheries that likely will be impacted by Asian carps.

Accomplishments:

Dr. Ivan finished calibrating the Saginaw Bay individual-based model with 6 fishes (walleye, yellow perch, rainbow smelt, round goby and silver and bighead carps). The model includes interacting prey using equations and parameters derived from Ecopath/Ecosim. Further, small changes to the code were made and tested in order to run simulations initialized with low numbers of silver or bighead carp to get at establishment likelihood. Baseline simulations were completed and results compared across different platforms to ensure uniformity of results. Simulations were completed for the following scenarios: 1million silver and 1 million bighead carps with high larval survival, 1million silver and 1 million bighead carps with low larval survival, 10 silver carp with high larval survival, 10 silver carp with low larval survival, 10 bighead carp with high larval survival and 10 bighead carp with low larval survival. Our group is currently analyzing these results to determine if any additional scenarios are required to answer the questions of establishment likelihood and impacts. Decisions were made as to what figures and comparisons were required for analyzing and displaying model

results, with Dr. Zhang developing the actual figures. Future work is required to finish input files, calibrate, and run scenarios for lakes Erie, near and offshore Michigan and offshore Huron. Priority will be given to the development of a report and manuscript for Saginaw Bay and the Lake Michigan offshore community.

Dr. Zhang has been working on the calibration of the Atlantis model for Lake Michigan. The model is stable (runs without crashing). More efforts are focused on tuning the model to represent the observed population dynamics of model groups. The Atlantis model for Lake Erie is under development by summer fellows. Data compiling and model configurations have been done, and model initialization and calibration are currently underway.

Dr Beletsky has been working on calibration and validation of hydrodynamic model of Lake Huron using 1991-1996 and 2008-2010 observations with the goal to improve initial climatology developed for this lake and provide additional advection and temperature fields for the Atlantis model during individual years. Meteorological forcing functions were generated for 2009-2011 for additional model runs in Lake Erie. The hydrodynamic model of Lake Erie was calibrated and validated using 2004, 2005, 2007 and 2009-2011 observations. Additional hydrodynamic model output will be used to specify advection and temperature fields in the Atlantis model during individual years.

Publications:
None.

Presentations:
None.

Outreach Activities:
Webinar entitled "Modeling risk and potenital impacts of silver and bighead carp invasion on Great Lakes food webs." Research results from this project were presented to an audience of 22 people. Mar 12, 2015.

E. Rutherford, H. Zhang, L. Ivan, Y-C. Kao, S. Adlerstein, A. Shakoor, D. Mason, D. Lodge, M. Wittmann, R. Cooke, J. Rothlisberger, and J. Breck. Modeling Risk and Effects of Bighead and Silver Carp on Great Lakes Food Webs.

H. Zhang, E. Rutherford, D. Mason, L. Ivan, D. Beletsky, A. Adamack, M. Hoff, E. Fulton, R. Barbiero, and R.J. Gorton. Forecasting Asian Carp Impacts on Lake Michigan's Food Web and Fisheries – Using the Atlantis Ecosystem Model.

L. Ivan, D. Mason, E. Rutherford, H. Zhang, and M. Hoff. Assessing the risk of Asian carps establishment in the Great Lakes across productivity gradients.

Relevant Websites:
http://www.regions.noaa.gov/great-lakes/?page_id=787

THEME III: ECOLOGICAL RISK ASSESSMENT

PROJECT TITLE: HABS, BACTERIA, AND BEACH QUALITY FORECASTING FOR THE GREAT LAKES OCEAN AND HUMAN HEALTH CENTER

PIs are listed below, by sub-project.

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

The NOAA Center of Excellence for Great Lakes and Human Health (CEGLHH) is a multi-disciplinary, multi-institutional research center that is developing tools to predict water quality in the Great Lakes. Focus areas for the Center include ecological forecasting, nearshore transport, drinking water, beach closings, and harmful algal blooms, with the ultimate goal of developing predictive tools to assist managers and public officials in public health decision-making. This project report describes research activities related to three main foci of the center including: Harmful Algal Bloom Forecasting; Beach Quality Forecasting and Microbial Monitoring; and Outreach and Education.

SUB-PROJECT 1: HARMFUL ALGAL BLOOM FORECASTING

CILER Lead: Tom Johengen (UM-CILER)
NOAA Technical Leads: Eric Anderson (NOAA-GLERL)

Overview and Objectives:

The Harmful Algal Bloom program continue to focus on the operational development of the Lake Erie HAB forecast and in determining microcystin concentrations in important human and food-web components. We continue to focus on the evaluation, validation and modification of the preliminary Lake Erie HAB bulletin being operated within NOS and on conducting research towards an improved forecasting model and dissemination plan. We continue to conduct field sampling and experimental work to: 1) determine whether significant amounts of the HAB toxin, microcystin, is entering the drinking water supplies of residents on two Lake Erie Islands, 2) elucidate what are the main drivers determining the timing and extent of bloom development, and its subsequent movements through the western and central basins of Lake Erie, 3) post field sampling results to a publically accessible website, and 4) share field sampling results with NOS to assist in validating and improving the current Lake Erie HAB Bulletin. We use both historical and our current evolving environmental data sets to

construct statistical models delineating factors regulating phytoplankton and Microcystis abundance patterns throughout western Lake Erie. We are developing and evaluating 'user friendly' models (i.e. incorporating readily-obtained hydrological-meteorological variables) for predicting Microcystis biomass.

Accomplishments:

A) Field Monitoring

In 2014, we conducted field sampling programs in western Lake Erie and Saginaw Bay, Lake Huron. For western Lake Erie we expanded our spatial sampling coverage by adding two additional stations further east, one near the Toledo water intake and one near West Sister Island which provides an early warning for blooms that might advect towards the Bass Island region. We conducted 21 surveys on Lake Erie over the time period from 5/27 – 11/3. Each sample was analyzed for nutrients, phytoplankton composition, extracted algal pigments, and toxins. Survey results are disseminated directly to over 65 stakeholders on a weekly basis. In addition to the standard surveys we conducted a Lagrangian 48-hour sampling survey where we sampled a constant water mass every 6 hours to examine how Microcystis alters its buoyancy over light/dark growing cycles. Mixing from waves appeared to diminish any clear trends in vertical distribution throughout the day.   For Saginaw Bay we conducted 9 sampling trips including a total of 36 samples. All data from the 2014 surveys have been entered into the programs database and is being shared with our Partners conducting statistical modeling, as well as, with NOS staff running the operational Lake Erie HABS Bulletin.

B) HABS modeling and data analysis

HABs monitoring data is being used to develop a new daily HABS forecasting model in conjunction with a new 3D FVCOM hydrodynamic model. Data have also been analyzed using artificial intelligence and neural network approaches to generate predictive understanding of bloom dynamics and environmental water quality conditions in Lake Erie.

Publications:

Millie, D. F., Weckman, G. R., Fahnenstiel, G. L., Carrick, H, J., Ardjmand, E., Young II, W. A., Sayers, M., & Shuchman, R. A. (2014). Using artificial intelligence for CyanoHAB niche modeling: discovery and visualization of *Microcystis*-environmental associations within western Lake Erie. Can. J. Fish. Aquat. Sci. **71**: 1642–1654 (2014) dx.doi.org/10.1139/cjfas-2013-0654

Presentations:

Understanding and Forecasting Harmful Algal Blooms
R. Kelley and T. Johengen, UROP Spring Symposium, April 22, 2015, University of Michigan, Ann Arbor, MI.

Investigating Environmental Chemistry to Understand Harmful Algal Blooms
K. Yuhas, et.al., UROP Spring Symposium, April 22, 2015, University of Michigan, Ann Arbor, MI.

Spatial and temporal trends in dissolved organic matter and hydrogen peroxide in Lake Erie
Sarah E. Page, Kate H. Yuhas, Katie Harrold, Michelle A. Berry, Paul Den Uyl, Tim Davis, Thomas H. Johengen, Melissa Duhaime, George W. Kling, Gregory J. Dick, Vincent J. Denef, Rose M. Cory. Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Examination of environmental drivers and seasonal dynamics associated with the development and persistence of Harmful Algae Blooms in western Lake Erie
Thomas Johengen, Danna Palladino, Ashley Burtner, Steve Ruberg, and Timothy Davis. Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Sensitivity of simulated Microcystis colony vertical distribution to turbulent mixing and buoyancy in a model for short-term forecasts of cyanobacterial harmful algal blooms in Lake Erie
M. D. Rowe, E. J. Anderson, H. A. Vanderploeg, D.L. Fanslow, D.C. Gossiaux, T. H. Johengen. Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Dynamics of the Lake Erie Bacterial Community During a Toxic Algal Bloom Event
Michelle A. Berry, Paul Den Uyl, Tim Davis, Thomas H. Johengen, Melissa Duhaime, George W. Kling, Rose M. Cory, Gregory J. Dick, Vincent J. Denef. Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Creating a More Complete Picture: Advancements in Harmful Algal Bloom Detection and Prediction in Western Lake Erie
Palladino[1], D., Johengen[1], T.H., Ruberg[2], S.A., Miller[1], R., Purcell[1], H.L. and Burtner[1], A.M. IAGLR, Burlington, VT, May 2015

Vertical mixing and buoyancy in a model for short-term forecasts of cyanobacterial HABs in Lake Erie
M. D. Rowe, E. J. Anderson, A. J. Vander Woude, T. H. Johengen, H. A. Vanderploeg
IAGLR, Burlington, VT, May 2015

Cyanobacteria Bloom Dynamics in Lake Erie in Relation to Environmental Drivers: Do different monitoring approaches tell the same story?
Bertani, I., Steger, C.E., Obenour, D.R., Bridgeman, T.B., Johengen, T.H., Sayers, M.J., Shuchman, R.A., Fahnenstiel, G.L. And Scavia, D
Iaglr, Burlington, Vt, May 2015.

Two presentations to NOAA Leadership (OAR-AA, NWS-AA, and NOAA Chief Scientist) describing CILER research activities during open house visit of NOAA-GLERL.   March 2015.

Relevant Websites
A new Website with real-time and archived project data and new daily and seasonal forecasts was developed and launched in August 2014. The current HABS Bulletin and Microsystin toxin data are being disseminated at:
http://www.glerl.noaa.gov/res/waterQuality/

Significant Interactions
Throughout the 2014 sampling program we collaborated with a team of scientists at the University of Michigan to expand our analysis to look at the potential impacts of radical oxygen species, microbial and virus interactions, and genetic strain variation on the intensity and toxicity of blooms. Several key publications are underway with this team and we have submitted several follow-on collaborative proposals, all unsuccessful to date.

SUB-PROJECT 2: BEACH QUALITY FORECASTING AND MICROBIAL MONITORING

CILER Leads: Lauren Fry, Alicia Ritzenthaler, and Eva Kramer, University of Michigan
NOAA Technical Leads: Eric Anderson, NOAA-GLERL

Overview and Objectives:

The fecal indicator bacteria component of Center of Excellence for Great Lakes and Human Health focuses on the development and application of process model-based bacterial water quality forecasting systems for targeted beaches throughout the Great Lakes. The systems are intended to improve the capability of local authorities to forecast water quality conditions which may lead to a violation of fecal indicator bacteria (FIB)-based water quality standards and present a threat to human health. Several near-shore plume models have been/are being developed (through GLCFS) near major beaches of the Great Lakes. The locations, or tributary outlets, which best describe these existing models, include: Grand Haven; Indiana Dunes; Saginaw Bay; and HECWFS (Huron to Erie connecting waterways forecasting system). A major goal of the ongoing and near-term work on this project is the development, calibration, and confirmation of watershed-scale, fecal indicator bacteria (FIB) fate and transport models to provide flow and loading estimates to hydrodynamic, near-shore plume models. The focus of this work is in Lake St. Clair and Clinton River.

In order to validate and calibrate these models, an intensive field monitoring program is necessary. The monitoring program involved weekly sampling encompassing a wide geographic area of the shoreline of Lake St. Clair, offshore transect sampling, and high frequency temporal sampling (every 15-20 minutes) to assess variability. An ADCP was also successfully deployed to support model calibration and validation.

Accomplishments:

Modeling:

- Developed linkage between the watershed model, HECWFS hydrodynamic model, and a bacteria particle model for automated forecast capability
- Producing watershed loading from the Clinton River mouths (natural channel and spillways), running in real-time automated mode in FY14
- Case studies of comparing modeled to observed bacterial concentration during select rainfall events
- Sensitivity analysis to bacteria watershed loading times and hydrodynamic diffusion was carried out

Field Component:

Oct '12-Sept '13
- Weekly routine monitoring for fecal indicator bacteria, conductivity, and surface water

temp at 17 shoreline sites and 3 riverine watershed sites.
- Monthly routine monitoring for fecal indicator bacteria, conductivity, and surface water temp at 15 offshore sites.
- Collection of fecal indicator bacteria samples at high temporal frequency (every 15-20minutes, for ~4 hours) at 3 different sites on 3-8 dates (depending on the site)
- Installation/deployment of ISCO automated sampler (Lake St. Clair)
- Deployment of ADCP (Lake St. Clair)

Oct'13-Sept '14
- Weekly routine monitoring for fecal indicator bacteria, conductivity, and surface water temp at 17 shoreline sites and 3 riverine watershed sites.
- Monthly routine monitoring for fecal indicator bacteria, conductivity, and surface water temp at 23 offshore sites.
- Installation/deployment of ISCO automated sampler (Clinton River)
- Deployment of ADCP (Lake St. Clair)

Lab Analysis:
-Analysis of 1184 routine weekly samples for total coliform concentration, E. coli concentration, and turbidity between June 2012 through September 2014
-Analysis of 509 high temporal frequency samples for total coliform concentration, E. coli concentration, and turbidity between June 2012 through September 2014
-Analysis of 175 offshore transect samples for total coliform concentration, E. coli concentration, and turbidity between June 2012 through September 2014

Public interaction
-Development of lab demonstration video for public outreach
-Demonstration of lab analysis for several GLERL visitor tours
- Regularly updated (approximately weekly) project website has a user friendly interface allowing the public the view and/or download all monitoring data. The website also contains project information and answers to frequently asked questions.
http://www.glerl.noaa.gov/res/Centers/HumanHealth/nearshoreFIB/

Publications:
In prep

Presentations:
*PAINE, A.L., A.A. RITZENTHALER, E.L. KRAMER, and A.D. GRONEWOLD. Monitoring and analysis of *Escherichia coli* in the nearshore waters of Lake St. Clair (poster). 56th Annual Conference of the International Association for Great Lakes Research, Purdue University, W. Lafayette, IN, June 2-6, 2013 (2013)

KRAMER, E.L., A.A. *RITZENTHALER, A.L. PAINE, and A.D. GRONEWOLD. Spatial, temporal, and analytical variability in nearshore water quality and its implications on management decisions. 56th Annual Conference of the International Association for Great Lakes Research, Purdue University, W. Lafayette, IN, June 2-6, 2013 (2013)

CLITES, A.H., E.L. *KRAMER, L.M. FRY, E.J. ANDERSON, and A.D. GRONEWOLD. Implications of an improved hydrologic model for understanding nearshore hydrodynamics: Impacts of the Clinton River spillway on predicting beach water quality (poster). 56th Annual Conference of the International Association for Great Lakes Research, Purdue University, W. Lafayette, IN, June 2-6, 2013 (2013)

*RITZENTHALER, A.A., E.L. KRAMER, L.M. FRY, A.D. GRONEWOLD, and E.J. ANDERSON. Spatial, temporal, and analytical variability in nearshore water quality and its implications on management decisions. State of Lake Michigan-Great Lakes Beach Association Conference, Sheboygan, WI, October 15-17, 2013 (2013)

*KRAMER, E.L., L.M. FRY, E.J. ANDERSON, A.A. RITZENTHALER, and A.D. GRONEWOLD. Comparing output from a linked hydrologic-hydrodynamic-particle model with real world bacterial concentrations. State of Lake Michigan-Great Lakes Beach Association Conference, Sheboygan, WI, October 15-17, 2013 (2013)

*FRY, L.M., A.A. *RITZENTHALER, E.L. *KRAMER, S. *JOSEPH JOSHI, and E.J. *ANDERSON. Connecting Tributaries to Nearshore Water Quality through Monitoring, Modeling, and Communication. GLERL Brown Bag Seminar Series, NOAA GLERL, Ann Arbor, MI, February 20, 2014 (2014)

*ANDERSON, E.J., L.M. FRY, E.L. KRAMER, K.B. CAMPBELL, and A.A RITZENTHALER. A linked hydrologic-hydrodynamic-bacteria model framework for beach water quality forecasting. 2014 Ocean Science Meeting, Honolulu, HI, February 23-28, 2014 (2014)

*KRAMER, E.L., A.A. RITZENTHALER, L.M. FRY, E.J. ANDERSON, and A.D. GRONEWOLD. Disentangling meteorological, terrestrial, and nearshore aquatic drivers of beach water quality by combining statistical and physically-based models. Water Microbiology Conference, University of North Carolina, Chapel Hill, NC, May 5-7, 2014 (2014)

*RITZENTHALER, A.A, E.L. KRAMER, L.M. FRY, and E.J. ANDERSON. Understanding Spatial and Temporal Variability in Nearshore Bacterial

Water Quality and its Implications on Effective Beach Management. 57th Annual Conference of the International Association for Great Lakes Research, McMaster University, Hamilton, ON, May 26-30, 2014 (2014)

*FRY, L.M., E.J. ANDERSON, E.L., and A.A. RITZENTHALER. Linking hydrologic and hydrodynamic models to determine the impacts of rivers on beach water quality. 57th Annual Conference of the International Association for Great Lakes Research, McMaster University, Hamilton, ON, May 26-30, 2014 (2014)

*RITZENTHALER, A.A., E.L. KRAMER, L.M. FRY, and E.J. ANDERSON. Bacterial monitoring to develop a linked watershed-hydrodynamic modeling framework. 14th Annual Great Lakes Beach Association Conference, Toronto, ON, Canada. November 12-14, 2014 (2014)

*ANDERSON, E.J., L.M. FRY, E. KRAMER, and A.A. RITZENTHALER. Linked hydrologic-hydrodynamic model framework to forecast impacts of rivers on beach water quality. American Geophysical Union Fall Meeting, San Francisco, CA December 15-19, 2014 (2014)

FRY, L.M., *A.A. RITZENTHALER, E. KRAMER, and E.J. ANDERSON. Monitoring bacterial water quality for application to watershed and nearshore fate and transport model development. American Geophysical Union Fall Meeting, San Francisco, CA December 15-19, 2014 (2014)

SUB-PROJECT 3: MICHIGAN SEA GRANT OUTREACH AND EDUCATION FOR THE NOAA CENTER OF EXCELLENCE FOR GREAT LAKES AND HUMAN HEALTH

CILER Lead: Sonia Joshi
NOAA Technical Leads: Eric Anderson (NOAA-GLERL)

Overview and Objectives:

The goal of this sub-project is to engage with public health and natural resource managers and decision- makers in order to guide beach water quality forecasting and harmful algal blooms research development as well as assess stakeholder research and communication needs to assist in the development of useful products and services. Ensuring the development of timely products, tools and services requires involving stakeholders in determining research priorities. One of the responsibilities of the Michigan Sea Grant Outreach Specialist is to translate research materials into a concise, easily understood format communicate research findings to stakeholders. The objectives of this work are to identify and assess user needs (related to harmful algal blooms and beach water quality forecasting) and disseminate scientific information, technology, and research materials to aid health officials, local governments, and communities in making sound environmental decisions.

This project addresses NOAA Strategic Plan Goal # 3): Serve society's need for weather and water information and falls in line with NOAA's mission of science, service and stewardship and sharing knowledge and information on predicting water quality changes of the Great Lakes coasts with specific end users.

Accomplishments:

- Co-organized a media briefing with NOAA Office of Congressional Affairs and Communications/ Public Affairs at the request of Congresswoman Marcy Kaptur. We have 10 journalists call in and participate. This media briefing was deemed highly successful by Congresswoman Kaptur's office. June 15, 2015.
- Organized and facilitated Lake Erie HABs Training for the NOAA National Weather Service and developed the agenda to ensure participation from both NOAA National Ocean Service and Great Lakes Environmental Research Laboratory as well as CILER. June 9, 2015
- New story interview "Early prediction: Toxic algae won't be as bad." Port Clinton News Herald story, May 19, 2015. http://www.portclintonnewsherald.com/story/news/local/2015/05/19/early-prediction-toxic-algae-bad/27610435/

- Organized and co-facilitated Stakeholder Forum for the Harmful Algal Blooms and Hypoxia Research and Control Act during the NSF-NOAA Harmful Algal Blooms Symposium at Bowling Green State University. We had 80 stakeholders and their affiliations ranged from university students, Congressional staffers, Ohio EPA, National Wildlife Federation, City of Toledo, Ohio Environmental Council, drinking water treatment plants (e.g. Norwalk, Sandusky), Lake Erie Water Keepers, Sierra Club, Michigan Department of Environmental Quality, Ohio Sea Grant, and **several** people from general public/ concerned citizens. April 15, 2015.

Publications:

Cooperative Institute for Limnology and Ecosystems Research Overview 2 pager:
http://ciler.snre.umich.edu/sites/ciler.snre.umich.edu/files/factsheets/CILER201504.pdf
JOSHI, S.J., A. Stevens, and L. Vaccaro. Saginaw Bay Multiple Stressors and Beyond workshop: Summary report. NOAA Technical Memorandum GLERL-166. NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 28 pp. (2015).
http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-166/tm-166.pdf

ROCKWELL, D.C., S.J. Joshi, A. Mednick and H. Wirick. Beach health information needs assessment: 9 years later -- results from follow-up survey. NOAA Technical Memorandum GLERL-163. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI (2014). http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-163/tm-163.pdf

Presentations:

JOSHI, S.J. Harmful Algal Blooms and Drinking Water. Michigan Chapter- American Waterworks Association Spring Regional Workshops. (webinar presentation) April 22, 2015.

JOSHI, S.J., T.W. DAVIS, E.J. ANDERSON, S.A. RUBERG, M.D. ROWE, T. JOHENGEN and A. VANDERWOUDE. Lake Erie Algal Blooms. Annual Western Lake Erie/ Detroit River Regional Fishery Workshop. Taylor, MI, April 16, 2015.

JOSHI, S.J., T.W. DAVIS, E.J. ANDERSON, S.A. RUBERG, M.D. ROWE, T. JOHENGEN and A. VANDERWOUDE. Lake Erie HABs Tracker. Lake Erie Water Treatment Plant Group, Avon Lake, OH, March 24, 2015 (2015).

JOSHI, S.J. Harmful Algal Blooms: Are they possible in Lake St. Clair? Lake St. Clair Waterfront Environmental Committee Annual Meeting, St. Clair Shores, MI, January 22, 2015 (2015).

JOSHI, S.J. Beach Water Quality Monitoring and Forecasting- Applications to Coastal Management. GLERL Science in Action meeting with NOAA Office of Coastal Management. Ann Arbor, MI, October 20, 2014.

JOSHI, S.J. HABs in the Great Lakes: Outreach, Collaboration, and Coordination. Michigan Sea Grant Program Planning, Implementation, and Evaluation (PIE) Assessment Review, Belle Isle Nature Zoo, Detroit, MI, October 28, 2014 (2014).

THEME III: ECOLOGICAL RISK ASSESSMENT

PROJECT TITLE: 2014 MONITORING ACTIVITIES FOR THE LAKE HURON AND LAKE MICHIGAN LONG-TERM ECOLOGICAL RESEARCH PROGRAMS

Principal Investigators: Allen Burton (CILER), Thomas Johengen (CILER)
NOAA Technical contacts: Henry Vanderploeg (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

CILER supports the Ecosystem Dynamics branch at NOAA-GLERL to continue its collection of long-term ecological data and conduct targeted fundamental research on ecosystem processes critical to understanding ecosystem structure and function for managing water quality, fisheries, and other ecosystem services in the Great Lakes. Towards this goal, NOAA-GLERL has developed a Long-Term Research (LTR) program that integrates a core set of long-term observations on biological, chemical, and physical variables, with short-term process-based studies for understanding ecosystem change. Such information is essential for the development of new concepts, models, and forecasting tools to explore impacts of various stressors on the ecosystem. This research will contribute to GLERL's core mission by providing data and understanding for the development of models and forecasting capabilities, and the application of new sampling technologies.

The proposed research activities are organized into two general projects: LTR observations and process-based studies. It is implicitly understood that all process studies are targeted to understand critical processes affecting Great-Lakes LTR sites or ecosystems. It is our ultimate goal to understand structure and function of Great Lakes food webs from viruses to fishes and work efficiently as team to be ready for Coordinated Science and Monitoring Initiative (CSMI) Year of Lake Michigan 2015, when we intend to take a major leadership role. The single most important stressor in the system remains dreissenid mussels, and our team recognizes that observation of the pelagic realm alone is no longer an option. Dreissenid mussels, because of their high filtration rates and high abundance in all depth zones of the lake, have decimated the spring phytoplankton bloom and have decreased the abundance of phytoplankton in the hypolimnion and deep chlorophyll layer during the stratified season. They have also reengineered the ecology of the entire food web by increasing water clarity and altering nutrient cycling. It is believed they have had a negative effect on the food web, which is putting the valuable sport fishery at risk and is exacerbating nuisance growths

of algae in the nearshore. We believe it is possible that dreissenid populations may be poised for a correction or crash.

<u>**Specific Aims/Milestones:**</u>
Project 1: LTR Observations
CILER will provide support for the following projects in Lakes Michigan and Huron:

<u>**1.1 Lake Michigan**</u>
- **Dreissenid Abundance and Condition** - Continue long-term observations of dreissenid abundance and condition in the Southern Lake Michigan basin   A benthic survey at 40 sites in the southern basin will be made in late summer, and monthly collections of mussels at our shallow, mid-depth, and deep sites along our Muskegon transect will be examined monthly for condition (based on weight), reproductive state, and nutrient content of soft tissue and shells. It is likely we will also examine mussels for filter area to see if this can be used as good metric for predicting filtering rate as a function of size. This project, the benthic boundary layer subproject and the feeding and nutrient excretion subproject will all work together to develop models of mussel population growth and bioenergetics and to develop models of impact to the food web.
- **Spatial Studies and Microbes -** As part of the CSMI Year of Lake Michigan 2010-2011 and CSMI Year of Lake Huron 2012 we examined the **structure and function of the open water food web, including how it relates to tributary inputs and spatial distribution of dreissenid mussels.** In cooperation with USGS-GLSC and Michigan DNR, we will continue to analyze the horizontal and vertical distribution of plankton, larval fish, juvenile fish, adult fish, and *Mysis*, and relate these observations to the distribution and feeding of invasive quagga mussels. Long-term, intensive field sampling is starting to improve our understanding of the importance of spatial coupling of the food webs within each of these two Lakes, and has raised many questions that have to be attacked with even more sophisticated technologies than we brought to bear so far on the field efforts. The focus in 2014 was on getting gear ready, including the recently acquired MOCNESS, and answering a few critical questions before our next major thrusts in CSMI Year of Lake Michigan 2015.

<u>**1.2 Lake Huron**</u>
- Continue to process and analyze data collected in 2012 for the CSMI benthic and spatial studies and continuing the small subproject defining benthos on hard and soft substrates in Thunder Bay. This latter study will be tied to mussel feeding work described below.

Project 2: Process-based Studies

In addition to maintaining core monitoring of key variables these LTR sites at appropriate time scales, we propose to conduct targeted process research to get at root causes of the changes, necessary for development of new concepts and forecasting capabilities. Research in this project area is concerned with process studies involving the main biotic driver of the system, the quagga mussel, and attacks the most critical issues concerning their interactions with the ecosystem. The subproject deals with the contentious problem as to the connection of the mussels with the overlying water column. Research will also support the development of a new Dreissena impacts model in Lake Michigan using the FVCOM framework and tie into the research on abundance and condition of mussels in Lake Michigan. Measurement of the chlorophyll at the benthic boundary layer and exchange will be important not only for understanding impact of the mussels on the water column but also for understanding mussel condition and growth to understand their population dynamics. We will also on occasion collect mussels and water from Lake Michigan to check on nutrient excretion interactions there. We have previously defined grazing on phytoplankton (using the chlorophyll techniques), but have not looked at nutrient excretion nor considered interactions in the benthic boundary layer.

2.1 Mussel Feeding and Nutrient Excretion
- Determine selective feeding on whole spectrum of seston (from bacteria to microplankton), quantify nutrient recycling, and examine factors limiting growth of mussels in Thunder Bay to determine their impact in Lake Huron. Similar experiments are planned for Lake Michigan in the approximate time frames for Thunder Bay.
- Three surveys are planned to occur in early May, early August and late September, to collect mussels from hard substrates for experiments. Sampling will be tied to benthic studies on hard substrates in Project 1. The research is intended to help determine spatial distribution of all elements of the food web in the vicinity of Thunder Bay National Marine Sanctuary, to characterize the composition, abundance, and long-term trends of the benthic community throughout the lake, and to determine role of Saginaw Bay acting as a nearshore shunt for P removal.

Accomplishments:
1. Lake Michigan - Dreissenid Abundance and Condition
Mussels and amphipods were collected in the annual southern basin of Lake Michigan survey in September 2014. Biomass estimates of mussels for 2011, 2012, 2013 were completed and presented at IAGLR in May 2015. Condition was measured monthly in mussels along the Muskegon transect in 2013, which produced a Master's thesis and a manuscript in press for the JGLR Lake Michigan special issue. Mussel condition was

also measured four times during the 2014 season, the values from which will be used to calculate the 2014 biomass estimates. The 2014 benthic samples have all been processed and data analysis is in progress.

2. Lake Michigan - Spatial Study and Microbes

Three major seasonal spatial cruises were carried out in 2013 and in 2014. Data are now being processed for these cruises and two manuscripts have been submitted to journals. A number of presentations were made at national meetings. (see attached list). One of the manuscripts on the microbial food web based on studies in 2013 was submitted to a special issue of J. Great Lakes Research ("Complex interactions in Lake Michigan's Rapidly Changing Ecosystem"). This special issue will include several papers from GLERL/CILER authors based on work done under this subproject and the larger project as a whole.

3. Lake Huron – Benthic Spatial Studies

All Lake Huron 2012 benthic species identification and measurements are complete. Summary of the data is in progress. Data are being processed for spatial studies. A number of presentations were made at national meetings. (See attached list)

4. Mussel Feeding and Nutrient Excretion

Three mussel feeding and excretion experiments were carried out in summer and fall of 2014, including additional analysis on the fate of pico-plankton and the microbial food web by collaborations with Hunter Carrick (CMU) and Vincent Denef (EEB, UM). Data are being analyzed and will be used to support ongoing ecological modeling of Dreissenid mussel impacts on the lower food web within Lake Michigan. Vincent Denef submitted a manuscript based on these experiments and observation done on spatial cruises.

Publications:

ROWE, M.D., E.J. ANDERSON, J. WANG, and H.A. VANDERPLOEG. Modeling the effect of invasive quagga mussels on the spring phytoplankton bloom in Lake Michigan. *Journal of Great Lakes Research* 41:17 pp. (DOI:10.1016/j.jglr.2014.12.018) (2015).http://www.glerl.noaa.gov/pubs/fulltext/2015/20150011.pdf

Bootsma, H.A., M.D. ROWE, C.N. Brooks, and H.A. VANDERPLOEG. Commentary: The need for model development related to *Cladophora* and nutrient management in Lake Michigan. *Journal of Great Lakes Research* 41:9 pp. (DOI:10.1016/j.jglr.2015.03.023) (2015).
NALEPA, T.F., D.L. FANSLOW, G.A. LANG, K. MABREY, and M. ROWE. Lake-wide benthic surveys in Lake Michigan in 1994-95, 2000, 2005, and 2010: Abundances of the

amphipod *Diporeia spp*. and abundances and biomass of the mussels *Dreissena polymorpha* and *Dreissena rostriformis bugensis*. NOAA Technical Memorandum GLERL-164. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 21 pp. (2014).http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-164/tm-164.pdf

A prescriptive stock market investment strategy for the restaurant industry using an artificial neural network methodology. In press - *International Journal of Business Analytics.*

Scanlan, A. M., Millie, D. F., Weckman, G. R., & Carrick, H. J. 2015. Abrupt shifts in stream algal biomass and diatom taxonomic composition along a gradient of changing land use.*Fundamental & Applied Limnology*. 186: 153–169.

Millie, D. F., Weckman, G. R., Fahnenstiel, G. L., Carrick, H, J., Ardjmand, E., Young II, W. A., Sayers, M., & Shuchman, R. A. 2014. Using artificial intelligence for CyanoHAB niche modeling: discovery and visualization of *Microcystis*-environmental associations within western Lake Erie. *Canadian Journal of Fisheries & Aquatic Sciences* (selected as an *Editor's Choice*article for 2014). 71: 1642-1654.

Presentations:

BALDRIDGE, A.K., and T.F. NALEPA. The status of Dreissenid mussels in the Great Lakes and suggested future research directions. 58th Annual Conference of the International Association of Great Lakes Research. Burlington, VT, May 25-29, 2015 (2015).

BALDRIDGE, A.K. Relative impacts of climate change and Dreissenid mussels on Lake Michigan zooplankton. Aquatic Invasive Species: Impacts and Resources ("The Current" Webinar Series), October 15, 2014. North Central Region Water Network (2014).

BALDRIDGE, A.K., G.L. FAHNENSTIEL, J.R. LIEBIG, T.F. NALEPA, S.A. POTHOVEN, E.S. RUTHERFORD, and H.A. VANDERPLOEG. Exploring the relative impacts of climate change and dreissenid mussels on the Lake Michigan zooplankton community. 57th Annual Conference of the International Association for Great Lakes Research, McMaster University, Hamilton, Ontario, Canada, May 26-30, 2014 (2014).

BALDRIDGE, A.K., G.L. FAHNENSTIEL, J.R. LIEBIG, T.F. NALEPA, S.A. POTHOVEN, E.S. RUTHERFORD, and H.A. VANDERPLOEG. Exploring the relative impacts of climate change and Dreissenid mussels on Lake Michigan zooplankton. Adaptation in the Great Lakes Region Conference, University of Michigan, Ann Arbor, MI, June 25, 2014 (2014).

ROWE, M.D., H.A. VANDERPLOEG, E.J. ANDERSON, J. WANG, S.A. POTHOVEN, J.R. LIEBIG, T.F. NALEPA, and T.H. JOHENGEN. Modeling the effects of stratification and bathymetry on the interaction of phytoplankton and invasive Quagga mussels in nearshore Lake Michigan. Joint Aquatic Sciences Meeting, Portland, OR, May 18-23, 2014 (2014).

ROWE, M.D., H.A. VANDERPLOEG, J. WANG, and E.J. ANDERSON. Modeling the effects of stratification and bathymetric depth on the interaction between phytoplankton and invasive quagga mussels in the nearshore zone of Lake Michigan. Great Lakes Adaptation Assessment for Cities' Adaptation in the Great Lakes Region Conference, Ann Arbor, MI, June 24-25, 2014 (2014).

RUTHERFORD, E.S., A. SHAKOOR, K. Bouma-Gregson, H. ZHANG, D.M. MASON, D.M. Lodge, M.E. Wittmann, J.E. Breck, and H.A. VANDERPLOEG. Relative importance of timing, life history, and habitat of non-indigenous species for invasion success and impact in Great Lakes ecosystems. Joint Aquatic Sciences Meeting 2014, Portland, OR, May 18-23, 2014 (2014).

RUTHERFORD, E.S., H.A. VANDERPLOEG, J.F. CAVALETTO, J.R. LIEBIG, D.M. MASON, T.F. NALEPA, T.H. JOHENGEN, D. Burnette, D. WELLS, K. MABREY, D.B. Bunnell, D.M. Warner, T. O'Brien, and J.E. Johnson. Effects of spatial and temporal variability in lower food web dynamics on larval fish feeding growth and survival in Thunder Bay, Lake Huron, 2012. 57th Annual Conference of the International Association for Great Lakes Research, McMaster University, Hamilton, Ontario, Canada, , May 26-30, 2014 (2014).

RUTHERFORD, E.S., H.A. VANDERPLOEG, J.F. CAVALETTO, J.R. LIEBIG, S.A. POTHOVEN, D.M. MASON, A. HOOVER, D. Burnette, D. WELLS, K. MABREY, D.B. Bunnell, D.M. Warner, and T. O'Brien. Compensatory response of the lower food web and larval fish growth and survival to multiple stressors in Lake Michigan and Lake Huron. 144th Annual Meeting of the American Fisheries Society, Quebec City, Canada, August 17-21, 2014 (2014).

Outreach Activities:
We participated in informational tabling events (e.g., the Ann Arbor Mayor's Green Fair) and volunteered for student science competitions (e.g., National Ocean Science Bowl and a local science fair).

Relevant Webcontent:
New you-tube videos were generated to provide the public with a summary of our LTR research programs. https://www.youtube.com/user/noaaglerl

THEME III: ECOLOGICAL RISK ASSESSMENT

PROJECT TITLE: LAKEWIDE ASSESSMENT OF LAKE ONTARIO BENTHIC MACROINVERTEBRATE COMMUNITIES

Principal Investigators: Tom Johengen (University of Michigan) and Thomas F. Nalepa (University of Michigan)
NOAA Technical contacts: Hank Vanderploeg (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives

This project examines temporal trends in abundances of benthic macroinvertebrate populations in Lake Ontario. Past surveys in the lake have documented abundances in 1998, 2003, and 2008, and samples will be collected at the same sites as these past surveys and recent trends determined. Of particular interest are trends in *Diporeia* and *D. r. bugensis* (quagga mussels). Abundances of the former taxa have been decreasing, and abundances of the latter taxa have been increasing. These changes have had severe impacts on the ecology of the lake.

Accomplishments

In 2013, samples were collected in triplicate at each of 47 sites located throughout the lake (total samples = 141). Partners that assisted in the sampling effort were EPA-GLNPO, EPA-Region 2, USGS, and DFO. In addition, quagga mussels were collected at 7 of the sites and processed for the determination of length-weight regressions. During the last reporting period, all organisms in the 141 samples were picked, counted, and sorted into major taxonomic groups. In addition, about ½ of quagga mussels in these samples were measured for shell length and. These measurements along with calculated length-weight regressions will be used to determine mussel biomass.

In this reporting period, the rest of the mussels collected in the survey were measured, regressions determined and applied to , and biomass calculated. Preliminary results were compared to that reported in 2008. While the dreissenid population in Lake Ontario appears to have decreased between 2008 and 2013, biomass has generally remained the same. This would indicate that the dreissenid population is now dominated by larger, older individuals, perhaps indicating the population has peaked.

Also in this reporting period, all oligochaetes and chironomids were mounted on microscope slides and prepared for identification. Some identifications were initiated.

Publications
None to date.

Presentations
None to date.

Outreach Activities
None to date.

THEME III: ECOLOGICAL RISK ASSESSMENT

PROJECT TITLE: THE EFFECTS AND IMPACTS OF HYPOXIA ON PRODUCTION POTENTIAL OF ECOLOGICALLY AND COMMERCIALLY IMPORTANT LIVING RESOURCES IN THE NORTHERN GULF OF MEXICO

Principal Investigators: Michael Roman and James Pierson (University of Maryland Center for Environmental Sciences), Stephen Brandt (Oregon State University), James Cowan (Louisiana State University), Shaye E. Sable (Louisiana Department of Fishes and Wildlife), Aaron Adamack (University of Michigan)
NOAA Technical Contacts: Doran Mason (NOAA-GLERL) and Craig Stow (NOAA-GLERL)

NOAA Strategic Goal 1: Healthy Oceans

Overview and Objectives:
Characterizing the effects of the spatial and temporal distribution of hypoxia on
1.   Diet habits of economically and ecologically critical fishes
2.   Food web structure and interactions
3.   Fish distribution

Accomplishments:
Objective 1: Diet
CaRT model defined three general size classes of Atlantic bumper, fish less 49 mm (small), fish equal to and greater than 49mm but less than 107 mm (medium), and fish greater than and equal to 107 mm (large) (Figure 1). These length classes closely resemble definitions of small juveniles, juveniles, and mature fish found in the literature 5). Sample size was not uniform across size classes. Most Atlantic bumper occupied the large fish size group with the fewest number of samples for the medium fish. Number of samples also varied with DO (Table 1, Figure 2).

Frequency of occurrence of zooplankton in fish guts was dominated by zooplankton for small and large fish, but by shrimp for medium size fish (Table 1). However, biomass of prey groups in the fish was dominated by shrimp for small and medium fish and larval fish for large Atlantic bumper (Table 2).

DO was a poor predictor of fish gut fullness using log-linear multiple regression model, numerical frequency of each prey group in stomach using multinomial logistic model, and biomass of each prey group in the diet using the beta regression model. In general,

the CaRT model was also a poor predictor of prey biomass in the guts, with the exception of shrimp. Shrimp were found to dominate the diet by biomass when DO was less than 3.8 mg L^{-1} (Figure 3).

References

da Costa, M, Albieri, RJ, Araujo, FG (2005) Size distribution of the jack *Chloroscombrus chrysurus* (Linnaeus) [Actinopterygii, Caranigae] in a tropical bay at Southeastern Brazil. Revista Brasileira de Zoologia 22(3): 580-586

Magro, M, Cergole, MC, Rossi-Wongtschowski, CLDB (2000) Sintese de conhecimentos dos principais recursos pesqueiros costeiros potencialmente explotaveis na costa Sudeste-Sul do Brasil: peixes. Sao Paulo, REVIZEE, 145 p

Figure 1: Atlantic bumper a) length frequency distribution from trawls and b) length of prey consumed by Atlantic bumper length. Dashed lines are where length divisions between the size classes were identified using a CaRT model.
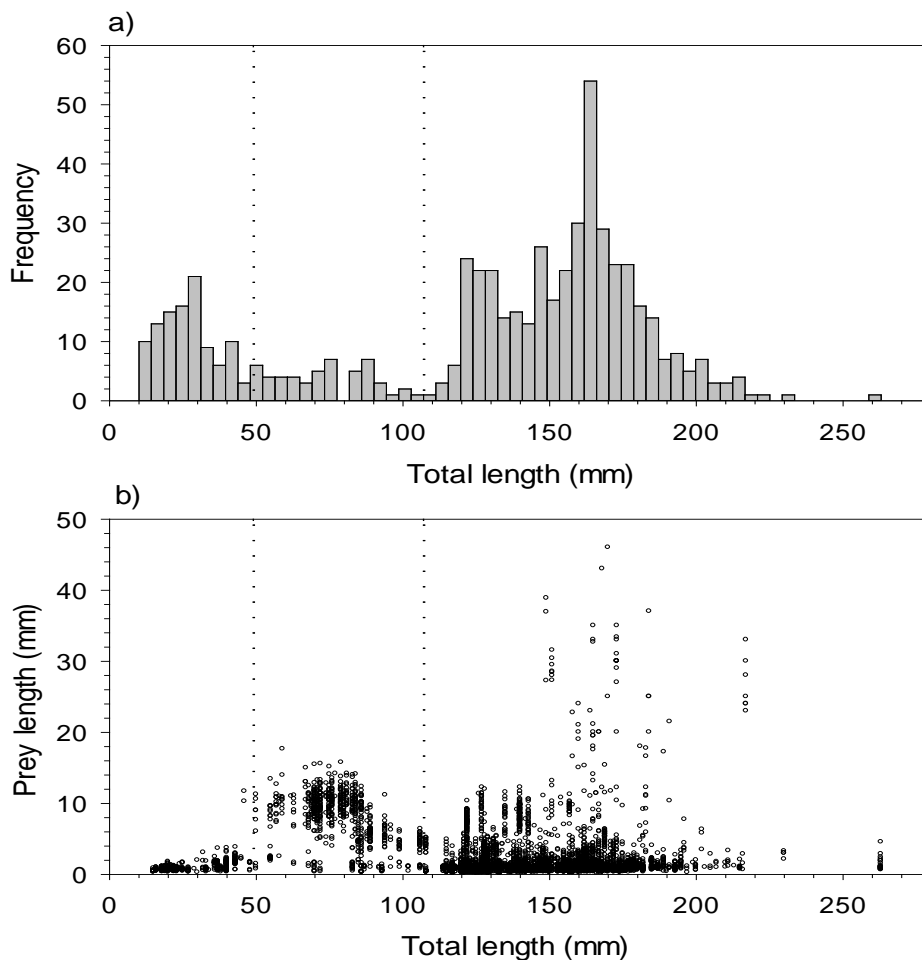
Figure 2: Distribution of observations for gut fullness (g g^{-1}, dry mass of prey divided by dry mass of bumper) with respect to DO for Atlantic bumper by length classes.
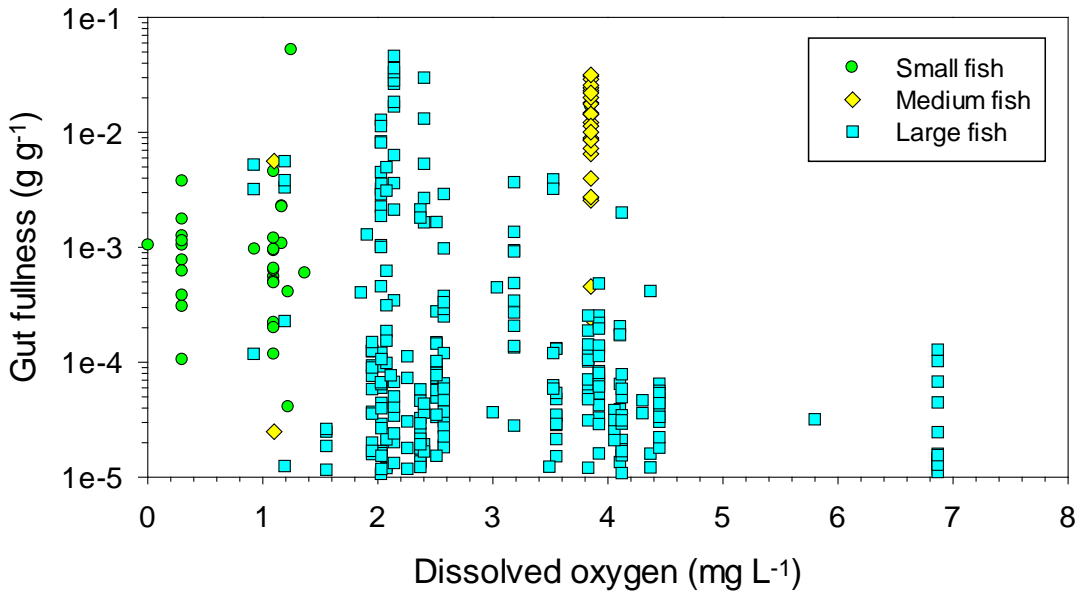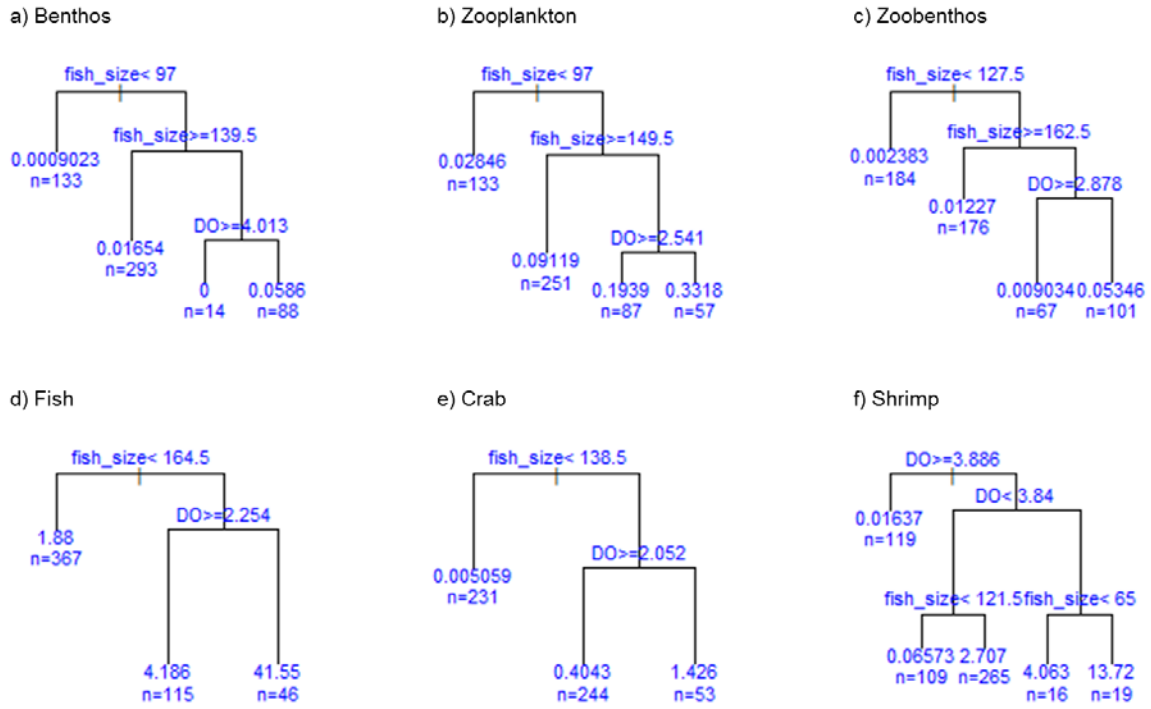
Figure 3. A Classification and Regression Tree (CART) predicting the mean biomass of a) benthos, b) zooplankton, c) zoobenthos, d) fish, e) crab, and f) shrimp conditional on the size of Atlantic bumper, and dissolved oxygen level. At each node an observation moves to the left branch when the condition shown at the node is satisfied.

a) Benthos

fish_size< 97
fish_size>=139.5
0.0009023 n=133
0.01654 n=293
DO>=4.013
0 n=14   0.0586 n=88

b) Zooplankton

fish_size< 97
fish_size>=149.5
0.02846 n=133
0.09119 n=251
DO>=2.541
0.1939 n=87   0.3318 n=57

c) Zoobenthos

fish_size< 127.5
fish_size>=162.5
0.002383 n=184
0.01227 n=176
DO>=2.878
0.009034 n=67   0.05346 n=101

d) Fish

fish_size< 164.5
DO>=2.254
1.88 n=367
4.186 n=115   41.55 n=46

e) Crab

fish_size< 138.5
DO>=2.052
0.005059 n=231
0.4043 n=244   1.426 n=53

f) Shrimp

DO>=3.886
DO<3.84
0.01637 n=119
fish_size< 121.5   fish_size< 65
0.06573 n=109   2.707 n=265   4.063 n=16   13.72 n=19

Table 1. Distribution of sample sizes with respect to fish size class and DO category.

Size group	DO<2	2≤DO<3	3≤DO<4	DO≥4	Total
Small	83	0	14	0	97
Medium	2	0	33	1	36
Large	43	175	82	95	395
Total	128	175	129	96	528

Table 2. Diet composition by percent frequency of occurrence and percent dry mass for dietary categories found in small (< 49 mm), medium (49-106 mm), and large (≥ 107 mm) Atlantic bumper for the five prey categories and all years combined. SUM is the sum of the columns (100%).

Prey Category	Frequency Small	Frequency Medium	Frequency Large	Mass Small	Mass Medium	Mass Large
Zooplankton	52.46	30.00	40.71	11.98	0.43	1.49
Zoobenthos	27.87	4.29	16.50	0.38	0.01	0.21
Benthos	11.48	4.29	14.30	0.52	0.13	0.23
Crab	0	10.00	10.15	0	5.87	4.82
Shrimp	8.20	50.00	16.63	87.12	92.97	17.72
Larval fish	0	1.43	1.71	0	0.58	75.52
SUM	100.00	100.00	100.00	100.00	100.00	100.00

**Objective 2: Food web structure and interactions**
Atlantis Ecosystem Model. Status- The 3-dimensional horizontal polygon grids and vertical strata are defined and completed. All the parameter files are completed and we are currently debugging the entries. The parameter files are extensive and require a significant amount of time to create.

Diet matrix for the food web interactions (Table 1) has been determined for most of the functional groups based upon the values provided by Kim de Mutsert from the EwE model and this was part of the ecology parameterization run files. This contained the functional group information and biogeochemical values for each layer and each box. This included the abundance, distribution of the reserve, structural and total nitrogen values for each one of the functional groups for the 10 different age classes, as well as the number of fish within each layer and box. The growth parameters come for a weight-at-age from the von Bertlanffy growth parameters, converted to nitrogen-weight. The benthos values only use one entry for the two-dimensional box instead of the three-dimensional vertical distribution and age groups associated with vertebrates. Describing the bottom surface type for each one of the boxes then follows this large file. These two files and the large biology parameter file with switches for initial conditions were incorporated into the biology netcdf file that is fed into the model. It is within the biology files that we set the initial conditions for dissolved oxygen to mimic hypoxia in the summer and fall, the threshold of dissolved oxygen for the functional groups and the type of oxygen limitation. We are at the point of testing which oxygen limitation is the best choice.

That last part before the model is operation was setting up the forcing files from the hydrodynamics, the physics parameters, the fishery and management parameters, the assessment and the economics. At this point the hydrodynamics, management and assessment and economic parameters are all turned off as. The developers in Australia are currently optimizing the code.

The progress to date has been slow as there has been continued debugging and hydrodynamics problems. Also, the post-doc on the project has been on maternity leave and it's not clear when she will be back. However, we intend to complete this component of the project.

Figure 1. Model grids for (A) the northern Gulf of Mexico model nested in the larger Atlantis Gulf of Mexico model, (B) a close up of the model grid for the Louisiana-Texas continental shelf, and (C) the vertical strata used in the model.

A.   B.

C.
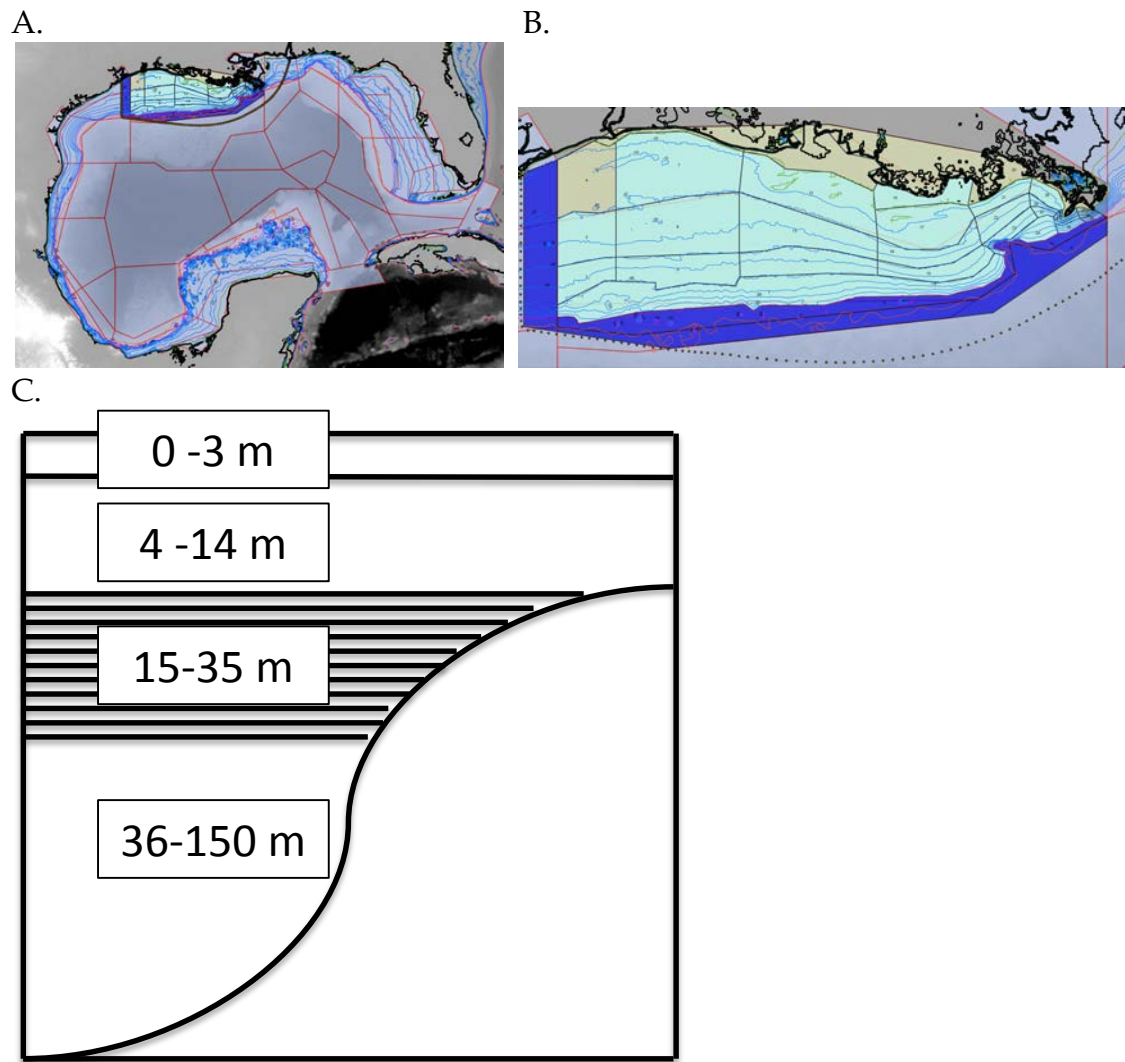
Table 1. Functional groups by organism category included in the Atlantis model

Category	Functional groups/species
Areal invertebrates and primary producers	Benthic algae
	Benthic Shrimp
	Echinoderms
	Benthic crabs
	Benthic worms
	Snails
	Benthic weeds
	Clams/scallops
	Sponges
Volumetric invertebrates and primary producers	Brown shrimp
	White Shrimp
	Other shrimp
	Jellyfish
	Phytoplankton (3 groups)
	Swimming crabs
	Calanoid copepods
	Copepodites
	Squid
Vertebrates	Anchovey
	Atlantic bumper
	Atlantic croaker
	Atlantic cutlassfish
	Catfish
	Eels
	Flounder
	Cadidae
	Groupers
	Gulf butterfish
	Herring
	Jacks
	Lizardfish
	Mackerel
	Menhaden
	Muller
	Perch

	Pinfish
	Porgies
	Rays and skates
	Red drum
	Red snapper
	Scad
	Scianidae
	Sea bass
	Sea robin
	Sea trout
	Serranids
	Sharks
	Other snappers
	Spot

Publications:

Zhang, H., D.M. Mason, C.A. Stow, A.T. Adamack, S.B. Brandt, Z. Zhang, D.G. Kimmel, M.R. Roman, W.C. Boicourt, and S.A. Ludsin. 2014. Effects of hypoxia on habitat quality of pelatic planktivorous fishes in the northern Gulf of Mexico. Marine Ecology Progress Series 505: 209-226

Manuscripts in preparation

Title: Summer feeding habits of Atlantic bumper in the northern Gulf of Mexico

Presentations: None in FY15

Outreach Activities: None to date

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: WEATHER READY NATION

Principal Investigators: Jeff Gunderson (University of Minnesota)
NOAA Technical contacts: Jennifer Day (NOAA – Great Lakes Regional Collaboration)

NOAA Strategic Goal 2: Weather-Ready Nation

Overview and Objectives:

This research and outreach project sought to evaluate the effectiveness of the Impact Based Warning (IBW) tool throughout the National Weather Service (NWS) Central Region. This tool was piloted and evaluated in five Weather Forecast Offices (WFOs) in 2012. The tool was made available to 38 WFOs for the severe weather season in 2013. It was evaluated with similar methodology used in the pilot offices following Gallupi, Losego, and Montoz (2013). Our study revealed how weather forecasters, broadcast meteorologist and emergency mangers use NWS severe weather warnings, the gaps that emerge between what NWS provides and what user groups need, and ideas for improving NWS products to better serve the broadcast meteorologist and the emergency management community.

Sea Grant partnered with the NWS to better support Weather Ready Nation and establish a relationship between the two groups. The research undertaken was summarized in various outreach products for the NWS including a summary report, fact sheet, webinar presentations for NWS staff and in-person presentations. Additionally, Sea Grant created recorded training modules that describe the Great Lakes Sea Grant mission and programs as well as specific case studies, which allowed interested NWS staff to further learn of opportunities to collaborate with Sea Grant. The materials were customized to short segments to lend wider viewing by NWS staff who are familiar with short modules as part of their ongoing training and development curriculum.

Accomplishments

Sea Grant's Great Lakes Social Science Network (GLSSN) Assists in Assuring National Hazard Preparedness Along With the NWS

Relevance: Hazard preparedness includes being ready for severe weather such as thunderstorms and tornadoes. The National Weather Service, Central Region (NWS) has adjusted severe weather language to be impact-based in an effort to improve hazard preparedness. The NWS's Central Region encompasses 14 states.

Response: The NWS turned to Sea Grant's GLSSN for critical knowledge of social science expertise in order to undertake a study of the effectiveness of impact-based warnings.

Results: The GLSSN conducted a study, which led the NWS to continue impact-based warnings in the Central Region, as well as expand impact-based warnings nationally in 2014. The study revealed the elements that make IBW effective, as well as limits and modifications needed for the product. Focus groups, interviews, and surveys were conducted with weather forecasters, emergency managers, and broadcast media. The study revealed that the product's simple, concise language allows hazard information to be digested more quickly by emergency managers and the media, while its urgent, descriptive language encourages emergency managers and media to take appropriate action in the event of severe-weather. Modifications suggested for the product included allowing weather forecasters to modify impact statements based on local weather patterns and population demographics, and providing in-person impact-based warning training to weather forecasters. The team's social scientists have shared this research at the American Meteorological Society, Social Coast Forum, NWS Central Region headquarters and a webinar for NWS Central Region weather forecasters and partners such as emergency managers and broadcast meteorologists. A fact sheet, an executive summary of the study's results, is available on Wisconsin Sea Grant's website.

Recap: The GLSSN helped to assure national hazard preparedness in the face of severe weather by assessing the impact-based warning product. The warnings are delivered in concise language allowing for the consequences to be more easily digested by emergency managers, the media and the public. The team's social scientists conducted an analysis of the warnings for the National Weather Service Central Region and the overall agency will adopt the warnings nationwide.

Partners: Wisconsin Sea Grant, Illinois-Indiana Sea Grant, Minnesota Sea Grant, New York Sea Grant, NOAA Coastal Services, National Weather Service

Sea Grant Training for NWS Staff

Sea Grant developed three case studies that were used to teach NWS staff, via Webinar, about what the Great Lakes Sea Grant Network is and what we do. This builds on similar training that the NWS provided to the Great Lakes Sea Grant Network in Duluth, MN which described the operation and function of the NWS. Together these efforts are designed to encourage Sea Grant and the NWS to work together to address Weather Ready Nation goals and objectives.

Ron Kinnunen developed a draft PowerPoint presentation that focused on education and outreach initiatives conducted by Michigan Sea Grant/Michigan State University Extension on rip current awareness. The presentation was forwarded to Sandra Enness, who then reviewed the presentation for editing and formatting. Ms. Elizabeth LaPorte and Mr. Todd Marsee, both of Michigan Sea Grant, provided additional gratis consultation. Dr. Kinnunen delivered the final product to Ms. Jennifer Day on or before April 30, 2014.

Jeff Gunderson, Minnesota Sea Grant, developed a Power Point presentation that describes what the Great Lakes Sea Grant Network is and how it functions. This was reviewed, modified and sent to Jennifer Day. Jesse Schomberg, also with Minnesota Sea Grant, developed a Power Point module to describe the Non-point Education for Municipal Officials (NEMO) program that the network is engaged in. This is an effort that looks at land use planning relative to impervious surfaces, stormwater runoff, and water quality. This presentation was also submitted and is ready for the Webinar that will take place this summer.

Publications
- Article: Conklin, Aaron R. October 24, 2013. The entire neighborhood will be destroyed. Wisconsin Sea Grant Aquatic Sciences Chronicle.
- Article: Brown, Jason. May 14, 2014. Social science researchers help evaluate more effective weather warnings. Illinois-Indiana Sea Grant. Lakeside Views.
- Report: Harrison, Jane, McCoy, Caitie, Bunting-Howarth, Kathy, Sorensen, Hilarie, Williams, Katie, and Chris Ellis. Evaluation of the National Weather Service Impact-based Warning Tool. Submitted to the NWS Central Region Headquarters April 10, 2014. WISCU-T-14-001.
- Fact Sheet: Harrison, Jane, McCoy, Caitie, Bunting-Howarth, Kathy, Sorensen, Hilarie, Williams, Katie, and Chris Ellis. Social science and severe weather:

Evaluating a new tornado risk communication tool. June 2014.
<www.seagrant.wisc.edu>

- Submission to the NOAA National Ocean Service news weekly.
- Feature on the National Sea Grant website.

Presentations:

- Social Coast Forum 2/20/14 – presentation to 60 attendees in Charleston, South Carolina.
- American Meteorological Society, Milwaukee Chapter 3/26/14 – presentation to 40 members in Milwaukee, Wisconsin.
- American Meteorological Society Meeting 2/5/14 – presentation to 60 NWS weather forecasters, emergency managers, and broadcast meteorologists, and NWS policy decision-makers in Atlanta, Georgia.
- NWS Central Region Webinar 4/15/14 – presentation to 240 NWS Central Region weather forecasters via webinar.
- NWS Central Region Headquarters 5/7/14 – presentation to 100 NWS leadership personnel, including all NWS Central Region Meteorologists-in-Charge in Kansas City, Missouri.
- Great Lakes Sea Grant Network meeting 6/18/14 – presentation to 100 attendees in Erie, Pennsylvania.

Outreach Activities: Report and fact sheet sent to the following:

- Jennifer Sprague, NOAA NWS Policy Analyst: She is interested in incorporating social science more broadly into NWS decision-making and will use our study and work as an example.
- Vankita Brown, NWS Social Scientist: She is interested in our study as she helps to develop NWS hurricane impact statements and further develop the IBW product.
- Stephanie Fauver, NOAA Coastal Services Center: Study results are relevant to the NWS Hurricane Center as they develop hurricane impact statements
- Danielle Nagele, NOAA Social Scientist: She is interested in our study because she is compiling NOAA funded risk communication and behavior literature.
- Leon Cammen, NSGO: He posted information on the study to the NSGO website.

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: NOAA EMERGENCY RESPONSE PROTOCOLS

Principal Investigator: Thomas Johengen (CILER)
NOAA Technical contacts: Doran Mason (NOAA-GLERL), Eric Anderson (NOAA-GLERL), & Jennifer Day (NOAA-OAR)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

CILER supports NOAA's Great Lakes Regional Collaboration Team in planning and implementing the Habitat Blueprint initiative in Muskegon, Michigan. Habitat Blueprint is a nationwide initiative that provides a framework for NOAA to better focus internal programs and expertise in addressing habitat loss and degradation. Habitat Blueprint is designed to help NOAA prioritize habitat related projects and activities. Ultimately, this initiative will allow NOAA to maximize our impact in supporting healthy habitats that contribute to resilient and thriving coastal communities and economies.

An essential component of Habitat Blueprint is the selection of regional Habitat Focus Areas (HFAs). These HFAs are specific geographic sites where NOOA intends to focus agency resources and expertise through the Habitat Blueprint initiative. For each HFA, NOAA and local partners will develop an Implementation Plan to guide NOAA's habitat research, restoration, and conservation efforts in the area over a five year time period. These plans will ultimately result in a place-based strategic approach to NOAA's habitat research and restoration efforts, increased collaboration across NOAA programs, and enhanced partnerships with local stakeholders. In the case of the Muskegon HFA the development of the Habitat Blueprint Implementation plan also presents a prime opportunity for GLERL to advance community partnerships in Muskegon and improve the effectiveness of research efforts at the Lake Michigan Field Station through collaboration with other research institutions active in the Muskegon Lake and River watershed.

Extensive community outreach efforts and a comprehensive stakeholder needs assessment process were used to inform the development of the Habitat Blueprint Implementation Plan and collect information on ongoing habitat related research and

restoration efforts in the HFA to avoid duplication. The final Implementation Plan provides a strategic approach to guide NOAA research, restoration, and outreach activities in the Muskegon HFA. The plan outlines NOAA's involvement in ongoing habitat related efforts in Muskegon and provides recommendations for future opportunities to bring new NOAA resources and expertise to bear in the Muskegon HFA. Ultimately, we expect this plan to increase collaboration across diverse NOAA programs and initiatives and enhance NOAA's effectiveness as a partner agency within the wider Muskegon community.

Specific Aims and Milestones:

Conduct a Stakeholder Needs Assessment

- Survey key stakeholders to better understand their perceptions of habitat restoration and research activities in the Muskegon HFA, their individual vision for resource use in the watershed, and potential opportunities for NOAA to provide added value to habitat related efforts and strengthen partnerships in the HFA. .
- Explain the goals and objectives of Habitat Blueprint and how they relate to ongoing habitat work in the HFA.

Community Outreach

- Establish a stronger NOAA presence at local stakeholder meetings and events.
- Foster NOAA partnerships with new organizations and institutions not just within the environmental community but also in the fields of economic development and education.
- Organize a workshop to connect researchers and local stakeholders with the ultimate goal of developing specific recommendations for ensuring research efforts are responsive to the needs and interests of the local community.

Draft Habitat Blueprint Implementation Plan

- Develop a leadership structure with representation from diverse NOAA line offices and relevant community stakeholders to act as the primary decision making body in creating an Implementation Plan.
- Draft an Implementation Plan to guide Habitat Blueprint efforts in Muskegon and provide a framework to strategically integrate NOAA habitat research, restoration, and outreach activities in the HFA.

Accomplishments:

Conduct a Stakeholder Needs Assessment

- Over the course of two months we conducted interviews with 40 individuals from 29 different organizations, agencies, and businesses. These outreach efforts encompassed stakeholders from across the Muskegon Lake and Muskegon River watersheds, as well as representatives from the private, public, and nonprofit sectors.
- Interview questions were tailored to fit the expertise and experience of each individual stakeholder but broadly covered five major topic areas 1) the ongoing and planned projects of the stakeholder group 2) ties between economic development and habitat restoration in Muskegon and the surrounding region 3) obstacles to effective habitat restoration and conservation 4) opportunities and gaps in ongoing projects or research 5) long-term vision for Muskegon Lake and the watershed.
- Detailed notes were taken for each of the interviews. We then used those notes to identify trending ideas and topics that were mentioned by multiple stakeholders in relation to a theme. The resulting analysis provided a broad view of community concerns and priorities that informed the design and implementation of Habitat Blueprint in Muskegon Lake.

Community Outreach
- The CILER summer intern attended community meetings and events as a NOAA representative including regular meetings of the Muskegon Lake Watershed Partnership.
- In part as a result of the relationships built during the community assessment process GLERL is currently partnering with the Lakeshore Museum Center to develop an educational exhibit on the history of mill debris in Muskegon Lake and modern restoration efforts.
- In November of 2015 GLERL partnered with the Grand Valley State University Annis Water Resources Institute and the West Michigan Shoreline Regional Development Commission to host the second in a series of three Lake Michigan-Muskegon Lake Connectivity workshops. This workshop brought together resource managers, restoration specialists, and stakeholders from across the Muskegon HFA with the goal of ensuring that long-term research efforts in the HFA are responsive to the needs and priorities of those working on the ground in habitat restoration and resource management.

Draft Habitat Blueprint Implementation Plan
- Established an Executive Committee composed of leadership from diverse NOAA line offices as well as representatives from Muskegon area research and nonprofit entities to guide the development of a Habitat Blueprint Implementation Plan.
- Completed an early draft the Implementation Plan for Habitat Blueprint in Muskegon Lake.

Products:
Muskegon Habitat Focus Area Stakeholder Assessment: Summary Report
Muskegon Research and Restoration Connectivity Workshop: Summary Report
Draft Habitat Blueprint Implementation Plan for the Muskegon Habitat Focus Area

Outreach Activities:
- Presentation to Muskegon Lake Watershed Partnership
- Muskegon Research and Restoration Connectivity Workshop
- Presentation to national Habitat Blueprint leadership team and representatives from other regional HFAs
- *Habitat Blueprint in Muskegon* fact sheet created and distributed

Relevant Websites:
http://www.habitat.noaa.gov/habitatblueprint/greatlakes.html
http://www.habitat.noaa.gov/habitatblueprint/MuskegonLake.html

PROJECT TITLE: NOAA GREAT LAKES STRATEGIES AND RESPONSE

Principal Investigators: Tom Johengen (UM-CILER)
NOAA Technical contacts: Jennifer Day (NOAA – Great Lakes Regional Collaboration);
Heather Stirratt (NOAA- NOS)

NOAA Strategic Goal 3: Climate Adaptation and Mitigation

Overview and Objectives:

NOAA has received funding through the FY13-14 GLRI allocation and through its Great Lakes Regional Collaboration Team budget to implement a comprehensive NOAA climate program in the Great Lakes. An important objective of this project focuses on providing community outreach and technical assistance for assessing climate change and hazards risks and vulnerabilities.

Specific Aims / Milestones:

1) Climate Forums – Including partners from the Upper Midwest and Great Lakes Landscape Conservation Cooperative (USFWS) and GLISA. The purpose of these workshops is to bridge the gap between science and management by creating an opportunity to bring together representatives from local management agencies, nongovernmental organizations, and interest groups with decision makers from planning organizations. Two workshops will be held – one in Minneapolis MN and the other in Ann Arbor MI.
2) Great Lakes Coastal Resilience Planning Guide – Author, review, edit, and post four case studies, four local stories, two callout-style stories, and the *Planning for Climate Change* portion of the Planning Guide. Also, create a framework and associated templates to guide others through the case study drafting process.
3) Climate Ready Great Lakes Cities – Assist in the development of materials for the online toolbox as well as methodology to keep content current and to provide public access to the informational content compiled.

Relationship to NOAA/CILER Goals

Lakes One of NOAA's primary goals relates to Climate Adaptation and Mitigation. The Great Lakes Regional Collaboration Team both with its base funding and through the GLRI is focusing on two strategic objectives: 1) a climate-literature public that understands its vulnerabilities to a changing climate and makes informed decisions and assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decision.

This project will provide the information necessary to coordinate the science across NOAA and the region with respect to climate in order to ultimately meet the goals of improved planning that facilitates restoration and protection of critical natural resources, that helps guide management decisions, and that supports sustainable economic development in the region.

Accomplishments

Project 1: Great Lakes Coastal Resilience Planning Guide (Content resides at http://www.greatlakesresilience.org/):

- Four case studies were developed (i.e., St. Joseph, Les Cheneaux Watershed, Port of Toledo, and Ottawa National Wildlife Refuge);
- Climate and Environment Updates were performed;
- Outreach and Engagement Framework was developed to guide further content creation over time.

Project 2: Online tools and training materials, including case studies and infographics:

- The National Oceanic and Atmospheric Administration (NOAA) will work in partnership with the Great Lakes St. Lawrence Cities Initiative (GLSLCI) to help accomplish their mutual goals of assisting Great Lakes municipalities to prepare for and adapt to climate change impacts over time.
- Specifically, the partnership supported the development of an online toolbox for municipalities that provides 1) training materials and resources with on-the-ground examples of how cities are incorporating climate hazards and impacts into planning, 2) infographics and visualizations that will assist cities in identifying potential hazards (i.e., flooding and inundation) and how best to plan for them and 3) funding opportunities for municipalities on a bi-annual basis.
- A project team of six masters candidates from the University of Michigan's School of Natural Resources and Environment, with assistance from NOAA OCM and GLSLCI, developed a range of materials to help municipalities with climate adaptation. As part of this group's effort, they produced the following products:
  - Five Case Studies - Evanston, Goderich, Traverse City, Niagara Region, and Milwaukee;
  - Infographics for Evanston and Great Lakes (general application);
  - Seven webinar training modules, delivered by Great Lakes St. Lawrence Cities Initiative to bi-national municipalities over the past year (details on participants, dates of delivery, and other stats are located here: https://docs.google.com/a/noaa.gov/spreadsheets/d/1GYy9Q__y7h8_l

u_q7AzWFEd8GrdqmJbM02Ia9FqIsTU/edit?usp=sharing;
- GIS Maps depicting Evanston, IL Cold Season Climate Vulnerability.

NOAA will pursue placement of these products on the NOAA Climate Resilience Toolkit webpage shortly.

Publications
None to date

Presentations:

MARS Webinar Series, see participant list at:
https://docs.google.com/spreadsheets/d/1GYy9Q__y7h8_lu_q7AzWFEd8GrdqmJbM02Ia9FqIsTU/edit#gid=1409249530

Outreach Activities:

MARS Webinar Series, see participant list provided above.

Relevant Websites:
http://www.greatlakesresilience.org/
see: https://www.youtube.com/channel/UCl_6viIUesmos6hZ7RkVahQ for piloted videos on specific municipal climate adaptation topics developed by the UM team.

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: IMPLEMENTATION OF THE GREAT LAKES SYNTHESIS, OBSERVATIONS, AND RESPONSE SYSTEM (SOAR)

Principal Investigator: Thomas Johengen (CILER)
NOAA Technical contacts: Steven Ruberg (NOAA-GLERL)

NOAA Strategic Goal 5: NOAA Enterprise-wide Capabilities

Overview and Objectives:

The implementation of the Great lakes Synthesis, Observations and Response System program (SOAR) is designed to coordinate and integrate regional coastal observations that support national and regional priorities including Great Lakes restoration. SOAR activities include the deployment and support of on-water and remote sensing platforms where observations from these systems are used to create database products for assessment and decision support. The project will provide an up-to-date (including real-time data) web presence to support accountability, management and restoration activities. The system will provide up to date information on ecosystem health to maintain high quality drinking water and bathing beaches through observations, data management, and forecast model development.

Observations of environmental parameters will be used to develop decision support tools to determine success of remedial actions, provide warnings to regional managers regarding phosphorous loads, hypoxia and harmful algal blooms, and support future remedial action decisions. These decision support tools include: real-time observing system components (buoys) deployed at Maumee Bay, Saginaw Bay, Muskegon and Cleveland, a web-based data management system, synthesized remote sensing products for predicting HABs, and coupled physical-chemical-biological models for Green Bay, Saginaw Bay, Maumee Bay and the St. Lawrence River AOCs. Instrumentation deployed in AOCs will provide observations of hypoxia, soluble reactive phosphorous and support detection of harmful algal blooms

Accomplishments

1. Development of Decision Support Tools

In 2014 three instrumented moorings were deployed in Western Lake Erie that incorporated the following: Wetlabs CYCLE-P nutrient analyzer, Turner Designs C6 fluorometer, and either an YSI EXO2 or an YSI 6600 multi-parameter sonde. Two of

these sites were operated in real-time mode for the first time and results made available through the projects web-site. Instrumentation was serviced approximately every month (see Supplemental Material; Table 1). Discrete samples were collected weekly or bi-weekly for laboratory analysis to evaluate the accuracy and consistently of the in-situ instrument measurements. All laboratory analysis for the 2014 sample collections has been completed and added to the project database.

In 2015 all monitoring buoys will be operated in real-time mode and the first two buoys have been deployed. We expect to have all four buoys operating by the end of the month.

Two ReCon buoys were deployed for the 2014 and 2015 navigational season to aid in the detection of harmful algal blooms and episodic hypoxia events. One was deployed north of Cleveland in 21 m of water to also detect internal waves and upwelling events, the other was deployed in Saginaw Bay.

2. Modeling Activities:
In partnership with Michigan Technological Research Institute we developed an inter-comparison of various remote sensed products and estimations of algal bloom and sediment plume concentrations and areal extent for western Lake Erie. Remote sensed estimates were compared against field monitoring data collected by the HABS monitoring program.

A 3D Lagrangian particle trajectory model has been implemented for Lake Erie and combined with FVCOM hydrodynamic model outputs (from NOAA/GERL.) The model is being operated in daily river plume (Maumee and Detroit Rivers) and HAB forecast modes. Work is ongoing to add biological processes (e.g. decay, buoyancy, etc.) to the particle model for enhanced HABs and FIBs modeling.

We initiated the development of a comprehensive mechanistic model to enhance the current forecasting model of harmful algal bloom intensity and distribution. Our initial efforts have involved integrated existing monitoring data from Lake Erie and our mechanistic understanding of chemical and biological processes into an existing water quality model (EcoLE, Zhang et al. 2008) and couple this NPZ mass balance model with an improved FVCOM hydrodynamics model (Anderson et al., 2009a; 2009b). Initial calibration of the model is focusing on the ability to parameterize key processes such as river flows, nutrient loads, water column mixing and sediment resuspension, with the ultimate goal of being to spatially resolve the annually occurring Microcystis blooms on a fine spatial (1-2 km) and temporal (hourly) scales.

Examination of environmental drivers and seasonal dynamics associated with the development and persistence of Harmful Algae Blooms in western Lake Erie
Thomas Johengen, Danna Palladino, Ashley Burtner, Steve Ruberg, and Timothy Davis. Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Sensitivity of simulated Microcystis colony vertical distribution to turbulent mixing and buoyancy in a model for short-term forecasts of cyanobacterial harmful algal blooms in Lake Erie
M. D. Rowe, E. J. Anderson, H. A. Vanderploeg, D.L. Fanslow, D.C. Gossiaux, T. H. Johengen
Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Evolution of optical signatures in western Lake Erie as related to HABS formation and senescence
T. Moore, C. Mouw, J. Sullivan, M. Twardowski, S. Ruberg, T. Johengen, A. Barnett, D. Palladino, N. Stockley, D. Stuart, and A. Yu. Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green, Ohio, April 13-14, 2015

Vertical mixing and buoyancy in a model for short-term forecasts of cyanobacterial HABs in Lake Erie
M. D. Rowe, E. J. Anderson, A. J. Vander Woude, T. H. Johengen, H. A. Vanderploeg
IAGLR, Burlington, VT, May 2015

Cyanobacteria Bloom Dynamics in Lake Erie in Relation to Environmental Drivers: Do different monitoring approaches tell the same story?
BERTANI, I., STEGER, C.E., OBENOUR, D.R., BRIDGEMAN, T.B., JOHENGEN, T.H., SAYERS, M.J., SHUCHMAN, R.A., FAHNENSTIEL, G.L. and SCAVIA, D
IAGLR, Burlington, VT, May 2015

Use of Continuous In Situ Water Quality Sondes for Monitoring Harmful Algal Blooms.
T. Johengen. Lake Erie Harmful Algal Bloom Monitoring Methods Workshop, U. Toledo Lake Erie Center, Oregon, OH. May 2015.

Outreach Activities:
Data from RECON buoys is currently displayed on the Real-time Coastal Observation Network web display and data management system, as well as the GLOS DMAC web

portal to be made available for access by GLRI managers, municipal water managers, beach managers, and researchers. Data from moored instruments and mobile platforms is being analyzed and protocols are being established with GLOS DMAC to receive and display the data.

Two presentation to NOAA Leadership (OAR-AA, NWS-AA, and NOAA Chief Scientist) describing CILER research activities on the use of our instrumented moorings and development of forecasting products for HABS and Hypoxia warnings during a site visit to NOAA-GLERL.   March 2015.

Dr. Johengen participated in a webinar with NOAA's National Weather Service Forecasting Offices within the region to inform their staff about the current suite of observations and forecast products being developed by CILER and GLERL and to discuss possible interactions for disseminating new forecasts and warnings to regional stakeholders. June 2015.

Relevant Web content:
A SOAR Dashboard HABs tracker is in progress, to display the HAB forecast model output. Also available on the GLERL website is the Experimental HAB bulletin, the microcystin concentration sampling data, and the real time water quality monitoring buoy data. (http://www.glerl.noaa.gov/res/waterQuality)

Addendum - Additional Content: Remote Sensing of Algal Blooms in support of the GLRI Synthesis, Observations, and Response (SOAR) Program

In 2014 we initiated several additional activities related to remote sensing estimations of Harmful Algal Blooms to support the ongoing SOAR program. The first element involves a continuation to work started in collaboration with the University of Toledo in 2012 to examine early bloom mapping in Lake Erie and comparisons to existing remote sensing products. The second element represents ongoing interactions with Michigan Technological Research Institute to developed and disseminate new remote sensing products in support of our current SOAR monitoring and public warning activities. The third element involves internal development of both additional algorithms and approaches for algal bloom estimation and retrospective analysis of past data to examine spatial persistence and variability.

Part 1. Early Bloom Mapping in Lake Erie: Satellite Imaging Data Comparison University of Toledo and NOAA Experimental HAB Bulletin for Lake Erie (PI: Richard Becker, U. Toledo)

The University of Toledo and Blue Water Satellite Inc. monitored Lake Erie Cyanobacteria from April 15-November 1, 2012, to understand incipient bloom formation in terms of aerial extent and duration. The purpose of this investigation is to compare the University of Toledo/Blue Water Satellite data with the NOAA Lake Erie Experimental HAB Bulletin and ground sample data. This work is a continuation of work begun in the Spring of 2012. Under this project, The University of Toledo compared the cyanobacterial bloom image data it developed with Blue Water Satellite for Lake Erie MODIS Cyanobacteria April 15-November 1, 2012 with the corresponding data from NOAA's Lake Erie Experimental HAB Bulletin. Methodology for cyanobacterial bloom image production is documented in Becker et. al (2009).

Accomplishments:
1. 47 MODIS Lake Erie images were processed for Cyanobacteria covering April 15, 2012 to November 1, 2012
2. 4 sets of ground sample data totaling 30 samples were collected between August 1, 2012-September 30, 2012.
3. A report was generated comparing pixel to pixel nine nearest neighbor comparison or an area by area average comparison depending on the data available from NOAA.
4. A report comparing both sets of satellite data with ground sampling data was developed and submitted to NOAA.

Part 2. Generation of Great Lakes Specific Satellite Remote Sensing Products to support SOAR and OHH Initiatives (PI: Robert Shuchman, MTRI)

Ocean color satellites such as SeaWiFS, MODIS, MERIS, and VIIRS which image or did image the Great Lakes on a daily basis provide the opportunity to generate a set of derived products that address the water quality throughout the basin. The derived remote sensing products include: chlorophyll (chl), dissolved organic carbon (doc), and suspended mineral (sm) concentrations; cdom absorption; Kd attenuation, Photosynthetically active radiation (PAR), and photic zone depth; sediment plume extent, and the location and severity of Harmful Algal Blooms (HABs). These derived products available on cloud free days are proving to be very useful to the greater Great Lakes stakeholder community.

This proposed effort would support the generation of additional satellite retrievals needed by GLERL. The retrievals would include both historical data as well as future data acquisitions. An element of the activity would be the generation and evaluation of 5-7 day composite maps that would be created using data from the useful portions of partially cloudy images. It is envisioned the proposed two year program would be collaborative in nature where the new remote sensing composite products would be jointly evaluated by both MTRI and GLERL scientists. Additionally the new derived satellite product set upon successful evaluation by GLERL and MTRI scientists would be provided to the greater Great Lakes community via the internet (i.e. NOAA Coast Watch as well as the GLOS DMAC).

Accomplishments:

1. On all cloud free days (75% visibility or greater), concentration maps of chl, doc, cdom and sm were generated for each Great Lake and delivered to GLERL.

2. Time series of derived products of SeaWiFS, MODIS, MERIS, or VIIRS images including maps for chl, doc, sm concentrations, cdom absorption, sediment plume maps, optical properties (Kd, PAR, photic zone) and HABs extent were produced covering a time span of 1998 to the present (see Fig 1 as example).

3. Gnerated 5-7 day representation of chl, doc, sm, sediment plume, and HABs extent by utilizing cloud-free parts of images of a region or whole lake using new MTRI algorithms to stitch the data together.

Part 3. Development and Analysis of Remote Sensing Products for Western Lake Erie to support SOAR and OHH Initiatives (PI: Andrea Vander Woulde, CILER)

<u>Accomplishments:</u>
Task I. Development of a new MODIS retrieval algal bloom products for Western Lake Erie based on bioregional analysis
1. A new chlorophyll algorithm combining the fluorescence line height and cyanobacteria index was used to estimate chlorophyll in Lake Erie from 2008 to 2014. Normalized water leaving radiances estimated were the input and then were converted to chlorophyll with the 2008-2014 GLERL-CILER in situ field data. OC3 and calculating new coefficients did not prove to be robust and these two algorithms together were a better estimate of chlorophyll and for use in estimating blooms.

2. The comparison of published algorithms for chlorophyll and harmful algal blooms from collaborating researchers has been initiated. We have compared the OC3 algorithm with newly revised coefficients, the MODIS 3-band and 2-band models and typical algorithms standard from NASA as well as the stand-alone FLH algorithm (which is also part of the NASA standard processing).

3. The Kohonen Self Organizing Maps (SOMs) were completed in Matlab utilizing the built in package that is available. The input to the SOM was modeled winds interpolated to 1 km grid size and satellite sea surface temperature data for Lake Erie. Therefore, the regions were significantly defined by the physical dynamics in the lake. We ran the SOM with also the FLH-CI chlorophyll input but since this was the purpose of creating the regions, we removed this variable. A 10x10 neural network grid was applied to the area and created 1000 classes within the lake. These classes are currently being refined and reduced using the Hierarchical Clustering algorithm. The last step will be to test the algorithms within each region to see how they behaving differently under different physical conditions (as defined by the regions).

Task III. A retrospective spatial analysis of algal bloom frequency and persistence in western Lake Erie based on MODIS imagery from 2002 – 2013 has begun as part of the harmful algal bloom tracker. The temporal and spatial frequency of blooms will be initiated as part of the current analysis to refine the chlorophyll and harmful algal bloom satellite data for the 2015 field efforts.
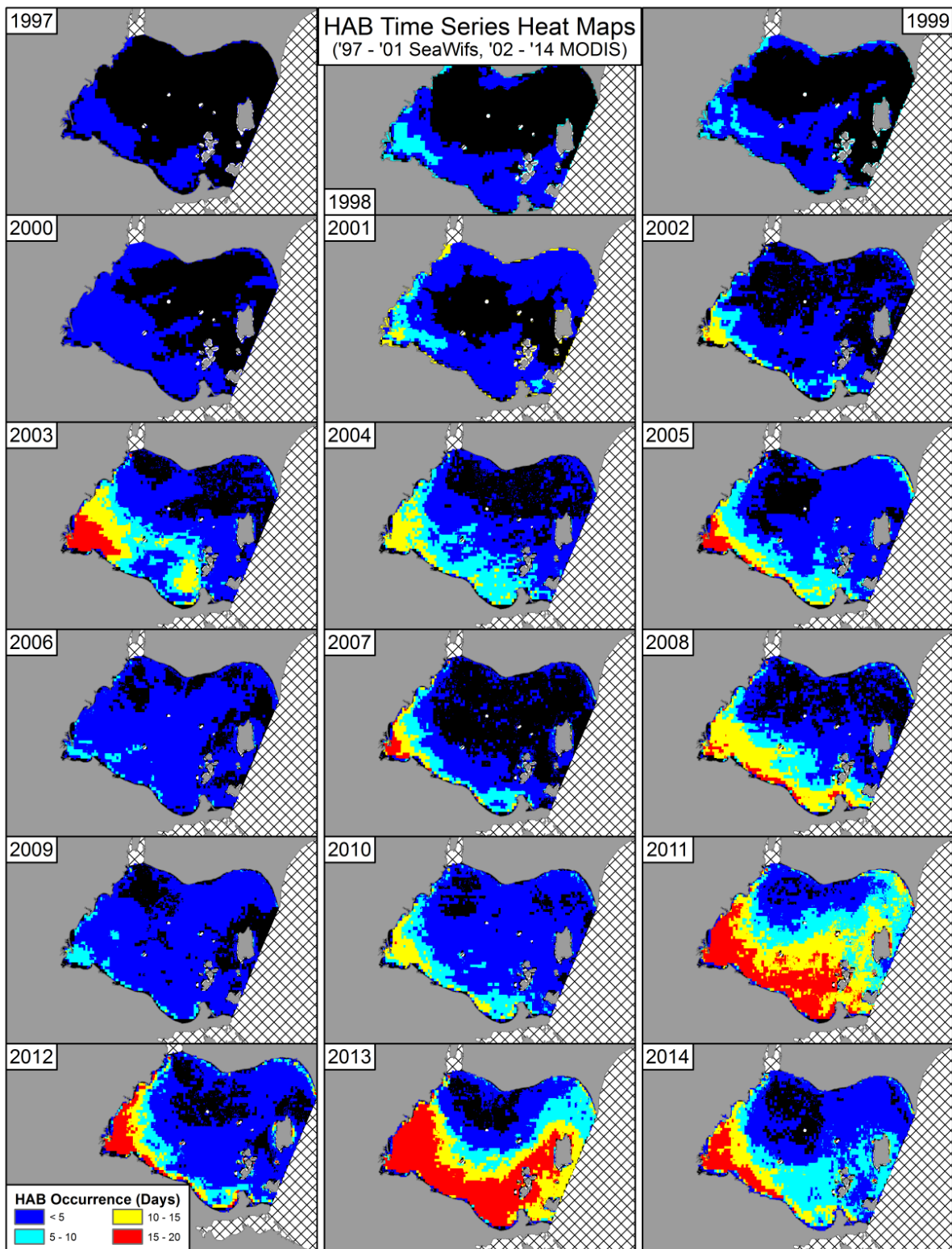
Figure 1. Annual estimation of harmful algal bloom frequency throughout the western basin of Lake Erie from MODIS satellite retrievals.

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: DECISION SUPPORT OF WESTERN LAKE ERIE PHOSPHORUS CONCENTRATIONS TO MITIGATE HARMFUL AND NUISANCE ALGAL BLOOMS

Principal Investigators: Tom Johengen (CILER)
NOAA Technical contacts: Craig Stow (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

In 2011, Lake Erie experienced a cyanobacterial bloom of unprecedented proportion (Michelak et al. 2013). This event, though noteworthy, was only one recent example of eutrophication symptoms that reappear in some areas of the Great Lakes more than 35 years after the establishment of phosphorus reduction targets under the 1978 Great Lakes Water Quality Agreement (GLWQA). Recognizing these enduring problems, the updated 2012 GLWQA calls for a reevaluation of the 1978 phosphorus targets. Additionally, the revised protocol directs Canada and the United States to "develop Substance Objectives for phosphorous concentrations for nearshore waters, including embayments and tributary discharge for each Great Lake" and to "complete this work for Lake Erie within three years of entry into force of this Agreement". Thus, there is an imperative to focus attention on management actions that will reduce ongoing eutrophication problems, which include extensive hypoxia, in Lake Erie.

While the fundamental drivers of algal proliferation in temperate lakes have been understood since the 1970s (Schindler 1977), there are lake-specific processes that influence the relationship between phosphorus and measures of algal productivity (Pace 1984, Stauffer 1991, Kamarainen 2008). Additionally, the Great Lakes have experienced profound changes since the initial phosphorus targets were developed in the 1970s. Most notably, invasive dreissenid mussels, which became abundant in the 1990s, have altered phosphorus cycling, promoted cyanobacterial growth (Vanderploeg et al. 2001) and altered the relationship between chlorophyll a and total phosphorus (Cha et al. 2013). Concurrently, phosphorus inputs to Lake Erie have changed with bioavailable phosphorus concentration increases in the western tributaries since the 1990s (Daloglu et al. 2012).

To provide information that will support pending decision-making for Lake Erie we will develop predictive models that describe the relationship between phosphorus concentration, and other logical predictor variables, and endpoints associated with algal production including cyanobacteria, *Microcystis*, and total algal biovolume, and chlorophyll a. Additionally, we will explore relationships between phosphorus inputs and in-lake phosphorus concentrations to examine whether the existing data support development of a simple network linking measures of algal concentration to watershed loads. Because phosphorus load is comprised of tributary flow and phosphorus concentration, which have distinct effects on the distribution and concentration of in-lake phosphorus, we will consider these two drivers separately in the model development.

One approach will involve the development of models using a Bayesian hierarchical framework (Borsuk et al. 2001). This approach will allow the models to capture relationships between predictor and response variables that differ spatially and temporally if the data indicate such differences. Additionally, the Bayesian framework provides probabilistic quantification of the uncertainty in these relationships as well as the predictive uncertainty between the predictor and response variables. We have recently developed a Bayesian network linking input phosphorus levels with in-lake phosphorus and chlorophyll concentrations in Saginaw Bay (Cha and Stow 2013); an analogous approach may be appropriate for Lake Erie.

A second approach will be to develop a coupled physical-biological deterministic model to examine relationships between key environmental factors (water temperature, river flows, nutrient loads, water-column mixing and sediment resuspension) on the *Microcystis* blooms on a fine spatial and temporal scale. We will update a previous mass-balance NPZD model (EcoLE, Zhang et al. 2008) and couple it with an updated hydrodynamics model (FVCOM, Anderson et al., 2010; Anderson and Schwab 2011). The horizontal resolution of the model ranges from 1.5 km in the central basin of the lake to 30 m in complex nearshore regions and near tributary mouths. Vertical resolution is provided by 21 terrain-following sigma layers, with a higher density of layers in shallow water columns.   The updated model will be calibrated and verified with the same existing database used for the statistical modeling approach.   Model projection of the spatial extent and intensity of HABS and in-lake phosphorus distributions will be compared under various potential phosphorus loading scenarios, and will be used to develop relationships between nutrient loads and the HABS (spatial extent and total *Microcystis* biomass) in the western Lake Erie

A. Bayesian Statistical Modeling

The first phase of our research was an analysis of the long-term nutrient inputs to western Lake Erie from the Maumee River. Phosphorus loads from the Maumee River into Lake Erie constitute the single largest phosphorus input to the Great Lakes. The data used in this analysis included daily Maumee River concentration data from Heidelberg University, Maumee River discharge data from the USGS, and regional precipitation data from NOAA.   The results of this work were published in Environmental Science & Technology (Stow et al. 2015) and included the following findings:

- Similar increases in precipitation and Maumee River discharges occurred from 1975-2013.
- Total and dissolved phosphorus concentrations declined from the 1970s into the 1990s; since then, total phosphorus concentrations have been relatively stable, while dissolved phosphorus concentrations have increased.
- Both total and dissolved phosphorus loads have increased since the 1990s because of the Maumee River discharge increases.
- Total nitrogen and nitrate concentrations and loads exhibited patterns that were almost the reverse of those of phosphorus, with increases into the 1990s and decreases since then.

The next phase of this project is underway and will include the development of an empirically-based probabilistic model to link Maumee River nutrient inputs to in-lake nutrient concentrations and ecological response indicators of interest, such as chlorophyll a and microcystin concentrations.

B. Physical-Biological Mass Balance Modeling

Two process-driven mathematic models, EcoLE and FVCOM-GEM, are used to study the Microcystis dynamics and how Microcystis respond to water temperature, river flow, nutrient loads, water column mixing and sediment resuspension. The EcoLE is two dimensional and based CE-QUAL-W2, which has been used to study nutrient dynamics, dreissenid impacts on phytoplankton, and hypoxia in Lake Erie (Boegman et al. 2008, Conroy et al. 2011, Zhang et al. 2011). Dr. Zhang is current using this model to test how storm affects sediment resuspension and consequently affect the nutrient dynamics in the west Lake Erie. The work of EcoLE is used to guide the development of FVCOM-GEM for Lake Erie. Dr. Zhang has merged the biological component of FVCOM-GEM for Lake Michigan which includes dreissenid mussels with FVCOM for Lake Erie. This merged model will be further modified to include *Microcystis* group as a state variable.

Publications

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

Presentations

Johengen, T. Presentation to NOAA Chief Scientist Rick Spinrad, OAR AA Craig McLean, and NWS AA Louis Uccellini on phosphorus and HABS monitoring related activities, February 20, 2015.

Zhang, H., Culver, D.A., Xu, X. And Boegman, L. Spatiotemporal distributions of phosphorus loads and their impacts on Lake Erie's water qualities. IAGLR 58th Annual Conference on Great Lakes Research, New Views New Tools, Burlington, Vermont, May 25-29, 2015.

Zhang, H. and Xu X. P response curves – EcoLE. Great Lakes Water Quality Agreement Phosphorus Load Response Ensemble Modeling Meeting. Ann Arbor, MI. Sept 29-30, 2014

Relevant Website:

http://www.glerl.noaa.gov/res/waterQuality/

Significant Interactions/Collaborations

We established a new sub-award with the University of Toledo to conduct the statistical analysis of our long-term monitoring data given the departure of our post-doc, Yoon Kyung Cha, who was originally slated to conduct this component of the research. We continue to interact closely with the SOAR and OHH-HABS projects within CILER that provide direct in-lake monitoring results and with Heidelberg College that provides the watershed loading data.

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: IDENTIFYING LAND USE TIPPING POINTS THAT THREATEN GREAT LAKES ECOSYSTEMS

Principal Investigators: Brian K. Miller (Indiana – Illinois Sea Grant), Bryan Pijanowski (Purdue University)
NOAA Technical Contact: Ed Rutherford (NOAA-GLERL)

NOAA Strategic Goal 4: Resilient Coastal Communities and Economies

Overview and Objectives:

Tipping Points and Indicators, a new research and extension program for Great Lakes coastal communities, helps local decision makers identify impacts of land-based activities that threaten the sustainability of ecosystems in their watershed. The program builds upon a three year GLRI/NOAA funded project to engage coastal communities through a region wide decision support and facilitation tool that empowers local communities to develop action plans and strategies that sustain aquatic ecosystems.

This program includes a web-based decision support system (http://tippingpointplanner.org) and facilitated forum to explore policy and management interventions necessary to keep coastal ecosystems from reaching critical tipping points and moving to unstable conditions. The decision support tool was based on a region wide user needs assessment, involvement from Sea Grant sustainable coastal development specialists in all Great Lakes states, and continuous input from pilot communities, consultants, researchers and facilitators. This tool helps watershed leaders identify land-based activities that threaten the sustainability of ecosystems in their watershed and provides a facilitated forum to explore policy and management interventions necessary keep their ecosystems from moving to an unstable condition. Communities are then led through a process to develop sustainable action plans for their watershed or community. This decision support tool was piloted in at least one community in seven of the eight Great Lakes states in spring, 2014.

Initially funded through the Great Lakes Restoration Initiative (GLRI), the Cooperative Institute for Limnology and Ecosystem Research (CILER), Illinois-Indiana Sea Grant and the Purdue Department of Forestry and Natural Resources, the eight-state,

collaborative program began in 2010 and was launched in Great Lakes states with pilot workshops during the spring of 2014.

The development of the Tipping Points and Indicators facilitation tool began with user needs assessments to determine desired elements in a decision support system for natural resources planning and management at a watershed scale. As part of her PhD dissertation, Dr. Kimberly Robinson received survey responses from 302 professional planners and Extension Specialists in all eight Great Lakes states and at multiple planning scales (Municipal, County/Township, and Regional). Purdue University and Illinois-Indiana Sea Grant additionally hosted focus groups comprised of Extension Specialists and partnering facilitators from each Great Lakes state. The users identified the need to develop a data driven tool to support community visioning discussions and action plan development that can be tailored to local planning initiatives. Both planners and Extension specialists identified the need to gather and present data on natural resources tied to the decision making process for long term planning, evaluation, and securing project support and funding. The decision support system was also identified as an opportunity to increase citizen participation and collaboration among stakeholder groups across planning jurisdictions. The resulting Tipping Points and Indicators Program was created to address these user needs. It was designed as a data driven facilitation tool to be used by trained Sea Grant Specialists, extension professionals, and consultants leading community visioning discussions and public involvement for land use or watershed planning and implementation projects. Feeback survey data colleced from the spring 2014 state pilots will be used to enhance the tool and facilitation processes in Great Lakes coastal communities.

The research and outreach teams met monthly from 2012-2014 during program development. As the teams move into program implementation, they will meet quarterly in 2014-2016. The research and outreach team members who have contributed to the development and delivery include:

Research Team
• Great Lakes Environmental Research Laboratory – Rutherford, Mason
• University of Illinois (IL-IN Sea Grant) – Miller
• Purdue University – Pijanowski, Doucette, Pekin, Salazar, Jung, Frederick, Robinson, Kim, Ghadiri
• University of Michigan – Wiley, Riseng
• Michigan State University – Stevenson, Hyndman, Rose, Kendall, Martin
• University of Minnesota - Duluth – Johnson
• University of Windsor – Ciborowski
• University of Illinois - Chicago – Jaffe

Outreach Team - Great Lakes Sea Grant Network Specialists
• Illinois-Indiana - Salazar, Miller, Doucette, Jaffe,TePas
• Michigan - Breederland
• Minnesota - Schomberg
• New York - Penney
• Ohio - Lucente
• Pennsylvania - Rafferty
• Wisconsin - Hart, Noordyk

NOAA GLERL, served as the Institutional lead for the project. Dr. Ed Rutherford, research fisheries biologist with NOAA Great Lakes Environmental Research Laboratory, served as PI for the overall GLRI/NOAA funded project and was the Research Team Leader.

Purdue University, Department of Forestry and Natural Resources and Illinois-Indiana Sea Grant are the institutional program leads for the Tipping Points and Indicators decision support tool development. Dr. Brian Miller, IL-IN Sea Grant Director, is a program Principal Investigator and oversees program development, multi-state implementation and long-term funding. Dr. Bryan Pijanowski, Professor of Forestry and Natural Resources, is a Principal Investigator and responsible for long-term funding and directs graduate students, and professional staff that developed the decision support tool and modules. Purdue University hosts the server and website infrastructure for the project. The program is designed for long term deployment and use throughout Great Lakes states by specialists and facilitators affiliated with the Sea Grant Network and Cooperative Extension Service and partnering natural resources professionals who have undergone facilitation training. Purdue University and IL-IN Sea Grant are committed to the long-term management and maintenance of the program through continually updating the decision support tool, facilitation processes and website infrastructure. All investments and upgrades implemented to the decision support tool and the facitliaton processes will be shared with the multi-state team for use within their repsective states in coastal communitiess.

The accomplishments for FY2014 are identical to those from FY2013, as the major research activities were completed in the previous year. The accomplishments from this project are detailed in the final report (Appendix 3).

THEME IV: PROTECTION AND RESTORATION OF ECOSYSTEM RESOURCES: LINKING TO HUMAN DIMENSIONS

PROJECT TITLE: FATE PROPOSAL: INCORPORATING AN ENVIRONMENTAL INDEX INTO SOUTHERN NEW ENGLAND MID-ATLANTIC YELLOWTAIL FLOUNDER STOCK ASSESSMENT WITH POTENTIAL PREDICTABILITY

Principal Investigators: Allen Burton (UM-CILER), Janet Nye (Stony Brook University)
NOAA Technical Contacts: Larry Alade (NOAA-NEFSC); Doran Mason (NOAA-GLERL)

NOAA Strategic Goal 1: Healthy Oceans

Overview and Objectives:
(a) Investigate the physical linkage between changes in atmospheric indices, temperature regime and yellowtail flounder recruitment and productivity for several years after a fluctuation in the Azores High pressure.
(b) Develop predictive relationships between environmental indices and recruitment and SSB and assess the skill of such a prediction scheme
(c) Incorporate the environmental indicator into the stock assessment in one of three ways.

Specific Aims/Milestones:
Our goals for Year 1 were to:
- Gather data from 2012 stock assessment, CTD cast data from NEFSC hydrographic database, and spring and fall bottom trawl surveys
- Develop time series of AZP, IL and associated environmental variables
- Explore mechanistic link between environmental variables and SNEMA YT recruitment
- Develop environmental stock-recruitment relationships
- Travel to Woods Hole to present results and coordinate an approach to incorporate indices into stock assessment

Accomplishments:
We have accomplished all of our goals for Year 1 and the student, PIs and other colleagues interested in the project met in Woods Hole, MA in May 2015 to discuss our findings. The student will present our findings at the American Fisheries Society meeting in Portland, OR in August. After obtaining all the necessary data, we constructed environmentally modified stock recruitment relationships and found the Beverton and Holt model to be the most suitable correlated with several climate indices,

including the pressures and latitudinal/longitudinal positions of the Azores high and Icelandic low (which are the two pressure centers of the NAO),winter NAO index, two
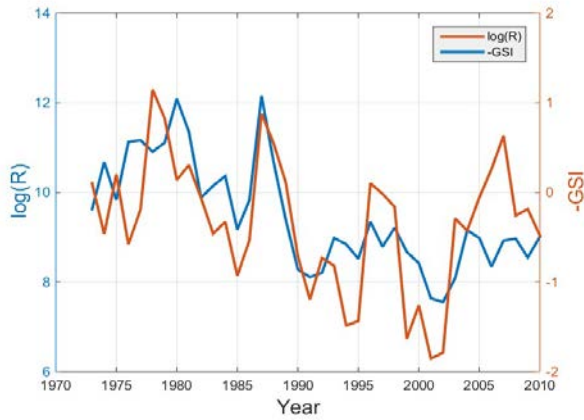

Figure 2: The natural log of yellowtail flounder recruitment (blue) and negative GSI (red).

Gulf Stream related indices (the GSI from Joyce et al. (2000) and the Gulf Stream North Wall (GSNW) from Taylor and Stephens (1998), and Cold Pool Index (CPI). Among all the climate indices, the GSI is the only index that is significantly correlated with the recruitment residuals at the 99% confidence level. The natural log of yellowtail flounder recruitment and GSI in the same year is correlated at the 99% confidence level. Moreover, incorporating the GSI into the yellowtail founder environmentally- explicit

Beverton-Holt function as a controlling, limiting, or masking factor were also explored according to Iles and Beverton (1998). In terms of AIC, all three Beverton-Holt stock-recruitment functions with the GSI provide better fits to the data than the SR relationship without GSI and the model with the GSI incorporated as a limiting factor has the best fit. Considering that the yellowtail flounder recruitment is negatively correlated with the GSI, the estimated yellowtail flounder recruitment drop since the 1990's was at least partially due to the notable positive trend of the GSI observed over the time series. In sum, the yellowtail flounder recruitment is significantly affected by the GSI and the GSI should be considered in the yellowtail flounder stock-recruitment relationship.

A Canonical Correlation Analysis (CCA) between the adult yellowtail flounder biomass density in 1968-2008 and seasonal SST (ERSST) on the NES in the previous three years indicates that they are significantly correlated (the first canonical correlation is -0.69). Loading vectors of ERSST show that spring SST in SNEMA two years ago has the highest correlation (negative, because the first canonical correlation is negative) with yellowtail flounder adult biomass. This can be explained if the correlation between the yellowtail flounder recruitment and spring SST is negative (note that the peak of yellowtail flounder spawning is in spring), and two years later, these recruits will be approximately age 2, reaching full maturity to contribute to the adult biomass. The absolute values of SST loading are low in the previous year, so we concluded that SST does not have direct effect on yellowtail flounder adults, rather this is likely a cumulative effect in the early stages. Combined with results from environmental-explicit stock- recruit function, the CCA, and the previous findings of Sullivan et al. (2005), we conclude that the yellowtail flounder recruitment is significantly and

negatively affected by temperature on the shelf, while temperature's effect on yellowtail flounder adults is negligible.

In addition to statistical analyses, an age-structured population dynamics model was built to understand the effects of the GSI in Southern New England yellowtail flounder population dynamics. We used a similar approach to Hare et al. (2010) to build an age-structured population dynamics model in which the GSI was incorporated into the Beverton-Holt stock-recruitment function. All the estimated yellowtail flounder parameter inputs in this age-structured population dynamics model were from the latest assessment (NEFSC 2012) and the yield referred in model output was calculated

by assuming an equilibrium population state. Since in the model the GSI influences Southern New England yellowtail flounder population dynamics only through modifying its recruitment level, the relationship between the GSI and the recruitment was first investigated. Comparison of the Beverton-Holt stock-recruitment functions under different GSI values clearly shows that the recruitment is dramatically and negatively affected by the GSI (Figure 2). The GSI's negative effect on recruitment then propagates to adult abundance and consequently influences the equilibrium yield (Figure 3). The GSI had a significant positive trend in the past four decades (Figure 1) and is predicted to keep increasing in the future, due to the observed and predicted AMOC weakening caused by climate change (Schmittner et al. 2005) . The observed change in GSI from our analyses sugrtgest that the Gulf Stream has played a significant role in the decline of yellowtail flounder and is likely to further contribute to the continued decline in Southern New England yellowtail flounder recruitment and yield.
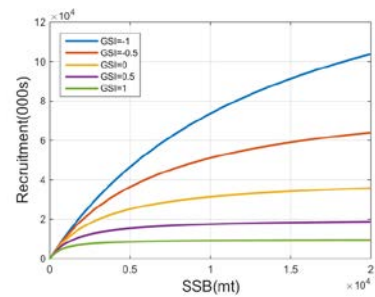
Figure 4: The Southern New England yellowtail flounder Beverton-Holt stock-recruitment functions with the GSI incorporated as a limiting factor. Different lines represent the stock-recruitment function under different GSI
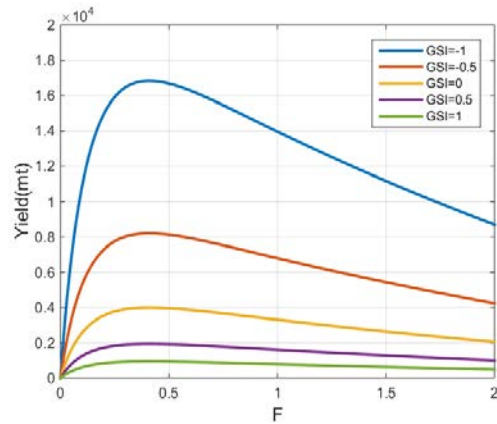
Figure 3: The Southern New England Yellowtail flounder equilibrium yield curve from the age-structured population dynamics model with the GSI incorporated in the Beverton-Holt stock recruitment function as a limiting factor. Different lines represent the equilibrium yield.

Presentations:
Xu, Haikun, Hye-Mi Kim, Janet A. Nye (poster presentation) "CMIP5 decadal SST prediction skill on the Northeast US Continental Shelf"

Xu, Haikun, Janet A. Nye, Sultan Hameed and Larry Alade (oral presentation). Incorporating the Gulf Stream Index into the Southern New England Mid Atlantic yellowtail flounder stock assessment and management. Oral presentation at the American Fisheries Society Meeting 2015 in Portland , Oregon.

Works Cited
Hare, J. A., M. A. Alexander, M. J. Fogarty, E. H. Williams, and J. D. Scott. 2010. Forecasting the dynamics of a coastal fishery species using a coupled climate-population model. Ecological Applications **20**:452-464.

Iles, T. and R. Beverton. 1998. Stock, recruitment and moderating processes in flatfish. Journal of Sea Research **39**:41-55.

Joyce, T. M., C. Deser, and M. A. Spall. 2000. The relation between decadal variability of subtropical mode water and the North Atlantic Oscillation. Journal of Climate **13**.

NEFSC. 2012. 54th Northeast Regional Stock Assessment Workshop (54th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 12-18; 600 p.

Schmittner, A., M. Latif, and B. Schneider. 2005. Model projections of the North Atlantic thermohaline circulation for the 21st century assessed by observations. Geophysical Research Letters **32**

Sullivan, M. C., R. K. Cowen, and B. P. Steves. 2005. Evidence for atmosphere-ocean forcing of yellowtail flounder (Limanda ferruginea) recruitment in the Middle Atlantic Bight. Fisheries Oceanography **14**:386-399.

Taylor, A. H. and J. A. Stephens. 1998. The North Atlantic oscillation and the latitude of the Gulf Stream. Tellus A **50**:134-142.

THEME V: EDUCATION AND OUTREACH

PROJECT TITLE: INTRODUCING SHARED SOFTWARE INFRASTRUCTURE INTO THE CLIMATE MODELING CURRICULUM

Principal Investigator: Christiane Jablonowski (Atmospheric, Oceanic & Space Sciences, University of Michigan
NOAA Technical Contacts: Cecelia DeLuca (NOAA Earth System Research Laboratory, NOAA Environmental Software Infrastructure and Interoperability (NESII) group)

NOAA Strategic Goal 2: Weather-Ready Nation

Overview and Objectives:
This project falls under NOAA's second strategic goal 'Understand climate variability and change' and puts emphasis on the educational side of climate modeling and change. Earth system models for future projections of the weather and climate system put strong demands on the modeling infrastructure. Next-generation models will for example require greater computing capabilities, transparent software designs with exchangeable model components, self-explanatory descriptions of data and models, online gateways and portals for data exchanges, and shared online workspaces for both tight and loose science collaborations. Such challenges demand a highly versatile and interdisciplinary workforce. In particular, atmospheric modelers need to be trained not only in the science aspects of atmospheric General Circulation Models (GCMs), but also in computational techniques that allow them to work effectively with the most modern computational infrastructure for the climate and weather sciences.

Our role in this NOAA collaboration is twofold. We are an educator for the future generation of atmospheric modelers by teaching a graduate-level climate modeling course at UM and organizing international summer schools at the National Center for Atmospheric Research (NCAR). We are also a communicator who provides feedback on the shared software infrastructure under development by the NOAA NESII group.

Accomplishments:
During the reporting period (7/1/2014-6/30/2015) the PI Christiane Jablonowski started planning the future Dynamical Core Model Intercomparison Project (DCMIP-2016) and its associated summer school on 'Future-Generation Non-hydrostatic Weather and Climate Models'. This 2.5-week-long event will take place at NCAR in Boulder, CO, from June/1-17/2016. The preparations include the definition of the scientific scope, like the formulation of new dynamical core test cases, fund-raising activities (NOAA, National Science

Foundation (NSF), Department of Energy (DoE) and NASA), and the review and promotion of the results from the predecessor event DCMIP-2012. Like DCMIP-2012, DCMIP-2016 will bring together an international group of graduate students, postdocs, atmospheric modelers, expert lecturers and computer specialists to create a stimulating, unique and hands-on driven learning environment. It will lead to a student-run model intercomparison project, and thereby train the future generation of scientists engaged in global atmospheric model developments. Special attention will be paid to the role of emerging non-hydrostatic global atmospheric models, the physics-dynamics interactions with simplified moisture processes and models with variable-resolution grids. We will host a wide variety of dynamical cores (some of them remotely) that represent a broad spectrum of the modeling approaches in the international weather and climate modeling community. Among the DCMIP-2016 models will be the new nonhydrostatic candidate dynamical cores for NOAA's Next Generation Global Prediction System (NGGPS). NGGPS is the backbone project for the future-generation GCMs that will be used at NCEP and by the National Weather Service. The summer school and model intercomparison project promotes active learning, innovation, discovery, mentorship and the integration of science and education.

The morning lectures during the DCMIP-2016 summer school will train graduate students in the newest climate modeling techniques. They will survey the many design decisions in atmospheric GCMs, the trends in GCM and dynamical core modeling and how GCMs are coupled to land, ocean and ice components in Earth System Models (ESM). Furthermore, next-generation ESMs will require greater computing capabilities, transparent software designs with exchangeable model components, self-explanatory (metadata) descriptions of data and models, online gateways and portals for data exchanges, and shared online workspaces for both tight and loose science collaborations. Therefore, the DCMIP-2016 lectures will review and utilize a variety of computational tools that will enable the participants to work effectively with the most modern software infrastructure for the climate and weather sciences.

NESII-supported software infrastructure will be the backbone of the DCMIP-2016 model intercomparison and collaborative work environment. The participants of DCMIP-2016 will utilize cyberinfrastructure tools and shared workspaces during the workshop. The cyberinfrastructure supports data (located on an Earth System Grid Federation server), searchable metadata for models and data, remote visualization and analysis capabilities through NOAA's Live Access Server (LAS), a communication platform for participants (Wiki functionality) and adheres to standards like the netCDF data format (CF-compliant). The entry points for the predecessor event DCMIP-2012 are:
http://earthsystemcog.org/projects/dcmip-2012/

Related Publications in 2014/2015:

Hall, D. M., P. A. Ullrich, K. A. Reed, C. Jablonowski, R. D. and H. M. Tufo (2015): Dynamical Core Model Intercomparison Project (DCMIP) Tracer Transport Test Results for CAM-SE, Quart. J. Roy. Meteorol. Soc., in review

Gross, M., S. Malardel, C. Jablonowski and N. Wood (2015), Bridging the (Knowledge) Gap between Physics and Dynamics, Bull. Amer. Meteorol. Soc., doi:10.1175/BAMS-D-15-00103.1, in press

Ullrich, P. A., K. A. Reed and C. Jablonowski (2015), Analytical initial conditions and an analysis of baroclinic instability waves in f- and β-plane 3D channel models, Quart. J. Roy. Meteorol. Soc., in press

Côté, J., C. Jablonowski, P. Bauer and N. Wedi (2015), Numerical Methods of the Atmosphere and Ocean, in: Brunet, G., S Jones and P. M. Ruti (Eds.), Seamless Prediction of the Earth System: from Minutes to Months, World Meteorological Organization (WMO) No. 1156, Geneva, available at http://library.wmo.int/pmb_ged/wmo_1156_en.pdf

Yao, W. and C. Jablonowski (2015), Idealized Quasi-Biennial Oscillations in an Ensemble of Dry GCM Dynamical Cores, J. Atmos. Sci., Vol. 72, 2201-2226

Wan, H., P. J. Rasch, M. A, Taylor and C. Jablonowski (2015), Short-term time step convergence in a climate model, J. Adv. Model. Earth Syst., Vol 7, 215–225, doi:10.1002/2014MS000368.

He, F., D. J. Posselt, C. M. Zarzycki and C. Jablonowski (2015), A Balanced Tropical Cyclone Test Case for AGCMs with Background Vertical Wind Shear, Mon. Wea. Rev., Vol. 143, 1762-1781

Whitehead, J. P., C. Jablonowski, J. Kent and R. B. Rood (2015), Potential vorticity: Measuring consistency between GCM dynamical cores and tracer advection schemes, Quart. J. Roy. Meteorol. Soc., Vol. 141, 739-751

Ullrich, P. A., T. Melvin, C. Jablonowski and A. Staniforth (2014), A proposed baroclinic wave test case for deep- and shallow-atmosphere dynamical cores, Quart. J. Roy. Meteorol. Soc., Vol. 140, 1590–1602

Zarzycki, C. M., M. N. Levy, C. Jablonowski, M. A. Taylor, J. R. Overfelt and P. A. Ullrich (2014), Aquaplanet Experiments Using CAM's Variable Resolution Dynamical Core, J. Climate, Vol. 27, 5481-5503

Kent, J., P. A. Ullrich and C. Jablonowski (2014): Dynamical Core Model Intercomparison Project: Tracer Transport Test Cases, Quart. J. Roy. Meteorol. Soc., Vol. 140, 1279–1293

Selected Related Presentations in 2014/2015:

Jablonowski, C., D. Thatcher, J. Ferguson, C. Zarzycki, A. Gettelman, J. Bacmeister, J. Richter, R. Neale, C. Hannay, P. Lauritzen, P. Callaghan, V. Larson, K. Reed, P. Ullrich, M. Wehner, M. Taylor, The Path Forward: High-Resolution Next-Generation CESM Simulations and Scale-Aware Physics, Oral presentation at the 20th Annual CESM Workshop, Breckenridge, CO, USA, June 15-18, 2015

Ferguson, J., C. Jablonowski, H. Johansen, P. McCorquodale and P. Colella, Assessing Adaptive Grid Refinement Techniques with the Chombo-AMR Model in Shallow Water Model, Poster Presentation at the 20th Annual CESM Workshop, Breckenridge, CO, USA, June 15-18, 2015

Jablonowski, C., J. Ferguson, H. Johansen, P. McCorquodale, P. A. Ullrich, P. Colella, C. Zarzycki and M. Taylor, High-Order Adaptive Mesh Refinement (AMR) and Variable-Resolution Techniques for Atmospheric General Circulation Models, invited presentation at the Workshop on Galerkin Methods with Applications in Weather and Climate Forecasting, Edinburgh, United Kingdom, March 23-27, 201574

Jablonowski, C. and W. Yao, Understanding the Impact of GCM Dynamical Cores and Dissipation Mechanisms on Idealized QBO-like Oscillations, oral presentation at the QBO Modelling and Reanalyses Workshop, Victoria BC, Canada, March 16-18, 2015

Ferguson, J., C. Jablonowski, H. Johansen, R. E. English, P. McCorquodale, P. Colella, J. Benedict, W. D. Collins, J. Johnson and P. A. Ullrich, Assessing Grid Refinement Strategies in the Chombo Adaptive Mesh Refinement Model, oral presentation at the American Geophysical Union (AGU) Fall Meeting 2014, Abstract A13M-06, San Francisco, CA, USA, December 15-19, 2014

Zarzycki, C. M., C. Jablonowski and M. A. Taylor, Recent application of variable-resolution CAM-SE to investigate extreme weather phenomena, invited seminar presentation in the NCAR Climate and Global Dynamics Seminar Series, Boulder, CO, December 2014

Jablonowski, C. and D. R. Thatcher, Physics-Dynamics Test Strategies: Bridging the Gap with Simplified Moist Test Cases, oral presentation at the Physics-Dynamics Coupling Workshop (PDC14), Ensenada, Mexico, December 2-4, 2014

Johansen, H., E. Goodfriend, P. McCorquodale, P. Colella, W. Collins, J. Johnson, D. Rosa, J. Benedict, P. Ullrich, J. Ferguson, C. Jablonowski, Progress towards a space-time adaptive non-hydrostatic dynamical core, oral presentation at the Physics-Dynamics Coupling Workshop (PDC14), Ensenada, Mexico, December 2-4, 2014

Zarzycki, C. M., C. Jablonowski and M. A. Taylor, Physics Scaling in Multi-Resolution CAM Simulations, oral presentation at the Physics-Dynamics Coupling Workshop (PDC14), Ensenada,

Mexico, December 2-4, 2014

Thatcher, D. R. and C. Jablonowski, Intercomparison of numerical methods in climate simulations with idealized moisture parameterization, poster presentation at the Michigan Institute for Computational Discovery and Engineering (MICDE) Fall 2014 Research Computing Symposium, Ann Arbor, MI, USA, November 6, 2014

Jablonowski, C., C. M. Zarzycki, J. O. Ferguson, M. A. Taylor, H. Johansen, W. D. Collins, R. E. English, P. McCorquodale, P. Colella and P. A. Ullrich, Variable-resolution modeling with the Spectral Element Community Atmosphere Model (CAM-SE) and the Adaptive Mesh Refinement dynamical core AMR-Chombo, invited talk at the joint 6th International Workshop on Global Cloud Resolving Modeling (GCRM) and 3rd International Workshop on Nonhydrostatic Numerical Models (NHM), Kobe, Japan, September, 24-26, 2014

Jablonowski, C. and C. M. Zarzycki, Advancing the Frontiers of Tropical Cyclone Modeling with the Variable-Resolution General Circulation Model CAM-SE, invited keynote talk at the World Weather Open Science Conference (WWOSC) 2014, Montreal, Canada, August 16-21, 2014

Outreach Activities:
The project is centered around educational activities. The DCMIP summer schools teach groups of multi-disciplinary students, postdocs and young researchers how today's and future atmospheric models are or need to be built. Furthermore, DCMIP hosts many dynamical core model developers at NCAR for the hands-on student-run model intercomparison projects. The project introduces new cyberinfrastructure tools to the GCM community that enable the participants to share and discuss the scientific results via shared workspaces. The latter connects data and information with web services like online data visualization software.

Relevant Websites:
http://earthsystemcog.org/projects/dcmip-2012/

THEME V: EDUCATION AND OUTREACH

PROJECT TITLE: PENN STATE UNIVERSITY SEABASS 2012: A MARINE BIOACOUSTICS SUMMER SCHOOL

Principal Investigators: Allen Burton (CILER), Jennifer Miksis-Olds (Pennsylvania State University)
NOAA Technical contacts: Doran Mason (NOAA-Great Lakes Regional Collaboration)

NOAA Strategic Goal 1: Healthy Oceans

Overview and Objectives

The goal of the SeaBASS (Marine BioAcoustics Summer School) was to provide the opportunity for graduate students interested in pursuing careers in marine bioacoustics to develop a strong foundation of both marine animal biology and acoustics, foster technical communication across disciplines, and develop professional relationships within the field. This course gave students an opportunity to learn from experts who discussed topics not often offered at universities due to the relatively small demand at any one institution.

1. To provide fundamental concepts of underwater sound and marine animal biology and behavior to graduate students interested in pursuing careers in marine bioacoustics.
2. To create an environment for the open exchange of ideas related to careers, current hot topics, and challenges facing the field of marine bioacoustics.
3. To foster professional relationships between graduate students and experts in the field.

SeaBASS was structured after the successful PASS (Physical Acoustics Summer Session) program that has been offered in alternate years for over two decades. SeaBASS was designed to support 30 graduate students and 10 expert lecturers. A week long curriculum was created where invited lecturers within the field of marine animal bioacoustics (academic, private, and management) provided half day seminars that described fundamental aspects of underwater sound and marine animal behavior, summarized the present state of the field, identified current obstacles and challenges, and discussed important "hot topics" areas (Table 1). Each seminar included an introductory lecture followed by group discussions or group projects to gain a more in-depth understanding of the issues and technology. Structured social activities also allowed for students and presenters to interact informally to develop lasting professional mentorships for guiding the next generation of marine bioacoustics scientists.

SeaBASS 2014 was convened at The National Conference Center outside of Washington, DC. The week long summer session took place June 15-20, 2014. Selection of student participants was through an open application process. The application process was online (http://www.arl.psu.edu/education_seabass.php), and preference was given to US citizens.

NOAA funds contributed support for Room and Board fees for all participants, conference facility fees, and travel grants to graduate student applicants based upon need and qualifications. Twenty one travel grants were awarded to defray costs of graduate student travel. Invited lecturers provided their time at no cost. Additional sponsors of the SeaBASS 2014 program included the Applied Research Laboratory at Penn State, the Office of Naval Research (ONR), U.S. Marine Mammal Commission, LGL, Limited, StatOil, Shell Exploration & Production Company, and the Acoustical Society of America (ASA).

<u>Accomplishments:</u>
SeaBASS 2014 took place at the National Conference Center in Leesburg, VA from 15-20 June, 2014. Thirty graduate student applicants were admitted to the program from 70 eligible applications. A total of 4 applications and 21 informal inquiries were declined because they did not meet the course application and eligibility requirements:

- GPA 3.0 or higher during previous 2 years of study
- Currently enrolled in a Graduate program
- Personal Statement

Applications were received from graduate students in 19 countries (USA & Puerto Rico, Italy, United Kingdom, Denmark, Canada, New Zealand, Portugal, Nigeria, Brazil, Uruguay, Poland, Turkey, Mexico, Ecuador, Slovenia, Peru, Malaysia, China, and Australia), and course attendees were accepted from 7 different countries (USA & Puerto Rico, Italy, United Kingdom, Canada, Poland, Peru, and Australia). Advertising for SeaBASS was distributed on the MARMAM and ASA Bioacoustics listservs. Informational flyers were distributed at Acoustical Society of America meetings and the 20th Biennial Society of Marine Mammalogy Conference (New Zealand, 2013).

The SeaBASS curriculum included a general introduction to underwater sound, 8 specialized marine bioacoustics topics, and a "Hot Topics" session on the effects of sound on marine animals (Table 1). Invited speakers presented material in half-day sessions that included a traditional lecture covering fundamental topic concepts and an interactive activity consisting of analysis software demonstration and problem solving, experimental

design exercises, group discussion, and a human echolocation exercise. Monday evening each student was given the opportunity to present a poster on their graduate research topic, methods, progress, or challenges. This gave students an opportunity to receive project feedback from peers and presenters. An informal career discussion took place mid-week where each invited presenter summarized their education and career path. Presenters openly shared personal experiences on issues not publically discussed in the field including family/career sacrifices, teaching vs research vs management pros/cons, value of post-doctoral experience, etc. Following the career synopses, students selected topics for additional round table discussions that consisted of family/career balance, challenges in a teaching career, pursuing post-doctoral positions, and obtaining research funding. Social activities provided the opportunity for informal interactions in the evening.

Abstract books were presented to each participant at registration and included course schedule, participant directory, lecture slides for select topics, group activity information, and suggested readings. Prior to the official opening of the SeaBASS program on Monday morning, students were able to download and become acquainted with software to be used in lectures and activities throughout the week.

Results

A summary of the SeaBASS 2014 program is available to the public at http://www.arl.psu.edu/education_seabass.php. The site has a summary document for download that contains topic outlines, participant and presenter list, and suggested readings for background information. SeaBASS participants were given the opportunity to formally evaluate the course through anonymous, online evaluation forms. Twenty-one evaluation forms were returned. Figure 2 summarizes the overwhelming positive response.

TASK 1: 2014 AND 2015 GREAT LAKES SUMMER STUDENT FELLOWS PROGRAM

As part of its efforts to educate and train a new generation of research scientists, CILER continues to administer an annual Great Lakes Summer Student Fellows Program. This program is a true partnership with NOAA-GLERL and helps place promising young undergraduate and graduate students with both University and Federal research mentors. Through this program, students get the opportunity to work on substantive research issues in the Great Lakes that, in turn, support CILER's and NOAA's research mission in the region.

Although the program primarily places students with research mentors at NOAA-GLERL, CILER is working on promoting opportunities at partnering universities. For the 2014 program, one summer fellow was placed at Michigan Tech University, for an opportunity to work with Drs. Guy Meadows and Pengfei Xue on nearshore hydrodynamic modeling. CILER will continue to build upon the success of the current program by continuing to promote it throughout the Great Lakes region to other institutes.

For the 2015 program, we had 15 positions available for students. Three of these positions placed students at locations other than NOAA-GLERL, including the NOAA-Lake Michigan Field Station, the University of Wisconsin – Milwaukee, and SUNY – ESF in Syracuse, NY. For those fellows working at the NOAA-GLERL facility, we organized educational events to help the students explore topics ranging from career options across sectors to how to look for funding for graduate school. We will again this year be providing fellows with an exit survey to assess the quality of their fellows experience and to evaluate ways to improve it for the future.

2014 Great Lakes Summer Student Fellows Cohort

Fellow: Sherika Gibson, University of Michigan - Dearborn
Worked on: Using ecosystem-based model to study the spatiotemporal impacts of remediation on the Food web of Great Lakes
Mentor: Hongyan Zhang, UM-CILER, Ed Rutherford, NOAA-GLERL, Doran Mason, NOAA-GLERL and Lori Ivan, UM-CILER

Fellow: Kevin Li, University of Michigan
Worked on: Impacts of Climate Change on Food Webs
Mentor: Ashley Baldridge, UM-CILER, Hongyan Zhang, UM-CILER, Ed Rutherford, NOAA-GLERL

Fellow: James Kessler, University of Michigan
Worked on: Extreme Precipitation Events in Regional Climate Models
Mentor: Brent Lofgren, NOAA-GLERL

Fellow: Kimberly Huynh, Northwestern University
Worked on: Data Analyst / Hydrodynamic Modeling
Mentor: Dmitry Beletsky, UM-CILER and Eric Anderson, NOAA-GLERL

Fellow: Guoting Kang, Michigan State University
Worked on: Satellite Remote Sensing
Mentor: George Leshkevich, NOAA-GLERL and Doran Mason, NOAA-GLERL

Fellow: Kyle Dettloff, Oregon State University
Worked on: Data Analyst: Simulating Effects of Dreissenid Mussels on Water Quality and Lower Food Web of Lake Michigan
Mentor: Hank Vanderploeg, NOAA-GLERL and Mark Rowe, NRC

Fellow: Jane Li, Skidmore College
Worked on: Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)
Mentor: Rochelle Sturtevant, NOAA-GLERL

Fellow: Katy Hintzen, University of Michigan
Worked on: Muskegon Lake Watershed Outreach
Mentor: Felix Martinez, NOAA-NOS and Jennifer Day, NOAA-OAR

Fellow: Justin Hart, University of Michigan
Worked on: Nearshore Fecal Indicator Bacteria (FIB)
Mentor: Lauren Fry, UM-CILER and Eric Anderson, NOAA-GLERL

Fellow: Paul Doerr, University of Michigan
Worked on: Computer or Electronics Engineer, Event Warning System Design
Mentor: Steve Ruberg, NOAA-GLERL and Ron Muzzi, NOAA-GLERL

Fellow: Ryan Keeling, University of Michigan - Dearborn
Worked on: Microcystis blooms in North American lakes – remote sensing analyses
Mentor: Tom Johengen, UM-CILER and Hongyan Zhang, UM-CILER

Fellow: Xueling Li, Michigan Tech University
Worked on: Nearshore Hydrodynamic Modeling
Mentor: Guy Meadows, Michigan Technological University and Pengfei Xue, Michigan Technological University

2015 Great Lakes Summer Student Fellows Cohort

Fellow: Whitney Conard, University of Michigan
Working on: Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)
Mentor: Rochelle Sturtevant (Michigan Sea Grant)

Fellow: Kyle Dettloff, Oregon State University
Working on: Advancing Dreissenid Mussel Biomass and Growth Estimates
Mentor: Ashley Baldridge (NOAA-GLERL), Henry Vanderploeg (NOAA-GLERL) and Hongyan Zhang (UM-CILER)

Fellow: James Kessler, University of Michigan
Working on: Great Lakes Modeling and Forecasting
Mentor: Ayumi Manome (UM-CILER)

Fellow: Drew Eppehimer, Arizona State University
Working on: Invasive Species, Fisheries and Food Web Dynamics Impacts
Mentor: Edward Rutherford NOAA-GLERL

Fellow: Megan Ewald, SUNY – College of Environmental Sciences and Forestry
Working on: Science Translation and Communications for CSMI – Lake Michigan
Mentor: Larissa Sano (UM-CILER), Catherine Riseng (Michigan Sea Grant) and Margaret Lansing)NOAA-GLERL)

Fellow: Jordan Frey, Ithaca College
Working on: Beach Information Communications, Marketing and Outreach
Mentor: Sonia Joshi (UM CILER)

Fellow: Trent Frey, University of Michigan
Working on: Weather Research and Forecasting Data Analysis
Mentor: Ayumi Manome (UM-CILER), Eric Anderson (NOAA-GLERL) and Jia Wang (NOAA-GLERL)

Fellow: Jeffery Houghton, University of Wisconsin
Working on: Nearshore Metabolism and Food Web Structure in Lake Michigan
Mentor: Val Klump (UW-Milwaukee) and Harvey Bootsma (UW-Milwaukee)

Fellow: Rosemary Kelley, University of Michigan
Working on: Monitoring and Forecasting *Microsystis* Blooms in the Great Lakes

Mentor: Tom Johengen (UM-CILER)

Fellow: Kevin Kijanka, University of Buffalo
Working on: Biophysical Measurements Using Video Imaging Analysis of Cyanobacteria
Mentor: Hank Vanderploeg (NOAA-GLERL) and Steve Ruberg (NOAA-GLERL)

Fellow: Scott Loeffler, University of Michigan
Working on: Assessing and Improving Regional Water Budget Forecasts
Mentor: Drew Gronewold (NOAA-GLERL) and Becky Bolinger (NOAA-NCAR)

Fellow: Lillian McGill, University of Notre Dame
Working on: Ecosystem-based Modeling of Remediation Action Effects on the Lake Erie Food Web
Mentor: Hongyan Zhang (UM-CILER), Ed Rutherford (NOAA-GLERL) and Doran Mason (NOAA-GLERL)

Fellow: Sabrina Shuman, University of Michigan
Working on: Muskegon Lake Watershed Outreach and Habitat Blueprint Coordination
Mentor: Felix Martines (NOAA-NOS) and Jennifer Day (NOAA-OAR)

Fellow: Zifan Yang, University of Michigan
Working on: Great Lakes Ice Data Compilation and Analysis
Mentor: Xuezhi Bai (UM-CILER), Xianglei Huang (UM-AOSS), Jia Wang (NOAA-GLERL) and Anne Clites (NOAA-GLERL)

Fellow: Morgan Zyzik, Clarkson University
Working on: Autonomous Monitoring Systems for Harmful Cyanobacterial Blooms
Mentor: Gregory Boyer (SUNY-ESF) and Michael Satchwell (SUNY-ESF)

In order to evaluate student experiences associated with this program, CILER conducts exit interviews with fellows to assess the strengths of the program and to identify areas for improvement. For the 2014 cohort, we developed a questionnaire that we reviewed for each fellow:

2014 CILER Summer Fellows - Exit Interviews

Name (optional): _____

1. **Please tell us a little bit about your day-to-day experience as a summer fellow. For example, what did your average day look like?**

2. **Did you have clear goals for your work and know what was expected of you in your fellowship? Did you receive adequate feedback about your performance day-to-day?**

3. **Describe how often you met with your mentor and his/her accessibility and level of input into your work activities.**

4. **Did you feel you had the resources and support to perform your fellowship. If not, what more was needed?**

5. **Did you have adequate opportunities to meet other people (e.g., at GLERL, the University of Michigan, etc.). What did you find was the easiest way to meet other researchers working at the lab?**

6. **Did you attend any of the CILER-GLERL seminars or BYO(b) events? Please comment on your impression of these events. Any recommendations for improvements?**

7. **Application Process: How did you hear about the CILER fellowship program? How was the application process. Please provide any suggestions for improvement.**

8. **Administrative Communications: How did you find the communication process once you were accepted to the fellowship program? Did you feel you had sufficient information about paperwork, arrival logistics, etc. Please provide any suggestions for improvement.**

9. **What are 3 things we could do to improve the experience for fellows?**

METRICS

Please rate the following:

	Please Bold Out One:									
	1 (low)									10 (high)
10. Rate the overall quality of your summer fellowship experience	1	2	3	4	5	6	7	8	9	10
11. Rate the quality of research skills you gained	1	2	3	4	5	6	7	8	9	10
12. Rate the amount of information you learned through your fellowship	1	2	3	4	5	6	7	8	9	10
13. Rate the quality of the mentoring you received during your fellowship	1	2	3	4	5	6	7	8	9	10

10. Finally, we would like to stay in touch in the future. Would you give us your best contact information and please keep us informed about your studies, research, or work?

TASK 1: LONG-TERM FELLOWSHIPS

In the spring of 2015, we issued an open call for request proposal for CILER long-term fellowships. We received 10 proposals, and awarded two fellowships based on scores and rankings from the CILER Management Council. Based on these ranking, we were able to award two fellowships this year - one to Purdue University and one to the University of Wisconsin – Milwaukee.

The student positioned at Purdue University will focus on characterizing the spatial variation in condition and trophic connections of larval fish as part of the 2015 Coordinated Science and Monitoring Initiative (CSMI) in Lake Michigan. The student working at UW-Milwaukee will be conducting research that evaluates the metabolism and biogeochemical cycling in benthic ecosystems of the Great Lakes.

2015 LONGTERM FELLOWSHIP AWARD #1

Tomas Höök, Associate Professor, Purdue University Department of Forestry and Natural Resources and Associate Director, Illinois-Indiana Sea Grant Program;

Paris Collingsworth, Assistant Research Professor, Purdue University Department of Forestry and Natural Resources and Illinois-Indiana Sea Grant Program; Liason to US Environmental Protection Agency, Great Lakes National Program Office

Edward Rutherford, Research Fishery Biologist, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA GLERL)

Title: Spatial Variation in Condition and Trophic Connections of Larval Fish in Lake Michigan: A CSMI Enhancement Fellowship

Summary: We seek support for a CILER graduate fellow to work collaboratively with NOAA-GLERL, Purdue University, Illinois-Indiana Sea Grant and EPA-GLNPO researchers to evaluate spatial variation in the performance and trophic interactions of larval fish in different areas of Lake Michigan. Field collections will be conducted during the spring and summer of 2015 as part of the 2015 Coordinated Science and Monitoring Initiative (CSMI). Specifically, we will conduct sampling along two replicate transects: 1) a Muskegon transect on-board the NOAA-GLERL R/V Laurentian and 2) a Racine transect, on-board the EPA-GLNPO R/V Lake Guardian. This proposal addresses CILER's research themes of Great Lakes forecasting and invasive species.

2015 LONGTERM FELLOWSHIP AWARD #2

PI: J. Val Klump, Professor, University of Wisconsin-Milwaukee, School of Freshwater Sciences Great Lakes WATER Institute

Co-Mentors: Thomas Johengen, Research Professor, CILER, School of Natural Resources and Environment, University of Michigan; Ashley Baldridge, Benthic Ecologist, NOAA-GLERL

Summary: The proposed fellowship would support Ms. Shelby LaBuhn, a doctoral student in the Klump lab, whose dissertation is focusing on the modeling and biogeochemistry of hypoxia and benthic-pelagic coupling in Green Bay. The proposed research will link with several of CILER's research areas including, observing and forecasting, invasive species, integrated assessment, and ecological risk assessment. We have successfully deployed eddy correlation method in both Lake Michigan and Green Bay (Koopmans et al. and LaBuhn et al. in prep.), in, we believe, the first such measurements in the Great Lakes. We would propose to extend this technique into Lake Michigan over Dreissenid populated regions, and in the western end of Lake Erie, and/or even in the Lake Huron sinkholes (Middle Island) contingent upon available access. In that regard, we have routinely deployed this instrumentation system from small boats. Where possible the system will be deployed in conjunction with near-by continuous monitoring systems, coupling ancillary measurements of thermal structure, currents, and bottom and surface water conditions. As an example, we are using the GLOS buoy in Green Bay to calculate daily net and gross primary production, from diel oxygen fluctuations and buoy data derived air-water gas exchange estimates. This places benthic metabolism within the context of primary production, to which it is closely coupled in shallow environments like Green Bay, Saginaw Bay and western Lake Erie.

LONG-TERM FELLOWSHIP REPORT: INTEGRATED FIELD AND LABORATORY INVESTIGATION OF LINKS BETWEEN NUTRIENTS, DISSOLVED ORGANIC CARBON, REACTIVE OXYGEN SPECIES, AND TOXICITY OF HARMFUL ALGAL BLOOM

Principal Investigators: Tom Johengen (UM-CILER), Gregory Dick (UM-CILER)
NOAA Technical Contacts: Tim Davis (NOAA-GLERL)

Overview and Objectives:

This project aims to uncover the environmental and ecological factors that shape the toxicity of cyanobacterial harmful algal blooms (CHABs). These CHABs are a threat to freshwater ecosystems and human health worldwide. Despite decades of study and advances in understanding the primary causes of CHABs, the drivers of toxicity are still poorly understood. Specific objectives are as follows:

1.   Sequence the genomes of a collection of Great Lakes cyanobacterial isolates to provide a genetic framework for interpreting laboratory and field experiments.

2.   Investigate the physiological and genetic response of toxic and non-toxic Great Lakes Microcystis strains, individually and in competition with each other, to elevated ROS (H_2O_2) concentrations under nitrogen (N) or phosphorus (P) replete and deplete conditions.

3.   Conduct field experiments spiking natural bloom populations with increased ROS concentrations to understand how the natural assemblage of phytoplankton in general and specifically the *Microcystis* cells are responding at a physiological and genetic level.

Accomplishments:

Although we were unable to find a PhD student to start in Fall of 2014 as hoped, the Long Term CILER Fellowship allowed us to recruit a graduate student, Derek Smith, who will start the Department of Earth and Environmental Sciences PhD program in Fall of 2015. As of June 1 Mr. Smith is working with PIs Dick, Johengen, and Davis as a temporary employee. He is participating in weekly sampling of Lake Erie, enabling our team to continue a molecular biology sampling program in 2014 that was funded by the U-M Water Center.

In the meantime, we have completed the first objective of the project, genome sequencing and annotation of 13 strains of Great Lakes cyanobacteria. These include major HABs species (*Microcysitis*, *Planktothrix*, *Dolichospermum/Anabaena* and *Synechococcus*). Interestingly, genes for catalase, the main enzyme for decomposing and thus tolerating H_2O_2, is absent from both of the Lake Erie *Synechococcus* isolates. This gene is also absent from *Prochlorococcu*s genomes, accounting for their sensitivity to H_2O_2. Searching publicly

available genomes on Integrated Microbial Genomes, we found that of the 30 *Synechococcus* genomes sequenced, 16 have genes for catalase, showing that its presence is variable in this clade. Curiously, only one of the 15 available *Microcystis aeruginosa* genomes has catalase, indicating that its high tolerance of oxidative stress must be due to other pathways or traits, such as microcystins.

To explore this hypothesis, initial field experiment were conducted on Lake Erie HAB communities. Whole lake water was incubated in 2L microcosms in triplicate and either left alone to serve as controls or supplemented with increased H_2O_2 (ROS), nitrogen and phosphorus or both. At the end of the experiment (48 hours) we sampled for microbial community composition, toxic and non-toxic strains of *Microcystis*, gene expression (RNA), total, dissolved and conjugated microcystins and pigments (chlorophyll *a* and phycocyanin). Our initial results show that ROS alone did not affect pigment or microcystin concentrations. However, increased in nutrients did elevate all pigments and total particulate microcystins. When ROS and nutrients were combined the results were similar to the nutrients only for pigment response but particulate microcystins were lower and no change in % conjugated microcystins was observed. In none of the treatments did the dissolved microcystins significantly differ from the control. These results are intriguing and follow up experiment are planned for this summer on-board the Canadian research vessel *Limnos*. Further the long-term fellow (Smith) is currently setting up laboratory experiments to investigate the response of microcystin-producing Lake Erie strains of *Microcystis* to varying N, P and H_2O_2 conditions.

Publications:

Four associated publications are currently in preparation. First, a review article focused on methods of molecular studies of CHABs for a special issue of Harmful Algae. Second, a study of the concentrations and sources of H_2O_2 in Lake Erie. Third, a study of microbial communities, toxins, ROS, and nutrients in Lake Erie CHABs throughout the 2014 season. Fourth, a study of the effect of experimentally added H_2O_2 to natural CHABs communities. We plan to submit the first three this summer while the fourth will likely be submitted this fall.

Presentations:

Davis, T.W. et al., Using an integrated approach to better understand the environmental drivers of toxic cyanobacterial harmful algal blooms in Lake Erie, USA, International HABs symposium, Korean Institute of Science and Technology, Seoul, South Korea, May 2015

Davis, T.W., et al., Why are our lakes the same color as our lawns? Understanding the role of eutrophication and climate change in promoting Cyanobacterial Harmful Algal Blooms (CHABs), University of Illinois HABs workshop, Champagne-Urbana, Il, May, 2015

Dick, G.J. et al. *Omic approaches to freshwater microbial communities and CHABs*. Workshop on Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green State University, April 2015. [oral presentation]

Meyer, K.A., T. Davis, S. Jain, S.B. Watson, G.S. Bullerjahn, R.M.L. McKay, and G.J. Dick. *Genome sequencing of thirteen Great Lakes cyanobacteria*. Workshop on Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green State University, April 2015. [poster presentation]

Jain, S. and G.J. Dick. *SuperMoM: A graph-based database to store and analyze community omics and environmental data*. Workshop on Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green State University, April 2015. [poster presentation]

Berry, M.A., P. Den Uyl, R.M. Cory, T. Davis, M. Duhaime, G.W. Kling, T.H. Johengen, G.J. Dick, and V.J. Denef. *Lake Erie bacterial community dynamics during a toxic algal bloom*. Workshop on Global Solutions to Regional Problems: Collecting Global Expertise to Address the Problem of Harmful Algal Blooms, Bowling Green State University, April 2015. [poster presentation]

Outreach Activities:

We helped to co-organize a symposium on CHABs held at BGSU April 13-15. This included two sessions for which we were the primary organizers: a poster session on CHABs April 13th (> 100 attendees) and a workshop and oral session on "omic approaches to CHABs on April 15th (~40 attendees).

Relevant Web content:

We are developing a public web portal for a database that will store the genome sequences and offer tools for analysis of omics data. In the meantime, we have constructed a github website to disseminate our code and tools: https://github.com/sunitj/SuperMoM

Supplemental Material:

None to date.

LONG-TERM FELLOWSHIP REPORT: A FIELD STUDY OF EVAPORATION ACROSS LAKE ERIE

Principal Investigators: Allen Burton (UM-CILER), Branko Kerkez (UM-CILER)

NOAA Technical Contacts: Drew Gronewold (NOAA-GLERL)

Overview and Objectives:

Our goal was to understand the complex processes that drive the Great Lakes water balance. To that end, the specific objective of this proposal was to carry out a field study of overlake evaporation across the 2014 GLERL field season, focusing specifically on Lake Erie. We have developed a prototype evaporation sensor platform, which was deployed by a graduate student to study the spatiotemporal variability of overlake evaporation in western Lake Erie. Data was successfully acquired during the 2014 seasons, and the sensors are again deployed on the Lakes this year.

Accomplishments:

Kevin Fries, the PhD student on this project, was awarded an NSF graduate fellowship due, in large part, to the preliminary work he completed during this CILER project. A radiation sensor and hygrometer were deployed on NOAA RECON's Cleveland buoy during the summer and fall of 2014. These measurements, in combination with other measurements from sensors already equipped on the buoy, were used to estimate hourly evaporation at the buoy's location. These estimates were made through a robust web infrastructure hosted on Amazon Web Services that is scalable to include future observation sites from both stationary and drifting buoys.

A drifting buoy prototype, equipped with a weather station and satellite modem, was developed and tested on Lake Erie. Further design iterations for the housing are necessary to ensure the buoy is robust enough to function for an entire season without swamping under aggressive wave action.

A large dataset of ship observations is currently collected by NOAA CoastWatch that includes measurements of many of variables we plan to measure on the above buoys. The ship data lacks quality control, though, and is sparse both spatially and temporally. Using a machine learning tool called Gaussian processes, we were able to assimilate these ship observations into current weather and lake models created by the National Weather Service and NOAA to get improved hourly estimates of air temperature, dew point, wind speed, and lake surface temperature for 2006-2014.

Publications:

Two papers are presently in preparation, to be published in 2015.

Presentations:

Fries, Kevin, Branko Kerkez. *Ship Data for Spatio-temporal Estimates of Hydrometeorological Conditions Across the Great Lakes*. Presented at the International Association for Great Lakes Research Annual Conference on Great Lakes Research, Burlington, VT, 2015.

Fries, Kevin, Branko Kerkez, Andrew Gronewold, John Lenters. *A sensor-based energy balance method for the distributed estimation of evaporation over the North American Great Lakes*. Presented at the American Geophysical Union Fall Meeting, San Francisco, 2014.

Outreach Activities:

None.

Relevant Web content:

See evaporation page on: http://tinyurl.com/bkerkez

Supplemental Material:

None.

LONG-TERM FELLOWSHIP FINAL REPORT: UNDERSTANDING AND FORECASTING METEOTSUNAMI IN THE GREAT LAKES

Principal Investigators: Allen Burton (UM-CILER), Chin Wu (UM-CILER)
NOAA Technical Contacts: Eric Anderson (NOAA-GLERL)

Overview and Objectives:

Meteotsunamis (or meteorological tsunamis) are propagating long water waves generated by fast moving atmospheric disturbances (squall line). Meteotsunamis exhibit many similarities with seismic tsunamis, having wave periods of 2 minutes to 2 hours and undergoing resonant amplification that transforms relatively small waves in the open water into destructive forces at the coast [Ravinovich and Stephenson 2004]. The meteotsunami impact in the Great Lakes is illustrated through many events which have resulted in destruction and death [Cleveland Plain Dealer 1882; New York Times, 1912; Grand Haven Tribune 1929; Toledo Blade 1942; Donn et al. 1956; NOAA 1998]. The most vivid Great Lakes meteotsunami on record occurred in 1954 on Lake Michigan when a 3 meter wave struck Chicago and swept many fishermen off a pier, killing seven [Ewing *et al.* 1954]. Recently, on May 27, 2012 a large meteotsunami unexpectedly swept three swimmers far into Lake Erie. Fortunately the swimmers survived, but the meteotsunami threat to the Great Lakes was made vividly clear. Other recent meteotsunamis have been observed at Sault Ste. Marie, MI (September 4, 2014) Traverse City, MI (June 10, 2015) with minor damage and flooding reported. While the threat of meteotsunamis in the Great Lakes is apparent, no characterization of meteotsunamis in the Great Lakes has been conducted and no infrastructure is available to reliably forecast an impending meteotsunami. To address these issues, the goal of the project was to develop a meteotsunami observation and modeling system to characterize meteotsunamis formation in the Great Lakes and apply this knowledge to improve prediction and awareness of this coastal hazard for enhanced public safety. The specific objectives of the project were:

- Characterize the Great Lakes meteotsunami climate from historical water level and meteorological records; addressing the questions *Where and how often do meteotsunamis occur?* and *What meteorological mechanisms cause meteotsunamis?*
- Establish hydrodynamic modeling requirements to simulate meteotsunamis in research and operational modes; *What spatio-temporal scales are necessary to model meteotsunamis?*

Accomplishments:

To investigate the recent occurrence of meteotsunamis in the Great Lakes, 6-minute water level data from 1996 to present were analyzed from the 10 NOAA National Oceanic

Service gauges distributed throughout the Lake Michigan. Meteotsunami events were identified from the water level records based on the criteria given by Monserrat et al. [2006] and recurrence levels were established using a Pareto Type 1 fit to the event heights. For example, the annual meteotsunami height at Calumet Harbor, IL is 0.75 meters with a 20-year return level of 1.4 meters. The seasonal distribution of meteotsunamis reveals spatial differences in occurrence, with a majority of the events in northern Lake Michigan occurring in April-May-June, meteotsunamis in southern Lake Michigan occurring primarily in May-June-July, and meteotsunamis in Green Bay occurring primarily in June-July-August. We also examined the storm structures associated with meteotsunamis at each station. At all stations, a majority of meteotsunamis were associated with strong linear or complex convective storms. Meteotsunamis in southern Lake Michigan were almost exclusively convectively forced while stations in northern Lake Michigan experienced up to 45% of meteotsunamis caused by frontal storms. These results provide valuable information into the causative meteorology behind meteotsunamis to help identify conditions conducive to meteotsunami formation. This work will be summarized in the manuscript "The meteorological tsunami climate of in the Great Lakes", currently in preparation for submission to the Journal of Geophysical Research Oceans. Furthermore, we have extended this analysis to all 36 NOAA/NOS water level gauges throughout the Great Lakes to understand the regional meteotsunami climate. Lake Michigan experiences the largest meteotsunamis followed by Lake Erie and Lake Huron, with much smaller meteotsunamis occurring in Lakes Superior and Ontario. Lakes Michigan, Huron, and Ontario share similar meteotsunami seasonality (late spring to early summer) while Lake Superior experiences meteotsunamis primarily in the summer season and Lake Erie exhibiting a primary summer meteotsunami season with a secondary fall seasons. This difference is likely attributed to lake depth, as Lakes Michigan, Huron, and Ontario are all of similar depths while Lake Erie is much shallower and Lake Superior far deeper. *These results provide important answers to the questions of where and when meteotsunamis occur throughout the Great Lakes.* This work will be summarized in the manuscript "Great Lakes meteotsunami occurrence", currently in preparation for submission to Geophysical Research Letters. This work was recently presented the 2015 IAGLR Annual Conference of Great Lakes Research in the paper "**Meteotsunami Occurrence and Trends: Great Lakes and Beyond".**

A hydrodynamic model of Lake Erie was configured to simulate meteotsunamis in response to a range of possible meteorological forcings to advance towards meteotsunami predictability. In particular, we simulated the May 27, 2012 meteotsunami near Cleveland, OH which swept three swimmers far into Lake Erie. Neither the wave nor the causative storm were resolved by the Great Lakes Coastal Forecasting System (GLCFS), so understanding the mechanics of this event as well as modeling requirements necessary to simulate this event is vital to improving the meteotsunami predictive capacity in the Great

Lakes. Analysis of surface meteorological and radar records revealed that three fast moving storms crossed Lake Erie within the timeframe of the meteotsunami, none of which were captured by the hourly interpolation-based scheme used to provide input winds to the GLCFS. The pressure and wind fields of these storms were reconstructed from these observations for use as input into a hydrodynamic model (FVCOM) of Lake Erie with 100 meter resolution. The hydrodynamic simulations revealed that the meteotsunami was the result of a storm traveling southward which struck the Cleveland area around 17:30 UTC on May 27. This storm produced a series of long waves which reflected off the southern shore of Lake Erie and then subsequently reflected off the northern shore back towards Cleveland. Owing to the concave shape of the north shore of Lake Erie, these reflected waves became spatially focused, growing the waves to their destructing and dangerous height. Furthermore, reflection made the meteotsunami waves appear long after the causative storms, giving recreationists a false sense of security of calm conditions after the storm. In light of these findings, we worked closely with Dr. Greg Mann at the Detroit National Weather Service Weather Forecasting Office to simulate the meteorological conditions with a high-resolution (4km) Weather Research and Forecasting (WRF) model for use as input into the hydrodynamic model. The WRF model was able to simulate wind and pressure perturbations associated with the causative storms and the subsequent hydrodynamic modeling produced meteotsunami waves similar to the observed event. *Overall, this study provides insight into the requirements for model-based forecasts of meteotsunamis, particularly the need for high resolution in both the spatial (km scale) and temporal domains (minute scale).* This work is summarized in the manuscript "Reconstruction of a meteotsunami in Lake Erie and the effects of enclosed basins on hydrodynamic response" which is in review at the Journal of Geophysical Research Oceans. This work was also recently presented at the 2015 IAGLR Annual Conference of Great Lakes Research in the paper **"Detection and Reconstruction of a Meteotsunami on Lake Erie".**

Publications:

Bechle, A.J. and Wu, C.H., 2014. The Lake Michigan meteotsunamis of 1954 Revisited. Natural Hazards, 74(1), 155-177.

Bechle, A.J. and Wu, C.H., 2014. An entropy-based velocity method for esturaine discharge measurement, *Water Resources Research*, 50(7), 6106-6128.

Anderson, E.J., Bechle, A.J., Wu, C.H., Schwab, D.J., Mann, G.E., and Lombardy, K.A.; Reconstruction of a meteotsunami in Lake Erie and the effects of enclosed basins on hydrodynamic response. *Journal of Geophysical Research Oceans*, Accepted under revision.

Bechle, A.J., Kristovich, D.A.R., and Wu, C.H.; Meteorological tsunamis occurrence in Lake Michigan. *Journal of Geophysical Research Oceans, in review.*

Bechle, A.J., Wu, C.H, Anderson, E.J., and Schwab, D.J., Great Lakes meteotsunami occurrence. *In preparation for submission to Geophysical Research Letters*

Bechle, A.J., Wu, C.H, Schwab, D.J. and Anderson, E.J., Meteotsunamis: Global occurrence and trends. *In preparation for submission to Nature*

<u>**Presentations:**</u>

Anderson, E.J., Bechle, A.J., Wu, C.H., Schwab, D.J., Mann, G.E., and Lombardy, K.A., **"Detection and Reconstruction of a Meteotsunami on Lake Erie";** International Association for Great Lakes Research (IAGLR), 58th Annual Conference on Great Lakes Research, Burlington, VT; May 26, 2015.

Bechle, A.J. and Wu C.H., "Meteorological Tsunami Occurrence and Trends: Great Lakes and Beyond"; IAGLR, 58th Annual Conference on Great Lakes Research, Burlington, VT; May 26, 2015.

Wu, C.H., Linares, A., Anderson, E.J., and Bechle, A.J.; "Meteorologically induced high-frequency water level fluctuations in northern Lake Michigan"; IAGLR 58th Annual Conference on Great Lakes Research, Burlington, VT; May 26, 2015.

Bechle, A.J. and Wu, C.H.; "Real-Time Water Imaging System: A Ground-based Water Quality Monitoring Tool"; 39th Annual Meeting of the American Water Resources Association – Wisconsin Section, Oconomowoc, WI; March 5, 2015.

<u>**Outreach Activities:**</u>

We plan to translate our research findings into tools that can be used to mitigate the risk of meteotsunamis throughout the Great Lakes. We have submitted a proposal to a Illinois-Indiana and Wisconsin Sea Grant Joint Request to fund the development of a Cyberinfrastructure for Risk Assessment and Forecasting Tool (CRAFT) that would translate our findings on meteotsunami occurrence into a user-friendly tool to help local planners, emergency managers, and forecasters understand the probability of destructive meteotsunami occurrence, as well as the potential damage associated with these events. In this proposed project, we would collaborate closely with the NWS offices to incorporate NWS needs and experiences into CRAFT. We would also work Sea Grant to communicate risk posed by coastal inundation and appropriate protective actions to the public.

TASK 1: 2014 CILER POSTDOCTORAL FELLOWS PROGRAM

This program provides salary and research support for a post-doctoral fellow who will work closely with a CILER Management Council or Council of Fellows member on a project of mutual interest. The program is administered as a Task IC activity, because it is competitively awarded position based on funds that are not associated with a specific research project. All CILER Management Council and Council of Fellows members are eligible to participate in the program.

For FY14, we had one CILER postdoctoral fellow, who started his work in December 2013. Dr. Peter Levi is working with Dr. Peter McIntyre at the University of Wisconsin – Milwaukee. Dr. Levi came to SNRE in January 2015 to report on his research that was funded through this program. While in Ann Arbor, Dr. Levi had a chance to network with NOAA-GLERL and UM researchers and to talk about his work:

Conservation Ecology Seminar – Speaker Agenda

Dr. Peter Levi, CILER Postdoctoral Fellow, Center for Limnology, University of Wisconsin-Madison
Seminar Title: Evaluating the ecological state of restored streams in urban watersheds

---

Friday, 30-January 2015

Time	Event	Location
c. 8:30	Transport to GLERL	
9:00 – 9:30	Terry Heatlie	NOAA-GLERL, rm 328
9:30 – 10:00	Drew Gronewold	NOAA-GLERL, rm 133
10:00 – 11:00	Michael Fainter	GLERL – Ontario Conf Rm
11:30	David Allan	UM-SNRE, Dana rm G520
12:00	Student Luncheon	UM-SNRE, Dana rm 2026
13:00	Paul Drevnick	UM-SNRE, Dana rm 4315A
14:30	Mike Wiley: To be confirmed	UM-SNRE, Dana rm 4315A
14:00	Branko Kerkez	UM-SNRE, Dana rm 4315A
14:30	Rose Cory	UM-SNRE, Dana rm 4315A
15:30	Seminar	UM-SNRE, Dana rm 1028
16:30	SNRE Student meeting, details TBD	

Research Title: Do stream restorations scale up? An analysis of ecosystem response to restorations throughout river networks in the Great Lakes basin

Postdoctoral Research Fellow: Peter Levi

Overview and Objectives:

Throughout the Great Lakes basin, urban stream restorations are being implemented to improve the ecological, economic, and social integrity of freshwater resources. These restorations often enhance ecosystem services, such as re-establishing natural flow regimes or increasing nutrient processing rates. However, similar restorations (e.g., channel reconfiguration) may have different effects on stream processes depending on the location of the restoration within the river network (e.g., tributary vs. river main stem). Using process-based measurements of ecosystem function, sites within a river network can be targeted for restorations that maximize ecosystem services and minimize economic and social costs.

The objective of our study is to provide a quantitative assessment of urban stream restorations using integrative metrics of ecosystem function (e.g., whole-stream metabolism, nutrient cycling dynamics). We are conducting our research in six watersheds in the Milwaukee metropolitan area. In each river, we have selected adjacent restored and unrestored reaches (>200m in all cases), generally consisting of replacement of concrete channels with rock/sand/mud substrates flanked by riparian vegetation. These sites represent a gradient of discharge and watershed position within the broader Milwaukee River system, enabling us to address broad patterns as well as site-specific restoration outcomes.

To execute this field project, we are partnering with local citizen groups (e.g., Milwaukee RiverKeeper), members of municipal (e.g., Milwaukee Metropolitan Sewerage District) and state agencies (e.g., Wisconsin DNR), and other academic institutions (e.g., UW-Milwaukee, Loyola University). In addition, we will seek to use the results from our study in southeastern Wisconsin to model the potential ecological benefits and economic costs for urban stream restorations throughout the Great Lakes.

Accomplishments:

We completed an extensive field study of six restorations and six paired concrete channels from July through September in 2014. Our effort has been greatly enhanced by collaborations with Milwaukee Metropolitan Sewerage District (MMSD), who provided additional funding in early 2014. We have also begun analyzing decades of water quality

data collected by MMSD that will complement our field assessments of restored and unrestored river reaches. In late June 2015, we started a second season of fieldwork, examining denitrification rates throughout the river networks in Milwaukee. This additional research will continue through Summer 2015 with data analysis in the Fall.

Publications:

CILER-related: None at this point.

Non-CILER-related: Levi, P.S., T. Riis, A.B. Alnøe, M. Peipoch, K. Mætzke, C.B. Pedersen, and A. Baattrup-Pedersen. 2015. Macrophyte complexity controls nutrient uptake in lowland streams. Ecosystems. DOI 10.1007/s10021-015-9872-y

Roley, S.S., J.R. Griffiths, P.S. Levi, C.J. Patrick, S. Sadro, and J.P. Zarnetske. 2014. State of the ecosystem: progress in quantifying ecosystem health in aquatic ecosystems. Limnology and Oceanography Eco-DAS X Symposium Proceedings, 101-118. DOI 10.4319/ecodas.2014.978-0-9845591-4-5.101

Levi, P.S. 2014. Finding the right words: A study of how and why we communicate our science with non-peers. British Ecological Society Bulletin.

Presentations:

Levi, P.S., S.I. Macchiavelli-Girón, and P.B. McIntyre. From concrete channels to restored reaches: evaluating the ecological state of re-naturalized streams in urban watersheds. Society for Freshwater Science. Milwaukee, WI, 05/2015. Oral presentation.

Levi, P.S., D. Fowler, and N. Bogue. River restorations: the ecological, engineering, and social dimensions. Clean Rivers Clean Lake Conference. Milwaukee, WI, 04/2015. Keynote address.

Levi, P.S. Scientists as communicators: a critical role for the 21st Century. Reilly Center 30th Anniversary Conference. University of Notre Dame, Notre Dame, IN, 03/2015. Keynote address.

Levi, P.S. Restoring a healthy Kinnickinnic River: from a neighborhood to a nation. Kinnickinnic River Neighbor's in Action. Milwaukee, WI, 02/2015. Invited seminar.

Levi, P.S., and P.B. McIntyre. Response of stream ecosystem structure and function to restorations in urban watersheds. Upper Midwest Stream Restoration Symposium. Dubuque, IA, 02/2015. Oral presentation.

Levi, P.S. Evaluating the ecological state of restored streams in urban watersheds. University of Michigan, Ann Arbor, MI, 01/2015. Invited seminar.

Levi, P.S. Freshwater ecosystem management in the Midwest: act locally, think globally. Drake University, Des Moines, IA, 12/2014. Invited seminar.

Levi, P.S. The chemistry of ecosystems: sources, cycles, and patterns. Oakland University, Rochester, MI, 10/2014. Invited seminar.

Levi, P.S., and P.B. McIntyre. Evaluating the ecological state of restored stream in urban watersheds. Science in the Northwoods. Boulder Junction, WI, 10/2014. Oral presentation.

Macchiavelli Girón, S.I., P.S. Levi, and P.B. McIntyre. Does restoration of urban streams improve ecosystem function? Society for Advancement of Hispanics/Chicanos and Native Americans in Science. Los Angeles, CA, 10/2014. Poster presentation.

Outreach Activities:
Conducted watershed model activity with middle school after-school program in South Milwaukee, WI (04/2015).

Speaker and guest at weekly meeting of the Watertown (WI) Rotary Chapter (4/2015).

Conducted watershed model activity with 7th grade science classes at Riverside Middle School, Watertown, WI (04/2015).

Discussed water quality and provided research demonstration during Milwaukee RiverKeeper's annual Earth Day clean-up, Milwaukee, WI (04/2015).

Led the environmental day of neighborhood summer camp in collaboration with the 16th Street Community Health Center, Milwaukee, WI (08/2014).

Mentored eight undergraduate and graduate students who assisted me at various times during my fieldwork in 2014.

Relevant Web content:
Milwaukee Public Radio had an audio and article related to our research, which was also picked up by National Public Radio and posted on their Facebook page:
http://wuwm.com/post/south-side-neighbors-engage-rebirth-milwaukees-kk-river

Video from Milwaukee RiverKeeper Earth Day activity:
https://www.youtube.com/watch?v=kmOlzub8KV8

Supplemental Material:

An interim report was submitted to the Milwaukee Metropolitan Sewerage District on December 31, 2014.

TASK 1: 2014 CILER-GLERL GREAT LAKES SEMINAR SERIES

As part of its efforts to achieve its scientific vision and its education and outreach missions, CILER proposes to continue sponsoring and coordinating a joint CILER-GLERL Seminar Series. This series brings in regional, national, and international researchers to talk about pertinent new and emerging scientific issues to GLERL, the University of Michigan, and to other universities and sites within the Great Lakes region. These events facilitate collaborations between researchers, provide an educational opportunity for NOAA and university scientists, and serve as an outreach forum for stakeholders and the general public to attend.

For FY14, we sponsored the following seminars:

Seminar #1
TITLE: The Genetics of Cyanobaterial Toxin Production
SPEAKERS: Dr. Brett Neilan
TIME: 10:30 – 11:30 am EDT on 18th July 2014
INFO: In many aquatic ecosystems world-wide, including drinking water supplies, cyanobacteria (blue-green algae) can proliferate into so-called "harmful algal blooms". Members of this bacterial phylum have been evolving on Earth for around 3 billion years and can produce an unparalleled array of bioactive secondary metabolites, some of which are potent toxins. The past ten years has witnessed major advances in our understanding of the genetic basis for toxin production by a number of groups of cyanobacteria and marine algae. Understanding the role of these toxins in the producing microorganisms and the responses of their genes to a changing climate may suggest the means for controlling toxic bloom events in water supplies. The information gained from the discovery of these toxin biosynthetic pathways has enabled the genetic screening of various environments for drinking water quality management. In addition, the information gained from studying the toxins has also provided the information needed to screen for contaminated seafood. This seminar addresses the evolutionary history of one of the oldest life forms on Earth, the molecular genetics underlying bacterial toxin production, and the exploitation of this information for risk analysis.

Seminar #2
TITLE: Measuring surface temperature in the cryosphere from space
SPEAKER: Dr. Dorothy Hall
TIME: 10:30 – 11:30 am EDT on 10th October 2014
INFO: Surface temperature measurements from space can provide accurate and consistent measurements of cryospheric features under clear-sky conditions. These measurements are useful for climate and modeling studies as well as for some applications. Moderate-Resolution Imaging Spectroradiometer (MODIS) data, available since February of 2000,

have been used to develop ice-surface temperature (IST) products of the Greenland ice sheet, polar sea ice and the Great Lakes. 14-yr trends in the clear-sky IST and melt extent of the Greenland ice sheet show increasing surface temperatures over most of the ice sheet. Over sea ice, the IST-derived temperature of ice and open water adjacent to sea ice has helped to document enhanced melting of sea ice in the 2012 spring/summer when the Arctic sea ice extent hit a record low. IST maps of the Great Lakes for the winter of 2012-13 show both the ice and adjacent water temperature providing insight into ice formation and breakup. The validation and consistency of the MODIS IST record reveals excellent correspondence with measured surface temperature at "high" temperatures, near 0°C, but the accuracy decreases as ice temperatures drop.

Seminar #3
TITLE: Sailing the Seas of Titan – Saturn's Earth-like Moon
SPEAKER: Dr. Ralph Lorenz
TIME: 3:30 – 4:30 pm EDT on 24st September 2014
INFO: Oceanography is no longer just an Earth Science. The ongoing NASA/ESA Cassini mission - still making exciting discoveries 10 years after its arrival in the rich Saturnian system - has found that three seas of liquid hydrocarbons adorn Saturn's giant, frigid moon Titan. Titan was already exotic, having a thick, organic-rich atmosphere, and a diverse landscape with mountains, craters, river channels and vast fields of sand dunes, but these seas, and hundreds of lakes, present a new environment (low gravity, dense atmosphere, hydrocarbon liquid) in which to explore familiar and important physical processes such as air:sea heat and moisture exchange, wind-driven currents and waves, etc. Moreover, Titan's seas (notably the two largest ones, Kraken Mare and Ligiea Mare, about 1000km and 400km across, respectively) offer an appealing and accessible target for future Titan exploration.
The webinar portion of this seminar was support by MConnex (UM-Engineering), see
http://www.engin.umich.edu/college/about/news/stories/2014/september/sailing-the-seas-of-titan-saturn-s-earth-like-moon

Seminar #4
TITLE: Do we have the tools and the smarts to quantify near shore conditions in Lake Michigan?
SPEAKER: Dr. James Pauer
TIME: 10:30 – 11:30 am EDT on 30th April 2015
INFO: The off-shore waters in Lake Michigan have been approaching the oligotrophic state, and the lake wide total phosphorus concentration has met the Great Lakes Water Quality Agreement (GLWQA) target since the early 1980s. However, environmental concerns in the near shore, such as excessive eutrophication and the colonization of invasive species, have resulted in the call for an overall assessment of this zone in the most recent GLWQA. Several studies have been published which assess the near shore area of Lake Michigan and the larger Great Lakes. Analysis of these

study results, along with preliminary results from a mathematical model provides insight into how to quantify and predict conditions in the near shore area.

Seminar #5
TITLE: Monitoring and modeling the water budget and water levels of Earth's largest lake system
SPEAKER: Dr. Andrew Gronewold
TIME: 10:30 – 11:30 am EDT on 21st May 2015
INFO: Abstract: The North American Great Lakes constitute the largest surface of fresh water on Earth (Lakes Superior and Michigan-Huron alone are the two largest lakes on Earth by surface area). Monitoring and modeling the major components of the Great Lakes water budget, including over-lake precipitation, over-lake evaporation, and runoff, involves an international, multi-institution partnership that leverages a complex combination of sensor networks and modeling platforms. In this presentation, we provide an overview of the drivers behind long-term changes in Great Lakes water levels, including findings from recent research focused on explaining the abrupt water level decline on Lakes Superior and Michigan-Huron in the late 1990s, and the recent record-setting water level surge. Insights from this research underscore the sensitivity of large freshwater systems to regional climate perturbations, and the need for improved understanding of how the future of these systems will be dictated by a combination of climate change, human intervention, and changes in consumptive use.

Seminar #6
TITLE: The Great Debate: Investigating the roles of nitrogen and phosphorus in driving the growth and toxicity of cyanobacterial harmful algal blooms in western Lake Erie
SPEAKER: Dr. Timothy Davis
TIME: 10:30 – 11:30 am EDT on 25st June 2015
INFO: Lake Erie is once again experiencing intense cyanobacterial harmful algal blooms (CHABs) in the western basin and more pronounced hypoxic events in the bottom waters of the central basin. While it is well known that cultural eutrophication is a primary driver of these phenomena, there is fierce debate over the roles of nitrogen (N) and phosphorus (P) in stimulating the growth and toxicity of CHABs. While it has been shown that estimates of bloom size can be made using spring P-loading values from the Maumee River to Lake Erie, to date no such model exists for estimating bloom toxicity. Furthermore, the role of N in stimulating CHAB growth and toxicity in Lake Erie has only recently been gaining attention. Several investigators have addressed this issue but to date no clear consensus exists. This lack of understanding is partially due to the fact that the limnological conditions in western basin Lake Erie are highly variable and blooms may be experiencing both P limitation and N limitation simultaneously, therefore sampling bias may skew conclusions. Furthermore, different organisms are responsible for the CHABs in

the open lake versus Lake Erie tributaries. For example, *Microcystis* spp. comprises much of the bloom biomass in the lake proper where as *Planktothrix* spp. comprises a majority of the biomass in Sandusky Bay and the Maumee River. Both genera have strains that are able to produce toxic microcystins, however, N and P can stimulate bloom growth differently throughout the season. I will present the results from long-term monitoring, microcosm experiments and advanced genetic techniques. Initial findings indicate that bloom biomass is P-limited in the lake proper during the early bloom stages and cellular nutrient limitation shifts from P to N in late summer. Furthermore, CHABs that form in tributaries such as Sandusky Bay were primarily N limited throughout the bloom season. Finally, metagenomic and eco-transcriptomic results have shed light on why a non-N-fixing cyanobacterium (*Planktothrix*) can dominate in a chronically N limited system and reveal mechanisms *Microcystis* can use to outcompete other phytoplankton during times of P limitation. All of these data indicate that while P is critical for initiating western Lake Erie CHABs, N may be more important for stimulating growth and toxin production in total, hence both N and P must be considered when developing nutrient mitigation strategies.

APPENDIX 1: PUBLICATIONS COUNT. Includes number of publications by year as well as the grand total to date from previous years up through the current new Cooperative Agreement.

Peer-Reviewed Publications

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CILER Lead	16	8	7	10	10	12	19	14	36	15	8
NOAA Lead	5	2	4	7	3	4	33	24	10	7	6
Other Lead	0	12	10	3	6	13	29	38	0	20	5
TOTAL	**21**	**22**	**21**	**13**	**19**	**29**	**81**	**76**	**46**	**42**	**19**

	2013	2014
CILER Lead	8	10
NOAA Lead	7	6
Other Lead	9	28
TOTAL	24	44

Non-peer Reviewed Publications

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CILER Lead	7	1	2	1	0	6	0	3	123	67	N/A
NOAA Lead	4	6	1	0	2	1	0	3	64	30	N/A
Other Lead	0	0	0	0	0	0	0	11	11	56	N/A
TOTAL	**11**	**7**	**3**	**1**	**2**	**7**	**0**	**17**	**198**	**153**	

	2013	**2014**
CILER Lead	3	5
NOAA Lead	4	2
Other Lead	2	1
TOTAL	9	8

APPENDIX 2: EMPLOYEE COUNT

Summary of Joint Institute Staff by Head Count 2013-2014 (Includes subcontracts)

Category	Number	B.S.	M.S.	Ph.D.
Research Scientists	3	0	0	3
Visiting Scientists	0	0	0	0
Postdoctoral Research Fellows	10	0	0	10
Research Support Staff	21	6	13	2
Administrative	5	2	1	2
Undergraduate Students	22	0	0	0
Graduate Students	29	18	4	7
Totals (≥ 50% support)	43	8	18	17
Totals (≤ 50% support)	47	22	0	7
Located at NOAA Lab	55-GLERL			
Obtained NOAA employment	0			

APPENDIX 3: FINAL REPORT: IDENTIFYING LAND USE TIPPING POINTS THAT THREATEN GREAT LAKES ECOSYSTEMS

Principal Investigators: Brian K. Miller (Indiana – Illinois Sea Grant), Bryan Pijanowski (Purdue University)
NOAA Technical Contact: Ed Rutherford (NOAA-GLERL)

Overview and Objectives:

Tipping Points and Indicators, a new research and extension program for Great Lakes coastal communities, helps local decision makers identify impacts of land-based activities that threaten the sustainability of ecosystems in their watershed. The program builds upon a three year GLRI/NOAA funded project to engage coastal communities through a region wide decision support and facilitation tool that empowers local communities to develop action plans and strategies that sustain aquatic ecosystems.

This program includes a web-based decision support system (http://tippingpointplanner.org) and facilitated forum to explore policy and management interventions necessary to keep coastal ecosystems from reaching critical tipping points and moving to unstable conditions. The decision support tool was based on a region wide user needs assessment, involvement from Sea Grant sustainable coastal development specialists in all Great Lakes states, and continuous input from pilot communities, consultants, researchers and facilitators. This tool helps watershed leaders identify land-based activities that threaten the sustainability of ecosystems in their watershed and provides a facilitated forum to explore policy and management interventions necessary keep their ecosystems from moving to an unstable condition. Communities are then led through a process to develop sustainable action plans for their watershed or community. This decision support tool was piloted in at least one community in seven of the eight Great Lakes states in spring, 2014.

Initially funded through the Great Lakes Restoration Initiative (GLRI), the Cooperative Institute for Limnology and Ecosystem Research (CILER), Illinois-Indiana Sea Grant and the Purdue Department of Forestry and Natural Resources, the eight-state, collaborative program began in 2010 and was launched in Great Lakes states with pilot workshops during the spring of 2014.

The development of the Tipping Points and Indicators facilitation tool began with user needs assessments to determine desired elements in a decision support system for natural resources planning and management at a watershed scale. As part of her PhD dissertation,

Dr. Kimberly Robinson received survey responses from 302 professional planners and Extension Specialists in all eight Great Lakes states and at multiple planning scales (Municipal, County/Township, and Regional). Purdue University and Illinois-Indiana Sea Grant additionally hosted focus groups comprised of Extension Specialists and partnering facilitators from each Great Lakes state. The users identified the need to develop a data driven tool to support community visioning discussions and action plan development that can be tailored to local planning initiatives. Both planners and Extension specialists identified the need to gather and present data on natural resources tied to the decision making process for long term planning, evaluation, and securing project support and funding. The decision support system was also identified as an opportunity to increase citizen participation and collaboration among stakeholder groups across planning jurisdictions. The resulting Tipping Points and Indicators Program was created to address these user needs. It was designed as a data driven facilitation tool to be used by trained Sea Grant Specialists, extension professionals, and consultants leading community visioning discussions and public involvement for land use or watershed planning and implementation projects. Feeback survey data colleced from the spring 2014 state pilots will be used to enhance the tool and facilitation processes in Great Lakes coastal communities.

The research and outreach teams met monthly from 2012-2014 during program development. As the teams move into program implementation, they will meet quarterly in 2014-2016. The research and outreach team members who have contributed to the development and delivery include:

Research Team
• Great Lakes Environmental Research Laboratory – Rutherford, Mason
• University of Illinois (IL-IN Sea Grant) – Miller
• Purdue University – Pijanowski, Doucette, Pekin, Salazar, Jung, Frederick, Robinson, Kim, Ghadiri
• University of Michigan – Wiley, Riseng
• Michigan State University – Stevenson, Hyndman, Rose, Kendall, Martin
• University of Minnesota - Duluth – Johnson
• University of Windsor – Ciborowski
• University of Illinois - Chicago – Jaffe

Outreach Team - Great Lakes Sea Grant Network Specialists
• Illinois-Indiana - Salazar, Miller, Doucette, Jaffe,TePas
• Michigan - Breederland
• Minnesota - Schomberg
• New York - Penney

- Ohio - Lucente
- Pennsylvania - Rafferty
- Wisconsin - Hart, Noordyk

NOAA GLERL, served as the Institutional lead for the project. Dr. Ed Rutherford, research fisheries biologist with NOAA Great Lakes Environmental Research Laboratory, served as PI for the overall GLRI/NOAA funded project and was the Research Team Leader.

Purdue University, Department of Forestry and Natural Resources and Illinois-Indiana Sea Grant are the institutional program leads for the Tipping Points and Indicators decision support tool development. Dr. Brian Miller, IL-IN Sea Grant Director, is a program Principal Investigator and oversees program development, multi-state implementation and long-term funding. Dr. Bryan Pijanowski, Professor of Forestry and Natural Resources, is a Principal Investigator and responsible for long-term funding and directs graduate students, and professional staff that developed the decision support tool and modules. Purdue University hosts the server and website infrastructure for the project. The program is designed for long term deployment and use throughout Great Lakes states by specialists and facilitators affiliated with the Sea Grant Network and Cooperative Extension Service and partnering natural resources professionals who have undergone facilitation training. Purdue University and IL-IN Sea Grant are committed to the long-term management and maintenance of the program through continually updating the decision support tool, facilitation processes and website infrastructure. All investments and upgrades implemented to the decision support tool and the facitliaton processes will be shared with the multi-state team for use within their repsective states in coastal communitiess.

Background Information

Throughout the Great Lakes Basin, community leaders are challenged with long-term management decisions that result in substantial impacts to ecological integrity and community quality of life. To protect natural resources and enhance community resiliency in the region, it is crucial to understand human-induced ecological stress, identify indicators of natural resource condition, and determine the tipping points at which systems enter undesirable states. Research conducted in five states has identified land use tipping points that impact aquatic ecosystems.

Theory of Change: Our Team has shown that aquatic ecosystems in Great Lakes watersheds exist in three conditions: intact, impacted, or in a transition zone. We have identified watershed-level land use tipping points that move an aquatic ecosystem into the next condition. Our research shows:

- It is best to keep ecosystems from moving from an intact condition to the transition zone.
- Ecosystems in the transition zone can move to either condition (intact or impacted) and watersheds influencing those ecosystems should be targeted for intervention and restoration.
- Ecosystems in the impacted condition are very difficult and costly to restore.

Tipping Points refers to the point at which something changes from one state to another. Research shows us that once an ecosystem changes, it is difficult to return the ecosystem to its previous condition. Extensive research across the Great Lakes has identified a number of tipping points for stream ecosystems based on land use, population, and other factors. For more information on tipping points, view the video by Bryan Pijanowski on Tipping Point Theory, located here:
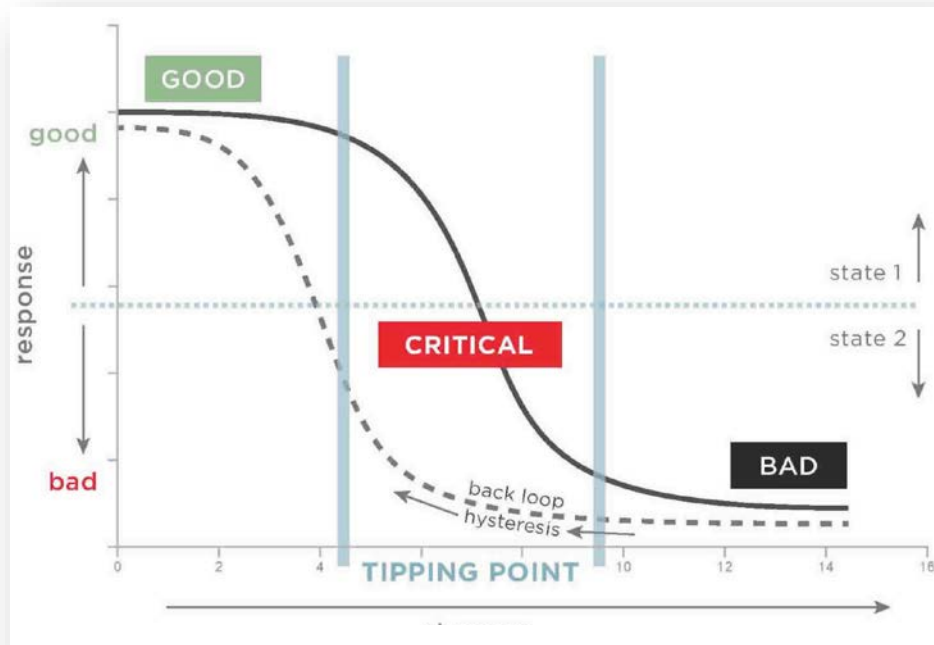
Figure 5. Stylized representation of a "tipping point".

http://tippingpointplanner.org/resources/research-presentations. The video takes 22 minutes. There are other videos here as well; you may find them interesting, and you're certainly welcome to review anything on the site. A login is required to get into the actual planning portion.

Turning research into actual changes on the ground is no small task. At the very conception of this project, it was recognized that this research on tipping points had direct

applicability to communities and watershed organizations across the Great Lakes region. To help develop a tool to guide communities through the tipping points, planners and extension educators from around the Great Lakes have participated in the creation of the tippingpointplanner.org website.

Managers and community leaders now have the data necessary to identify land use limits, evaluate the environmental impacts of proposed land use scenarios, and identify critical areas requiring protection or restoration. Through this project (http://tippingpointplanner.org), trained facilitators can help communities plan and prepare for a sustainable future by directly linking research and data to the local decision making process.

Tipping Points and Indicators is designed to empower land use planners, natural resource managers, and watershed stakeholder groups to identify and mitigate land use and coastal storm impacts, thereby sustaining Great Lakes communities and ecosystems. The decision support tool and facilitation process enables diverse citizen participation in land use decisions and natural resources management strategies to plan and maintain projects within a HUC 12 watershed scale that affect the Great Lakes. Innovative visualization dashboards, paint tools, and interactive community visioning exercises provide the framework to learn what is important in a community and to explore land use strategies and policies that enhance community values while protecting their ecosystems. Participants are led through a process where they examine past and predicted land use changes, identify environmental threats, and delineate valuable natural resource assets in need of protection or restoration. Community or watershed leaders can then use land use painting tools, maps, gauges and growth projections to evaluate the effects proposed land use changes may have on water quality or coastal ecosystems. Participants select action goals (eg. reduce runoff) most needed to sustain water quality and ecosystem integrity and action strategies (e.g., limit or mitigate impervious surfaces) that meet their goals and favor local community values. The facilitation process ultimately results in an Action Plan that includes an overview of the current community status, whether the community is nearing or exceeding Great Lakes tipping points, and provides customized implementation steps (eg. planning options, example policies, sample ordinances, educational programs, municipal BMP's) needed to improve current conditions and avoid exceeding environmental tipping points. Great Lakes Sea Grant Extension specialists, watershed consultants, planning professionals, and state watershed officials now use the six modules to facilitate sustainable community and watershed planning processes.

YOUR NAME :

AVAILABLE STARS : 0/20

CHARACTERISTIC	RATING
I can walk, bike, or take public transit.	⊖ ★★★★★
There is common open space or park near house.	⊖ ★★★★★
I am safe from flooding	⊖ ★★★★★
Outdoor recreation areas are easily accessible.	⊖ ★★★★★
I can have a large yard.	⊖ ★★★★★
I can always find a parking spot quickly.	⊖ ★★★★★
I can live a rural lifestyle	⊖ ★★★★★
My house will significantly appreciate in value	⊖ ★★★★★
My community has clean air and water	⊖ ★★★★★
The natural beauty around me is protected	⊖ ★★★★★

Submit

Accomplishments

The Tipping Points Process

There are six steps in the tipping points process, with each step described below.

Step 1: Visioning

The heart of this component is the selection of community characteristics that the participants feel are important to them. A variety of characteristics are included, some of which will not fit for every community. Characteristics include the ability to live a rural lifestyle, clean air and water, outdoor recreation, large yards, flooding, and others. These characteristics are used at the end to determine which on-the-ground actions may best fit your community.

Participants identify the characteristics that are most important in their community. The averaged results will help determine which action strategies need to be included in the community watershed action plan. Characteristics include the ability to live a rural lifestyle, clean air and water, outdoor recreation, large yards, flooding, and others.

Step 2: Community Overview

This section explores past, current, and future population and land use changes, looks at areas of known environmental concern, and identifies natural resource assets: forests, wetlands, croplands, surface water, and others. This is largely informational, and sets the stage for delving into the tipping points.

Step 3: Tipping Points

Based on research completed across the great lakes, land use, wetlands, and other factors are used to determine where

Figure 6. Tipping Point Indicators.

your watershed falls in relation to invertebrate, fish, and diatom indices. The results are displayed in gauges, with green indicating high quality, red indicating poor conditions, and yellow indicating watersheds where conditions are at or near the tipping point.
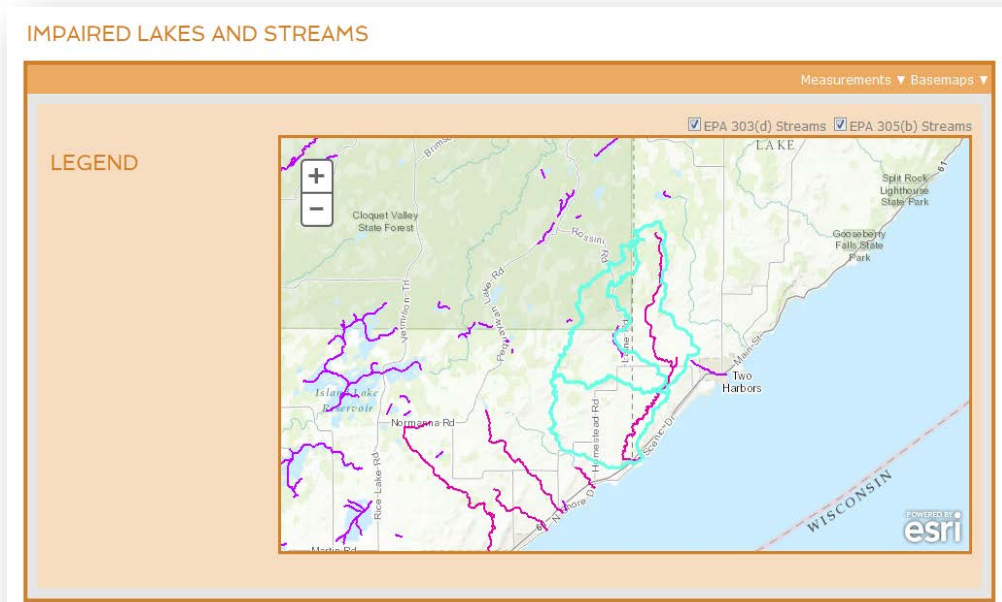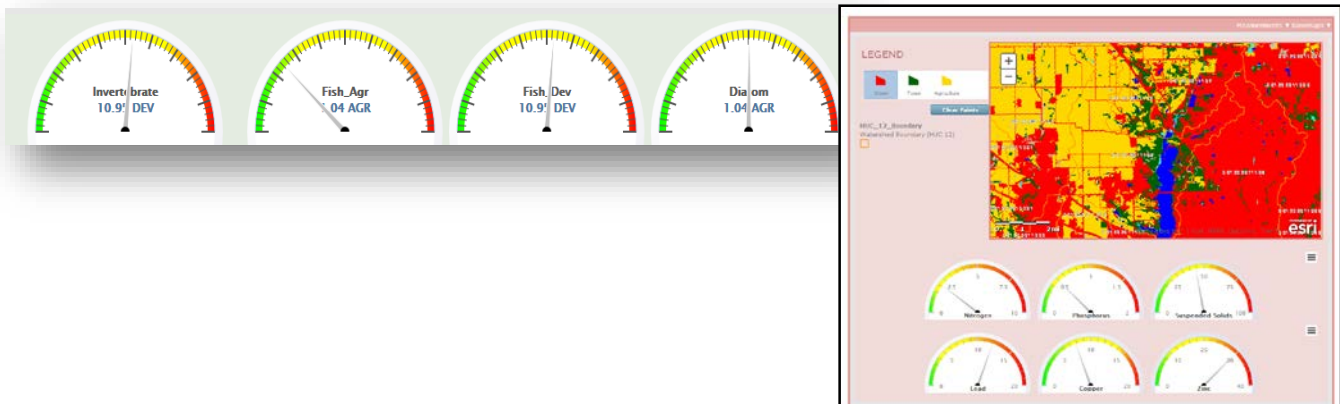

169

Step 4: Land Use Planning Tools

These tools help identify critical areas within your watershed: forests, wetlands, croplands. Large patches of forest or wetlands, for instance, can be identified and highlighted. There's also a tool that lets you interactively change land uses in the watershed, and watch how these changes affect runoff. All of the maps that you create here get saved and become a part of your final plan.

Step 5: Action Strategies and Plans

Based on all of the previous information and analysis, here is where you would select your overall goals for the watershed. Not all goals are appropriate for all areas. Once these goals are selected, specific *action strategies* to help achieve these goals are listed. These *action strategies* are divided into 5 categories: Planning, Ordinances, Incentive Options, Community Practices, and Education. Each of the ~70 possible *action strategies* includes a description, strengths and weaknesses, and examples from around the great lakes region. This is also where your community's preferences, selected in Step 1, come back into play. For every *action strategy*, you get to see visually how this would affect those things that your community cares about. For example, landowner education programs would positively benefit water quality, but have no effect on property values or recreational opportunities, and a stormwater utility fee may negatively affect property values and parking, but

Reduce / Mitigate Impervious Surfaces	Reduce Volume & Rate Of Runoff Runoff	Reduce Pollutant Loading
Reduce Nutrient Loading From Crops	Reduce Nutrient Loading From Livestock	Reduce Nutrient Loading From Lawns
Reduce Nutrient Loading From Treatment Plants	Protect Existing Forests/ Wildlands	Limit Ag Expansion
Buffer Streams	Limit Urban Expansion	Expand Forest Land/ Wild Lands
Farmland Protection	Vegetative Corridors	Reduce Nutrient Loading And Pathogens From Septic Systems
Protect Surface Water Intake	Protect Shallow Ground Water Aquifer	

Figure 4. List of possible watershed goals.

170

improve protection from flooding. The group would go through the list of possibilities, and select those that they think make the most sense for the organization.

For each *action strategy* selected, the group could add action items/next steps, a schedule, and who is responsible, if desired.

Step 6: Action Plan Document

As communities work through each step, the results are saved and archived. The final step is a review to make sure each module is complete and a publication of the final action plan document. This PDF will include the results from every step with maps, charts, tables, and descriptive text. It will also include your selected *action strategies*, along with the action items, next steps, dates, and responsible parties, if you included these. This PDF can be used however your group decides. The website will store your templates and it is possible to go back and make changes later, if needed.

Research Activities

The research efforts supporting this project have been funded through EPA-GLRI, EPA-STAR, USGS, and NOAA. Funding for the DSS includes: Great Lakes Restoration Initiative (GLRI), the Cooperative Institute for Limnology and Ecosystem Research (CILER), IL-IN Sea Grant and the Purdue Department of Forestry and Natural Resources. We have used this research to build an interactive decision support system and facilitated process. Our program helps local decision bodies easily access data and model projections about the choices they are making, evaluate the aquatic ecosystem impact of choices they are considering, and work through a facilitated process that results in action strategies and an implementation plan that moves their watersheds to a healthier state. Consequently, managers and community leaders now have the data necessary to identify land use limits in their watershed, evaluate the environmental impacts of proposed land use scenarios, and identify critical areas requiring protection or restoration.

Researchers from 5 universities have conducted research to identify and refine both land use and agricultural tipping points and water quality indicators. For the past 3 years, these researchers participate in monthly collaborative phone meetings to discuss each study's progress and to coordinate work so the individual research efforts culminate into a comprehensive decision support tool for communities.

A meeting was held at U.S. EPA's Great Lakes National Program Office in May 2013 with Dr. Pijanowski and members of the executive committee for State of the Lakes Ecosystem Conference (SOLEC). Pijanowski provided an overview for the committee of the indicator work that has taken place by project researchers. Afterwards, there was a discussion among the government officials about potential indicators to consider for use in the SOLEC assessment.

Publications:

Robinson, K. 2013. Deciding the future: Informing the development of a decision support system for water resource management by Great Lakes Region Land Use Planners. Dept. of Forestry and Natural Resources, Purdue Univ. West Lafayette, IN.   Ph.D Dissertation

N. Kim. MS thesis. Purdue University

Presentations:

The researchers involved in this project and their discoveries are leading the scientific discussion of Tipping Points internationally. Tipping Point Research conducted in this project was featured in 3 stand- alone sessions at 2 international Scientific meetings:

- *Ecosystem Tipping Points: Science and Decision Making Symposium*. 56th Ann. Conf. International Assoc. of Great Lakes Research. W. Lafayette, IN 2013
- *Tipping Points Science: From global theories to local tools – A Plenary Themed Special Integrated Session.* Joint Aquatic Sciences Meeting. Portland, Oregon 2014
- *Tipping Points Town Hall Meeting.* Joint Aquatic Sciences Meeting. Portland, Oregon 2014

A total of 11 presentations concerning the Land Use and Agricultural Tipping Points project were given during the 2013 International Association of Great Lakes Research (IAGLR) annual conference held in West Lafayette, Indiana as part of the *Ecosystem Tipping Points: Science and Decision Making symposium* that took place on June 5 and 6.

Six presentations from this project were presented at a Plenary Themed Special Integrated session (organized by S. Martin, B. Pijanowski, and E. Rutherford) at the Joint Aquatic Sciences 2014 meeting in Portland Oregon entitled *Tipping Points Science: From global theories to local tools.* This session invited scientists from around the world to

present the Tipping points (threshold shifts in the state of a system from small changes in a driver) they have found in studies of climate, populations, ecosystems, and behavior. When a tipping point is crossed, the system is pushed into an alternative state, which often times requires larger changes to return to the previous state. Tipping points are sometimes hysteretic but in other cases they are irreversible. Recent discussion has focused on uncertainties in scaling up tipping points from local to global scales. Nevertheless, the tipping point concept can be useful to help communities make informed decisions. This session invited presentations that 1) discuss examples of empirical or theoretical tipping points over local, regional, and global scales, and 2) demonstrated the creation and application of decision making tools based on tipping points. This session brought together researchers working with tipping points and enhanced opportunities for interdisciplinary collaborations.

Tipping Points Town hall: This town hall followed and expanded upon some of the ideas from the plenary session 002: Tipping Points Science: From global theories to local tools and session 083: Restoration of European wetlands: thresholds and tipping points at the Joint Aquatic Sciences Meeting in Portland, Oregon 2014 and integrated them around climate impacts. Participants explored how the themes introduced in these sessions could improve efforts to detect impacts of climate change on coastal ecosystems and provide information and tools for the management of changing aquatic ecosystems.

Research Presentations

International Association of Great Lakes Research Annual Conference Session Ecosystem Tipping Points: Science and Decision Making Symposium *June 2013*

PIJANOWSKI, B.C. and KIM, N., Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN, 47906. Tipping points: science and policy.

MILLER, B.K., TEPAS, K., SALAZAR, K., DOUCETTE, J.S., SCHOMBERG, J., HART, D., JAFFE, M., MCCORMICK, R., BREEDERLAND, M.A., LUCENTE, J., RAFFERTY, S., and PENNY, M., Engaging Great Lakes Communities to Develop Tipping Point Action Plans.

ROBINSON, K.D., PIJANOWSKI, B.C., and MILLER, B.K., User needs assessment: will they come if we build it

DOUCETTE, J.S., MILLER, B.K., and POLICINSKI, L Tipping Points and Indicators: Supporting Sustainable Communities in Great Lakes States.

WILEY, M.J., RISENG, C.M., RUTHERFORD, E.S., and PIJANOWSKI, B.C Land use tipping points in Midwestern streams.

VERHOUGSTRAETE, M., MARTIN, S.L., KENDALL, A.D., HYNDMAN, D., and ROSE, J.B., Microbial Responses to Land, Physical, Chemical, Environmental, and Hydrological Factors.

STEVENSON, R.J., NOVITSKI, L., HYNDMAN, D., QI, J., ESSELMAN, P., KENDALL, A.D., LAWAWIROJWONG, S., LUSCZ, E.C., MARTIN, S.L., and SUEPA, T. Relating Coastal Algal Blooms to Rivers, Nutrients, Watershed Land Use, and Storm Events.

KENDALL, A.D., LUSCZ, E.C., MARTIN, S.L., and HYNDMAN, D. From Landscape Application to the River Mouth: A Fully Explicit Simulation of Nutrient Loads Across Lower Michigan, USA.

CAI, M., KOVALENKO, K.E., JOHNSON, L.B., CIBOROWSKI, J.J.H., and BRADY,V.J. Modeling land and water stress impacts on macroinvertebrates in the Great Lakes costal wetland.

KOVALENKO, K.E, Congruence of community thresholds in response to anthropogenic stress in Great Lakes coastal wetlands

Presentation for Tipping Points and Indicators pre Workshop Webinar Series

KOVALENKO, K.E, JOHNSON, L.B., CIBOROWSKI, J.J.H., and BRADY, V.J. What's tipping at the tipping point: examining functional changes in biota

RUTHERFORD, E.S., VANDERPLOEG, H.A., CAVALETTO, J1, LIEBIG, J.R., POTHOVEN, S.A., MASON, D.M., BURNETTE, D., BOURDEAU, P.E., PEACOR, S.D., CLARAMUNT, R.M., BUNNELL, D.B., ROSEMAN, E.F., O'BRIEN, T.P., and WARNER, D.M Consequences of Altered Spatial Structure of Zooplankton for Fish Larvae Growth and Survival in Newly Illuminated Environments of Lake Michigan and Lake Huron.

Joint Aquatic Sciences Meeting Plenary Themed Special Integrated Session - Tipping Points Science: From global theories to local tools Portland Oregon May 18-23, 4014

Kendall, A. D.; Martin, S. L.; Luscz, E. C.; Hyndman, D. W.; IDENTIFYING STREAM NUTRIENT TIPPING POINTS FROM SPATIALLY EXPLICIT SOURCE MAPPING IN THE US GREAT LAKES BASIN

Kao, Y. C.; Adlerstein-Gonzalez, S.; Rutherford, E. S.; Zhang, H.; IDENTIFYING ECOOGICAL TIPPING POINTS FOR A GREAT LAKES FOOD WEB: AN ECOPATH WITH ECOSIM ANALYSIS

Kovalenko, K. E.; Johnson, L. B.; Gathman, J. P.; Ciborowski, J. J.; Brady, V. J.; WHAT'S TIPPING AT THE TIPPING POINT: EXAMINING FUNCTIONAL CHANGES IN BIOTA

Wiley, M. J.; Riseng, C. M.; Rutherford, E. S.; Pijanowski, B. C.; Waite, I. R.; Munn, M. D.; MULTIPLE LAND USE TIPPING POINTS IN MIDWESTERN STREAMS: ANALYSIS AND NATIONAL-SCALE VALIDATION TEST

Pijanowski, B. C.; Miller , B. K.; Doucette, J. S.; Salazar, K. A.; TePas , K. S.; AN ONLINE DECISION SUPPORT SYSTEM TO ENGAGE GREAT LAKES COMMUNITIES IN DEVELOPING TIPPING POINT ACTION PLANS

Verhougstraete, M.; Martin, S.; Kendall, A.; Hydman , D.; Rose, J.; MICROBIAL TIPPING POINTS OF *ESCHERICHIA COLI* AND HUMAN SPECIFIC BACTERIA IN GREAT LAKES RIVER SYSTEMS

Other Scientific Conference Presentations

Salazar, K., Miller, B., Doucette, J., TePas, K., Schomberg, J., Jaffe, M., Jung, J., Frederick, D., Pijanowski, B. Engaging Great Lakes Communities in Applying Science to Develop Tipping Point Action Plans. International Annual Conference of the Soil and Water Conservation Society, Lombard, IL. *(Accepted- July 27-30, 2014)*

Miller B., J. Doucette, K. Salazar, K. TePas, J. Schomberg, M. Jaffe, J. Jung, D. Frederick, B. Pijanowski. 2014. An Online Facilitation Tool to Engage Great Lakes Communities in

Developing Watershed Action Plans. UCOWR/NIWR/CUHASI Conference. Tufts University, Medford, MA. *(Accepted - June 18-20. 2014)*

Outreach Presentations

K. Salazar, B. Miller, J. Doucette, K. TePas, J. Schomberg, M. Jaffe, J. Jung, D. Frederick, B. Pijanowski. 2014. Helping Communities Identify Environmental Tipping Points and Use Land Use Indicators, National Association of Community Development Extension Professionals Conference, Grand Rapids, MI, *(Accepted- June 22-25, 2014)*

J. Doucette, B. Miller, B. Pijanowski K. Salazar, J. Jung, D. Frederick,. 2013. Tipping Points and Indicators: A SDSS for Great Lakes Communities. ESRI International User Conference, San Diego, Ca.

Outreach Activities:

The outreach team convened by monthly conference call meetings through June 2014 to collaboratively complete the website interface and finalize the components of the facilitation process. Outreach materials developed include presentations, videos clips, a visioning/scoping document, white papers, and customized state-specific action strategies. The outreach materials provide technical and facilitation information to prepare specialists to implement Tipping Points and Indicators pilot workshops in each state. The specialist teams conducted community-based Tipping Points and Indicators pilot workshops targeting planners and watershed managers in pilot workshops in seven states (IN, IL, OH, MN, WI, MI and NY) during spring 2014. Each state team convened introductory meetings and presentations with community stakeholder groups to identify projects and locations for their spring 2014 pilot workshops.

Purdue University hosted a series of four webinar sessions in September and October 2013 featuring Tipping Points and Indicators research team members. Each Research PI prepared a 20-30 minute presentation summary on their research findings and an explanation of how the work was done and underlying assumptions. The purpose of these taped web presentations available on the front page of tippingpointplanner.org is to provide a series of background and summary information to non-researchers who are interested in learning more about the studies and research results.

The recorded webinar sessions include:

Session 1: Tipping Points and Indicators Introduction

- Dr. Bryan Pijanowski (Tipping Points Theory)
- Dr. Brian Miller (Needs Assessment and Decision Support System Overview)
- Mr. Jarrod Doucette (Demonstration of Tipping Points and Indicators Decision Support System)

Session 2: Stream Biodiversity and Health Indicators

- Dr. Mike Wiley, University of Michigan (Land Use Tipping Points in Midwestern Streams)
- Dr. Joan Rose, Michigan State University (Microbial Responses to Land, Physical, Chemical, Environmental, and Hydrological Factors).

Session 3: Nutrients

- Dr. R. Jan Stevenson, Michigan State University (Relating Coastal Algal Blooms to Rivers, Nutrients, Watershed Land Use, and Storm Events)
- Dr. Anthony Kendall, Michigan State University (From Landscape Application to the River Mouth: A Fully Explicit Simulation of Nutrient Loads Across Lower Michigan

Session 4: Coastal Wetland Biodiversity and Tipping Points

- Dr. Katya Kovalenko, University of Windsor/University of Minnesota-Duluth (Congruence of community thresholds in response to anthropogenic stress in Great Lakes coastal wetlands)
- Dr. Ed Rutherford, NOAA Great Lakes Environmental Research Laboratory (Nutrient Tipping Points for Great Lakes Nearshore Food Webs: An Ecopath with Ecosim Analysis)

The purpose of the webinar sessions was to 1) introduce the Extension Specialists attending the October facilitation workshop to the science associated with the data driven decision support system and 2) record the sessions to post and use as educational tools for future facilitators on the Tipping Points and Indicators website.

Great Lakes Sea Grant Extension Specialists from OH, MN, MI, IL, IN and NY attended the Tipping Points and Indicators Train the Trainer workshop at Purdue University, October 28-29, 2013. The specialists received detailed training on the Tipping Points and Indicators website interface, customized tools, action plan wizards, weTable set up and touch screen monitor use during the two day workshop. The meeting time also served as an evaluation

mechanism to receive feedback and suggestions to further refine and customize the website content prior to conducting the pilot community workshops.

The outreach specialists group has continued to work on development of the Tipping Point and Indicators website containing the decision support tool. Website work has focused on refining the interface design and flow, finalizing the action plan matrix and associated action strategies content, and integrating crowd source technology. Specialists incorporated background information such as white papers, presentations, and descriptive text to enhance the usability of the site. Additionally, specialists worked with graduate students at the University of Illinois-Chicago to finalize the action plan matrix, which includes over 70 localized examples of best management practices, ordinances and education activities. These recommended actions with examples are now available for communities to choose from to address specific indicator-related objectives. Those chosen actions are incorporated into the community action plan. Community Visioning capability has been fully integrated into the community characteristics step of Tipping Points and Indicators. The feature will allow workshop participants to select their preferred community priorities and links the relationship between actions to changes in community priorities (e.g. choosing to implement conservation design ordinances will result in "I can walk, bike, or take transit to important destination").

In Spring 2014 the tipping point planner Decision support system and facilitation tool was piloted on 7 Great Lakes States. 4 states conducted train the Trainer workshops for extension and planning professionals.

Statewide train the trainer for extension professionals (land use team)
- New York
- Michigan
- Ohio
- IL (CMAP)

Additionally, Sea Grant facilitators worked with 4 watershed groups in 3 states to use tipping point planner in land use or watershed planning and implementation exercises.
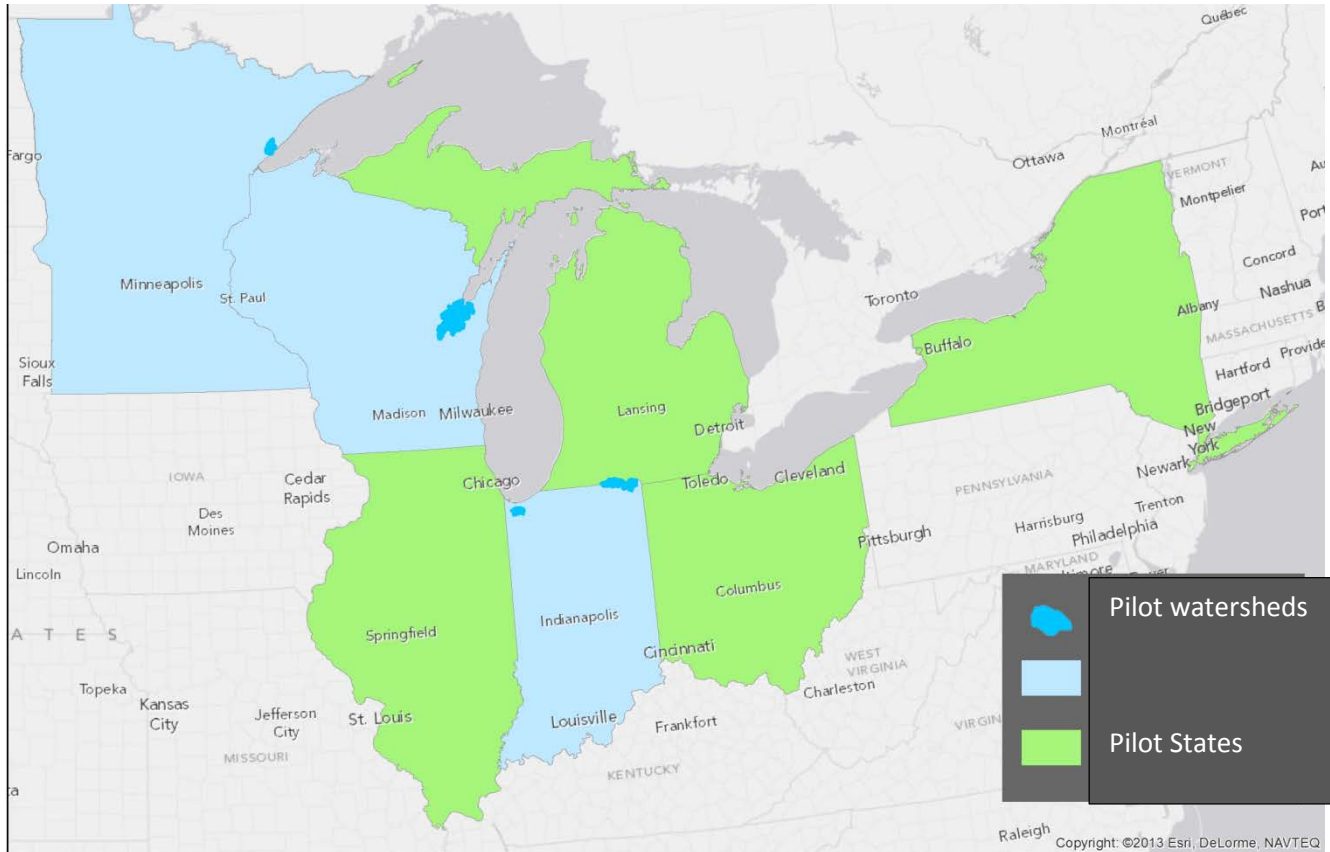
Watersheds piloting Tipping Point Planner
- MN - Knife River Watershed Group
- WI - Bay Lake Regional Planning Commission
- IN - Fawn River Watershed Group

Feedback from users and facilitators gathered in Spring 2014 will be used to improve the site and facilitation process.

OVERVIEW OF TEAM

Outreach/Community Engagement Team - *Great Lakes Sea Grant Network Specialists*

The seven Sea Grant Programs bordering the Great Lakes comprise the Great Lakes Sea Grant Network (GLSGN). GLSGN staff meets every 18 months to coordinate programs and collaborate regularly on proposals and projects Great Lakes wide. One of Sea Grant's 4 National Focus Areas is Sustainable Coastal Development (SCD). Three members of the National SCD focus team (Miller is national co-chair) are involved in this project and all

outreach team members below are part of the Great Lakes Sustainable Coastal Communities Development Network (Illinois-Indiana - Salazar, Jaffe, Doucette, TePas; Michigan – Breederland; Minnesota – Schomberg; New York – Penney; Ohio – Lucente; Pennsylvania – Rafferty; Wisconsin - Hart, Noordyk).

Research and DSS Development Team - Most of the project team has worked together for over a decade on research projects that examine changes in land use and associated impacts on water quality at regional watershed scales. The team includes:

Jarrod Doucette has been a GIS and Database Specialist with Purdue University for six years. He has experience in GIS, web based Decision Support Systems, High Performance Computing, and Data Management. He has been the technical team lead for the Tipping Points and Indicators DSS for the past three years.

David Hyndman is a Professor and Chair of Geological Sciences at Michigan State University. He will oversee the hydrological modeling, and guide synthesis. He is an internationally recognized leader in data integration, aquifer characterization, hydrologic modeling, and quantifying impacts of changes in climate and land use on hydrology and ecosystem services. Hyndman has extensive experience leading successful interdisciplinary projects, including a NSF Water Sustainability and Climate (WSC) project that couples socioeconomic and biophysical models to quantify historical and projected changes in water sustainability across the High Plains aquifer.

Martin Jaffe is the **C**oastal Business & Environment Specialist for the Illinois-Indiana Sea Grant College Program, and serves as outreach Program Leader. He is Director of Graduate Studies and Associate Professor of Planning at the Great Cities Institute, College of Urban Planning and Public Affairs at the University of Illinois Chicago.   He leads the development of the action strategy section in the DSS.

Lucinda Johnson is Director and Senior Research Associate in the Natural Resources Research Institute at the University of Minnesota Duluth. She leads the Great Lakes Environmental Indicator (GLEI-II) project, which has developed a basin-wide map of anthropogenic stress and identified multiple indicators of condition for coastal ecosystems of the Great Lakes. Her research focuses on effects of multiple stressors on aquatic communities and testing indicators of coastal ecosystem integrity using fish and macroinvertebrates. Lucinda leads research used to develop the coastal wetland impact section of our DSS.

Anthony Kendall was the lead developer of the Integrated Landscape Hydrology Model (ILHM) as a part of a prior NSF project. He has considerable expertise in landscape hydrology, including surface water/groundwater and soil/plant water interactions. Since 2002 he has worked with a large, interdisciplinary team including Hyndman to study the impacts of climate and land use change on stream ecosystems in Michigan. Kendall will lead the landscape hydrology modeling and will be involved in hydrology data collection and synthesis.

Sherry Martin is a limnologist focused on understanding the impacts of historical land use on water quality across stream, wetland, and lake ecosystems. She has employed a hybrid statistical and numerical modeling approach to examine legacy mechanisms in those systems, which has been underpinned by extensive field data collection. She has worked with the senior members of the team since 2009

Brian Miller is a Natural Resource Social Scientist and Wildlife Biologist. He is the Director of the Illinois-Indiana Sea Grant College Program and the Illinois Water Resources Center. His research focuses on factors influencing natural resource planning and decision making. He has developed, led, or been involved in many land use engagement programs and online DSS projects including Planning with POWER, Local Decision Maker, TippingPointPlanner.org , and Great Lakes Monitoring.org. He is the National Co-Chair of Sea Grant's Sustainable Coastal Development Focus team and a member of NOAA's Great Lakes Regional Collaboration Team. He is experienced in facilitating community land use discussions and currently serves as the facilitator for the development of the Illinois Nutrient Reduction Strategy to reduce nutrient inputs resulting in Gulf Hypoxia.

Bryan C. Pijanowski developed the Land Transformation Model that has been used to forecast the entire lower 48 states from present to 2050. It has also been reverse-engineered to run backwards to create historical land use maps to presettlement. Pijanowski is a Professor and University Faculty Scholar at Purdue University, Associate Editors for Landscape Ecology, Land Use Science, British Journal of Environment and Climate Change and Editor-in-Chief of Journal of Coupled Natural Human Systems. He is also co-developer of the Tipping Points Decision Support System.

Catherine Riseng is an Assistant Research Scientist at SNRE and the Research Program Director at Michigan Sea Grant. She has worked with this project team on several collaborative projects that integrate research from various disciplines to address impacts to

watershed and coastal resources related to land use tipping points. She is the PI for the Great Lakes Aquatic Habitat Framework project and has been working bi-nationally with scientists and resource managers across the Great Lakes basin to develop a GIS database and mapping resource to link land use, tributary loads, coastal resources, lake circulation patterns, and climate change.

Joan Rose is a Professor at MSU and the Homer Nowlin Chair in Water Research. She co-directs the Center for Water Sciences and Center for Advancing Microbial Risk Assessment. Dr. Rose is an international expert in water microbiology, water quality and public health safety, publishing more than 250 manuscripts. She conducts research on microbial pathogen transport in coastal systems and leads our efforts to identify septic system tipping points in watersheds.

Ed Rutherford is a research fisheries biologist with NOAA Great Lakes Environmental Research Laboratory. He has worked on food web models to quantify nutrient loading and invasive species impacts on Great Lakes food webs, and collaborated with Wiley and others to model climate and land use impacts on sport fish abundance and habitat suitability. Rutherford helped coordinate the first phase of funding from GLRI and NOAA for the Tipping Points project.

Kara Salazar is the Sustainable Communities Extension Specialist for Illinois-Indiana Sea Grant and Purdue Extension housed in the Department of Forestry and Natural Resources at Purdue University. As Sustainable Communities Extension Specialist, Kara serves as a link between communities and scientists conducting research on sustainability. She works with campus-based scientists specializing in areas of sustainability and develops programs and tools that transfer new technologies and discoveries to communities that can apply this work to enhance local sustainability efforts. Kara works with multidisciplinary teams throughout Purdue University, Extension, and the Sea Grant college network to engage local officials and decision makers in evaluating, prioritizing, and implementing sustainability strategies for their communities. Kara leads the outreach team for this project.

R. Jan Stevenson is an algal ecologist that has worked with the USEPA to develop guidance for bioassessment methods and developing nutrient criteria. He is currently serving on EPA working groups to select and refine indicators of nutrient effects on streams and climate change effects of freshwater ecosystems. He is co-Director for the

Center for Water Sciences at Michigan State University and leads three EPA funded projects, to integrate ecosystems services into current water policy frameworks and projects to relate nutrient pollution to algal blooms in coastal zones of the Great Lakes and to relate nutrient pollution to phytoplankton bloom vulnerability to climate change in lakes across the US.

Michael Wiley is an ecologist and Professor at the School of Natural Resources and Environment, University of Michigan; and Roosevelt Chair of Ecosystem Management at SNRE from 2008-2012. He is a leader in developing model-based approaches to ecological assessment and ecosystem management. From 2001-2008 he led a multi-modeling effort by this project team to evaluate the effects of climate and land use change to aquatic ecosystems in Muskegon River basin. He currently leads a cooperative study with USGS collaborators modeling agricultural land use impacts on stream communities.

APPENDIX 4: PUBLICATIONS

Peer-reviewed

Alves, J.H., A. Chawla, H.L. Tolman, D.J. SCHWAB, G.A. LANG, and G. Mann. 2014. The operational implementation of a Great Lakes wave forecasting system at NOAA/NCEP. *Weather and Forecasting* 29(6):1473-1497 (DOI:10.1175/WAF-D-12-00049.1) http://www.glerl.noaa.gov/pubs/fulltext/2014/20140069.pdf

Bai, X., H. Hu, J. Wang, Y. Yu, E. Cassano, and J. Maslanik. 2015. Responses of surface heat flux, sea ice, and ocean dynamics in the Chukchi-Beaufort Sea to storm passages during winter 2006/2007: A numerical study. *Deep Sea Research I* 102:101-117 (DOI:10.1016/j.dsr.2015.04.008). Link valid until 7/22/15: http://authors.elsevier.com/a/1R81Z3RueHDJ7v

Bai, X., J. Wand, J. Austin, D.J. Schwab, R.A. Assel, A.H. Clites, J.F. Bratton, M.C. Colton, J. Lenters, B.M. Lofgren, T. Wohlleben, S. Helfrich, H.A. Vanderploeg, L. Luo, and G.A. Leshkeich. 2015. A record-breaking low ice cover over the Great Lakes during winter 2011/2012: Combined effects of a strong positive NAO and La Nina. *Climate Dynamics* 44(5-6):1187-1213 (DOI:10.1007/s00382-014-2225-2).

Bechle, A.J. and Wu, C.H., 2014. The Lake Michigan meteotsunamis of 1954 Revisited. Natural Hazards, 74(1), 155-177.

Bechle, A.J. and Wu, C.H., 2014. An entropy-based velocity method for esturaine discharge measurement, *Water Resources Research*, 50(7), 6106-6128.

Bennington, V., M. Notaro, and K.D. Holman, 2014: Improving climate sensitivity of deep lakes within a regional climate model and its impact on simulated climate. *Journal of Climate*, 27, 2886-2911.

Bootsma, H.A., M.D. Rowe, C.N. Brooks, and H.A. Vanderploeg. 2015. Commentary: The need for model development related to *Cladophora* and nutrient management in Lake Michigan. *Journal of Great Lakes Research* 41:9 pp. (DOI:10.1016/j.jglr.2015.03.023).

Cha, Y.K., and C.A. Stow. 2015. Mining web-based data to assess public response to environmental events. *Environmental Pollution* 198:97-99 (DOI:10.1016/j.envpol.2014.12.027).

Clites, A.H., J. Wang, K.B. Campbell, A.D. Gronewold, R.A. Assel, X. Bai, and G.A. Leshkevich. 2014. Cold water and high ice cover on Great Lakes in spring. *EOS* 95(34):305-306 (DOI:10.1002/2014EO340001) (2014). http://www.glerl.noaa.gov/pubs/fulltext/2014/20140042.pdf

Cooke, R.M., M.E. Wittmann, D.M. Lodge, J.D. Rothlisberger, E.S. Rutherfod, H. Zhang, and D.M. Mason. 2014. Out-of-sample validation for structured expert judgment of Asian Carp establishment in Lake Erie. *Integrated Environmental Assessment and Management* 10(4):522-528. http://www.glerl.noaa.gov/pubs/fulltext/2014/20140047.pdf

Cote, J., C. Jablonowsky, P. Bauer, and N. Wedi. 2015. Numerical Methods of the Atmosphere and Ocean. *In* Brunet, G., S. Jones, and P.M. Ruti (Eds.). Seamless Prediction of the Earth System: from Minutes to Months, World Meteorological Organization (WMO), No.1156, Geneva. ISBN 978-92-63-11156-2.

Foley, C.J., G.J. Bowen, T.F. Nalepa, M.S. Sepulveda, and T.O. Hook. 2014. Stable isotope patterns of benthic organisms from the Great Lakes region indicate variable dietary overlap of *Diporeia* spp. and dreissenid mussels. *Canadian Journal of Fisheries and Aquatic Sciences* 71:1784-1795 (DOI:10.1139/cjfas-2013-0620). http://www.glerl.noaa.gov/pubs/fulltext/2014/20140050.pdf

Fry, L.M., A.D. Gronewold, V. Fortin, S. Buan, A.H. Clites, C. Luukkonen, D. Hotsschlag, D. L., T.S. HUNTER, F. Seglenieks, D. Durnford, M. Dimitrijevic, C. Subich, E. Klyszejko, K. KEA, and P. Restrepo. 2014. The Great Lakes Runoff Intercomparison Project, Phase 1: Lake Michigan (GRIP-M). *Journal of Hydrology* 519(Part D):3448-3465 (DOI:10.1016/j.jhydrol.2014.07.021).

Fujisaki, A., H. Mitsudera, J. Wang, and M. Wakatsuchi. 2014. How does the Amur River discharge flow over the northwestern continental shelf in the Sea of Okhotsk? *Progress in Oceanography* 126:8-20 (DOI:10.1016/j.pocean.2014.04.028).

Gronewold, A.D., E.J. Anderson, B.M. Lofgren, P.D. Blanken, J. Wang, J.P. Smith, T.S. Hunter, G.A. Lang, C.A. Stow, D. Beletsky, and J.F. Bratton. 2015. Impacts of extreme 2013-2014 winter conditions on Lake Michigan's fall heat content, surface temperature, and evaporation. *Geophysical Research Letters* 42:7 pp. (DOI:10.1002/2015GL063799).

Gronewold, A.D., A.H. Clites, J. Bruxer, K.A. Kompoltowicz, J.P. Smith, T.S. Hunter, and C. Wong. Water levels surge on the Great Lakes. 2015. *Eos* 96(6):7 pp.

(DOI:10.1029/2015EO026023). https://eos.org/project-updates/water-levels-surge-on-great-lakes

Gross, M., S. Malardel, C. Jablonowski and N. Wood (2015), Bridging the (Knowledge) Gap between Physics and Dynamics, Bull. Amer. Meteorol. Soc., doi:10.1175/BAMS-D-15-00103.1, in press

He, F., D. J. Posselt, C. M. Zarzycki and C. Jablonowski (2015), A Balanced Tropical Cyclone Test Case for AGCMs with Background Vertical Wind Shear, *Mon. Wea. Rev.*, Vol. 143, 1762-1781

Hunter, T.S., A.H. Clites, A.D. Gronewold, and K.B. Campbell. 2015. Development and application of a North American Great Lakes hydrometeorological database - Part I: Precipitation, evaporation, runoff, and air temperature. *Journal of Great Lakes Research* 41(1):65-77 (DOI:10.1016/j.jglr.2014.4.12.006) (2015). http://www.glerl.noaa.gov/pubs/fulltext/2015/20150006.pdf

Ivan, L.N., D.G. Fielder, M.V. Thomas, and T.O. Hook. 2014. Changes in the Saginaw Bay, Lake Huron, fish community from 1970-2011. *Journal of Great Lakes Research* 40:922-933 (DOI:10.1016/j.jglr.2014.09.002).

Kent, J., P. A. Ullrich and C. Jablonowski (2014): Dynamical Core Model Intercomparison Project: Tracer Transport Test Cases, Quart. *J. Roy. Meteorol. Soc.*, Vol. 140, 1279–1293

Kult, J.M., L.M. Fry, A.D. Gronewold, and W. Choi. 2014. Regionalization of hydrologic response in the Great Lakes basin: Considerations of temporal scales of analysis. *Journal of Hydrology* 519:2224-2237 (DOI:10.1016/j.jhydrol.2014.09.083).

Mayer, A., R. Winkler, and L.M. Fry. 2014. Classification of watersheds into integrated social and biophysical indicators with clustering analysis. *Ecological Indicators* 45:340-349 (DOI:10.1016/j.ecolind.2014.04.030).

Millie, D. F., Weckman, G. R., Fahnenstiel, G. L., Carrick, H, J., Ardjmand, E., Young II, W. A., Sayers, M., & Shuchman, R. A. (2014). Using artificial intelligence for CyanoHAB niche modeling: discovery and visualization of *Microcystis*-environmental associations within western Lake Erie. Can. J. Fish. Aquat. Sci. **71**: 1642–1654 dx.doi.org/10.1139/cjfas-2013-0654

Nalepa, T.F. Relative comparison and perspective on invasive species in the Laurentian and Swedish Great Lakes. 2014. *Aquatic Ecosystem Health and Management* 17(4):394-403 (DOI:10.1080/14634988.2014.972494).

Niu, J., C. Shen, S.G. Li and M.S. Phanikumar. 2014. Quantifying storage changes in regional Great Lakes watersheds using a Coupled Subsurface-land Surface Process Model and GRACE, MODIS products. Water Resources Research 50:7359-7377.

Notaro, M., V. Bennington, and S. Vavrus, 2015: Dynamically downscaled projections of lake-effect snow in the Great Lakes Basin. *Journal of Climate*, 28, 1661-1684.

Obenour, D.R., A.D. Gronewold, C.A. Stow, and D. Scavia. 2014. Using a Bayesian hierarchical model to improve Lake Erie cyanobacterial bloom forecasts. *Water Resources Research* 50(10):7847-7860 (DOI:10.1002/2014WR015616).

Rowe, M.D., E.J. Anderson, J. Wang, and H.A. Vanderploeg. 2015. Modeling the effect of invasive quagga mussels on the spring phytoplankton bloom in Lake Michigan. *Journal of Great Lakes Research* 41:17 pp. (DOI:10.1016/j.jglr.2014.12.018). http://www.glerl.noaa.gov/pubs/fulltext/2015/20150011.pdf

Scanlan, A. M., Millie, D. F., Weckman, G. R., & Carrick, H. J. 2015. Abrupt shifts in stream algal biomass and diatom taxonomic composition along a gradient of changing land use. *Fundamental & Applied Limnology*. 186: 153–169.

Smith, S.D.P., P.B. McIntyre, B.S. Halpern, R.M. Cooke, A.L. Marino, G.L. Boyer, A. Buchsbaum, G.A. Burton, L.M. Campbell, J.J.H. Ciborowski, P.J. Doran, D.M. Infante, L.B. Johnson, J.G. Read, J.B. Rose, E.S. Rutherford, A.D. Steinman, and J.D. Allan. 2015. Rating impacts in a multi-stressor world: A quantitative assessment of 50 stressors affecting the Great Lakes. *Ecological Applications* 25(3):717-728 (DOI:10.1890/14-0366.1).

Stow, C.A., Y.K. Cha, L.T. Johnson, R. Confesor, and R.P. Richards. 2015. Long-term and seasonal trend decomposition of Maumee River nutrient inputs to western Lake Erie. *Environmental Science & Technology* 49:3392-3400 (DOI:10.1021/es5062648). http://www.glerl.noaa.gov/pubs/fulltext/2015/20150009.pdf

Stow, C.A., Y.K. Cha, and S.S. Qian. 2014. A Bayesian hierarchical model to guide development and evaluation of substance objectives under the 2012 Great Lakes Water Quality Agreement. *Journal of Great Lakes Research* 40(Supplement 3)):49-55d

(DOI:10.1016/j.jglr.2014.07.005).

Ullrich, P. A., T. Melvin, C. Jablonowski and A. Staniforth (2014), A proposed baroclinic wave test case for deep- and shallow-atmosphere dynamical cores, Quart. J. Roy. Meteorol. Soc., Vol. 140, 1590–1602

Ullrich, P. A., K. A. Reed and C. Jablonowski (2015), Analytical initial conditions and an analysis of baroclinic instability waves in f- and β-plane 3D channel models, Quart. J. Roy. Meteorol. Soc., in press

Wan, H., P. J. Rasch, M. A, Taylor and C. Jablonowski (2015), Short-term time step convergence in a climate model, J. Adv. Model. Earth Syst., Vol 7, 215–225, doi:10.1002/2014MS000368

Wang, D., Y. Yang, J. Wang, K. Mizobata, and X. Bai. 2015. A modeling study of the effects of river runoff, tides, and surface wind-wave mixing on the eastern and western Hainan upwelling systems of the South China Sea, China. *Ocean Dynamics* 65:24 pp. (DOI:10.1007/s10236-015-0857-3).

Whitehead, J. P., C. Jablonowski, J. Kent and R. B. Rood (2015), Potential vorticity: Measuring consistency between GCM dynamical cores and tracer advection schemes, Quart. J. Roy. Meteorol. Soc., Vol. 141, 739-751

Wittmann, M., R. Cooke, J. Rothlisberger, E.S. Rutherford, H. Zhang, D.M. Mason, and D. Lodge. 2014. Use of structured expert judgment to forecast invasions by Bighead and Silver carp in Lake Erie. *Conservation Biology* 29(1):187-197 (DOI:10.1111/cobi.12369) . http://www.glerl.noaa.gov/pubs/fulltext/2014/20140041.pdf

Xu H, Kim H-M, Nye JA, Hameed S (2015) Impacts of the North Atlantic Oscillation on sea surface temperature on the Northeast US Continental Shelf. *Continental Shelf Research* 105:60-66.

Yao, W. and C. Jablonowski (2015), Idealized Quasi-Biennial Oscillations in an Ensemble of Dry GCM Dynamical Cores, *J. Atmos. Sci.*, Vol. 72, 2201-2226.

Zarzycki, C. M., M. N. Levy, C. Jablonowski, M. A. Taylor, J. R. Overfelt and P. A. Ullrich (2014), Aquaplanet Experiments Using CAM's Variable Resolution Dynamical Core, *J. Climate*, Vol. 27, 5481-5503

Zhang, H., D.M. Mason, C.A. Stow, A.T. Adamack, S.B. Brandt, Z. Zhang, D.G. Kimmel, M.R. Roman, W.C. Boicourt, and S.A. Ludsin. 2014. Effects of hypoxia on habitat quality of pelatic planktivorous fishes in the northern Gulf of Mexico. *Marine Ecology Progress Series* 505: 209-226

Zhou, Y., A.M. Michalak, D. Beletsky Y.R. Rao, and R.P. Richards. 2015. Record-breaking Lake Erie hypoxia during 2012 drought. *Environmental Science & Technology* 49(2):800-807 (DOI:10.1021/es503981n).

Non-peer reviewed

Beletsky, D., H. Hu, J. Wang, and N. Hawley. 2014. Modeling thermal structure, circulation, and ice in Lake Erie. Proceedings, 22nd IAHR International Symposium on Ice 2014, Singapore, August 11-15, 2014. International Association of Hydro-Environment Engineering and Research, 449-451 pp. http://www.glerl.noaa.gov/pubs/fulltext/2014/20140053.pdf

Beletsky, R., D. Beletsky, N. Hawley, and J. Wang. 2014. Interannual variability of winter circulation and ice in Lake Erie. Proceedings, 22nd IAHR International Symposium on Ice 2014, Singapore, August 11-15, 2014. International Association of Hydro-Environment Engineering and Research, 905-907 pp. http://www.glerl.noaa.gov/pubs/fulltext/2014/20140055.pdf

Harrison, J., C. McCoy, K. Bunting-Howarth, H. Sorensen, K. Williams, and C. Ellis. 2014. Evaluation of the National Weather Service Impact-based Warning Tool. Report. Submitted to NWS Central Region Headquarters. Wisconsin Publication: WISCU-S-14-001. http://aqua.wisc.edu/publications/pdfs/ImpactBasedWarningTool.pdf

Joshi, S.J., A. Stevens, and L. Vaccaro. Saginaw Bay Multiple Stressors and Beyond workshop: Summary report. NOAA Technical Memorandum GLERL-166. NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 28 pp. (2015). http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-166/tm-166.pdf

Nalepa, T.F., D.L. Fanslow, G.A. Lang, K. Mabrey, and M. Rowe. 2014. Lake-wide benthic surveys in Lake Michigan in 1994-95, 2000, 2005, and 2010: Abundances of the amphipod *Diporeia spp*. and abundances and biomass of the mussels *Dreissena*

polymorpha and *Dreissena rostriformis bugensis*. NOAA Technical Memorandum GLERL-164. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 21 pp. http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-164/tm-164.pdf

Rockwell, D.C., S.J. Joshi, and H. Wirick. 2014. Beach health information needs assessment: 9 years later -- results from follow-up survey. NOAA Technical Memorandum GLERL-163. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI. http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-163/tm-163.pdf

Wang, J., X. Bai, J.F. Bratton, B. Wu, and C.H. Greene. 2014. Accelerating Arctic summer sea ice decline driven by the dipole anomaly. Proceedings, 22nd IAHR International Symposium on Ice 2014, Singapore, August 11-15, 2014. International Association of Hydro-Environment Engineering and Research, 745-742 pp. http://www.glerl.noaa.gov/pubs/fulltext/2014/20040056.pdf

Wang, J., X. Bai, A. Fujisaki-Manome, H. Hu, and D. Beletsky. 2014. Great Lakes ice and climate research and forecast. Proceedings, 22nd IAHR International Symposium on Ice 2014, Singapore, August 11-15, 2014. International Association of Hydro-Environment Engineering and Research, 48-55 pp. http://www.glerl.noaa.gov/pubs/fulltext/2014/20140054.pdf.