2011-2012
ANNUAL REPORT

Cooperative Institute for Limnology and Ecosystems Research (CILER)

NA07OAR4320006 — Year Five
April 1, 2011 - March 31, 2012

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<td>182</td>
</tr>
<tr>
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<td>183</td>
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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:
CILER’s overarching mission is to serve as a focal point for collaborations between the National Oceanic & Atmospheric Administration and University researchers in the Great Lakes region. The research mission of the institute is to improve the understanding of the fundamental physical, chemical, biological, and ecological processes operating in the Great Lakes region in order to improve observation and forecasting systems that help guide management. CILER is also tasked with translating and disseminating science for the general public, highlighting NOAA initiatives, and promoting educational training opportunities in the region through postdoctoral research fellow positions and the student summer fellowship program.

Executive Summary:
The Cooperative Institute for Limnology and Ecosystems Research (CILER) was originally established in 1989, with the objective of fostering University and NOAA partnerships in the Great Lakes region. The renewal of the CILER Cooperative Agreement went into effect in July of 2007. This agreement was awarded to the University of Michigan (host institution) and nine partner universities (Michigan State University, University of Toledo, Grand Valley State University, University of Minnesota-Duluth, University of Wisconsin, University of Illinois at Urbana-Champaign, Ohio State University, State University of New York at Stony Brook, and
Penn State University). Since the renewal of this new agreement has been in effect, CILER has supported 104 amendments that total $17.7 million in research funding. During the past year (i.e., current reporting period), CILER administered 19 additional CI project grants totaling $3.9 million.

In October, 2010, NOAA convened an external panel of scientists to conduct a 5-year review of CILER management, science, and outreach. CILER addressed recommendations made by the panel. These tasks have been worked on, and were reported to Phil Hoffman, the CI Program Director, in interim and 1-year reports. Results of the interim report were also presented to NOAA Administrator Jane Lubchenco and NOAA’s Science Advisory Board during their annual meeting at GLERL last Summer.

Specific tasks undertaken during this reporting cycle that continue to address the 5-year review include:

1) CILER proposed new vision and mission statements showing CILER’s unique role as a part of Great Lakes research. These new statements seeded development of a 5-year strategic plan for the CI, which was submitted last year as a separate document, and also incorporated into a newly proposed 5-year Cooperative Agreement with NOAA for July, 2012 – June, 2017.

2) CILER engaged more partners through changes in management structure i.e., continued to expand the former Council of Fellows into a promoted Management Council that includes more academic professors. The new Management Council continues to focus on moving CILER in new and unique research directions.

3) CILER continued to expand our new Council of Fellows that includes Great Lakes academic researchers willing to mentor and rotate top tier and innovative postdoctoral fellows through their laboratory programs every 1 to 2 years via a highly competitive nationwide advertisement and application process. The Council of Fellows now includes over 30 well known researchers from around the Great Lakes region who represent academic and federal interests. And, CILER currently has its first round of postdoctoral fellows on board, two of which are located at separate Great Lakes universities, and one of which is located at GLERL.

4) CILER continues to mentor younger staff in regard to publications, travel, networking, and university roles.
CILER Research Overview:

Research conducted under the ecosystem **forecasting** theme aims to develop forecasts for physical hazards, water levels, harmful algal blooms (HABs), and fish recruitment and production.

This year, the focus was adding sediment transport and water quality components to the Distributed Large Basin Runoff Model (DLBRM). More specifically, the goal is to improve the DLBRM’s hydrology component to better reflect land use influence on water level forecasts and predicting near-shore water quality. Testing of the LBRM recalibration will be conducted at beaches, and the recalibrated LBRM runoff will be used to determine loadings as input to hydrodynamic and pathogen models.

In addition, university scientists are developing a hydrodynamic model for the St. Louis River Estuary using Finite Volume Coastal Ocean Model (FV-COM) software. In concert with an ongoing empirical study, they will use the hydrodynamic model to identify sources of water and retention times of water throughout the estuary, to help explain observed patterns of nutrients and organic carbon. They will also use measured biogeochemical rates to parameterize a water quality model, which will allow them to evaluate nutrient processing in the estuary under a variety of conditions, and to simulate the effects of various management scenarios in the estuary.

For the St. Lawrence River hydrodynamic model, university and federal researchers aim to provide predictions of water levels and currents to the recreational boating community, shipping industry, and general public in a real-time format. For the Fox River and Saginaw Bay, these same researchers plan to develop high-resolution plume models that are able to track river water transport as it enters lakes Michigan and Huron, and to provide the hydrodynamic model based support necessary for beach forecasting.

Better estimates of nutrient and bacterial loads to coastal areas continues, with improved model descriptions of vegetation processes by adding a crop model into MSU’s Process-based Adaptive Watershed Simulator (PAWS). In addition, models for bacterial fate and transport have taken sediment –bacteria interactions into account. Finally, new methods for microbial fecal source tracking and human sewage markers have been explored.

To determine the utility of and potential limitations for a *Microcystis* forecast ‘tool’ based upon remote-imagery data, existing field, or ground-truth data (supplied by NOAA-GLERL) has been correlated to imagery-derived estimates of surface-dwelling cyanobacterial biomass. The 2011 harmful algal bloom in Lake Erie turned out to be one of the largest on record in terms of its spatial extent and duration. Measured toxin concentrations were about 1200 ppb (WHO’s recommended guideline for recreational
exposure is 20 ppb). The bloom grew and continued in intensity until late October. A major finding of the cell count data is the significant presence of a second toxin-producing cyanobacterium, *Anabaena*.

Lake ice cover is an important predictor of regional climate. Lake ice extent also modifies the circulation patterns and thermal structure. Heat and moisture exchange between the atmosphere and the lake water can differ significantly (as much as an order of magnitude) with and without lake ice, thus leading to a striking difference in evaporation in wintertime due to wind mixing. A major publication involving CILER scientists as co-authors recently analyzed the statistical relationship between lake ice cover and climate indices in both spatial and temporal spaces (40 year time span). A generalized relationship between lake ice cover, lake levels, and atmospheric circulation patterns continues to be analyzed. Additional climate scenario simulations have been carried out using CHARM (Coupled Hydrosphere-Atmosphere Research Model) at GLERL. As expected, these lead to higher temperatures in air and water and reduced lake ice cover. They also lead to increased precipitation, particularly in the lake effect zones.

**Research in the second theme, invasive species, focuses on the prevention, monitoring, detection, and control of invasive species, and on a better understanding of the range of their ecosystem impacts.**

CILER is working with NOAA (GLERL) scientists who oversee GLANSIS to 1) develop a prioritized list of potential high-risk invader species and compile associated fact sheets; 2) identify range expansion species and develop full profiles for their addition to the system; 3) develop a simple screening tool to apply to all GLANSIS species for improved consistency of the database with respect to realized and potential impacts; 4) add a new field to species profiles for management information, including current regulations, best management practices, and control methodologies, and 5) develop non-technical (public) fact sheets for each of the species in the GLANSIS database, in collaboration with the Great Lakes Sea Grant Network. The addition of fact sheets and distribution information about these species will allow for monitoring, detection, and the rapid response to new invasion risks should the Great Lakes warm as projected by climate change predictions.

Work continues on the biomass status of primary producers, and native and non-native pelagic crustaceans and macroinvertebrates in Lakes Michigan, Huron, Ontario, and the Muskegon Lake AOC. Data will ultimately be used in food-web models to evaluate how non-indigenous invertebrates have altered the lower food-web structure and to predict the production of various components of the food-web of particular interest to resource managers. For Muskegon Lake, the Degradation of Benthos BUI was listed because of impacts to species diversity from the discharge of municipal sewage and
sediment toxicity related to heavy metals and organic chemicals. Improvements were seen after municipal and industrial wastewater to Muskegon Lake was eliminated by the construction of an advanced tertiary wastewater treatment facility in 1974. Currently, GLERL and CILER researchers are establishing baseline information on the benthic community, and developing a robust method for classifying sediments for assisting in the selection of baseline monitoring sites and to map improvements of lakebeds after restoration efforts are begun.

CILER and GLERL researchers are taking a much more detailed look at the potential for Asian carp to survive, grow and impact other fish species and food webs at various locations throughout the Great Lakes Basin. A spatially-explicit modeling approach allows a more detailed look at the effects of Asian carp 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) that may result in compensatory mechanisms by which native Great Lake species can coexist with Asian carp. In relation to the Asian carp work, these researchers also plan to investigate the use of ecological models and GIS databases to support the NOAA-CSCOR proposal by Dr. David Lodge et al. from the University of Notre Dame entitled: “Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes”. Products resulting from this work 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, and Ecopath/Ecosim food web models and predictions of bioeconomic impacts of invasive species on Great Lakes food webs and fisheries.

Research in the third theme, coastal observing systems, focuses on providing observing system data and platforms, data management and communications, and data products and forecasts needed for effective environmental management, and for monitoring and understanding ecosystem responses to natural and anthropogenic conditions.

CILER and associated partners within the nearshore Great Lakes Observing System team have continued to help 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.

CILER ran AUV missions in Saginaw Bay in order to determine the bottom substrate of certain fish reefs and to support Cladaphora modeling, and in western Lake Erie to map the distribution and influence of the Maumee River plume.

MTRI developed and tested a new satellite algorithm that maps TSS found in river plumes. The development of a MODIS and MERIS Primary Productivity algorithm for
Lake Michigan was also completed. MTRI supported GLERL work in Lake Erie by providing field spectral radiometer measurements recording a Harmful Algal Bloom (HAB) event. Initial tests have begun using a modified HAB algorithm on a Lake Erie satellite dataset. MTRI provided satellite-based water clarity analysis for inclusion in the “State of the Great Lakes 2012” report.

The fourth theme, protection and restoration of resources, supports research to protect, restore, or enhance priority coastal land and water habitats throughout the basin.

When communities are armed with science-based environmental limits or “tipping-points”, they are able to institute land use policies and restoration plans that ensure critical green infrastructure and habitat sustaining Great Lakes ecosystems are maintained. A project under this theme has been using existing Great Lakes water quality, biological monitoring, and corresponding watershed land use data to identify tipping points that impact Great Lakes ecosystems.

Objectives of the work include: 1) identifying land use indicators, 2) developing coarse scale analysis of land use tipping points, 3) comparing estimates of tipping points from coarse and fine-scale analyses, 4) extending the tipping point analysis to include bacterial contaminants, 5) developing and applying food web modes to evaluate land use tipping points for Saginaw Bay, 6) integrating the modeling approaches, 7) identifying specific land use tipping points that change biological and/or contaminant outcomes, and 8) conducting a demonstration of use.

Research projects in the fifth theme, integrated assessments, generate policy-relevant and synthetic efforts to help guide long-term resource use in the basin.

For the past several years, a group of university and NOAA-GLERL collaborators have been developing an Adaptive Integrated Framework (AIF) for facilitating information collection, implementing adaptive modeling approaches, and guiding research needs to improve management decision making in the Saginaw Bay AOC related to such measures as invasive species, changing land-use patterns, and climatic change. This framework uses input from agency managers, researchers and modelers, including both data to characterize ecosystems and socio-economic factors to drive modeling approaches and management actions.

The work recognizes the crucial need for developing models that are adaptable across ecological systems and multiple stressors as well as one that provides managers with a means to understand and manage stressor interactions unique to their system. The five
year project has been accomplishing these goals by coupling modeling, observational, and experimental studies with stakeholder workshops and socio-economic analyses. The resulting AIF approach will be broadly applicable to evaluate the nation’s coastal and estuarine ecosystems impacted by multiple stressors.

Implications after 4 years of implementing this program:

There is still evidence of Quagga mussel influence on altering phosphorus dynamics and light conditions in the Saginaw Bay. And they may still have an influence on Cladophora production and Microcystis bloom formation. Modeling suggests that increasing Dreissenid density will increase both Cladophora and Microcystis production problems in the bay.

Prior to this study, the inner Saginaw Bay was generally thought to be vertically well-mixed. However, temperature profiles at several locations around the inner bay indicate periodic, short-lived stratification. There is a potential for sediment phosphorus release in a region where bottom water oxygen is rapidly depleted during these stratified conditions.

The failure to attain target TP loads and ambient TP concentrations contributed to regular muck problems before the mussel invasion. Evidence from this work that the algal muck precursors are phosphorus limited suggests that further phosphorus reductions will reduce the muck that results from decaying benthic algae, such as Cladophora, and their associated high levels of fecal indicator bacteria. Reduced P loads from the Saginaw Bay watershed would also limit harmful algal growth.

Based on multiple re-sampling and multivariate analyses, from 1970 to 2008 the Saginaw Bay fish assemblage changed with a) increased richness, b) decreased prevalence of eutrophic-tolerant species, and c) increased relative abundance of many moderately tolerant species. In addition, small cladocerans still account for 80% of the cladoceran size classes, reflecting high planktivory pressures in the bay, which would indicate a more oligotrophic system.

Finally, projects conducted under the sixth theme, Education and Outreach, facilitate education and outreach activities for NOAA in the Great Lakes region.

The overall objective of a CILER undergraduate fellow, in partnership with NOAA’s National Ocean Service, was to build, support, and strengthen climate partnerships in the Great Lakes region to ensure effective and timely delivery of NOAA products and services. To that end, this fellowship position provided resources facilitating,
participating in, and delivering regional climate workshops and coastal projects to ensure better coordination across NOAA and GLRI efforts. These provided resources include regular partner interaction and support, as well as developing high level plans and documents to inform regional policy, funding, and science decisions.

Michigan Sea Grant Outreach and Education for the NOAA Center of Excellence for Great Lakes and Human Health (CEGLHH) continued for this reporting year. CEGLHH’s outreach coordination serves two roles: 1) identifying and assessing user needs (related to Great Lakes and human health), and 2) disseminating scientific information, technology, and research materials to aid health officials, local governments, and communities in making sound environmental decisions.

For the Lake Erie HAB experimental forecast weekly distribution, the subscribership for the Bulletin increased from 185 at the beginning of the field year to 474 subscribers in 2011. The Lake Erie HAB Bulletin predicted one of the worst blooms in Lake Erie in recent decades and due to the severity of the 2011 bloom in Lake Erie, interest in information on Lake Erie’s algae problem escalated, which led to the surge in subscribership to the Weekly Forecast Bulletin. And, according to a Michigan water quality survey, respondents claim algal blooms are having negative economic impacts on selling lakefront homes and are deterring tourists from recreating on the Great Lakes.

Outreach Director’s Report

In February of 2012, the 15th annual Great Lakes regional National Ocean Sciences Bowl competition was hosted again by CILER and other local federal, university, and non-profit partners for 16 high school teams. Almost 200 students, coaches, and volunteers convened at the School of Natural Resources and Environment on the University of Michigan’s campus. Two new teams joined the competition. The Great Lakes Bowl is one of 25 regions from around the country. Each year, CILER’s Regional Coordinator accompanies the winning team to a national competition at the end of April. The 2011 competition was held in Galveston, TX. The 2012 competition will be held in Baltimore, MD.

CILER organized their 13th Summer Student Fellows Program, which supported 16 undergraduate and graduate students. Over 85 applications were received for this national competition. Students participated on research projects with NOAA and other federal agencies, and university scientists within the Great Lakes region. Again this year, CILER also hired Long Term (9-12 month) Student Fellows (2 students) to supplement the Summer Student Fellows Program.
The Partners for Excellence program has been expanded to include all Ann Arbor public high schools. This program promotes Great Lakes research to younger high school students looking into college careers. These young students are mentored by CILER and GLERL scientists while working on specific research projects.

The CILER-GLERL seminar series continues to bring in research and education and outreach experts from around the Great Lakes region and other coastal areas throughout the U.S. We have expanded this program through enhanced list serves, such as the Great Lakes Information Network, Great Lakes Days, and online webinars. Attendee participation through these venues has increased significantly over the past year, especially after including e-mail lists from other university partners, and University of Michigan departments besides the School of Natural Resources and Environment.

Based on recommendations from the external review of CILER’s education and outreach over the past 5 years, we continue to actively engage local partners and museums to include user-friendly information about CILER in a Great Lakes interactive kiosk and display currently on tour around Michigan. The kiosk is currently located at NOAA’s Thunder Bay National Marine Sanctuary in Alpena, MI.

We have also been working with our school’s communications director and web master to enhance CILER’s website to ultimately make it a one-stop shopping source for all things-CILER. With that, we have hired a 2012 Summer Fellow who will focus on making our website even more attractive to stakeholders and the public. Other public education and Great Lakes research outreach included a visit by CILER’s Outreach Director at a local middle school in order to engage students interested in environmental careers, and exhibiting CILER’s research at the annual Great Lakes Beach Association and State of Lake Michigan conference in Michigan City, Indiana. CILER will also run an exhibit at the annual International Association for Great Lakes Research conference in May this year, which will be located in Cornwall, Ontario.

**Administrative Summary:**

As part of the 5-year review held last October, CILER’s administrative functions were assessed. The final admin review report from NOAA is still pending. CILER will continue to follow the research guidelines and practices established by the University of Michigan and NOAA. Based on recommendations during the CILER review, CILER is ramping up its Outreach and Education involvement. Sander Robinson’s duties in this position are being expanded. Sander is taking an active role by working closely with
the local NOAA and Sea Grant outreach personnel to make CILER more visible in the region. Other recommendations made during the review, such as administering the PEERRS training to Post Docs, and the creation of a CILER handbook for researchers are in effect.

Dr. Colton of GLERL and Dr. Burton of CILER continue working together on ways to improve the NOAA-CILER relationship to better meet the mission and goals of both organizations.
Executive Board - Management Council - Council of Fellows:

Executive Board:
The Executive Board makes recommendations concerning CILER’s administration, budget, future cooperative agreements, and Management Council members. The Board last met in June.

The members of the Executive Board include:

Al Powell (Director, NOAA Center for Satellite Applications and Research), Russell Callender (Acting Director, NOAA National Centers for Coastal Ocean Science), Marie Lynn Miranda (Dean, SNRE), Mark Banaszak-Holl (Associate Vice-President for Research, UM), Allen Burton (CILER Director, ex-officio) and Marie Colton (GLERL Director, ex-officio).

Members of the new 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. This Council last met in May. Members include:

Jim Diana, University of Michigan; Director, Michigan Sea Grant Program  
Brian Miller, University of Illinois; Director, Illinois-Indiana Sea Grant Program  
Jeff Gunderson, University of Minnesota; Director, Minnesota Sea Grant Program  
Jeffrey Reutter, Ohio State University; Director, Ohio Sea Grant Program  
Jim Ammerman, State Univ. New York-Stony Brook; Director, N Y Sea Grant Program  
David Schwab, Ecosystem Modeling/Forecasting Branch Chief, NOAA-GLERL  
Henry Vanderploeg, Ecosystem Dynamics Branch Chief, NOAA-GLERL  
Doran Mason, CILER Program Manager, NOAA-GLERL  
Craig Stow, Principal Investigator, NOAA-GLERL  
Edward Rutherford, Principal Investigator, NOAA-GLERL  
Lucinda Johnson, Univ. of Minn.; Director, Natural Resources Research Institute  
Val Klump, Univ. Wisconsin – Milwaukee; Director, Great Lakes Water Institute  
Al Steinman, Grand Valley State Univ.; Director, Annis Water Resources Res. Institute  
Jan Stevenson, Michigan State University; Professor, Department of Zoology  
Chin Wu, University of Wisconsin – Madison; Professor, Civil and Env. Engineering
They are also listed alphabetically on CILER’s website: http://ciler.snre.umich.edu/content/management-council, with a link to their online profiles, which includes their affiliations, contact information, and research interests.

**Members of the new Council of Fellows:**

The new Council of Fellows include over 30 Great Lakes academic and federal researchers willing to mentor and rotate postdoctoral fellows through their laboratory programs every 1 to 2 years. This Council last met in August.

- **Joe Atkinson**, Professor, State University of New York - University at Buffalo
- **Jay Austin**, Asst. Professor, Univ. of Minnesota-Duluth’s Large Lakes Observatory
- **Niladri Basu**, Asst. Professor, University of Michigan’s School of Public Health
- **Stuart Batterman**, Professor, University of Michigan’s School of Public Health
- **Dima Beletsky**, Associate Research Scientist, CILER
- **John Bratton**, Deputy Director, GLERL
- **Brad Cardinale**, Asst. 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
- **Drew Gronewold**, Hydrologist, GLERL
- **Nathan Hawley**, Oceanographer, GLERL
- **Thomas Hook**, Asst. Professor, Purdue University
- **Tom Johengen**, Associate Director, CILER
- **Donna Kashian**, Asst. Professor, Wayne State University
- **Peter Lavrentyev**, Professor, University of Akron
- **Brent Lofgren**, Physical Scientist, GLERL
- **Nancy Love**, Professor, University of Michigan
- **Rex Lowe**, Professor, Bowling Green State University
- **Stuart Ludsin**, Asst. Professor, Ohio State University
- **Phanikumar Mantha**, Assoc. Professor, Michigan State University
- **Peter McIntyre**, Asst. Professor, University of Wisconsin-Madison
- **Guy Meadows**, Professor, University of Michigan
- **Cheryl Murphy**, Asst. Professor, Michigan State University
- **Scott Peacor**, Assoc. Professor, Michigan State University
- **Lutgarde Raskin**, Professor, University of Michigan
- **Jen Read**, Executive Director, Great Lakes Observing System
- **Carl Ruettz III**, Assoc. Professor, Grand Valley State Univ., Annis Water Resources Inst.
- **Paul Seelbach**, Eco. Hlth. & Restor. Branch Chief, USGS-Great Lakes Science Center
Carol Stepien, Director, Lake Erie Research Center, University of Toledo
Robert Sterner, Professor, University of Minnesota
Cary Troy, Asst. Professor, Purdue University
Mike Wiley, Professor, SNRE, University of Michigan

They are also listed alphabetically 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 report details project activities through the fifth year of the new cooperative agreement with updates covering the period through March 31, 2012. CILER has administered 104 amendments distributed as shown in Figure 1. The total funding level through year five is $17.7 million.

![Pie Chart - Funding distribution for CILER by theme through 03/31/12.](image)

**Figure 1.** Pie Chart - Funding distribution for CILER by theme through 03/31/12.
Table 1. Breakdown of funding by Theme awarded to CILER for the current Cooperative Agreement, NA07OAR4320006, through March 31, 2012.

<table>
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<th>Task</th>
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<th>#Amendments</th>
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<td>I</td>
<td>Administration</td>
<td>5</td>
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<tr>
<td>II</td>
<td>Theme I: Great Lakes Forecasting</td>
<td>29</td>
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<td>II</td>
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<td>II</td>
<td>Theme III: Observing Systems</td>
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<td>$3,699,435</td>
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<td>II</td>
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<td>II</td>
<td>Theme V: Integrated Assessment</td>
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<td>II</td>
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<td>Totals</td>
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<td>104</td>
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Table 2. Breakdown of subcontract funding by institution:

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<td>Case Western Reserve University</td>
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RESEARCH PROJECT TITLES BY THEME:

THEME I: GREAT LAKES FORECASTING

COMPARATIVE ANALYSIS OF NET BASIN SUPPLY COMPONENTS AND CLIMATE CHANGE IMPACTS ON THE UPPER GREAT LAKES

NEXT GENERATION LARGE BASIN RUNOFF MODELS

CHARACTERIZING REGIONAL HYDROLOGIC RESPONSE AND IMPROVING ESTIMATES OF RUNOFF TO THE GREAT LAKES BASIN

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BEACH QUALITY FORECASTING COORDINATOR

AN INTEGRATED APPROACH TO MONITORING, FORECASTING, AND UNDERSTANDING HARMFUL ALGAL BLOOMS (HABs) IN THE GREAT LAKES

MODELING MICROCYSTIS ABUNDANCE: WHAT TO DO WITH ALL THOSE ZEROS?
CSCOR NGOMEX: The Effects and Impacts of Hypoxia on Production Potential of Ecologically and Commercially Important Living Resources in the Northern Gulf of Mexico

Modeling Great Lakes Ice and Revealing Linkages between Lake Ice and Climate Patterns

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Modeling Sea Ice-Ocean-Ecosystem Responses to Climate Changes in the Bering-Chukchi-Beaufort Seas with Data Assimilation of RUSALCA Measurements

Theme II: Invasive Species

Enhancement of the NOAA Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)

Status and Trends in Benthic Macroinvertebrates in the Great Lakes

Status of Macroinvertebrates in Lake Ontario and Muskegon Lake

Status of Pelagic Crustaceans in Southern Lake Michigan / Food Web Dynamics in Southern Lake Michigan

Assessing the Risk of Asian Carp Invasion and Impacts on Great Lakes Food Webs and Fisheries

Population Dynamics of the Non-indigenous American Shad Alosa sapidissima along the West Coast of the U.S. and Anticipated Effects of Climate Change on Range Expansion

Larval Dispersal, Habitat Classification and Food Web Modeling

GIS Ecoregion Classification and Food Web Modeling
MECHANISTIC APPROACH TO IDENTIFY THE ROLE OF PATHOGENS IN CAUSING Diporeia spp. DECLINE IN THE LAURENTIAN GREAT LAKES

THEME III: OBSERVING SYSTEMS

IMPLEMENTATION OF THE GREAT LAKES OBSERVING SYSTEM (GLOS), 2008-2012

GREEN BAY HYPOXIA

GREAT LAKES COASTWATCH RESEARCH ASSISTANT FOR NOAA COASTWATCH PROGRAM ELEMENT

SUPPORTING PREDICTIVE MODELS THAT IMPROVE COASTAL, HUMAN HEALTH AND BEACH FORECASTING

A ROBOTIC SAMPLER-MASS SPECTROMETER FOR IN-WATER DETECTION OF CYANOTOXINS

RAPID BIOSSENSOR TECHNOLOGY FOR RECREATIONAL FRESH WATERS

THEME IV: PROTECTION AND RESTORATION OF RESOURCES

GREAT LAKES RESTORATION INITIATIVE – NOAA PROGRAM SUPPORT

IDENTIFY LAND USE TIPPING POINTS THAT THREATEN GREAT LAKES ECOSYSTEMS

IMPACT OF TEMPERATURE AND OXYGEN LEVEL ON GROWTH AND SURVIVAL OF FIRST FEEDING YELLOW PERCH LARVAE

THEME V: INTEGRATED ASSESSMENT

ADAPTIVE INTEGRATED FRAMEWORK: A NEW METHODOLOGY FOR MANAGING IMPACTS OF MULTIPLE STRESSORS IN COASTAL ECOSYSTEMS

ECOFORE: FORECASTING THE CAUSES, CONSEQUENCES AND REMEDIES FOR HYPOXIA IN LAKE ERIE
THEME VI: EDUCATION AND OUTREACH

CLIMATE CHANGE IMPACTS INFORMATION AND OUTREACH

MICHIGAN SEA GRANT OUTREACH AND EDUCATION FOR THE NOAA CENTER OF EXCELLENCE FOR GREAT LAKES AND HUMAN HEALTH
RESEARCH PROJECT REPORTS BY THEME

THEME I: GREAT LAKES FORECASTING

CILER activities that fall under the theme of Great Lakes Forecasting include research focusing on developing forecasts for physical hazards, water levels, harmful algal blooms, and fish recruitment and production.
**Project Title:** Comparative Analysis of Net Basin Supply Components and Climate Change Impacts on the Upper Great Lakes

*University Principal Investigators:* Allen Burton (CILER), Carlo DeMarchi (Case Western Reserve University)

*NOAA Technical Leads:* Brent M. Lofgren (GLERL)

**Overview and Objectives:**

A better understanding of the water balance of the Great Lakes is necessary to face present and future challenges to the Great Lakes, such as extraordinarily low water levels in the recent years and future impacts of climate change. One of the principal tools that help scientists in this quest is the NOAA Great Lakes Environmental Research Laboratory’s Net Basin Supply (NBS) estimates. These data are used for statistical analysis of the water balance of the lake and its components. In this study we will quantify the uncertainty in the NBS’ single components and final values, test a new method for overlake precipitation estimation, and recalibrate the GLERL’s model for lake evaporation with more recent data. We will also perform the traditional downscaling of GCM’s data for comparison with more advanced methods.

This project will try to fill a gap in the knowledge of Great Lakes hydrology important both for operational purposes as well as for assessing the effects of climate change.

The Project Addresses the following NOAA Strategic Plan Goal(s):

1) Understand climate variability and change to enhance society’s ability to plan and respond;
2) Serve society’s needs for weather and water information;
3) Support the nation’s commerce with information for safe, efficient, and environmentally sound transportation;

**Accomplishments:**

We compared NOAA-GLERL’s lake evaporation estimates for Lake Superior with evaporation data collected in 2008-2010 and with the MESH model by Environment Canada for all lakes for the period 2004-2009. We used a new linear regression approach for deriving adjustment coefficients to back-project the Mesh evaporation data to the
period 1948-2004 using the GLERL model for lake evaporation as input. We also derived the error distributions of such back-projections.

We compared NOAA GLERL's lake direct precipitation (overlake precipitation) estimates with the MESH and CaPA models by Environment Canada for all lakes for the period 2004-2009. We used a new linear regression approach for deriving adjustment coefficients to back-project the Mesh and CaPA precipitation data to the period 1948-2004 using the GLERL PrcLk model for overlake precipitation as input. We also derived the error distributions of such back-projections.

We compared NOAA-GLERL's lake river runoff estimates with the MESH model by Environment Canada for all lakes for the period 2004-2009. We used a new linear regression approach for deriving adjustment coefficients to back-project the Mesh river runoff data to the period 1948-2004 using the GLERL model for river runoff as input. We also derived the error distributions of such back-projections.

We updated the analysis of NOAA-GLERL's lake river runoff estimates biases and errors based on a gage-model comparison to the period 1948-2009 for all lakes adopting a linear regression approach for deriving adjustment coefficients similar to the work done with the comparison with MESH data.

We estimated updated NBS and relative uncertainty in NOAA GLERL's NBS using different combinations of the results we produced for over-lake precipitation, river input, and lake evaporation using a Monte Carlo simulation.

We reported our work to the International Joint Commission’s International Upper Great Lakes Study.


Publications and Presentations:

No peer-reviewed publications or presentations during this period

Outreach Activities: None for this period
PROJECT TITLE: NEXT GENERATION LARGE BASIN RUNOFF MODELS

University Principal Investigators: Allen Burton (CILER), Carlo DeMarchi (Case Western Reserve University)

NOAA Technical Leads: Brent M. Lofgren (GLERL)

Overview and Objectives:

Adding sediment transport and water quality components to the Distributed Large Basin Runoff Model (DLBRM). Improving DLBRM’s hydrology component to better reflect land use influence. Apply the DLBRM to simulate sediment and nutrient load in the Grand River basin (Michigan), in the AuGres-Rifle, Pigeon-Wiscoggin, Kawkawlin-Pine, Saginaw and Maumee Rivers, Sandusky River, Cuyahoga River, and Grand River (Ohio).

The Project Addresses the following 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

Accomplishments:

We recalibrated the DLBRM hydrology model for the AuGres-Rifle, Kawkawlin, Saginaw, Pigeon-Wiscoggin, and Maumee River using a newer (2008) characterization of the land surface (The older one was created in 2008.). We also extended the calibration period to 2009 for the AuGres-Rifle and Saginaw.

We are working to transform geo-referenced databases of point sources with relative monthly discharge for the Cuyahoga, Grand (Ohio), Maumee, and Sandusky basins in a format compatible with the DLBRM.

Regarding model development, we have begun expanding the DLBRM for adding sediment and nutrient transport.

Publications and Presentations: None for this period.

Outreach Activities: None for this period.
Overview and Objectives:

The primary goal of this project is to improve NOAA-GLERL’s forecasts of daily runoff from land to the Great Lakes for the purpose of both improving water level forecasts and predicting near-shore water quality. Seasonal forecasts of Great Lakes water levels are important for many sectors within the region. The transportation industry relies on maintenance of water levels that are sufficient for freight traffic and continued use of docks and harbors. Changes in water levels may result in changes in hydropower potential, altered beaches and recreational areas, changes in fish habitat, and water quality issues at municipal water intakes. Advanced notice of changes in water levels allows for improved planning of flow regulation to maintain water levels for these important economic sectors in the region.

NOAA GLERL’s Great Lakes Advanced Hydrologic Prediction System (AHPS) provides probabilistic seasonal forecasts of hydrometeorologic variables including water levels, and is used by public and private agencies in the region. AHPS translates the net basin supply (equal to runoff to the lakes plus over-lake precipitation minus over-lake evaporation) to the water level using a lake routing and regulation model. Current runoff forecasts that are input into the Great Lakes AHPS system are provided by the Large Basin Runoff Model (LBRM).

Recently, GLERL conducted an assessment of the forecasting skill of the Great Lakes AHPS by comparing 13 years of 3 and 6-month average water level forecasts with observations for each of the Great Lakes, except Lake Ontario (Gronewold, Clites, Hunter, & Stow, 2011). This analysis resulted in several recommendations for improving water level forecasts. Among these was the recommendation to recalibrate the LBRM, incorporating recent advances in methods for prediction in ungauged basins (PUB), and to consider alternative models for predicting runoff from the subbasins.
Improvements in modeled runoff to the Great Lakes addresses the NOAA Strategic Plan goals in the following ways:

1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;

Improved forecasts of runoff will result in improved predictions of water quality at river mouths and provide information that may be used for managing runoff and contaminant loading to river mouths. In fact, testing of the LBRM recalibration will be conducted at locations where current efforts exist at NOAA to predict water quality at beaches, and the recalibrated LBRM runoff will be used to determine loadings as input to hydrodynamic and pathogen models. Additionally, runoff forecasts contribute to the management of near shore and coastal ecosystems in order to maintain habitat and aesthetics.

2) Understand climate variability and change to enhance society’s ability to plan and respond;

While long term forecasts of changes in runoff resulting from climate change are not a goal of this research, a new calibration of the LBRM will reflect recent changes to the landscape and climate and the resulting impacts on hydrologic response. Incorporation of these changes into an improved regionalized model will allow for better management of the Great Lakes water levels to respond to the different hydrologic responses that result.

3) Serve society’s needs for weather and water information;

The Great Lakes provide valuable services to society within the region, and a recalibration of the LBRM will result in improved water level forecasts as well as potentially new information regarding discharge at river mouths. Society depends on such information for management within economic sectors and for determining the safety of water quality at beaches and municipal intakes.

4) Support the nation’s commerce with information for safe, efficient, and environmentally sound transportation;

The Great Lakes provide a significant transportation route for many commodities. Improved estimates of runoff to the Great Lakes will allow for better management of Great Lakes water levels for the purpose of sound transportation.
**Accomplishments:**

In the three months since the project began, progress has been made toward characterizing hydrologic response (runoff to precipitation ratio, in this case) in the U.S. portion of the Great Lakes basin. Figure 1 shows the runoff ratio in the U.S. portion of the basin. Several potential drivers of hydrologic response have been identified for use in developing a regionalized calibration of the LBRM. Future work will involve exploring additional hydrologic responses such as unit hydrograph shape as well as expanding the investigation to include the Canadian portion of the basin.

![Figure 1. Average annual ratio of runoff to precipitation in the U.S. portion of the Great Lakes basin.](image)

The relationships between hydrologic response and watershed characteristics are important for predicting hydrologic response in the ungauged portions of the basin. Several potential drivers of hydrologic response have been identified for use in developing a regionalized calibration of the LBRM.

Several watersheds have been identified in which the recalibration methods can be tested. These watersheds were identified as watersheds where focused work is currently planned for predicting water quality at beaches.
Publications: No publications have resulted yet from this project.

Presentations:


Outreach Activities:

Outreach activities to date have consisted of meeting with individuals from several organizations to share the objectives of the project and identify areas of overlap and research needs for large scale hydrologic modeling in the Great Lakes basin. These organizations include Environment Canada, USGS, US Army Corps of Engineers, and NOAA’s National Weather Service.
PROJECT TITLE: HYDRODYNAMIC MODELING AND OBSERVATIONS IN SUPPORT OF GLRI DECISION SUPPORT TOOLS

*University Principal Investigators:* Allen Burton and Eric J. Anderson (CILER)
*NOAA Technical Leads:* David Schwab and Steven Ruberg (GLERL)

**Overview and Objectives:**

The Finite Volume Coastal Ocean Model (FVCOM) and the Princeton Ocean Model (POM) have been implemented successfully in the Great Lakes, and have proven to be robust hydrodynamic modeling bases for lake- to beach-scale predictions. We have implemented these models in three areas identified as areas of interest by GLOS and GLRI participants, which include the Upper St. Lawrence River, Saginaw Bay, and the Fox River in Green Bay. In each of these areas, the objectives were to develop a model of the river or beach-scale hydrodynamics and take the necessary steps to implement an operational model, via data collection, model calibration, model refinement, or development. For the St. Lawrence River model, the primary objective is to provide predictions of water levels and currents to the recreational boating community, shipping industry, and general public in a real-time format. For Fox River and Saginaw Bay, the primary objective is to develop high-resolution plume models that are able to track river water transport as it enters the lake and to provide the hydrodynamic model based support necessary for beach forecasting.

Development of these real-time hydrodynamic models directly supports NOAA Strategic Plan Goals to: (1) serve society’s needs for weather and water information and (2) support the nation’s commerce with information for safe, efficient, and environmentally sound transportation.

**Accomplishments:**

The Upper St. Lawrence River model has been developed and operationalized for real-time prediction of currents and water levels. The model provides web-based outputs of nowcasts (every 3 hours) and 48-hour forecasts (every 3 hours) to the public through partnership with GLOS. In a cooperative effort with Environment Canada, model calibrations to water levels, discharge, and currents have proven successful.

In Saginaw Bay, several instrument deployments were carried out in summer 2011 (2 ADCPs, 2 YSIs, 9 drifter buoys) to collect current information, waves, water levels, temperature, conductivity, and particle transport. These data have been used to calibrate both a POM and FVCOM model of Saginaw Bay, in particular aiding in the development of an FVCOM model of Lake Huron / Saginaw Bay with a high-resolution...
Saginaw River plume. The operational POM model of Saginaw Bay (and river plume) has been tested successfully against drifter tracks, currents, and water levels using the 2011 data.

In Green Bay, instrument deployments in summer 2011 have been carried out to measure currents, water levels, waves, and temperatures in the nearshore zone around the Fox River plume. This data and Lake Michigan 2008 data has been used to calibrate and develop an FVCOM model of Lake Michigan, including a high-resolution Green Bay model. The newly developed model also has the ability to couple with the aforementioned Lake Huron / Saginaw Bay model. The Fox River model is under development, but successful calibration thus far enables the continued validation and development of an operational plume model of the Fox River.

Publications:

No articles in relation to this GLOS-GLRI source of funds yet.

Presentations:


Outreach Activities:

A workshop conducted with several members of the St. Lawrence River boating community in May 2011 through a partnership with GLOS. Feed back with the public is being used to tailor the model and output to the needs of the boating and shipping community. In addition, model output and descriptions are currently being placed on NOAA and GLOS websites to engage the Great Lakes user community. Real-time forecasting pages have been put in place for the Upper St. Lawrence River and Saginaw Bay models.
**PROJECT TITLE:** QUANTIFICATION OF LARVAL WALLEYE (*Sander vitreus*) DRIFT: ESTIMATING EXPORT FROM THE MAUMEE RIVER USING A MULTILEVEL BAYESIAN MODEL

*University Principal Investigators:* Allen Burton, CILER; Christine Mayer and Mark DuFour, Department of Environmental Sciences and Lake Erie Center, University of Toledo

*NOAA Technical Lead:* Craig Stow, GLERL

**Overview and Objectives:**
The goal of this project is to quantify the annual export of Maumee River larval walleye to Lake Erie, while differentiating sources of in-river mortality. Additionally, because larval fish exhibit high spatial and temporal variability, we are using a Bayesian hierarchical model to account for these sources of variability in our final estimates. The specific objectives of this project are to quantify the daily larval drift at key locations along the river including: upstream near the spawning grounds, downstream near the river mouth, and within a power plant cooling water intake canal. Daily estimates can be summed through the season to produce annual estimates. The annual estimates from each location of the river can be used to calculate a percent loss (i.e. mortality) during the downstream drift of larval fish open lake habitats (Figure 1). By using a Bayesian hierarchical framework we can present our estimates in a distributional format explicitly displaying uncertainty.

![Figure 1. A graphic showing the longitudinal relationship between key locations (yellow circles) along the larval walleye drift to open lake habitats. Daily quantification allows for annual estimates of abundance and mortality within the Maumee River.](image)

The goals and products of this study support each cog of NOAA’s mission: science, service, and stewardship.

Quantification of larval walleye export from the Maumee River will help identify the stock’s role in lake-wide recruitment. Quantifying sources of in-river mortality can lead to the identification of significant anthropogenic contributors and support the need for protection and restoration of an important resource. Annual patterns in export and mortality can be correlated with environmental conditions leading to a better understanding of functional relationships and help predict impacts of a changing climate. This information will be shared with managers to promote the development of effective
management strategies, providing the sustained use of an important local resource. Additionally, we will share our results in a public format to educate resource users about basic walleye ecology and anthropogenic impacts.

**Accomplishments:**

We have developed a Bayesian hierarchical model to estimate daily and annual abundance of Maumee River larval walleye at distinct locations in the larval drift taking into account both spatial and temporal variability (Figure 2). The model has been applied to data from the years 2010 and 2011. Our results show that at times, there are highly aggregated spatial patterns in the walleye larval drift, with high concentrations near the thalwag. Densities of larval fish vary significantly on a daily basis and exhibit a distinct peak hatching period in early to mid-May. Because of the great temporal variability, confidence in annual estimates can be improved by increasing days sampled during a season. There is significant mortality occurring during the downstream transport of larval walleye, however power plant entrainment does not contribute substantially. And finally, export of larval walleye from the Maumee River can vary greatly on an annual basis.

The graduate student (DuFour) and U.T. PI (Mayer) have presented these results at eight venues. Future presentations will be given in public formats and at scientific conferences. This work will result in the MS thesis of DuFour. The authors will submit this work for publication in a scientific journal.

![Image of graphs showing daily and annual upstream walleye production.](image)

**Figure 2.** Model results of daily upstream production of larval walleye in 2011 including 95% credible interval values (top). The summation of daily estimates produces an annual upstream production estimate of larval walleye in 2011 (bottom).
Publications:


Presentations:


**Outreach Activities:**

**Community Groups**
M. DuFour gave a presentation at the Lake Erie Waterkeeper Conference at North Cape Yacht Club in La Salle, Michigan. The Lake Erie Waterkeepers strive to, “preserve, protect, and improve the watershed, waters, and fish of Lake Erie, the Great Lakes’ warmest, shallowest, most biologically productive waters, and to increase public awareness through collaboration, education and advocacy.” The presentation was designed to educate the general public and environmental interest groups about the impact of the Bay Shore power plant on larval fish communities in the Maumee River. A description of the initial design of this current project was provided during this presentation. We look forward to providing an updated presentation to the same group in 2012. We also provide the association president with copies of annual reports related to this project and post these reports on the Lake Erie Center website to facilitate public access: [http://www.utoledo.edu/nsm/lec/news/index.html](http://www.utoledo.edu/nsm/lec/news/index.html)

**Undergraduate and STEM Education**
C. Mayer presented an overview of this project to a meeting of SETGO students and faculty at Bowling Green University in March 2012. SETGO is a collaboration in which Bowling Green State University and Owens Community College partner with local community-based organizations to increase the number of students graduating with associates and bachelor’s degrees in the STEM fields. The talk was preceded by time for discussion with undergraduates about career paths in science in general.

C. Mayer presented overviews of this project at Departmental Colloquia at Case Western University and Wayne State University. These presentations were tailored to graduate and undergraduate audiences. Both of these schools are urban universities with diverse student populations.
PROJECT TITLE: IMPROVED UNDERSTANDING AND FORECASTING OF VIRAL AND BACTERIAL SOURCES AND TRANSPORT IN THE GREAT LAKES

University Principal Investigators: Allen Burton, CILER; Joan B. Rose and Phanikumar Mantha, Michigan State University

Overview and Objectives:

Our overall objectives were to address processes affecting human health issues in coastal areas (and in watersheds that contribute to these areas). Beach and watershed modeling continue to be the focus of our research and we have made further progress in both areas. The project addresses the following 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

Accomplishments:

Recognizing the need for better estimates of nutrient and bacterial loads to coastal areas, we have made significant progress in developing improved models for river and watershed-scale flow and transport models during the reporting period. Considering the fact that large areas of Michigan and other Great Lakes states have agricultural land use, we have improved model descriptions of vegetation processes by adding a crop model into our watershed model PAWS (Process-based Adaptive Watershed Simulator). This was accomplished by coupling the latest version of the NCAR Community Land Model (CLM) into PAWS. Model results for the Grand River and Saginaw Bay watersheds (the two largest watersheds in Michigan) based on this model were presented at the IAGLR meeting in 2011. Several papers based on our watershed models are currently in preparation for submission to peer-reviewed journals.

We continue to make progress in improving model descriptions of nearshore processes relevant to coastal water quality. During the reporting period graduate student Pramod Thupaki successfully defended his doctoral research. His research resulted in models for bacterial fate and transport taking sediment–bacteria interactions into account. He
presented some of his research at the IAGLR meeting in Duluth, MN and is currently working on several journal papers.

The Rose group has continued beach monitoring using the tool box approach and focused in on new methods for microbial fecal source tracking. Currently a paper on the research for Saginaw Bay has been prepared and will be submitted soon. Several publications on human sewage markers were published. The Rose laboratory also participated recently in the State of California Source Identification Pilot Project (SIPP) Method Evaluation Study. The results of the blind analyses found that the B. theta marker achieved sensitivity of 78% and a specificity of 96%. A paper is currently under preparation. During the reporting period graduate student Sangeetha Srinivasan, successfully defended her doctoral dissertation.

**Publications:**


Presentations:


4. M.S. Phanikumar (Invited): Linking Lakes and Watersheds: Application of Large-Scale Physically-Based Models to the Great Lakes Region. 03-29-2011. Modeling Symposium to Honor Prof. Catherine Kling from Iowa State University (Michigan State University Union, Parlor C)

5. Rose, JB. Invited Speaker: Overview—Molecular Diagnostics of Water Pollution, Beach 101, National Beach Conference USEPA, Miami FL, March 15-17.

Outreach Activities:

Dr. Mantha has been working with students at Williamston High School who developed a low cost rip-current alert system for deployment in coastal areas. Mantha presented results of this NOAA project to the high school students and offered to help them by sharing data and instruments in his lab. During the reporting period, Mantha worked with a student (Mr. Sina Yakshi-Tafti) from Kalamazoo College (Zoology Department) for two months during summer 2011. Sina and his faculty advisor at Kalamazoo were interested in understanding the dispersal of shoreline plant communities in Northern Lake Michigan. They used models in Mantha’s group to understand the complex relation between winds, currents and the dispersal of plant communities.
Dr. Rose has been presenting to a number of stakeholder groups about the overall goals of the water quality and health program:

Rose, JB. Sea Grant Advisory Board meeting: Invited presentation: Water Perturbations- Health Risk Research and Outreach Needs of Great Lakes Coastal Communities, Henry Center, MSU. April 15th:
Rose, J.B. The Spartan Insight Series, sponsored by the MSU Alumni Club of Mid MI. Feb. 16th, MSU. Michigan's Water Assets: The Threats to Water Quality and Our Health
Rose, J.B. Invited Lecturer: Water Quality in the State of Michigan, SOAR (Society of Active Retirees) Detroit, MI May 11.
Rose, J.B. Invited Speaker and panelist for Knight Center for Environmental Journalism Workshop for journalists, Beachfront News: Sewers, farms and water quality. MSU, E. Lansing MI, May 19th
Overview and Objectives:

Statistical models for beach closures rarely achieve a coefficient of determination ($R^2$) of 0.6 or above which means 40% of the variability is not explained by the models. The objective of this project is to develop accurate models for beach closures by (a) understanding the dominant processes impacting the fate and transport of fecal indicator bacteria (FIB) in the near-shore region and (b) developing hybrid models based on a combination of wavelet, neural-network and mechanistic models that can be used to predict beach bacteria levels accurately and in real-time.

The project addresses the following NOAA Strategic Plan Goals: (1) Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management; and 3) Serve society’s needs for weather and water information;

Accomplishments:

During this reporting period, we have published two papers in peer-reviewed journals and a third paper is currently in review. In one of the published papers, we explored in detail a fundamental mechanism that can explain the significant nighttime increase in *Escherichia coli* concentrations observed at many beaches in the Great Lakes region (e.g., Chicago 63rd Street beach). It is well-known that the ultraviolet (UV) component of solar radiation tends to decrease *E. coli* concentrations in nearshore water throughout a day; however, reasons for the nighttime increase in concentrations have never been fully understood, especially since nighttime resuscitation or regrowth of *E. coli* has not been unambiguously observed in nearshore Lake Michigan waters and laboratory rates for dark DNA repair were found to be extremely low. Understanding the reasons for this nighttime increase is important for developing water quality monitoring protocols and better predictive models. We found that a wave-induced mass transport mechanism can facilitate a significant base supply of material shoreward at night resulting in elevated concentrations in the morning. A model based on this mechanism was used to explain the observed nighttime increase at the Chicago 63rd street beach.

During the reporting period, we conducted a fundamental study (field experiments and modeling) of processes affecting bacterial fate and transport in
embayed beaches. Unlike open beaches which are characterized by a relatively high alongshore velocity component, embayed beaches have complex flow patterns and received little attention in the past. This study was published in the journal *Limnology and Oceanography*.

We have also made significant progress in developing and testing hybrid models for beaches in the Great Lakes region using a combination of wavelets and neural networks to make highly accurate \( R^2 > 0.6 \) short-term (up to 24 to 48 hours ahead of time) forecasts. Results based on this work are in review.

**Publications:**


**Presentations:**

None during the reporting period.

**Outreach Activities:**

We are working on a web page to showcase our hybrid modeling approach to the public and stakeholders interested in Great Lakes beaches. The datasets and models will also be made available to the public. The web page will be linked to the PI’s university web pages at [http://www.egr.msu.edu/~phani/research.html](http://www.egr.msu.edu/~phani/research.html).
Overview and Objectives

NOAA Strategic Plan Goal(s) the Project Addresses:

3) Serve society’s needs for weather and water information.

The Beach Water Quality Forecasting Coordinator role is best located in this NOAA Strategic Plan Goal.

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. CEGLHH hired a Beach Quality Forecasting Coordinator to coordinate ongoing efforts of CEGLHH and other agencies with the purpose of developing and implementing a generalized approach to beach quality nowcasting and forecasting.

Specific responsibilities for the Coordinator include:

1. Inventory and document ongoing activities related to beach quality forecasting, such as:
   - USGS Project SAFE
   - USGS Ohio beach nowcasting
   - Lake County Illinois Swimcast
   - Great Lakes Information Network Beachcast
   - NOAA/GLERL research on process-based beach quality modeling
   - EPA AMI bacterial exposure project

2. Develop a generalized process for beach quality nowcasting, forecasting, and product delivery. The process should include a protocol for identifying appropriate parameters to use as independent variables, gathering water quality records, obtaining the required independent variables, developing a statistical model relating water quality to the independent variables, implementing a
system for routine operation of the model in nowcast and forecast mode as well as dissemination to users, and evaluation of the accuracy of the system. The coordinator might not be the person carrying out all these activities, but would be responsible for coordinating the required activities, documenting the protocol, and ensuring that the protocol could be applied and sustained at any new beaches.

3. Work with EPA, USGS, NOAA, Sea Grant, appropriate state and local agencies, and the Great Lakes Beach Association to make sure that the end result is a product that will be useful for both nowcasting and forecasting of conditions at Great Lakes beaches. The product should also be transferable to other beaches and operationally sustainable.

4. In addition, the Coordinator will be expected to possess existing knowledge on methods for predicting recreational water quality at beaches and the processes needed to develop data sets capable of providing useful explanatory variables for model development.

Accomplishments

- Prepared Technical Report for NOAA documenting generalized process. Completed Forecast Decision Support Systems for 24 Beaches for Great Lakes Restoration Initiative Grant GL-00E00658 titled 60 Hour Beach Forecasting Models Grant (GL 00E00658-0). Prepared five Forecast Decision Support systems for five beaches in Michigan, (2 in Ottawa County, one in Bay County and two in Macomb County). The NWS Detroit Pontiac office in White Lake Michigan will be running a forecast test bed during the month of May and June. NOAA-GLERL is prepared to provide a backup test bed in the event severe weather prevents the NWS from performing these duties. Provided phase two scope of work for Lake Superior and Lake Ontario in the 2012 NOAA Beach Water Quality Forecasting Grant.

- Great Lakes Beach Health Interagency Coordination Team (BHICT) is now comprised of three members from USEPA, four from USGS, three from NOAA,
and one from CDC. Invited guests involved in pathogen studies routinely number five or more. Regular meetings have been held.

Membership:

USEPA: Holly Wirick, Frank Anscombe, and Dr. Richard Zepp
USGS: James Morris, Sandra Morrison, Norman Grannemann & Dr. Richard Whitman
NOAA: Richard Wagenmaker, Sonia Joseph Joshi, and Dr. David Schwab
CDC: Dr. Mark Johnson

Beach Quality Forecasting Coordinator: David Rockwell

Frank Anscombe<Anscombe.Frank@epa.gov>, Norman Grannemann <nggranne@usgs.gov>, Sonia Joseph Joshi <Sonia.Joseph@noaa.gov>, James Morris <jrmorris@usgs.gov>, David Schwab <David.Schwab@noaa.gov>, Richard Wagenmaker <Richard.Wagenmaker@noaa.gov>, Richard Whitman <rwhitman@usgs.gov>, Richard Zepp <Zepp.Richard@epa.gov>, Holly Wirick <Wirick.Holiday@epa.gov>, Sandra Morrison <smorrison@usgs.gov>, Mark Johnson <mdjohnson@cdc.gov>, David Rockwell <dcrockwe@umich.edu>,

• BHICT report to Great Lakes National Program Office, R2&R5. And Office of Water Quality Management Training Module on December 7, 2011 presenting QAPP developed by BHICT membership for use in GLRI Grants using Secondary (Existing) Data. QAPP format used by WDNR in GLRI Grant “Expanded Beach “Nowcast” Modeling across Wisconsin”, NOAA’s Develop Forecasting Predictive Models to Improve Coastal and Human Health and Beach Forecasting; and University of Michigan, CILER’s 60 Hour Beach Forecasting Models and in MDNR grants in the state of Michigan.

• Reported to Macomb County Health Officials the results of the forecast decision support systems for Memorial and Metro beaches on Dec 15 showing decreasing impact of the Clinton River on these beaches bacterial concentrations since 2009.

• LimnoTech briefed on Beach Water Quality Management Decision Support Systems for Forecasting the Probability of Exceeding E. coli Levels 11-10-2011
• Prepared Metro and Memorial Beach report for Dr. Shannon Briggs to use for 11-7-2011 MI Congressional Public Meeting on Beach Problems in Lake St. Clair.

Mission for Beach Health Interagency Coordination Team

a. Meet regularly to help coordinate Beach Health activities at the management level for the three federal agencies via video/phone conferencing and bi-annual face to face meetings.

b. Capitalize on the unique research capabilities of each agency in the Great Lakes region.

c. Utilize our individual resources more effectively and efficiently by understanding our programmatic goals, sharing tasks and capabilities whenever possible by identification of common geographical work areas and common research objectives.

d. Develop coordinated responses to emerging issues (e.g. Great Lakes Restoration Initiative) for Beach Health in the Great Lakes through communication with each other and our beach health partners.

• Developed BHICT information 2-pager November 2011

• Proposed in January 2012 two Sessions for the International Association for Great Lake Research. These sessions resulted in a full day on May 16, 2012.

  (1) “Beach Water Quality and Human Health” Chaired by David Rockwell and Sonia Joshi. This session drew 14 papers.
  (2) “Connecting the Dots” Chaired by James Morris drew 4 oral and two poster presentations.

• Implementation of the GLRI grant (GL 00E00658-0) 60 Hour Beach Forecasting Models. This grant represents a general process for forecasting beach water quality and product delivery.

  • Five MI beaches forecast models developed in 2011 for testing by the NWS in 2012. Prepared option for NOAA-GLERL using Kent Campbell’s
skills to provide a backup for the NWS in the event severe storms prevent NWS from providing these tests during the months of May and June 2012.

- Working with Computer Programmer to support GL 00E00658-0.
  - Completed 2010 forecast decision support systems for twenty four beaches. This resulted in over 84 different decision support equations.
  - Preparing technical report for NOAA and report for Grant GL-00E00658

**Publications** None

**Presentations**


USEPA Grant GL-00E00658
Grant Title “60 Hour Beach Forecasting Models”


CILER Grant F021307-059594
Grant Title “Beach Forecasting Coord.

*David C. Rockwell and *Holly Wirick*, Beach Health Interagency Coordination Team (BHICT). Presentation to the Regional Working Group the activities of the RWG Beach Subgroup, March 12, 2012

CILER Grant F021307-059594
Grant Title “Beach Forecasting Coord.

**Outreach Activities**

*David C. Rockwell and Dr. Dima Beletsky.* General Process of 120 Hour Beach Forecasting Models. CILER Presentation for NOAA Administrator Jane Lubchenco, Ann Arbor, Michigan, July 19, 2011
*Sander Robinson and David Rockwell. CILER Ad for SOLM and GLBA Conference, Michigan City, IN, September 26-28


PROJECT TITLE: AN INTEGRATED APPROACH TO MONITORING, FORECASTING, AND UNDERSTANDING HARMFUL ALGAL BLOOMS (HABS) IN THE GREAT LAKES

Principal Investigators:
Thomas Johengen - CILER, University of Michigan
David Millie – University of South Florida
Rick Rediske – Grand Valley State University
Mike McCormick – private consultant

NOAA Technical contacts:
Gary Fahnenstiel and Juli Dyble Bressie – NOAA GLERL

Overview and Objectives:
Harmful algal blooms (HABs) are a significant concern for ecosystem and human health in the Great Lakes. Blooms can reduce the aesthetic qualities of a water supply and cause complaints about taste and odor in drinking water; the decomposition of blooms can result in hypoxia or anoxia in the bottom water resulting in fish kills and benthic invertebrate mortality; and blooms can produce toxins that have direct detrimental impacts on human and animal health (Hawkins et al 1985, Teixera et al. 1993, Kuiper-Goodman et al. 1999). 

*Microcystis aeruginosa* is the dominant bloom-forming, toxic cyanobacterium occurring in the Great Lakes and has again become a dominant component of the summer phytoplankton in both Saginaw Bay and western Lake Erie. The toxin of highest concern in the Great Lakes is the hepatotoxin microcystin and recent studies have measured up to 5 µg/L intracellular microcystin (Dyble et al, 2008), exceeding the recommended limit for microcystin in drinking water (1 µg/L; World Health Organization 1998). Since the Great Lakes are such a highly utilized resource for both recreation and drinking water, the ability to predict the location of HAB blooms, especially in relation to drinking water intakes and recreational beaches, would allow protection of human and ecosystem health.

The most commonly used method for detecting HAB blooms is to do ship-based sampling on transects followed by microscopy-based detection methods (including cell counts). This process is time and resource intensive and the spatial and temporal frequency of sampling is generally not sufficient to provide timely warning about the presence of HAB bloom at a drinking water intake or recreational beach, thus potentially threatening human health. Thus, there is a significant need for a HAB forecasting system that can predict the presence of blooms at significant points of interest. Such an approach currently is utilized in the Lake Erie Harmful Algal Bloom
(LE HAB) Bulletin, whereby *Microcystis* blooms are depicted based upon spectral signatures as detected by the medium resolution imaging spectrometer (MERIS; Wynne et al. 2008). The LE HAB Bulletin then relies upon multi-day projections of select physical parameters (e.g. wind velocity/direction, water movement, etc.) to forecast passive bloom transport.

The main focus of this project is to validate and improve the preliminary Lake Erie HABs bulletin through a series of observations and modeling. Interactive environmental predictors and/or quantifiers for *Microcystis* abundance are not incorporated into Bulletin simulations and as a consequence, actual prediction for, and validation of *Microcystis* abundance is lacking. To improve on this deficiency routine data acquisition is being acquired of HAB measures (e.g. cell , toxin and pigment concentrations, etc.) and key environmental and meteorological variables (e.g., nutrients, light, temperature, wind speed, etc) . To determine the utility of and potential limitations for a *Microcystis* forecast ‘tool’ based upon remote-imagery data, the proposed work will relate existing field, or ground-truth data (supplied by NOAA-GLERL) to imagery-derived estimates of surface-dwelling cyanobacterial biomass. Specifically, computer-intensive, statistical models will be used to 1) delineate key endogenous and/or exogenous factors (e.g. hydrological/meteorological conditions, etc) corresponding to holistic *Microcystis* patterns; 2) develop models for visualizing and predicting remotely-derived *Microcystis* abundance in relation to dynamic environmental constraints; and in consultation with Dr. Stumpf and GLERL researchers, 3) identify knowledge and/or candidate models for integration into a ‘next generation’ Great Lakes HAB bulletin. Finally, forecasting the physical movement of a HAB depends upon the reliability of the time evolution of the forcing field, and its successful integration to an appropriate hydrodynamic model. The Great Lakes Forecasting System (GLFS), which is utilized in the LE HAB bulletin, has met with much success over a variety of applications. However, tracking the flow at the very surface or near surface such as with a HAB remains a challenge. To test the adequacy of a particle trajectory model for HAB application requires Lagrangian data on the surface waters. To meet this need we proposed to employ several surface drifting buoys that fix their GPS position at high frequency time intervals (approximately 1 minute). The drifters will be deployed during a HAB episode and the deployment location will be dictated in coordination with satellite imagery and logistical considerations.

This project addresses NOAA Strategic Plan Goal(s): (1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management, and (3) Serve society’s needs for weather and water information.
**Accomplishments:**

In 2011 the OHH/GLRI HABs program conducted another intensive field year in Lake Erie. The 2011 HAB bloom turned out to be one of the largest on record in terms of its spatial extent and duration. During this year several critical sampling projects were continued or initiated. Field sampling in western Lake Erie was conducted approximately once a month throughout the summer to support the HAB bulletin. Eleven surveys were conducted between June 21st and October 25th, 2011. The exact location and numbers of sites varied depending on the spatial extent of the HAB bloom based on remotely sensed data. In total, 110 samples were collected and analyzed for temperature, conductivity, light transmittance, kPAR, total phosphorous, total dissolved phosphorous, soluble reactive phosphorous, ammonium, nitrate-nitrite, silica, chloride, total suspended material, volatile suspended material, dissolved organic carbon, chlorophyll-α, particulate carbon and nitrogen, phytoplankton abundance and composition, phycocyanin fluorescence and concentration, microcystin, and photosynthetic capacity and yield. All laboratory analyses have been completed for the 2011 surveys and the data are presently being analyzed for inclusion in a series of 3-4 publications to describe the initiation and progression of the extensive 2011 bloom.

On July 16, 2011, the largest *Microcystis* bloom ever recorded in western Lake Erie was detected by NOAA through satellite imagery (Figure 1) and confirmed in the field on July 22 with measured toxin concentrations of about 1200 parts per billion (World Health Organization’s recommended guideline for recreational exposure is 20 ppb). The bloom grew and continued in intensity until late October. The size of the bloom encompassed 10% of the surface area of western Lake Erie. A major finding of the cell count data is the significant presence of a second toxin-producing cyanobacterium, *Anabaena*, during the latter phases of the bloom. The presence of *Anabaena* is of particular concern due to its ability to produce the neurotoxin anatoxin-a, which was not analyzed for in the 2011 samples.

A second field sampling effort involved a drifter experiment. Two pairs of drifters were deployed in the Western Basin of Lake Erie on 28 July and 23 August, of 2011 respectively (Figure 2). The tracks shown here represent the longest tracks with fewest lost positions. Data gaps were a more frequent occurrence this year due to the transmitter being swamped by waves as well as a couple of drifters being picked up by boaters. Several drifters were also released in Lake Michigan in July for preliminary trials to test shipboard data acquisition in anticipation of conducting dye/drifter studies in 2012. All tests were successful and further work is planned pending funding. Data analyses from the 2010 and 2011 drifter experiments are complete and a manuscript describing those results is in preparation.
Figure 1. MERIS satellite imagery of the initiation of a harmful algal bloom in western and central Lake Erie on July 16, 2011.

Figure 2. Drifter trajectories in western and central Lake Erie from 2011. The red tracks are from the 28 July and the black tracks are from the 23 August deployments. The green dots are the starting locations while the black dots represent the last good position.
A third new sampling effort involved the establishment of two fixed moorings in western Lake Erie located at the Channel Entry (Light #2) and at the Toledo Harbor Light. Both moorings were equipped with a WETLabs Cycle-P in-situ phosphate analyzer to provide continuous measurements of SRP along with a Turner Designs C6 fluorometer equipped with Chlorophyll, Phycocyanin, Phycoerythrin, CDOM and Turbidity sensors. Instruments were deployed between July 1 – October 13, 2012. Over 517 and 683 SRP analyses were completed at the two locations, respectively. These data are also contributing to the analysis of the limnological conditions present during the initial development and subsequent promotion of the HAB bloom.

To meet the needs of local public health and environmental managers on addressing the harmful algal bloom issue, the NOAA Center of Excellence for Great Lakes and Human Health developed a decision support tool, the Lake Erie Harmful Algal Bloom (HAB) Experimental Forecast Bulletin, for weekly distribution to local managers in Ohio and Michigan for water quality decision-making. The Forecast Bulletin features a map of the current Microcystis location based on analysis of satellite imagery, along with a three-day prediction of where the Microcystis bloom will move based on forecasts of winds and currents. Dissemination of the weekly Lake Erie Experimental HAB Forecast Bulletin began on June 15, 2011 and continued through the end of October 2011. Distribution of the Bulletin increased significantly throughout the summer with the number of subscribers at the start of the summer at 201 in June 2011 and to date there are 430 subscribers receiving the HABs bulletin each week. Compilation and evaluation of historical incidence of HABs in Lake Erie using MERIS and other satellite imagery is underway to assist in determining the validity of the sampling to the harmful algal bloom forecasts to determine when the Lake Erie Experimental Harmful Algal Bloom Forecast can be transitioned into operations. Evaluation of Lake Erie HAB bulletin forecasts and comparison analysis of field data to forecasts is now underway.

Publications:


Presentations:


Outreach Activities:

A number of groups toured GLERL, ranging from review teams to elementary students. Ashley Burtner served as lab host to these tours, spending about 15-20 minutes talking about projects, methods, or Great Lakes issues in general, depending on the interests of the groups. Harmful algal blooms and this project were frequently discussed.
Overview and Objectives:
Since the invasion of dreissenid (zebra) mussels, *Dreissena polymorpha* Pallas, into Saginaw Bay (Lake Huron, USA) during the early 1990s, annual, late-summer blooms of the cyanobacterium, *Microcystis*, have occurred. *Microcystis* comprises a significant proportion of the Bay’s late-summer phytoplankton assemblage and blooms are professed to threaten public health and the use of the Bay as a natural resource. Data-driven models based upon locally dependent environmental/biotic influences and projecting the spatial/temporal fields of *Microcystis* abundance are desirable tools from which to derive information for resource management and guide bloom mitigation efforts.

Although the environmental factors that singularly promote cyanobacterial proliferation generally are known, characterization and prediction of abundance distributions for *Microcystis* within the context of the holistic phytoplankton assemblage and environmental constraints are particularly challenging. Intuitively, modeling ‘success’ for *Microcystis* dynamics will be contingent upon initially capturing information regarding biotic-environmental relationships for a taxon that displays ‘patchy’ dispersions and then reproducing a heteroscedastic abundance distribution typically comprised of numerous instances where no or few cells are present and infrequent instances of significant cell accumulations.

Utilizing NOAA-GLERL’s 1990-1996 dataset addressing water quality and zebra mussel invasion, artificial neural networks (ANNs) were used to infer the intrinsic intra-/inter-annual variance (and magnitude) of chl a throughout Saginaw Bay. Similar attempts to model *Microcystis* initially generally were unsuccessful; ANNs consistently produced correlation ($r^2$) coefficients between modeled-measured biovolumes of less than 0.40. Approximately 53 percent of *Microcystis* biovolumes within the tested dataset were zero values; notably, the majority of non-zero values were of minimal biomass and only few instances of maximal biomass existed. Undoubtedly, the zero-inflated nature of a data distribution plagued with (large-value) outliers precluded successful reproduction of overall biomass patterns; network training focused upon the zero values (rather than the continuous portion of the data) and the insufficient number of ‘large values’ afforded inadequate data representation for training.
In this final year (Year 5) of the project, work has attempted to improve the use of neural network technologies for modeling the complex and stochastic interactions among environmental factors and cyanobacterial abundances within Saginaw Bay, Lake Huron.

This work supports NOAA’s Strategic Goals/Plans of: 1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management and 2) NOAA Mission support (‘Managing the Impact of Multiple Stressors in Saginaw Bay’, GLERL).

**Accomplishments:**

- An ANN was developed to model presence-absence (i.e. zero values or not) of *Microcystis* from environmental variables (1990-1996). The resulting network successfully classified *Microcystis* presence-absence in 96% (training/cross-validation data subset) and 83% (test data subset) of the cases. For the continuous portion of the dataset (i.e. biomass > 0), a predictive ANN utilizing environmental variables accounted for 95% and 89% of variability (training and test data sets, respectively) in biomass.

- Synthetic Minority Over-sampling Technique (or ‘SMOTE’) then was conducted within the continuous portion of the dataset to provide oversampling of the minority data class. SMOTE (essentially a re-sampling tool) randomly generated synthetic samples through interpolation between neighboring minority values (i.e. large biomass data) and randomly chose a new data point in between the minority pair. In this manner, the number of data points within the continuous portion of the data set became more ‘balanced’ with that of the ‘zero-inflated’ portion.

- For the SMOTE-enhanced dataset, ANNs were again developed and validated. The ANN modeling presence-absence of *Microcystis* similarly classified presence-absence as in the initial modeling attempt (97% and 83% for training/cross-validation and test data subsets, respectively). For the continuous portion of the dataset, a predictive ANN accounted for ca. 97 of variability (in both training and test data subsets) in biomass. Proxy variables for overall algal biomass (e.g. chlorophyll a) and physical conditions known to affect *Microcystis* accumulations in near-surface waters (e.g. irradiance, wind-speed) were denoted as principal predictors for the continuous data.

- An ANN-based ‘Grey Box’ model (see Millie et al. 2012, in review below) also was developed in an attempt to provide interpretable, multi-dimensional response surfaces depicting modeled environmental – phytoplankton biomass relationships, and from which, the environmental influences and interactions for algal biomass could be quantified (through the summation of the response-surface equations).
• Prepared and submitted manuscript (revision currently under review). Note: related manuscript utilizing technologies originally developed for Saginaw Bay project:


• ‘Data mining’ of environmental and phytoplankton relationships within the 2008-2010 dataset (supplied by C. Stow) has been initiated. In particular, decision tree analyses (utilizing the C4.5. algorithm) is being utilized to denote environmental influences (and theoretical concentration ‘break points’) upon algal biomass within Saginaw Bay (for 2008-2010).

**Publications:**


**Presentations:**


**Outreach Activities:**

Workshop: *Autonomous measurement and network modeling of water quality: Adaptive & Integrative Technologies to Govern Mitigation Strategies for Anthropogenic Stressors;* Florida Coastal Management Program (see presentations above, August, 2011). Note: although directed towards and intended for marine/estuarine research and management perspectives, Saginaw Bay data was presented and discussed.
CSCOR NGOMEX: THE EFFECTS AND IMPACTS OF HYPOXIA ON PRODUCTION POTENTIAL OF ECOLOGICALLY AND COMMERCIALLY IMPORTANT LIVING RESOURCES IN THE NORTHERN GULF OF MEXICO

Principal Investigators: Allen Burton and Aaron Adamack, CILER
NOAA Technical Leads: Doran Mason and Craig Stow (NOAA-GLERL)

Overview and Objectives:

To assess the full impact of hypoxia on living resources of the Northern Gulf of Mexico (NGOMEX) requires a multi-scale (both time and space) and multi-stressor approach. This project proposes a framework to simultaneously account for direct and indirect effects of hypoxia, including their linear and non-linear interactions on key organisms to support ecosystem-based management in the NGOMEX. A battery of modeling approaches of varying complexity (individual - to ecosystem-level), spatial configuration (near-field plume to fine-scale spatial pelagic to entire NGOMEX), and temporal duration (hourly to inter-annual) will be employed to provide both understanding and forecast capabilities to the management community of the NGOMEX.

Multiple models will be used to evaluate:
- What is the effect of the spatial extent and seasonal timing of hypoxia on fish growth, recruitment and production potential?
- How does hypoxia affect food web interactions in the pelagic zone? Specifically:
  - How will hypoxia affect the spatial distribution and predator-prey interactions of mobile organisms and zooplankton?
  - How does hypoxia affect habitat quality and suitability for economically and ecologically important fishes?
- How will management decisions on loadings affect fisheries through its impact on the timing and extent of hypoxia?
- What is the potential of strong wind events (and their relationship to climate change) to re-aerate the water column and alter the interactions of fish and their prey?
- What are the most effective tools to forecast food-web interactions, habitat suitability, and fish production in relation to hypoxia?

It is hypothesized that hypoxia in the NGOMEX can strongly impact pelagic food webs and production through unexpected, indirect pathways, potentially leading to changes
in production potential (both positive and negative) of economically and ecologically important fishes. Our overall goal is to provide quantitative tools to probabilistically forecast the effects of hypoxia on the living resources in the NGOMEX. Direct linkages to fisheries management will ensure continued interaction with, and attention to, the critical management issues.

Researchers from CILER have been focusing on developing an ecosystem-based model for the Louisiana-Texas continental shelf which will be used to evaluate most of the major questions being addressed by this project. CILER researchers have also been developing an individual-based model for fish eggs and larvae which will be used to screen species for susceptibility to hypoxia conditions in the Northern Gulf of Mexico.

This work addresses NOAA’s Strategic Plan Goals of “Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management” through our development of an ecosystem-based model for the Northern Gulf of Mexico.

**Accomplishments:**

Development of the ATLANTIS model (Figure 1) moved forward between July and November 2011, but has since slowed with Aaron Adamack leaving the University of Michigan for a new position at the University of Canberra.

During June through November, Adamack and Kim de Mutsert (George Mason University) worked together to develop a uniform set of functional groups for the ATLANTIS and Ecopath with Ecosim and Ecospace models that are being developed for the Louisiana-Texas continental shelf. As a part of this work, Adamack started work on setting the initial biomasses of functional groups and on setting the diet composition of function groups using Ecopath with Ecosim and Ecospace data from de Mutsert (Table 1). The focus for much of August through October was on the development of the model grid for the Atlantis model (Figure 2).

Doran Mason and Aaron Adamack attended a workshop on Atlantis model development in Seattle, Washington in early September. At that meeting, we discussed our modeling efforts with the developer of the Atlantis model, Beth Fulton and several U.S. researchers who are developing Atlantis models for other regions. One of the participants, Cameron Ainsworth (University of South Florida), is developing an Atlantis model for the Northern Gulf of Mexico. As our proposed model grid overlapped with his model grid, and with recent developments in the Atlantis modeling framework allowing for Atlantis models to be coupled with one another, we began coordinating our model development work with Ainsworth. Doing this will
allow us to link the two models more readily in the future, allowing Ainsworth’s Northern Gulf of Mexico model to force our Louisiana-Texas continental shelf model. As a part of working with Ainsworth, we have structured our model grid so that it aligns well with the Ainsworth’s grid. Additionally we have coordinated our functional groups with his functional groups to a limited extent.

During October, we developed a poster which was presented in the “Hypoxia Effects on Living Resources” session (co-chaired by Adamack) at the CERF conference in Daytona Beach, Florida (November 6-10, 2011). We also attended a project meeting for the NGOMEX project on the Sunday preceding the conference. Adamack spent the remainder of November concluding efforts and collating materials and files to be transferred to others following his departure.

Publications: None

Presentations:

Session organized and co-chaired by Adamack entitled “Hypoxia Effects on Living Resources” at the annual meeting of the Coastal and Estuarine Research Federation (CERF), November 6-10, 2012 at Daytona Beach, FL

Development of an Atlantis Ecosystem-Based Model for the Louisiana-Texas Continental Shelf. Adamack, Mason, DeMutsert, Ainsworth, and Drexler. the Coastal and Estuarine Research Federation (CERF), November 6-10, 2012 at Daytona Beach, FL (Poster)

Outreach Activities: None
Table 1. Functional groups by organism category included in the Atlantis model

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<thead>
<tr>
<th>Category</th>
<th>Functional groups/species</th>
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<tr>
<td>Areal invertebrates and primary producers</td>
<td>Benthic algae</td>
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<td>Benthic Shrimp</td>
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<td>Echinoderms</td>
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<td>Benthic crabs</td>
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<td>Benthic worms</td>
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<td>Snails</td>
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<td>Benthic weeds</td>
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<td>Clams/scallops</td>
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<td>Volumetric invertebrates and primary producers</td>
<td>Brown shrimp</td>
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<td>White Shrimp</td>
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<td>Other shrimp</td>
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<td>Jellyfish</td>
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<td>Phytoplankton (3 groups)</td>
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<td>Swimming crabs</td>
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<td>Calanoid copepods</td>
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<td>Squid</td>
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<td>Other snappers</td>
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Figure 1. Atlantis a 3D ecosystem model that considers all parts of marine ecosystems - biophysical, economic and social. It’s structure is made up of model components which include Hydrographic submodel (climate, ocean currents, temperature, nutrients), ecological submodel (food web), and human impacts (fisheries).
Figure 2. Model spatial grid for the northern Gulf of Mexico Atlantis model. Blue lines with numbers are depth contours at 10 m depth increments. Green/blue dots along the coast and brown dots in the water represent the edges of the hydrodynamic model. Olive green line near coast = 5 m depth contour. Pink line = 100 m depth contour. Orange line = 200 m depth contour. Green region is NGOMEX model grid region with black lines marking the edges of individual cells.
PROJECT TITLE:  MODELING GREAT LAKES ICE AND REVEALING LINKAGES BETWEEN LAKE ICE AND CLIMATE PATTERNS

Principal Investigators: Allen Burton, Haoguo Hu and Xuezhi Bai, CILER
NOAA Technical Contact: Jia Wang, GLERL

Overview and Objectives

Lake ice cover is an important predictor of regional climate. Lake ice extent also modifies the circulation patterns and thermal structure because: 1) wind stress drag is different in magnitude over the water surface than over the ice surface; 2) the albedo over ice vs. water differs, and 3) heat and moisture exchange between the atmosphere and the lake water can differ significantly (as much as an order of magnitude difference) in magnitude with and without lake ice, thus leading to a striking difference in evaporation in wintertime due to wind mixing.

The Great Lakes ice severity conditions are determined by surface air temperature (SAT), water temperature, heat flux, and water heat storage that is directly proportional to water depth. These factors are associated with global (hemispheric) and regional climate patterns, such as the Arctic Oscillation (AO) or the North Atlantic Oscillation (NAO), and Pacific-North America (PNA) pattern.

The Great Lakes are located at the edge of the Icelandic Low, far away from the action center. Thus, although being influenced by the Icelandic Low whose intensity is associated with AO/NAO (+/-AO means a stronger/weaker Icelandic Low), ice cover may not have a statistically significant relationship with AO/NAO. A similar doubt/hypothesis is also applied to the PNA pattern. Based on previous research (Wang et al. 1994; Mysak et al. 1996), the PNA pattern may have a marginally significant impact on ice cover in the Great Lakes, because the Great Lakes are located between the Alberta High and the SE-US Low.

The objective of this study is to use generalized statistical analyses of the NCEP/NCA reanalysis and climate GCM products and historical sea ice observations including recent satellite measurements to analyze the statistical relationship between lake ice cover and climate indices in both spatial and temporal spaces. A generalized relationship between lake ice cover, lake levels, and atmospheric circulation patterns will be concluded. The second objective is to develop and test an ice model of Lake Erie.
The NOAA Strategic Plan Goal(s) the Project Addresses include:

1) Understand climate variability and change to enhance society’s ability to plan and respond;
2) Serve society’s needs for weather and water information;
3) Support the nation’s commerce with information for safe, efficient, and environmentally sound transportation

**Accomplishments**

A coupled Great Lakes Ice-circulation Model (GLIM) of Lake Erie was developed based on POMGL and CIOM and tested during the 2003-2004 winter. Model results compared favorably with observations. A full-length paper was in press in the *Journal of Great Lakes Research*. Furthermore, a process study was conducted using GLIM to investigate the dynamic feature of lake ice along with measurements. This resulted in a paper submitted to the IAHR international conference proceedings.

We further investigated the impacts of ENSO and AO on Great Lakes ice cover using lake ice observations for winters 1963-2008 and NCEP reanalysis data to revise the previous submitted paper by Bai et al., which was published in JGR-Oceans. We also examined the unique ice feature in the 2008-09 ice season as a case study and published this AGU EOS featured article.

**Publications**


**Presentations**

**2011 (Invited):**

2011 (Oral):


Wang, J. Great Lakes Ice Research: Diagnosis and modeling. PPNW (Physical Processes in Natural Waters) Symposium, Burlington, July 11-14, 2011


2011 (Poster):


2012 (Oral):


Wang, J., Bai, X., Teleconnection patterns associated with severe and mild ice cover in the Great Lakes, IAGLR, Cornwall, Canada, May 14-17, 2012.

2012 (Poster):


**Outreach Activities:**

Many (~3 dozen) interviews regarding Great Lakes ice and regional climate change. In particular, recent national and international (Canada mainly) coverage and interviews of our recently published paper in *J. Climate*, entitled “Wang, J., X. Bai, H. Hu, A. Clites, M. Colton, and B. Lofgren, Temporal and spatial variability of Great Lakes ice cover, 1973-2010.” Two of the co-authors, Dr. Xuezhi Bai and Haoguo Hu, are from CILER. The medias’ coverage and interviews are listed as follows:


[http://www.abovetopsecret.com/forum/thread818277/pg1](http://www.abovetopsecret.com/forum/thread818277/pg1)


Video: [http://video.ca.msn.com/watch/video/vanishing-lake-ice/16atfg73d](http://video.ca.msn.com/watch/video/vanishing-lake-ice/16atfg73d)


Saudi Gazette:

**Overview and Objectives:**

This project’s main effort lies under the NOAA Strategic Goal: “Understand climate variability and change to enhance society’s ability to plan and respond.” However, it also has aspects relating to: “Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management.”

In order to give greater spatial detail to potential changes in climate than is afforded by global-scale climate modeling, and to ensure greater end-to-end consistency among the atmospheric, lake, and land components of the system and depict the interactions among these components, we are carrying out regional modeling activities. This involves simulation using current models with a simplified 1-dimensional treatment of lake dynamics and river flow treatment using some post-processing steps, and simultaneously taking steps toward developing a more integrated model. This will have the treatment of lake dynamics and ice formation and transport included, as well as a more complete integration of runoff into the modeling system.

All of these activities will contribute toward downscaling of the climate simulated by global models (dynamical downscaling). One of the particular aspects of this approach that have already been found to give value added relative to global models is the depiction of lake effect precipitation. Superimposed on a generalized increase in precipitation under higher greenhouse gas concentrations is intensification particularly over the lake effect zones, and particularly during the winter season. Greater accuracy in the physical modeling of ice processes and full coupling to the atmosphere should lead to greater confidence in this result.

**Accomplishments:**

A sub-contract was awarded to the University of Maryland for development of a Great Lakes regional implementation of the Climate Weather Research and Forecasting (CWRF) model. This effort is led by Prof. Xin-Zhong Liang, and assisted by Dr. Min Xu.
They have made progress toward development of this model, and Dr. Lofgren visited their lab and presented a seminar.

Additional climate scenario simulations have been carried out using CHARM (Coupled Hydrosphere-Atmosphere Research Model) at GLERL. As expected, these lead to higher temperature in air and water and reduced lake ice cover. They also lead to increased precipitation, particularly in the lake effect zones (generally on the land that is immediately south and east of each lake). The overall balance in changes of evapotranspiration from both lake and land surfaces vs. changes in precipitation, which is the basis for projecting changes in lake levels, has not yet been quantified.

Dr. Bennington ran the ICTP regional climate model (RegCM4) for the Great Lakes region, simulating historical time periods for the purpose of validation of the results. These simulations showed good agreement with observed temperature and precipitation, both in terms of the annual cycle and in terms of interannual variability.

Projections for the future using ICTP suggest that by the mid 21st century, Lake Superior will receive less water from its basin, while the lower lakes may actually have increased water supply from their watersheds. Analysis of inter-lake flows and lake levels will occur later. Dr. Bennington is working to improve the simulation of lake temperatures at deep lake points in the regional model.

A coupled Great Lakes Ice-circulation Model (GLIM) of Lake Erie was developed based on POMGL and CIOM and tested during the 2003-2004 winter. Model results compared favorably with observations.

A 5-lake hydrodynamic model has been implemented in the Great Lakes. A Lake Michigan ecosystem model has been incorporated into this system.

Analysis was carried out on historical trends in lake ice cover, leading to a publication. Teleconnection patterns associated with severe and mild ice cover on the Great Lakes have been revealed.

Joseph Smith, working with Drew Gronewold of GLERL, has prepared a prototype version of a Great Lakes water level data and forecast visualization tool. The tool fulfills user needs by building upon recent advancements in displaying time series data, such as those in NOAA’s climate dashboard and the WeatherSpark (weatherspark.com) page. The tool currently has a web-based, user-friendly and flexible display of monthly and annual average water level data for each of the Great Lakes. Near-term plans include incorporating longer-term (i.e. climate scale) water level forecasts, and historical data on major components of the Great Lakes water budget.
Publications:


Wang, J. and X. Bai, Atmospheric teleconnection patterns associated with severe and mild ice cover on the Great Lakes. (submitted)

Presentations:

Keynote Speaker:

Invited:

Oral:
Lofgren, B. M., and M. Perroud, Future regional climate scenarios and the importance of ice. International Association for Great Lakes Research Annual Conference, Duluth, MN, June 1, 2011.


Bai, X and J. Wang. Severe ice conditions in the Bohai Sea, China and mild ice conditions in the Great Lakes during the 2009/2010 winter: Links to El Niño and a strong negative Arctic Oscillation. IAGLR, Duluth, May 30-June 3, 2011.


Wang, J. Great Lakes Ice Research: Diagnosis and modeling. PPNW (Physical Processes in Natural Waters) Symposium, Burlington, ON, July 11-14, 2011


Bennington, V., and M. Notaro, Future Great Lakes water levels. Great Lakes Research Initiative Climate Project Coordination Meeting, November 2011, East Lansing, MI

Poster:

Bennington, V., and M. Notaro, How will the Laurentian Great Lakes respond to climate change?, American Geophysical Union Ocean Sciences Meeting, February 2012, Salt Lake City, UT.
Luo, L, and J. Wang. Modeling ecosystem in Lake Michigan, American Geophysical Union Ocean Science Meeting, Feb. 2012, Salt Lake City, UT.


Bennington, V., and M. Notaro, How will the Laurentian Great Lakes respond to climate change?, CCR/ SAGE Symposium, March 2012, UW-Madison, Madison, WI

**Outreach Activities:**

Lofgren had interviews with these media outlets:

Associated Press—over 40 pick-ups
Lake Orion Review
Wisconsin Public Radio
Milwaukee Public Radio
Interlochen Public Radio
Canadian Broadcasting Corporation
Sandusky Register

Wang and Bai had interviews with these media outlets:

Detroit Free Press
NBC News
MSNBC
Duluth News
KAAL TV (Austin, MN)
Abovetopsecret.com
Canadian Broadcasting Corporation

**Project Title:** Modeling Sea Ice-Ocean-Ecosystem Responses to Climate Changes in the Bering-Chukchi-Beaufort Seas with Data Assimilation of RUSALCA Measurements
Principal Investigators: Allen Burton, Haoguo Hu and Xuezhi Bai, CILER

NOAA Technical Contact: Jia Wang, GLERL

Overview and Objectives:

This project addresses 1), 2) and 3) of the following 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;

This proposed study is to use the combination of an IARC high-resolution (4-km) Coupled Ice-Ocean Model (CIOM, Wang et al. 2002, 2004, 2005; Wu et al. 2004) and Princeton Regional Ocean Forecast (and Hindcast) System’s (PROFS) data-assimilation methodologies to improve our understanding of ocean and sea ice circulation in the Bering-Chukchi-Beaufort (BCB) seas, driven by ocean tides, Alaska Stream (AS) and Alaska Coastal Current (ACC) inflow/outflow, freshwater discharge, and synoptic wind stress. We propose to implement the data assimilation approach based on PROFS to cover the Bering Sea, Chukchi Sea, and part of the Beaufort Sea. That will allow assimilations of existing and on-going hydrographic data and moorings across the Bering Strait in addition to those data in the Chukchi Sea and Bering Sea. Importantly, the PROFS’ Lagrangian assimilation scheme will also assimilate the Argo data (http://www.argo.ucsd.edu/). Particularly, the developed PROFS approach will allow CIOM to assimilate hydrographic data measured during the period (2007-2012) when the RUSALCA’s moorings will be deployed near the Bering Strait. A high-resolution coupled atmosphere-ice-ocean global climate model (from Japan) will provide the BCs to both CIOM and PROFS. Then, a series of sensitivity simulations with CIOM combined with PROFS will be conducted to examine in: 1) AS inflow 2) Response to a change in position of the Aleutian Low, 3) Both positive and negative phases of AO (Arctic Oscillation) and PDO (Pacific Decadal Oscillation) to identify the similarity and difference of the ice-ocean response to AO and PDO, and 4) Response to Arctic Dipole Anomaly (DA) to investigate the DA’s impact on SST, and sea ice concentration (retreat) in the Alaska Arctic water due to the enhanced Bering Inflow. In return, the modeling
results will be discussed with those PIs with RUSALCA field observation projects and an optimal sampling strategy will be designed for better coverage.

A 3-D, 9-compartment, Physical-Ecosystem Model (PhEcoM), coupled to CIOM, will be used to study the ice-ocean-ecosystem dynamics in the same region. The data from RUSALCA nutrient and plankton moorings will be used for conducting independent data analysis to also validate this model, and for assimilation by PROFS. This model will be used to test our proposed hypotheses: 1) North-south connection/advection of nutrients and planktons, 2) West-east seesaw of plankton blooms due to a change of location of the Aleutian Low, and 3) On-shelf nutrient supply by mesoscale eddies for sustainable “Green Belt” blooms. Therefore, this proposed study using PhEcoM-CIOM-PROFS 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 in the BCB seas, and 2) ice edge variability due to climate changes and the impacts on primary and secondary productivity.

**Accomplishments:**

1) Ran 3-D PhEcoM into the Bering-Chukchi-Beaufort seas and tested the capability of PhEcoM for modeling ice-ocean-ecosystem dynamics for the period 2007-2008.

2) Processed field measurements from R/V Oshoro-maru and from the BEST Project for both physical and ecosystem variables

3) Compared the model results with measurements and tested Hypotheses

4) Wrote a manuscript for submission to JGR

At the same time,

1) We have collected and processed SSMI-measured sea ice concentrations from 1990 to 2010.
2) Dr. Mizobata participated in IPY cruises via Oshoro-maru and Mirai in the Bering, Chukchi, and Beaufort seas in 2011, and obtained CTD and other datasets.

Publications:


Presentations:

2011 (Invited):

Wang, J. and Bai, Interannual and intraseasonal variability of Arctic DA and summer sea ice Minima. AGU Fall Meeting, San Francisco, Dec. 5-9, 2011.

2011 (Oral):


Wang, J. and X. Bai, Can we project future Arctic summer ice minima using DA index? IUGG, Melbourne, June 28-July 7, 2011.
2012 (Oral):

Wang, J., and H. Hu, Modeling sea ice and ecosystem in the Bering and Chukchi Seas. NOAA RUSALCA PIs Workshop, March 9-11, 2012, Miami, FL.

Wang, J. and Bai, Interannual and intraseasonal variability of Arctic DA and summer sea ice minima. IPY Conference, Montreal, Canada, April 23-27, 2012.

2012 (Poster):


Hu, H. and J. Wang, Modeling sea ice and ecosystem in the Bering and Chukchi Seas. IAGLR, Cornwall, Canada, May 14-17, 2012.

Outreach Activities:

Climate change has real and serious implications for communities that have for centuries lived along the arctic coasts.

Five requests for our AO and DA indices.

THEME II: INVASIVE SPECIES
CILER activities that fall under the theme of Invasive Species include research focusing on the prevention, monitoring, detection, and control of invasive species, and on a better understanding of the range of their ecosystem impacts.

PROJECT TITLE: **ENHANCEMENT OF THE NOAA GREAT LAKES AQUATIC NONINDIGENOUS SPECIES INFORMATION SYSTEM (GLANSIS)**
Overview and Objectives:

The Great Lakes have been heavily impacted by aquatic nonindigenous species (ANS) since the 1800s, and now over 180 ANS appear to be established here. A huge wealth of data is distributed among journals, gray literature, electronic literature sources, and online databases, making it unmanageable for any individual. Despite the regional importance of ANS, the Great Lakes were underrepresented in Internet-accessible databases. GLANSIS was created to provide a comprehensive, up-to-date, quality controlled, easily accessible on-line database of Great Lakes ANS. Among the goals of GLANSIS are to 1) provide a comprehensive source of authoritative up-to-date Great Lakes ANS information and 2) compile and update information relevant to the species in the database. The present version of GLANSIS does not include any information on potential invaders, nor does it include species such as the rusty crayfish that are considered native to part of the Great Lakes basin but invasive in others parts of the basin. GLANSIS includes a field for impacts, but the information in these fields has been inconsistent—sometimes including impacts only in the Great Lakes, sometimes impacts in other U.S. ecosystems, and sometimes potential impacts based on observations elsewhere in the world. Management-specific information describing regulations and recommendations for the prevention and/or control of invaders has also not been addressed by GLANSIS. Lastly, the current GLANSIS species profiles are highly technical, which limits their usefulness to non-technical stakeholders, such as students, regulators, and the general public.

The University of Michigan (CILER) proposes to work with NOAA (GLERL) scientists who oversee GLANSIS to 1) develop a prioritized list of potential high-risk invader species and compile associated fact sheets; 2) identify range expansion species and develop full profiles for addition to the system; 3) develop a simple screening tool to apply to all GLANSIS species for improved consistency of the database with respect to realized and potential impacts; 4) add a new field to species profiles for management information, including current regulations, best management practices, and control methodologies; 5) develop non-technical (public) fact sheets for each of the species in the GLANSIS database, in collaboration with the Great Lakes Sea Grant Network.

This project addresses the following NOAA Strategic Plan Goal:
1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management

- GLANSIS provides critical up-to-date information needed by decision makers for Great Lakes management.
- The distribution of many potential invaders and range expansion species in the Great Lakes is currently restricted by water temperature and over-wintering capabilities. The addition of fact sheets and distribution information about these species will allow for monitoring, detection, and rapid response to new invasion risks should the Great Lakes warm as projected by climate change predictions.
- The compilation of ANS regulations, best management practices, and control methodologies will enhance the value and usability of GLANSIS to the management stakeholder community.
- The addition of non-technical fact sheets will make GLANSIS information more available to public stakeholders.
- Ballast and biofouling of ships have historically been key vectors in the introduction of new ANS. GLANSIS profiles on species with a high probability of invasion if introduced to the Great Lakes, as well as standardized organism impact assessments, will provide critical information on potential vectors of introduction. These vectors include those involving recreational boating and commercial shipping practices.

Accomplishments:

Objective 1: Develop a prioritized list of potential high-risk invader species and compile associated fact sheets

A list of 53 watchlist species was developed prior to this reporting period. Over the course of her 12-week appointment, CILER summer student Gabriela Núñez conducted a thorough review of domestic and international invasive species risk assessments and primary literature to develop Great Lakes specific tools for evaluating the introduction and establishment potential of these high-risk aquatic invaders. These tools were reviewed by members of the GLANSIS Expert Review Panel following implementation trials with four watchlist species spanning taxonomic groups and pathways (a fish introduced to the US through the live food trade, a crustacean capable of cross-oceanic transport in ballast, a parasite infecting native birds and introduced snails in the upper Midwest, and a plant popular in the water garden trade). In total, fact sheets and/or assessments for 15 watchlist species have been drafted.
Recent USGS Nonindigenous Aquatic Species (NAS) programming has laid the foundation for querying watchlist species fact sheets through GLANSIS once they are imported to the system.

A 2012 CILER GLANSIS returning student (Kyle Dettloff) will continue to assess additional watchlist species and compile their fact sheets with the GLANSIS research associate (Abigail Fusaro).

**Objective 2: Identify range expansion species and develop full profiles for addition to the system**

During his 2011 CILER Summer Fellowship, Kyle Dettloff contributed to eight of the previously developed list of 12 range expansion species technical fact sheets. These fact sheets included assessments of the species' realized and potential impacts. Completion of the remaining fact sheets is underway by the GLANSIS research associate.

**Objective 3: Develop a simple screening tool to apply to all GLANSIS species for improved consistency of the database with respect to realized and potential impacts**

During her 15 months as a CILER student, Julie Larson (now a graduate student studying invasive plants at Oregon State University) developed and applied a standardized organism impact assessment (OIA) to more than 80 species. Last summer, Julie also prepared a NOAA technical report summarizing the assessment tool and the results of her species assessments. Since last reported, all OIAs were reviewed and approved by the GLANSIS Expert Review Panel, and the impact assessment narratives were posted on GLANSIS.

CILER student Lauren Berent currently is working to assess plant impacts. Of the remaining taxa, 11 plant assessments are drafted (some by J. Larson), leaving 94 plant, algae, parasite, and pathogen taxa left to complete. A 2012 CILER GLANSIS summer fellow and/or student hire (L. Berent) will continue to assess additional established species with the GLANSIS research associate.

**Objective 4: Compile and synthesize available management information on each GLANSIS species for inclusion on species fact sheets**
A new section for management information was added to species fact sheets over the last year, but it has yet to be completed. Regulations and control methods were determined for two new GLANSIS species additions—the common reed and the red swamp crayfish. Additionally, CILER student Lauren Berent is working to compile plant management information from a variety of sources, including government agency websites and scientific journal articles. A 2012 CILER GLANSIS summer fellow and/or student hire may continue to compile the remaining management information with the GLANSIS research associate.

**Objective 5: Develop non-technical (public) fact sheets for each of the species in the GLANSIS database, in collaboration with the Great Lakes Sea Grant Network**

Illinois-Indiana Sea Grant (IISG) has finalized 15 of 50 non-technical fact sheets on GLANSIS species for the general public. This first batch is expected to be released online in the next several weeks, with completion by June 2012.

**Publications:** None.

**Presentations:**


**Outreach Activities:**

**Presentations:**


Sturtevant, R.A. 2011. Outreach to Great Lakes Panel on ANS at their semi-annual meetings via member updates, committee meetings, and discussion.

Reports:

PA, 26-27 October 2011. (Final indicator report will be included in the State of the Great Lakes 2012 technical report)

Overview and Objectives:

This research project monitors trends in benthic macroinvertebrate populations in Lakes Michigan and Huron. Changes in the abundance and composition of benthic populations provide a measure of environmental response to anthropogenic influences such as nutrient enrichment and invasive species. Specific objectives are thus to determine and assess changes in benthic populations over the long term.

These objectives fit the goals of NOAA’s strategic plan to protect, restore, and manage use of coastal and ocean resources through ecosystem-based management.

For instance, the project tracks spatial and temporal trends in the invasive mussels *Dreissena polymorpha* (zebra mussel) and *Dreissena rostriformis bugensis*. These two species have caused broad changes in ecosystems of the Great Lakes, and have motivated a re-assessment of management strategies. In Lake Michigan, the original program was initiated in 1980 at 40 sites in the southern basin of the lake, and samples have been collected at these same sites for two consecutive years every five years since. Because population changes in some taxa (i.e., zebra mussel, quagga mussel, and the native amphipod *Diporeia*) were occurring so rapidly in the late 1990s, the monitoring program was expanded in 1998 and samples are now collected every year at these 40 sites. To determine trends in dreissenids and *Diporeia* over the entire lake, samples were collected in late summer at 160 sites located throughout the lake in 1995, 2000, 2005, and 2010. In Lake Huron, samples were collected at 75 sites in the main basin in 2000, 2003, and 2007, and at 30 sites in Georgian Bay and North Channel in 2002 and 2007. Extensive sampling was also conducted in Saginaw Bay in 2007, 2008, and 2009. We collected samples at the same sites sampled in 1991-1996 to determine trends in the total benthic community. Samples were collected with the Ponar grab to assess changes in the total benthic community and also with divers to assess changes in the dreissenid population on hard substrates.
Efforts during this reporting period focused on processing samples (counting, sorting organisms) and collecting new samples as part of the study design. In August 2010, samples were collected at 130 sites located throughout Lake Michigan, and in this reporting period all organisms in these samples were counted, sorted, and abundances determined. In addition, samples were collected at 40 sites in the southern basin of Lake Michigan in August 2011. In this reporting period, approximately one-half of these samples have been processed. When completed, abundances of quagga mussels and Diporeia in 2011 will be compared to abundances found in previous years and long-term trends determined. These mussels are now the dominant benthic taxa in the lake and their great filtering capacity has caused broad ecosystem changes. Quagga mussel abundances appear to be decreasing at sites in the 31-50 m-interval, or stopped increasing at sites in the 51-90 m interval. However, abundances are still increasing at > 90 m, whereas abundances at 16-30 m are too variable to evaluate trends. The plan is to continue processing the rest of the samples collected in August 2010 to determine if trends noted in the southern basin are also occurring in the central and northern basins.

In Saginaw Bay, samples of dreissenid mussels collected in 2010 were processed; that is, all mussels were counted and size-frequencies determined. The latter will be used to estimate biomass.

**Publications:** None

**Presentations:**


**Outreach Activities:**


**Project Title:** Status of macroinvertebrates in Lake Ontario and Muskegon Lake
Overview and Objectives:

Lake Ontario

Watkins et al. (2007) documents from 1990 to 2003 that invasive dreissenids mussels have extended their distribution from 38 m in 1995 to 174 m in 2003 and reached densities averaging 8,000/m² at all sites < 90 m. During the same period, *Diporeia* populations have almost disappeared at depths < 90 m. At depths between 31-90 m, average densities of *Diporeia* have declined from 1,380/m² to 63/m² from 1997 to 2003. At deeper depths (>90 m), average densities have declined from 2,182/m² to 545/m² between 1999 and 2003.

The objective of this project is to document the results of the LOLA 2008/2009 Lake Ontario benthic invertebrate survey. We show the lake-wide replacement of a native species, (*Diporeia*) by an invasive mussel (*Dreissena rostiformis bugensis*) from 1994 to 2008. Prior to the introduction and spread of two dreissenid species, *Dreissena polymorpha* and *D. r. bugensis*, *Diporeia* was the dominant benthic organism in deeper waters (>20m) of Lake Ontario.

Muskegon Lake

Muskegon Lake is a 16.8 km² drowned river mouth lake located in western Michigan. In 1987, the lake was listed as an Area of Concern (AOC) by the Environmental Protection Agency because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Degradation of Benthos, was listed because of impacts to species diversity from the discharge of municipal sewage and sediment toxicity related to heavy metals and organic chemicals. Evans (1976) showed that pollution tolerant oligochaete worms comprised 89% of the total benthic population, chironomid numbers were low (< 200/m²), and species diversity was only 0.68 (Shannon Weaver). Improvements were seen after municipal and industrial wastewater to Muskegon Lake was eliminated by the construction of an advanced tertiary treatment facility in 1974.

There are three major objectives for the benthic monitoring program in Muskegon Lake.

1. Establish baseline information on the benthic community
a. The objectives included re-sampling the historical, lake-wide sites sampled by Carter and Rediske. Sampling would continue 2-3 years to establish year to year variability in community structure and composition.
b. Establish a yearly monitoring of benthic community at areas adjacent to restoration work.

2. Develop a robust method for classifying sediments for assisting in selection of baseline monitoring sites and to map improvements of lakebeds after restoration efforts are begun.

In an effort to understand the role of sediment in the restoration of Muskegon Lake, lakebed classification will be performed along with the collection of over three hundred sediment samples over three years. Acoustic systems are the natural solution to mapping areas where the lakebed is not visible from overhead imagery. The advantages of single-beam systems include relatively low costs, low data volumes, and easy portability.

Lakebed classification is the organization of lakebeds into discrete units based on characteristics of acoustic responses generated by a sounder. The echo signal shape is a measurement of the acoustic energy redirected to the echo sounder transducer. The signal shape is influenced by seabed characteristics – physical properties of the surface material or immediate lakebed subsurface. The acoustic response represents an average volume of material, the size of which is a function of the transducer beam width and the frequency of the transmitted pulse.

Once the acoustic clusters have been labeled, they will be quantitatively compared with "ground truth" data. The ground truth datasets acquired at each site will be independent of the qualitative observations used for cluster labeling.

Accomplishments:

Lake Ontario

Completed report for EPA on the Status of Lake Ontario Benthos.

Abstract:
The benthic macroinvertebrate community of Lake Ontario continues to change
in nearshore and offshore areas. In 2008, *Diporeia* is very rare throughout the lake at all depths. There were only four of 52 locations where the densities were greater than 100 per m\(^{-2}\). The maximum density of *Diporeia* in 1994 and 2008 was 13,280 per m\(^{-2}\) and 248 per m\(^{-2}\), respectively. *Dreissena* continues to be an important member of the benthic macroinvertebrate community. *Dreissena* is more abundant in deeper waters (greater than 90 m) in 2008 compared to 2003 but lake-wide density appears to be declining in sediments less than 90 meters between 2003 and 2008. Fingernail clams (*Sphaeridae*) are less abundant between 1994 and 2008 while worms (*Oligochaeta*), and midge larva (*Chironomidae*) densities remain constant.

**Muskegon Lake**

**Benthos**

- Design: Collect macroinvertebrates at 27 historical sites, 9 targeted sites adjacent to Habitat Restoration Sites, and three control sites (total of 39 stations). At each site take triplicate PONAR samples. Repeated for three consecutive years, 2009-2011.
- All 351 PONAR samples were collected.
- For 2009 and 2010 macroinvertebrates were counted. Specimens of Chironomids and *Oligochaeta* were to be mounted on slides and shipped to a contractor for identification. All other invertebrates were identified to lowest taxonomic level.
- Counts of macroinvertebrates from 2011 will be completed by June 2012.
- Worms and midges are identified and counted for 2009. For samples collected in 2010, the contractors will finish with ID and counts of worms and midges by August 30, 2012. Slides for 2011 will be sent to the contractor by June 15, 2012. Identification and counts will be completed by October 2012.
- Final report will be done by December 31, 2012.

**Sediment Survey**

- The acoustic survey was completed in August and November of 2011 with 200 kHz sounder.
  - MIL, CILER, and LMFS survey majority of lake bed greater than 1 m depth (Figure 1)
  - Post-processing completed by December 2011
  - Sediment classification completed December 2011
- Field plans for June and July 2012
  - Attempt to extend sediment survey into shallow areas
- Conduct supplement survey using 50 kHz sounder
- Ground truth acoustic classes with drop camera and sediment cores
- Analyze sediments for grain size and TOC

**Publications:** None

**Presentations:** Stephen Lozano. 2011. Status of Benthic Community in Lake Ontario. IAGLR 2011

**Outreach Activities:** None
**Overview and Objectives:**

**Overview:** This project will assess the current status of the primary producer community, pelagic crustacean community and associated environmental variables in southern Lake Michigan. Data from this project will ultimately be used in food-web models to evaluate how non-indigenous invertebrates have altered the lower food-web structure and to predict production of various components of the food-web of particular interest to resource managers, e.g. forage fish production, recruitment, condition, and growth.

The project addresses the NOAA Strategic Plan Goal to “Protect, restore, and manage use of coastal and ocean resources through ecosystem based management.”

**Objectives:**
1) Evaluate the primary producer community within the water column at the sampling stations as well as the important environmental variables driving the primary producers.  
2) Evaluate the status of pelagic crustaceans, including zooplankton, *Mysis relicta*, *Hemimysis anomala*, *Bythotrehes longimanus*, *Cercopagis pengoi*, at sites in southern Lake Michigan.  
3) Compare data to historical data collected from the same region since the 1980s.  
4) Compare data to that collected by USGS partners at northern Lake Michigan sites in 2010.  
5) Begin integrating data into food-web model analyses.

**Accomplishments:**
Field sampling was done biweekly for nutrients/primary producers and monthly for zooplankton and *Mysis* during April-December 2011. Most samples have been processed and enumerated in the laboratory and compiled into appropriate databases. A number of important observations were made, including:

1) Chlorophyll levels remain low during spring relative to historical levels found in the 1980s and 1990s. These pronounced changes in water column properties
during the isothermal period in 2007-2010 were primarily attributed to the filtering activities of the quagga mussel (*Dreissena rostriformis bugensis*) and to a lesser extent to phosphorus load reductions.

2) The summer deep chlorophyll layer is greatly reduced compared to levels in the 1980s and 1990s.

3) Cyclopoid copepod numbers appeared to increase in 2011 relative to previous years (2007-2009). The reason for this unexpected change is unknown. Cyclopoid copepods are an important food source for fish especially during spring.

4) *Mysis* abundance has been stable over the past five years, but remains lower than in the 1990s. *Mysis* lipid content suggests animals may be facing starvation conditions. *Mysis* are the key macroinvertebrate in the food web following the loss of *Diporeia*.

5) In Lake Michigan, energy densities of deepwater sculpin in 2001 were similar to those reported in 1969-71. In contrast, energy content declined at least 26% at Muskegon between 2001 and 2009. Overall, energy density was 31-34% higher at a site with abundant *Diporeia* spp. compared with two sites without *Diporeia* spp.

**Publications:**


Presentations:

RUTHERFORD, E.S., H.A. *VANDERPLOEG, A. HOOVER, J.F. CAVALETTO, J.
LIEBIG, S.A. POTHOVEN, D.M. MASON, P. Bourdeau, and S. Peacor. Fish recruitment
dynamics in the newly-illuminated, spatially-complex food web of Lake Michigan. 54th
Annual Meeting of the International Association for Great Lakes Research, Duluth, MN,

VANDERPLOEG, H.A., S.A. POTHOVEN, G.L. FAHNENSTIEL, E.S. RUTHERFORD,
J.F. CAVALETTO, J. LIEBIG, C.A. STOW, T.F. NALEPA, C.P. Madenjian, D.B. Bunnell,
illuminated, spatially complex food web of Lake Michigan. 54th Annual Meeting of the

Outreach Activities:

1) Inland Seas invasive species field course faculty seminar “Aquatic invasive species and
recent food web disruptions in the Great Lakes” 6/27/11

2) Hope College lecture (10/24/11)

3) Pack 4027 Cub Scouts, Fruitport MI (1/12/12)

4) Beach elementary school Fruitport, MI (2/9/12)

5) Pothoven, S. Lower trophic food web update. Lake Michigan Technical Committee
winter meeting, Chesterton, IN. Jan. 24, 2012.

6) Pothoven, S. Status of Lake Michigan lower trophic food web. Lake Michigan
Committee, Lake Committee Meetings, Great Lakes Fishery Commission, Windsor, ON,
Over view and Objectives:

The project focuses on assessing the risk of Asian carp invasion and its potential impacts on the Great Lakes food webs and fisheries. Asian carps, specifically the bighead (Hypophthalmichthys nobilis) and silver (H. molitrix) carps, threaten to disrupt aquatic ecosystems through their consumption of lower trophic levels. They have the potential to cause shifts in species composition and relative abundances resulting in algal blooms. In river and lake ecosystems in North America, Asia, and Europe, the introductions of Asian carps have led to the decline of many native fish species, particularly those that feed on zooplankton and phytoplankton.

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 that 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.

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 vary substantially throughout the water column and across space and time. Using a single set of numbers to represent environmental conditions at a location can 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) that may result in compensatory mechanisms by which native Great Lake species can coexist with Asian carp.

**Our overall goals** are to 1) assess the ability of bighead and silver carps to survive and grow (using ambient plankton and benthos prey densities) in Lakes Michigan, Huron, and Erie; and 2) determine the potential impacts of Asian carps on population dynamics and biomass of important native and state-managed fishes. To achieve these goals, we propose using two bioenergetics based modeling frameworks: the first is an individual-based model of Asian carps and selected key species in near shore and off shore environments; the second is a spatially-explicit model of Asian carps impacts on food webs in near shore and open lake habitats of Lakes Erie, Huron and Michigan. For both model types, selected key fish species of near shore environments include: walleye, yellow perch, alewife, gizzard shad, and emerald shiner; selected key fish species of offshore environments include: lake trout, lake whitefish, rainbow smelt, Chinook salmon, deepwater sculpin and bloater. To complement our work, we propose to translate several papers on Asian carps from the Chinese literature into English in order to make them available for our models and to other U.S. scientists.

**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.
This project addresses the NOAA Strategic Plan Goal - protect, restore, and manage use of coastal and ocean resources through ecosystem-based management. This project also addresses a CILER Goal – to improve forecasts that facilitate restoration and protection of critical natural resources, help guide management decisions, and support sustainable economic development in the region.

**Accomplishments:**
Drs. Hongyan Zhang (on the Atlantis model) and Lori Ivan (on multi-species IBM model) both began work on the project starting Jan. 1, 2012. The project team meets every 2 weeks to review progress and suggest course corrections where necessary. Below is an overview of progress on both models.

**A Multi-species, Individual Based Model of Asian Carp Impacts on Great Lakes Food Webs**

**Objectives 1, 2:** To estimate the minimum population size required for the establishment of silver and bighead carps in the Great Lakes, as well as the potential impacts these two species would have on the Great Lakes fish community, we are developing a multispecies, spatially-explicit, individual-based bioenergetics model for nearshore and offshore habitats and food webs of lakes Erie, Michigan and Huron. Currently, we are focusing our efforts on modeling dynamics in Saginaw Bay Lake Huron, and will expand to offshore Lake Huron and the remaining lakes in the future.

1) **Personnel Changes:** Dr. Lori Ivan was hired to replace Dr. Adamack to develop the multi-species IBM of Asian carp impacts, and began work Jan. 1, 2012. In her postdoctorate fellowship at Purdue University, Dr. Ivan completed a 2-species IBM of age-0 walleye and yellow perch dynamics in Saginaw Bay, Lake Huron, and a dynamic factor analysis of the Saginaw Bay food web. Lori got her Ph.D at the University of Michigan School of Natural Resources and Environment, studying ecosystem effects of salmonids spawning in Great Lakes tributaries.

2) **Model Progress:** We have obtained model parameters from a variety of sources for the species groups from either the peer-reviewed literature or unpublished data sources. We now have most of the parameter values required for the model, and currently are working to obtain the remaining values. The IBM is based on a model previously developed by Dr. Shaye Sable (now at Dynamic Solutions, LLC) and Kenneth Rose at Louisiana State University to simulate dynamics of
marsh biota under scenarios of sea level rise. We are modifying Sable’s code to simulate carp impacts on Great Lakes nearshore and offshore communities, and to increase running speed.

3) Future work: By July 1, 2012, we will have finished configuring the IBM model for Saginaw Bay, Lake Huron, and run Asian carp simulation experiments to determine the likelihood and potential impacts of Asian carp establishment. We will present preliminary simulation results to program managers (i.e. M. Hoff) at the IAGLR meeting in June, and formally at the 2012 AFS meeting (abstract submitted).

The Atlantis Ecosystem Model of Asian carp Impacts on Great Lakes Food Webs

Objective 2: To forecast the potential impacts of Asian carps on Great Lakes food webs, and on the production, recruitment and harvest of key prey and predator fish species.

We have chosen to develop the Atlantis modeling approach for Lake Michigan first, and have made progress in the following areas:

1) Model configuration: defining the model domain is one of the first steps for the Atlantis model. We have been working with the Great Lake GIS folks at the University of Michigan Institute for Fisheries Research to define the model spatial resolution (referred as ‘box map’ hereafter). The box map draft is currently under revision based on criteria including 30m isobaths, water temperature, spring warming rate, substrate, current, fetch, light and Chl. a (not available yet), etc.

2) Model groups: We have 46 model groups/species, including 3 phytoplankton, 8 zooplankton, 4 benthos, 2 benthic algae, 3 detritus, 19 fish, and 7 nutrient groups. Model groups might change slightly later on after further review and discussion.

3) Data collection: We have been collecting and compiling data including nutrient loads, water temperature, light, currents, and biological data (biomass, abundance or density of model groups, size-at-age information, diets, growth rates, spawning times, habitat preferences, etc.). Data sources include published literature, federal and state agencies, unpublished data and model output (e.g., Ecopath with Ecosim model).

4) Communications: Communications with the model developer, Dr. Beth Fulton at CSIRO, Australia have been frequent and smooth. We are scheduling Skype
meetings and arranging for Bec Gorton, a computer programmer from Beth’s lab, to train us on the model. We have a bi-weekly meeting among PIs at GLERL.

5) Our poster abstract on this project to IAGLR 2012 has been accepted, and we just submitted an oral presentation to AFS 2012.

6) Beletsky’s progress: 1. Provided Lacey with lat/long of Lake Michigan model grid for GIS; 2. Updated the hydrodynamic model code to base it on the most recent version of the Princeton Ocean Model; 3. Will proceed with extraction of currents and temperature data from the hydrodynamic model output when the Atlantis model grid is finalized.

Objective 3. Survey the Chinese literature for relevant information on Asian carps’ energetic, vital rates and ecology.

1) Zhang continues to survey the Chinese literature for relevant information on Asian carps.

Publications: None.

Presentations:


Outreach Activities:

Ed Rutherford attended the Binational Asian Carp Risk Assessment for the Great Lakes Scientists in Chicago, May 11-12, 2011, and presented an update on this project.
Overview and Objectives:

American shad (Alosa sapidissima) (hereafter shad) are an anadromous clupeid fish native to the Atlantic coast of North America that were introduced to the Sacramento River in 1871. Since that time they have dispersed along the Pacific coast and have been reported from Baja Mexico to Russia. Shad have been reported from several rivers along the Pacific coast that constitute critical habitat for one or more native salmon conservation units, several of which are federally listed as threatened or endangered. Although the impacts of this non-native planktivore on Pacific coastal ecosystems is uncertain, shad may alter trophic community structure and negatively impact native Pacific salmon species.

There are three objectives to this research:

1) Resolve the distribution and relative abundance of self-sustaining shad spawning runs among Pacific coastal rivers, and identify the source population of migrants for the colonization of additional drainages;

2) Identify habitats susceptible to shad colonization and the potential for range expansion under climate change scenarios, and predict the timelines for invasion of specific rivers;

3) Characterize the life history variation exhibited by non-indigenous shad.

This research will aid NOAA in achieving its mission by resolving the invasion risk posed by non-indigenous shad to the long term persistence and economic viability of native Pacific salmons, and it addresses the following NOAA Strategic Plan Goals:
i) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;
ii) Understand climate variability and change to enhance society’s ability to plan and respond.

**Accomplishments:**

Collections of shad (N=1026) were obtained from multiple rivers across the species' introduced range, including the Sacramento, Russian, Klamath, Rogue, Umpqua, Columbia, and Snake rivers, as well as Millerton Lake, South Ten Mile Lake, and Lake Washington. These collections included spawning adults, emigrating juveniles, and 'mini-shad' (a life history variant exhibiting extended freshwater residency). All collected specimens have been processed, and biological materials have been collected for molecular analyses, examination of age structure/distribution, degree of iteroparity, examination of isotopic signatures, and geometric morphometrics.

Collection of data for examining relative trophic structure (isotopic signatures) is complete, and preliminary analyses are about to commence. Molecular work (microsatellite genotyping) is ongoing, but much of the data (~80%) has already been collected. Data for shad age structure and parity are being collected.

Multiple oral presentations on invasive shad have been given to various interest groups in the Pacific Northwest to raise awareness about shad in the region. This includes the 'Invasive American Shad' symposium at the 141st American Fisheries Society Annual Meeting entitled: 'American shad of the Pacific coast: a benign introduction or harmful invasive species?'

Multiple publications are now in various stages of completion (recently published, in press, in review, or in preparation) (See below.).

**Publications:**


Presentations:

Hasselman, D.J. 2011 (Jan. 12). From founding fish to invasive species: contrasting views of American shad in their native and introduced range. NOAA Monster Jam Seminar Series, Northwest Fisheries Science Center, Seattle, WA. Support: NOAA/CILER; Grant number: NA07OAR4320006

Hasselman, D.J. 2011 (Dec. 15). From founding fish to invasive species: contrasting views of American shad in their native and introduced range. Washington Department of Fish and Wildlife, Olympia, WA. Support: NOAA/CILER; Grant number: NA07OAR4320006

Hasselman, D.J. 2011 (Dec. 1). From founding fish to invasive species: contrasting views of American shad in their native and introduced range. School of Aquatic and Fishery Sciences Seminar Series, University of Washington, Seattle, WA. Support: NOAA/CILER; Grant number: NA07OAR4320006


Hinrichsen, R.A., D.J. Hasselman, C.C. Ebbesmeyer, B.A. Shields. 2011 (Sept. 6). The effects of increased water temperature and dam construction on the spatial distribution and increased abundance of American shad in the Columbia River basin. Invasive American Shad Symposium; 141st American Fisheries Society Annual Meeting, Seattle, WA. Support: NOAA/CILER; Grant number: NA07OAR4320006

**Outreach Activities:**

I have not participated in outreach activities in the Great Lakes region. The geographic location of my research (Pacific Northwest region of the U.S.) makes such outreach activities difficult to accomplish effectively.
PROJECT TITLE: LARVAL DISPERSAL, HABITAT CLASSIFICATION AND FOOD WEB MODELING

University Principal Investigators: A. Burton, D. Beletsky, H. Zhang (University of Michigan, SNRE, CILER), L. Mason, J. Breck, A. Hoover (University of Michigan, SNRE)

NOAA Technical Investigator: E. Rutherford (NOAA-GLERL)

Overview and Objectives:

Invasive species are one of five key NOAA-identified stressors of native biodiversity and ecosystem function in the Laurentian Great Lakes (GL), where at least 184 nonindigenous species are established (http://www.glerl.noaa.gov/res/Programs/invasive/, Ricciardi 2006). Invasive species whose original site of establishment in North America was the GL cause great damage to the GL and at least $200 million annually to the whole US (Pimentel et al. 2005). In the context of on-going management and policy discussions, it is therefore critical to forecast species invasions and their costs, and to predict the effectiveness and costs of potential management responses to these invasions. This will guide more cost effective investments in prevention, education and rapid response to new invasions, slow-the-spread, and control efforts for species that are already well established in the GL or connected basins.

By integrating ecology and economics at the 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. Alternative management or policy choices will be presented in environmental as well as dollar units, which are critical to inform decisions that must always be made in the context of limited budgets. Focusing on all five GLs, we will produce and make freely available a richer and more finely resolved set of GIS layers and ecological classifications than are currently available; these will be useful for many other researchers, agencies, NGOs, and policy makers for applications to many other issues.

We propose to use ecological models and GIS databases to support the NOAA CSCOR proposal by Dr. David Lodge et al. from the University of Notre Dame entitled: “Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes”.

Products resulting from this proposed subcontract 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 bioeconomic impacts of invasive species on Great Lakes food webs and fisheries. Specific objectives include:
1. Inventory, map and classify physical and biological habitat data for Great Lakes aquatic ecoregions.
2. Construct food web models for inshore and offshore waters of Lake Michigan, Lake Huron and Lake Erie.
3. Simulate bioeconomic impacts of invasive species on Great Lakes food webs.

Dr. Dmitry Beletsky will model dispersal of 3 species across nearshore and open water habitats of 4 Great Lakes. Drs. Hongyan Zhang, Rutherford and a research technician (A. Hoover) will model food webs in ecologically distinct regions of the Great Lakes to determine potential impacts of invasive species on food webs and fisheries, which will suggest alternatives for management. Breck will revise the food web model code to allow estimates of parameter uncertainty obtained from expert judgement analysis, and to connect the food web models to economic models developed by Dr. David Finnoff of the Univ. Wyoming. Zhang and Doran Mason’s (GLERL) effort on food web modeling and habitat classification are shared on a related CILER project entitled “GIS Ecoregion Classification and Food Web Modeling”.

This project meets a goal of NOAA’s Strategic Plan to protect, restore, and manage use of coastal and ocean resources through ecosystem-based management.

**Accomplishments:**

**Objective 1.** Inventory, map and classify physical and biological habitats for Great Lakes aquatic ecoregions.

We assembled additional data for classification purposes of physical and biological habitats in Lake Michigan and Lake Erie. The data included physical (surface temperature, temperature change, growing degree days, subsurface temperature, fetch, turbidity, transmittance, PAR), chemical (oxygen, nutrients) and biological data (chlorophyll a, phytoplankton biovolume, benthos and zooplankton biomass). We are mapping and classifying these variables together with other physical variables (proximity to rivers and wetlands, substrate composition, bathymetry, gradient, current velocity and direction) to develop ecoregion classifications in a hierarchical framework. We are integrating habitat data into a new spatial framework that extends from watersheds to the Great Lakes. On December 14, 2011, we discussed classification approaches and data sets with collaborating scientists from several Great Lakes universities, the Nature Conservancy, state (Michigan DNR), federal (USGS-GLSC, NOAA-GLERL), and provincial resource agencies (OMNR). Specific physical/chemical/biological data sets included were:
- EPA_GLNPO macroinvertebrate biomass data for the five Great Lakes from 1997 to 2006.
- NOAA-GLERL phytoplankton and zooplankton data for Saginaw Bay from 1990-1996
- MDNR – Bottom trawl fish survey data for Saginaw Bay from 1981- present.
- USGS-GLSC and state and provincial fish monitoring data from 1985-present.

**Objective 2:** Construct food web models for inshore and offshore waters of lakes Michigan, Huron and Lake Erie.

**Lake Erie food web model (Hongyan Zhang, Ed Rutherford):** We have carefully configured and calibrated the Ecopath with Ecosim (EwE) model for Lake Erie’s central basin with data from 1994-2007. Currently, we are drafting a manuscript about this model. We also modified an EwE model for the whole Lake Erie basin based on previous work by our Canadian collaborators Drs. X. Zhu (DFO) and T. Johnson (OMNR). Jason Breck modified the EwE code to dynamically link the whole lake EwE model with an economic model (CGE) to assess economic impacts of invasive species on the region. Output from the EwE model (fish biomass and fish catch) was used as input to the economic model, and output from the economic model (fishing effort) was used as input to the EwE model. To quantify uncertainty in our EwE model predictions, Jason Breck helped us prepare for expert solicitation by modifying the EwE code to incorporate uncertainty distributions around parameter values into the simulation modeling framework.

**Lake Michigan Food Web Model (Hongyan Zhang, Ed Rutherford):** We have completed an Ecopath model of nearshore and offshore food web models in Lake Michigan. We used available databases from isotope studies of energy flow in Muskegon Lake and nearshore Lake Michigan (Marko 2008), from NOAA-GLERLs and USGS-GLSCs long-term monitoring programs (Bunnell et al. 2009, Fahnenstiel et al. 2010), and from recent GLRRIN studies in the nearshore zone by US EPA, Purdue University, Illinois Natural History Survey and Univ. Wisconsin at Milwaukee. We collaborated on a EwE model of Muskegon Lake, a drowned-river mouth lake in southeastern Lake Michigan, with scientists from Annis Water Resources Institute at Grand Valley State University, who provided long-term observation data on fish, nutrients and algae.

**Saginaw Bay and main basin Lake Huron Food Web Models (Sara Adlerstein, Yu-Chun Kao (Univ. Michigan), Rutherford):** Input parameters have been refined for implementing Ecopath and Ecosim (EwE) models for Saginaw Bay and the main basin
of Lake Huron that will allow characterization of the food webs before and after the dreissenid and round goby invasions. We also included changes in the architecture of the food web to represent migratory species, and also included the microbial loop in the lower food web level as well as additional fish prey and predator species. Finally, we also explored alternative ways within EwE to model new (invasive) species (such as Asian carps) entering Great Lakes ecosystems.

**Objective 3:** Simulate invasive species impacts on Lake Michigan, Lake Erie and Lake Huron food webs.

We conducted a preliminary food web simulation of Asian carp impacts on the central Lake Erie food web, and on the Muskegon Lake food web with other partners from University of Michigan and Annis Water Resources Institute. Model results were sensitive to assumptions of Asian carp diet, and of vulnerability of young carp to predation by native species. Future work will define impacts of Asian carps and other invaders (eg. Dreissenid mussels, round goby, ruffe, Hydrilla) on food webs in each lake, and evaluate sensitivity of model predictions to input parameters.

**Objective 4:** Larval Dispersal - To forecast dispersal mechanisms of invasive species via natural lake currents: Beletsky and team have tested hydrodynamic model runs for Lake Michigan for 2004 (cold year), 2005 (warm year) and 2007 (average year). Modeled temperature was used to determine hatching dates of Eurasian ruffe. Larval drift of passive neutrally buoyant ruffe larvae was simulated for all three years and followed general cyclonic circulation patterns in the mid-lake region with larval dispersal distances varying by year. Simulations in Green Bay showed that larvae were largely confined to the Big Bay de Noc and lower portions of Green Bay; only in one out of three years modeled did some larvae escape into Lake Michigan. To predict larval dispersion in a typical year, Beletsky and team have developed 3D climatology of Lake Michigan currents (3-hourly) and temperature (6-hourly) based on 1998-2007 model results. This climatology will be used for Eurasian ruffe (*Gymnocephalus cernuus*) and golden mussel (*Limnoperna fortunei*) dispersal simulations.

**Publications:** None.

**Presentations:** 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.

**Outreach Activities:** None.
PROJECT TITLE:  GIS ECOREGION CLASSIFICATION AND FOOD WEB MODELING

University Principal Investigators: Hongyan Zhang (University of Michigan CILER), Lacey Mason (University of Michigan, SNRE)

NOAA Technical Lead: Ed Rutherford (NOAA-GLERL)

Overview and Objectives:

Invasive species are one of five key NOAA-identified stressors of native biodiversity and ecosystem function in the Laurentian Great Lakes (GL), where at least 184 nonindigenous species are established (http://www.glerl.noaa.gov/res/Programs/invasive/, Ricciardi 2006). Invasive species whose original site of establishment in North America was the GL cause great damage to the GL and at least $200 million annually to the whole US (Pimentel et al. 2005). In the context of on-going management and policy discussions, it is therefore critical to forecast species invasions and their costs, and to predict the effectiveness and costs of potential management responses to these invasions. This will guide more cost effective investments in prevention, EDRR to new invasions, slow-the-spread, and control efforts for species that are already well established in the GL or connected basins.

By integrating ecology and economics at the 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. Alternative management or policy choices will be presented in environmental as well as dollar units, which are critical to inform decisions that must always be made in the context of limited budgets. Focusing on all five GLs, we will produce and make freely available a richer and more finely resolved set of GIS layers and ecological classifications than are currently available; these will be useful for many other researchers, agencies, NGOs, and policy makers for applications to many other issues.

We propose to use ecological models and GIS databases to support the NOAA CSCOR proposal by Dr. David Lodge et al. from University of Notre Dame entitled: “Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes”. Dr. Rutherford and GIS analyst Lacey Mason will provide habitat databases and use multivariate statistical models to classify ecoregions in each Great Lake to support food web modeling. Drs. Hongyan Zhang and Rutherford will model food webs in ecologically distinct regions of the Great Lakes to determine potential impacts of invasive species on food webs and fisheries, which will suggest alternatives for management.
Products resulting from this proposed subcontract include: maps and predictions of invasive species larval dispersal in each of the Great Lakes; developed databases and ecoregional habitat classifications for environmental niche modeling; Ecopath/Ecosim food web models and predictions of invasive species impacts on Great Lakes food webs and fisheries.

This project meets a goal of NOAA’s Strategic Plan to protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management. Specific objectives include:

5. Inventory, map and classify physical and biological habitats for Great Lakes aquatic ecoregions.
7. Simulate invasive species impacts on Lake Michigan and Lake Erie food webs.

Accomplishments:

Objective 1. Inventory, map and classify physical and biological habitats for Great Lakes aquatic ecoregions.

We assembled additional data for classification purposes of physical and biological habitats in Lake Michigan and Lake Erie. The data included physical (surface temperature, temperature change, growing degree days, subsurface temperature, fetch, turbidity, transmittance, PAR), chemical (oxygen, nutrients) and biological data (chlorophyll a, phytoplankton biovolume, benthos and zooplankton biomass). We are mapping and classifying these variables together with other physical variables (proximity to rivers and wetlands, substrate composition, bathymetry, gradient, current velocity and direction) to develop ecoregion classifications in a hierarchical framework. We are integrating habitat data into a new spatial framework that extends from watersheds to the Great Lakes. On December 14, 2011, we discussed classification approaches and data sets with collaborating scientists from several Great Lakes universities, the Nature Conservancy, state (Michigan DNR), federal (USGS-GLSC, NOAA-GLERL), and provincial resource agencies (OMNR). Specific physical/chemical/biological data sets included were:

- EPA_GLNPO macroinvertebrate biomass data for the five Great Lakes from 1997 to 2006.
- NOAA-GLERL phytoplankton and zooplankton data for Saginaw Bay from 1990-1996
- MDNR – Bottom trawl fish survey data for Saginaw Bay from 1981- present.
- USGS-GLSC and state and provincial fish monitoring data from 1985-present.

**Objective 2:** Construct food web models for inshore and offshore waters of Lake Michigan and Lake Erie.

**Lake Erie food web model (Hongyan Zhang, Ed Rutherford):** We have carefully configured and calibrated the Ecopath with Ecosim (EwE) model for Lake Erie’s central basin with data from 1994-2007. Currently, we are drafting a manuscript about this model. We also modified an EwE model for the whole Lake Erie basin based on previous work by our Canadian collaborators Drs. X. Zhu (DFO) and T. Johnson (OMNR). We are linking the whole lake EwE model with an economic model (CGE) to assess economic impacts of invasive species on the region. To quantify uncertainty in our EwE model predictions, we are preparing for an expert solicitation of distributions around parameter values, and are modifying the model code to incorporate the solicitation results into the modeling framework.

**Lake Michigan Food Web Model (Hongyan Zhang, Ed Rutherford):** We have completed an Ecopath model of nearshore and offshore food web models in Lake Michigan. We used available databases from isotope studies of energy flow in Muskegon Lake and nearshore Lake Michigan (Marko 2008), from NOAA-GLERLs and USGS-GLSCs long-term monitoring programs (Bunnell et al. 2009, Fahnenstiel et al. 2010), and from recent GLRRIN studies in the nearshore zone by US EPA, Purdue University, Illinois Natural History Survey and Univ. Wisconsin at Milwaukee. We collaborated on a EwE model of Muskegon Lake, a drowned-river mouth lake in southeastern Lake Michigan, with scientists from Annis Water Resources Institute at Grand Valley State University, who provided long-term observation data on fish, nutrients and algae.

**Saginaw Bay and main basin Lake Huron Food Web Models (Sara Adlerstein, Yu-Chun Kao (Univ. Michigan), Rutherford):** Input parameters have been refined for implementing Ecopath and Ecosim (EwE) models for Saginaw Bay and main basin Lake Huron that will allow characterization of the food webs before and after the dreissenid and round goby invasions. We also included changes in the architecture of the food web to represent migratory species, and also included the microbial loop in the lower food web level as well as additional fish prey and predator species. Finally, we also
explored alternative ways within EwE to model new (invasive) species (such as Asian carps) entering Great Lakes ecosystems.

**Objective 3:** Simulate invasive species impacts on Lake Michigan, Lake Erie and Lake Huron food webs.

We conducted a preliminary food web simulation of Asian carp impacts on the central Lake Erie food web, and on the Muskegon Lake food web with other partners from the University of Michigan and the Annis Water Resources Institute. Model results were sensitive to assumptions of Asian carp diet, and of vulnerability of young carp to predation by native species. Future work will define impacts of Asian carps and other invaders (eg. Dreissenid mussels, round goby, ruffe, Hydrilla) on food webs in each lake, and evaluate sensitivity of model predictions to input parameters.

**References:**


**Publications:** None.

**Presentations:**


of the International Association for Great Lakes Research May 30-June 3, Duluth, MN.


Outreach Activities:

Ed Rutherford and Hongyan Zhang have been actively involved in a Great Lakes EwE modeling group which includes modelers from NOAA/GLERL, CILER/UM, USGS, the Institute for Fisheries Research at the University of Michigan, and Michigan State University. This EwE modeling group will produce guidelines for ecosystem modeling efforts in the Great Lakes and compile a list of data sources used for model development. Fourteen experts participated in the second of two workshops on July 12-13, 2011 at Kellogg Biological Station. A final report led by Dr. Mark Rogers (USGS) about these two workshops was submitted to GLFC in January, 2012.

We also attended a NOAA-CSCOR sponsored project meeting of research collaborators, managers, and interested agencies from Oct. 24-27, 2011 in Chicago, IL.
PROJECT TITLE: MECHANISTIC APPROACH TO IDENTIFY THE ROLE OF PATHOGENS IN CAUSING Diporeia spp. DECLINE IN THE LAURENTIAN GREAT LAKES

**Principal Investigators:** Allen Burton, CILER; and Mohamed Faisal, MSU

**NOAA Technical Lead:** Thomas F. Nalepa, NOAA Emeritus

**Overview and Objectives:**

For nearly 20 years, the decline of the benthic amphipod *Diporeia* in all the Great lakes except Lake Superior has puzzled scientists and managers alike. While the loss of *Diporeia* is temporally linked to the introduction and spread of the zebra mussel (*Dreissena polymorpha*) and the quagga mussel (*Dreissena rostriformis bugensis*), the exact mechanism for the negative response of *Diporeia* is not clear. A common hypothesis is that dreissenids are outcompeting *Diporeia* for available food. Filter-feeding dreissenids occur at the substrate surface and ingest organic material settling from the water column before it becomes available to *Diporeia*. *Diporeia* is a detrivore that burrows within the substrate. Yet when *Diporeia* populations are declining, individuals show no sign of starvation, that is, lipid levels and weight per length do not decline.

This project will examine the possibility that the decline of *Diporeia* may have been caused by pathogenic bacteria, by changes in the community structure of bacteria associated with *Diporeia*, or by changes in environmental conditions that would make *Diporeia* more vulnerable to bacterial infection. All of these bacterial-related hypotheses may be directly or indirectly related to the activities of large dreissenid populations. To test these hypotheses, preserved specimens of *Diporeia* from Lakes Michigan and Ontario, that were collected in the period of time before and after dreissenids, will be analyzed. The specific analysis and corresponding methods are: 1) changes in bacteria communities associated with *Diporeia* will be screened using T-RFLP (terminal-restriction fragment length polymorphism); 2) identification of certain beneficial bacteria or the emergence of pathogenic bacteria will be achieved by partial gene sequencing of bacterial 16S rDNA; 3) to determine if shifts in the bacterial community or emergence of pathogens are associated with tissue destruction in vital organs, tissue will be variously stained and examined microscopically.

*Diporeia* was a keystone species in the Great Lakes ecosystem and played a vital role in the movement of energy and nutrients from the lower food web (phytoplankton) to the upper food web (fish). This project will provide new insights into the loss of *Diporeia* and potential linkages to dreissenids. Thus, we may better predict if *Diporeia* will re-colonize offshore regions if dreissenid populations stabilize or decline. As such,
it addresses the goals in the NOAA Strategic Plan to protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management.

**Accomplishments:**

Accomplishments over this reporting period have focused on the extraction and amplification of high-quality bacterial DNA from the Diporeia specimens, and on histopathological analysis. On the former topic, major accomplishments were:

The ability to extract high-quality DNA from our custom extraction method was examined in an experiment that used DNA from a commercially-available DNA “ladder”. The test confirmed that the custom extraction method was capable of obtaining high yields of DNA, including small genomic fragments.

Bacterial DNA was successfully amplified from a number of samples. One amplified sample was successfully excised from an agarose gel, cloned, and sequenced to produce a total of five cloned sequences.

Phylogenetic analysis of sequences revealed the presence of both *Flavobacterium* sp. and *Pseudomonas* sp. in preserved *Diporeia* specimens.

After successful amplification and sequencing of a preliminary set of samples, a larger scale screening of samples for bacterial DNA was performed on 20 samples representing a period of 29 years. Surprisingly, greater amplification success was achieved for particular years, most notably in 1986 and 1992. Work continues on screening all samples for bacterial DNA.

Accomplishments for the histopathological analysis were:

Major progress was made in the analysis of stained histological sections. Currently, 52% of stained *Diporeia* and *Mysis* sections have been analyzed.

Microscopical examination of historic *Diporeia* collected from Lake Michigan indicated a range of tissue alterations. Two identified pathogens, *Acanthocelphalans* and *Amoeba* sp., have not been previously reported in *Diporeia*.

Cyclical trends in infections rates were observed at most stations in Lake Michigan. This suggests a reoccurring episode of disease, rather than a point source epidemic.
Work continued on analyzing all stained sections of Diporeia (and Mysis) to determine long term trends of pathogens for each age class (juvenile and adult), station, and year.

**Publications:** None

**Presentations:**


**Outreach:** None
THEME III: OBSERVING SYSTEMS

CILER activities that fall under the theme of Observing Systems include research focusing on providing observing system data and platforms, data management and communications, and data products and forecasts needed for effective environmental management, and for monitoring and understanding ecosystem responses to natural and anthropogenic conditions.
Overview and Objectives:

The GLOS-RA proposed to implement key observing system and modeling improvements over the 2008-2012 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

**Accomplishments:**

**University of Michigan**

The University of Michigan Ocean Engineering Laboratories (OEL) deployed two S2 coastal monitoring buoys for the Great Lakes navigational season. The first buoy was deployed in Little Traverse Bay in partnership with the local communities of Harbor Springs and Petoskey, and the second off the coast of Ludington, Michigan. The buoys, contained an inertial wave sensor (IWS) designed by the OEL as well as a met package and a thermistor string. The thermistors reported water temperature at eight separate depths every ten minutes. The Ludington buoy also carried a Nortek Acoustic Doppler Current Profiler (ADCP) for current measurement in the water column below the buoy. The OEL also deployed an S2 coastal monitoring buoy in collaboration with LimnoTech, Inc. off shore of the Cook Nuclear Power plant south of St. Joseph, Michigan for the season. This buoy carries an IWS, met station, thermistor and ADCP. A fourth S2 buoy was deployed in Douglas Lake in partnership with University of Michigan’s Biological Station. It will be used as a test bed for experimental sensors in the future. All of the buoys transmitted all their data real-time in ten minute reports to the OEL website, the GLOS website and the NDBC.

In addition to buoy observations, CILER ran AUV’s missions in Saginaw Bay, in order to determine the bottom substrate of certain fish reefs and to support Cladaphora modeling and in western Lake Erie to map the distribution and influence of the Maumee River plume. Both AUV’s had issues that required they be returned to the
manufacturer for repair. This cut into the deployment season, limiting the number of missions. CILER took delivery of the glider too late in the season to implement a safe deployment; it will be deployed in May in Lake Charlevoix for its shake-down cruise.

University of Wisconsin- Milwaukee

The Great Lakes WATER Institute (GLWI) GLUCOS (Great Lakes Urban Coastal Observing System) Nearshore Endurance Buoy was fully deployed for the 2011 sampling season (mid-May through early November) and is being refurbished for deployment in early spring 2012. Buoy based measurements include: surface meteorology, lake surface temperatures, dissolved O2, conductivity, turbidity, algal fluorescence, and CO2 concentrations in the lake and atmosphere. Some of these data are made available near-real-time through the website of the UW-Milwaukee Great Lakes WATER Institute. A new standard GLOS buoy was deployed for the 2011 season several km northeast of Milwaukee. In addition to the basic measurements systems mentioned above, the buoy had a thermistor string, a wave height sensor, an ADCP, and a multi-spectral algal pigment sensor.

The Lake Express high speed ferry monitoring had several breaks in data collection due to equipment malfunction and repair of one of the ferry’s engines. The data continues to be analyzed and collated, and will be used in the calibration and validation of a Lake Michigan carbon model that was initiated fall of 2011. It is currently undergoing refurbishment and upgrades, in anticipation of deploying on the ferry over its entire operating season, from May 1 to the end of October 2012. The monitoring system will continue to be operated as in previous years; with data on temperature, dissolved oxygen, chlorophyll a, and air/water CO2 being collected at 30-second intervals during almost all of the ferry’s lake transects (4 to 6 daily.)

In cooperation with the Milwaukee County Parks, Miller-Coors, and the Milwaukee Municipal Sewerage District, the WATER Institute has developed a buoy deployable in the immediate vicinity of Bradford Beach – the principal swimming beach on Milwaukee’s waterfront, and a web cam on the beach house. This system monitors wave conditions and water temperature.

State University of New York

An S2 buoy was deployed in Lake Ontario for the fall season. The buoy was late in being deployed due to vandalism of the anchor floats, making it necessary to have a new anchor fabricated. A continuous water quality sampling system was installed in July, and both systems collected and transmitted data while deployed. This data was uploaded to the GLRC and GLOS websites.
University of Minnesota-Duluth

UMD placed a meteorological buoy in the western arm of Lake Superior, in the vicinity of the water intake for the City of Duluth. The buoy had the same suite of instrumentation it had the previous year (wind speed and direction, air temperature, relative humidity, barometric pressure, downward shortwave and long-wave radiation, PAR, and water temperature at a number of depths), with the following improvements: the thermistor measured water temperature down to 40m, and carried a sub-surface PAR sensor at 3m below the surface.

The second GLOS-sponsored meteorological buoy was deployed next to the first for sensor inter-comparison. CILER fellow Brandy Forsman completed a detailed analysis of the data comparing the data from both buoys. While the comparison was largely favorable, there were some significant differences that were worth documenting so that data from the two buoys, now separated, can be compared. Both buoys ported data to NDBC (45027 and 45028).

Enhancements were made to the UMD Webb Research electric glider. These involved the addition of sensors for Chlorophyll-A, turbidity, and dissolved oxygen and an improved communications protocol (RUDICS).

Michigan Technological University

MTU deployed two S2 buoys over the 2011 season, both with meteorological packages, IWS’s and thermistors. They were deployed on the north shore and the southern shore of the Keweena Peninsula. The northern buoy also carried a 6600 YSI sonde and a Nortek ADCP. iButton water temperature thermistor chains were deployed for the season at both ends of the Keweena waterway. 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 Ranger III ferry box was successfully deployed in late April, and collected data through the 2011 season.

Michigan Tech Research Institute

MTRI developed and tested a new satellite algorithm that maps TSS found in river plumes. The development of a MODIS and MERIS Primary Productivity algorithm for Lake Michigan was also completed. MTRI supported Dr. Fahnenstiel’s work in Lake Erie by providing field spectral radiometer measurements recording a Harmful Algal Blooms (HAB) event. Initial tests have begun using a modified HABs algorithm on a Lake Erie satellite dataset. MTRI provided satellite based water clarity
analysis for inclusion in the “State of the Great Lakes 2012” report. MTRI also collaborated with Professor Boyer to spatially summarize chlorophyll data collected during Lake Erie and Ontario ship surveys.

**Publications:**


**Publications in Review:**


Yousef, F., Kerfoot, W.C., Shuchman, R., Brooks, C., Sabol, B., Graves, M. 2012 (in review). *Using LiDAR to reconstruct the history of a coastal environment.* J. Great Lakes Res.

**Presentations:**


Austin, J., *An Extraordinary Upwelling Event in Lake Superior during Summer 2010.* IAGLR, May - 3 June 2011,


Green, S., Shuchman, R., Kerfoot, W., Brooks, C., Sayers, M., Endsley, K., Jessee, N. 2011. *Supporting GLOS through taking remote sensing algorithms operational and increasing access to sensor data.* Presented at IAGLR’s 54th Annual Conference on Great Lakes Research. Duluth, WI.


**Outreach Activities:**


Klump, V. *A Perspective on Global and Great Lakes Water Resources*. Guest Lecturer, Marquette University Law School, Milwaukee WI, 29 Nov. 2011.


OEL in concert with the UMBS hosted an NSF funded conference on Advanced Aquatic Sensors. This conference highlighted the capabilities of the GLOS buoy as well as the AUVs. The conference attendees were members of the Global Lake Ecological Observatory Network.

Jay Austin spoke on GLOS-related issues in a guest lecture to a Freshwater Ecology course on UMD campus this semester.: 22 March 2012, "There's physics in lakes too"

UMD continued our collaboration with the Great Lakes Aquarium, relaying real-time buoy information to a display there. The display runs full time while buoys are deployed, relaying real time data and information about why we make the measurements we do.

Jay Austin participated in a COSEE cruise last July, retrieving the glider during one of their cruises and talking to K12 educators about the role of observations both in doing science and in promoting water quality and marine safety: 21 July 2011, "Lake Temperature Structure Basics"

Jay Austin also presented glider data results at ASLO Ocean Sciences, 21-25 February 2012, "GLIDER OBSERVATIONS OF PHYSICAL AND BIOGEOCHEMICAL PROPERTY DISTRIBUTIONS IN LAKE SUPERIOR."
PROJECT title: GREEN BAY HYPOXIA

University Principal Investigators: Val Klump, Univ of Wisconsin – Milwaukee

NOAA Technical Leads: Dave Schwab, GLERL

Overview and Objectives:

The NOAA CHRP project “Green Bay Hypoxia” includes the development and validation of a hydrodynamic and oxygen transport model for the Green Bay estuary of Lake Michigan. The field data will also be used by NOAA-GLERL to validate their model of the Fox River plume mixing in Green Bay. UW-Milwaukee and the Green Bay Metropolitan Sewerage District prepared a monitoring plan, in consultation with Dr. David Schwab from NOAA GLERL.

The plan consists of the deployment in Green Bay of three Nortek Aquadopp profilers for the acquisition of current and wave data, between May and September of 2011. NOAA GLERL loaned two Nortek Aquadopp and the third one belongs to UWM. The current and wave data will be used to validate the hydrodynamic model mentioned above.

NOAA Strategic Plan Goal(s) the Project Addresses:

1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;
3) Serve society’s needs for weather and water information;

Accomplishments:

The field data collection tasks include the deployment of three ADCPs for current and wave measurements, and the measurement of temperature, DO and other water quality variables. Funding through this project was used to measure currents and waves.

Currents and wave data were measured using three Nortek Aquadopp ADCPs (2 MHz) deployed at three stations in southern Green Bay. Temperature was measured continuously at two stations, and on a grid during several cruises of the UWM research vessel.
Field data and hydrodynamic modeling results to date are providing evidence of the physical links between circulation, stratification, and hypoxic conditions in Green Bay. The model reproduces measured currents quite well.

Current measurements showed evidence of surface flows out of the bay and bottom flows into the bay. Field data showed a clear relationship between stratification and low dissolved oxygen concentration.

Publications: None to report at this time

Presentations:

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<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Title</th>
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<tr>
<td>S. A. Hamidi, H. R. Bravo, J. V. Klump, D. Beletsky, and D. J. Schwab</td>
<td>2/14/12</td>
<td>Hydrodynamic Model for Green Bay, Lake Michigan</td>
<td>CSCOR Joint Project Meeting, Ann Arbor MI</td>
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<td>S. A. Hamidi, H. R. Bravo, J. V. Klump, D. Beletsky, and D. J. Schwab</td>
<td>2/20/12</td>
<td>Circulation and thermal regime in Green Bay, Lake Michigan</td>
<td>AGU Ocean Sciences Meeting, Salt Lake City UT</td>
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Outreach Activities:

None to report at this time
**PROJECT TITLE:** GREAT LAKES COASTWatch RESEARCH ASSISTANT FOR NOAA COASTWatch PROGRAM ELEMENT

*Principal Investigators:* Allen Burton, CILER

*NOAA Technical Contact:* George Leshkevich, NOAA

**Overview and Objectives**

CoastWatch is a nationwide National Oceanic and Atmospheric Administration (NOAA) program within which the Great Lakes Environmental Research Laboratory (GLERL) functions as the Great Lakes regional node. In this capacity, GLERL obtains, produces, and delivers environmental data and products for near real-time observation of the Great Lakes to support environmental science, decision making, and supporting research. This is achieved by providing Internet access to near real-time and retrospective satellite observations, in-situ Great Lakes data, and derived products to Federal, state, and local agencies, academic institutions, and the public via the Great Lakes CoastWatch web site (http://coastwatch.glerl.noaa.gov).

The goals and objectives of the CoastWatch Great Lakes Program directly support NOAA’s statutory responsibilities in estuarine and marine science, living marine resource protection, and ecosystem monitoring and management. Great Lakes CoastWatch data are used in a variety of ways including monitoring of algal blooms, plumes, ice cover, and water temperatures, two and three dimensional modeling of Great Lakes physical parameters (such as wave height and currents), damage assessment modeling, research, and for educational and recreational activities.

The CoastWatch project contributes to NOAA Strategic Goal(s):

- Serve society’s needs for weather and water information;
- Support the nation’s commerce with information for safe, efficient, and environmentally sound transportation;
- NOAA Mission support
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) and/or MODIS 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. Communications requirements and data distribution are accomplished electronically via the Internet. A goal is accurate and reliable data and products from sustained and integrated satellite observing systems.

**Accomplishments**

1. **Monitor, develop and/or improve the operational program to receive, process, analyze, and archive the CoastWatch data.** eg. Write operational program to make the AVHRR/GLSEA images available for Google Earth.

   *Google Earth (KLM) programming complete - finished the operational program to make the GLSEA available in klm and kmz format and implemented on the CoastWatch Great Lakes website.*

2. **Maintain and improve the CoastWatch Great Lakes Node web server, design and develop the web site,** eg., make image gallery section on web page, check the images and links on web site.

   *Continue the evaluation and testing of the Thredds/LAS server for possible use on the CoastWatch Great Lakes web site.*

   *Aid data transfer from CD/DVD to new Great Lakes CoastWatch web server*

   *Updated the Photo Gallery section on CoastWatch Great Lakes web page throughout the year with examples of plumes, blooms, lake effect snow, etc.*

   *Wrote the PHP script for the STATISTIC section and GOES section on CW web page, that replaced the old CGI script.*
3. Design, modify, and develop the software to analyze and process the CoastWatch data, eg., write programs to create kml and png files for Google Earth, write programs to create turbidity product when the new algorithm becomes available.* Wrote the IDL program to subset, land mask, and interpolate the MODIS images for Lake Eire and made an animation of the 2011 algal bloom for presentation.

4. Participate in CoastWatch related research and prepare presentations for meetings. eg. Prepare presentations for meetings and conferences (such as: CoastWatch Node Managers Meeting, IAGLR, etc.).

*Wrote and modified IDL programs to process the RADARSAT images for ice classification research project.

Prepared/preparing presentations for:


Leshkevich, G. and S. Liu, “Delivering Environmental Satellite and In Situ Data to the Great Lakes User Community-New Great Lakes CoastWatch Server” presentation at IAGLR Conference, Cornwall, Ont., May 13-17, 2012

Leshkevich, G. and S. Liu, “CoastWatch Great Lakes Node Summary” presentation at CoastWatch Node Manager Meeting, Kona, Hawaii, April 10-12, 2012

5. Assist in the mentorship of a Great Lakes summer fellow.

*Plan to assist summer fellow with activities related to new CoastWatch server implementation including data conversion, data transfer, web development, etc.

6. Document CoastWatch software, including path designations and data source input/output. Construct flow chart depicting data and code relationships.

*Create flow chart and documentation for documenting the operational process of the Great Lakes CoastWatch site. (Continuing with new server).

*Assisted in the development of new directory structure for new CoastWatch server.
**Publications**

Leshkevich, G. and S. Nghiem, Great Lakes Ice Classification Using Satellite C-band SAR Multi-Polarization Data, JGLR, Special Issue on Remote Sensing (in progress)

**Presentations**

See Section 4 above.

**Outreach Activities**

Assisted in development of CoastWatch poster for National Weather Service booth at NOVI Boat Show.
PROJECT TITLE: SUPPORTING PREDICTIVE MODELS THAT IMPROVE COASTAL, HUMAN HEALTH AND BEACH FORECASTING

University Principal Investigators: Allen Burton, CILER; Richard R. Rediske, Annis Water Resources Institute, Grand Valley State University

NOAA Technical Leads: Gary Fahnenstiel, GLERL

Overview and Objectives:

1. Analyze samples from Lake Erie for microcystins by HPLC/MS to provide confirmation of ELISA data.
2. Analyze samples from Lake Erie for microcystins by HPLC/MS to provide confirmation of in situ measurements from robotic sampler. (See: “A Robotic Sampler-Mass Spectrometer for In-Water Detection of Cyanotoxins”)
3. Data were used for protecting coastal resources through ecosystem based management

NOAA Strategic Plan Goals the project addresses:

1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;
3) Serve society’s needs for weather and water information;

Accomplishments:

A series of water samples were analyzed for total microcystins (n=56) and dissolved microcystins (n=16) by HPLC/MS. Congener specific data were provided for microcystin LR, RR, and YR. ELISA data continues to overestimate the microcystin LR concentrations and is more similar to the sum of the three congeners. In addition, a series of 15 samples from the in situ microcystin analyzer were confirmed by HPLC/MS. The data is still under review by the University of Florida.

Publications: None during this reporting period

Presentations: None during this reporting period

Outreach Activities: Data provided for Harmful Algal Bloom Event Response Database. Data was available for public access on the NOAA website: http://www.glerl.noaa.gov/res/centers/HABS/
**Project Title:**  A Robotic Sampler-Mass Spectrometer for In-Water Detection of Cyanotoxins

*University Principal Investigators:* Allen Burton, CILER; David Fries, University of South Florida; David F. Millie, Florida Institute of Oceanography (now with Palm Island Enviro-Informatics, LLC)

*NOAA-GLERL Technical Lead:* Gary L. Fahnenstiel

**Overview and Objectives:**

Blooms of toxic cyanobacterium, *(particularly Microcystis aeruginosa)* annually occur throughout nutrient-enriched waters of the Great Lakes and threaten aquatic resources and potentially human health. To minimize impacts and potentially mitigate health risks, the time-series detection, measurement and source tracking of cyanotoxins are the objectives of federal, state, academic, and private partnerships.

Sensor-based monitoring of chemical analytes is a current monitoring practice, with many instruments currently available commercially. Importantly, the monitoring of toxins and contaminants throughout dynamic Great Lakes waters requires complex technological innovations capable of both time-series sampling and accurate detection/quantification of material fluxes/transformation across diverse spatial scales. The development/validation of automated sensors and probes to detect and identify harmful algal species and their toxins are central to specific goals mandated by NOAA’s *Oceans & Human Health Research Initiative*.

This project will construct, validate, and deploy within selected Great Lake coastal waters, an operational, bio-chemical sensor comprised of a robotic sampler coupled with an in-water mass spectrometer based on an ion trap technology. This prototypical precision system provides programmability for time-series measurement of singular (or suites of) ‘target’ chemical/biochemical agents, coincident with the automated sample purification/extraction/archiving and mass spectrometer confirmation/quantification. Initially, sensor development/verification will target the heptapeptide hepatotoxin congeners known as microcystins, with verification of other cyanotoxins and chemical analytes, as time/work allows. The stability of and quantitative recovery for microcystin within the sampler will be assessed with the incorporation of novel isotope dilution-enabled automation technology.

This work supports NOAA’s Strategic Goals/Plans of 1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management and 2)
NOAA Mission support (Center of Excellence for Great Lakes & Human Health, GLERL)

**Accomplishments:**

- Demonstrated use of stand-alone, field-deployable MS for monitoring cyclocitrul detection during short time series (no sample prep required)
- Extended previous work in the field indicating association of cyclocitrul detection with *Microcystis* and microcystin production
- New example of a VOC target for bio-organismal association all done in situ
- Completed transects with this auto-sampler concurrent with field-based mass spec identification for dissolved microcystin.
- Demonstrated selective separations in real time (without post-human sample preparation)
- Demonstrated automation additions to a boat simplifying the size of boat and size of crew
- Demonstrated Near Real Time Analysis from a small adaptive boat and compact sampler system
- Made first experiments in an Automated & "Tethered", Reactor Coupled-Membrane Introduction Mass Spectrometry (RC-MIMS) for direct transfer of microcystin fragments across a membrane interface

**Publications:**

Listed manuscripts (below) currently are ‘in preparation’. Submittal expected in the near future:

- In Situ B-Cyclocitrul/(VOC) Detection During a *Microcystis* bloom in Western Lake Erie Using a self-contained Underwater Mass Spectrometer - in preparation, intended for submittal to *Environmental Science and Technology*
- Selective Molecular Sampling in the Field Using a Field Portable Automated Purification Robot with Subsequent Mass Spec and ELISA Identification Back in the Lab - in preparation, intended for submittal to *Analytical Chemistry 2012*

**Presentations:**

- Solar Robotic Material Sampler System for Chemical, Biological and Physical Ocean Observations  *Unmanned Untethered Submersible Technology* - August 21st-August 24th
Outreach Activities:

- Graduate Student Hands On Training in Lab/Lecture Classes: Systems Technology Course- CMS: CRN 23528, OCE 6934 Section 621
- High School Student Training in Field- Bright Futures Program- Field Portable Sampling Techniques – 2 students
- High School Student Training in Field- Executive Internship Program- Sampling Technology – 2 students
- Graduate Student Training in College of Engineering-Sandra Pettit- B-Cycloctiral Mass Spectrometer Training and Development
- Autosampler Merged with a “Tweeting” Solar Autonomous Underwater Vehicle (AUV) for cells/chemicals and featured via various news media including American Broadcasting Corporation (ABC) Action News, Tampa FL affiliate:
     b. http://news.usf.edu/article/templates/?a=4299&z=123
     c. http://content.usatoday.com/communities/sciencefair/post/2012/03/meet-
        d. http://www.cbc.ca/strombo/technology-1/can-a-bird-tweet-underwater-it-
        f. http://chronicle.com/campusViewpointArticle/Tweeting-from-the-

2011 Portsmouth, NH

- IMAPS (Int’l Microelectronics and Packaging Society)- Mobile Systems and Flexible Packaging for Inner Space Systems, Scottsdale AZ, March 5-7 2012
Overview and Objectives:
Recent advancements in sensor technology for detection of pathogenic organisms have been applied to a variety of fields where rapid results are important such as in food safety. Sensors using lateral flow devices typically focus on pathogenic strains of microorganisms. However, some companies are specializing in *Escherichia coli* (*E. coli*) and coliform sensors for drinking, waste and recreational waters. One of the major issues which emerges from the biosensor technology is the detection limit and the resulting false negatives. In addition evaluating environmental samples other than clean water can often result in false positives. Rapid methods for beaches have focused on two primary technologies: i) immunomagnetic separation (IMS/ATP) and ii) DNA amplification (qPCR-based), and both are compared to the gold standard, namely bacterial culturing (CFU-based). These have been focused on two bacterial targets, namely enterococci and *E. coli*. We have made important evaluations in terms of the limitations of rapid methods and biosensor technologies for waterborne *E. coli*. For current technologies to be able to generate a rapid, quantifiable result issues such as poor sensitivity and specificity need to be overcome. After much research four technologies were chosen for this project based on their rapid detection, prevalence among the community and the ability to obtain the equipment. The suite of assays chosen for this investigation includes IDEXX Colilert Defined Substrate Technology, RAZOR EX –Field BioDetection Instrument from Idaho Technology Inc., qPCR utilizing the *E. coli* *uidA* gene assay and IMS/ATP. The forthcoming work plan was developed to determine the effectiveness of the techniques selected for the investigation.

Our objectives are:
- To evaluate rapid sensor methods for the detection of *E. coli* as this is most often what the technology targets
- To compare the performance of these sensors against each other in terms of application complexity, use with environmental matrices and false positives.

This work will advance our understanding of rapid and cost-effective identification of water-associated human health threats; and provide monitoring and detection information to protect public health and reduce public health risks in recreational waters of the Great Lakes basin.

The NOAA Strategic Plan Goal(s) the Project Addresses includes serving society’s needs for weather and water information.
Accomplishments:

Project Plan

Work to date has focused mostly around developing and executing a work plan that would effectively compare the four technologies. The project plan that was developed has two stages the first being the comparison of the four machines, which is made up of a beach sampling regime shown in Table 1 and a waste water sampling regime shown in Table 2. The second stage of the project plan was a specificity test for the Razor EX machine, which is shown in Table 3. The Razor EX machine was the main focus of this work plan due to the availability of the machine for only a six month period starting August 1, 2011 and ending January 31, 2012. A problem that was encountered during the work with the Razor EX was the availability of test strips. We were only able to acquire 24 test strips during the six month period, which greatly reduced our analysis options. The path we chose to take with the Razor EX was to test it against a mix of environmental samples, along with a specificity analysis against 9 strains to see if it truly only detects for \textit{E. coli} O157:H7 (Table 3). The strains selected for the specificity aspect were ordered from the Shiga Toxin-Producing Escherichia Coli Center under Dr. Shannon D. Manning. The strains were chosen based on their close relationship to O157:H7. We had originally planned on also conducting a sensitivity analysis to determine the detection limits of the Razor Ex, but this had to be put aside due to the lack of test strips during the 6 month period. An also important factor that affected the project plan was the need to collect recreational beach samples during the 2011 summer swimming season. The reason the beach samples were particularly important is due to the lack of an IMS/ATP machine in our laboratory. This deficit was overcome through the cooperation of the Ottawa County Health Department. We have coordinated our beach sampling schedule with a currently active project for Ottawa County in order for them to process the samples for Colilert and IMS/ATP. One issue with the utilization of this existing project is under the USGS and Michigan DEQ project mandate the project results are required to be kept confidential until the end of 2012. We are currently under negotiation to allow an early release of our beach data, but there is nothing to report for IMS/ATP as of yet. The beach locations that were selected were three beaches in Ottawa County (Grand Haven City Beach, Grand Haven State Park Beach, and Rosy Mound Recreational Area Beach) and one beach in Bay County (Bay City Recreational Area Beach). Another stage in the environmental analysis was the waste water samples from the East Lansing Waste Water Treatment Plant (WWTP). These samples were chosen in order to provide contrast with the recreational beach water samples. The East Lansing WWTP was chosen as a sampling location due to our existing contacts with the facility and convenience. A detailed list of the type of samples that were chosen and the methods used to analyze them is shown in Table 2.
Table 1. Environmental sampling strategy for the evaluation of four rapid detection methods

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Number Of Samples</th>
<th>Method Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Colilert</td>
</tr>
<tr>
<td>Grand Haven City Beach</td>
<td>1</td>
<td>Yes (Ottawa Co.)</td>
</tr>
<tr>
<td>Grand Haven State Park Beach</td>
<td>1</td>
<td>Yes (Ottawa Co.)</td>
</tr>
<tr>
<td>Rosy Mound Recreational Area Beach</td>
<td>1</td>
<td>Yes (Ottawa Co.)</td>
</tr>
<tr>
<td>Bay City Recreational Area Beach</td>
<td>1</td>
<td>Yes (Ottawa Co.)</td>
</tr>
</tbody>
</table>

|                                  |                   | IMS/ATP                |
| Grand Haven City Beach           |                   | Yes (Ottawa Co.)       |
| Grand Haven State Park Beach     |                   | Yes (Ottawa Co.)       |
| Rosy Mound Recreational Area Beach|               | Not Analyzed           |
| Bay City Recreational Area Beach |                   | Not Analyzed           |

|                                  |                   | qPCR                   |
| Grand Haven City Beach           |                   | Yes (MSU)              |
| Grand Haven State Park Beach     |                   | Yes (MSU)              |
| Rosy Mound Recreational Area Beach|               | Yes (MSU)              |
| Bay City Recreational Area Beach |                   | Yes (MSU)              |

|                                  |                   | uidA                   |
| Grand Haven City Beach           |                   | Yes (MSU)              |
| Grand Haven State Park Beach     |                   | Yes (MSU)              |
| Rosy Mound Recreational Area Beach|               | Yes (MSU)              |
| Bay City Recreational Area Beach |                   | Yes (MSU)              |

|                                  |                   | Razor EX               |
| Grand Haven City Beach           |                   | Yes (MSU)              |
| Grand Haven State Park Beach     |                   | Yes (MSU)              |
| Rosy Mound Recreational Area Beach|               | Yes (MSU)              |
| Bay City Recreational Area Beach |                   | Yes (MSU)              |

Table 2. Sewage sampling strategy for the evaluation of four rapid detection methods

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Number Of Samples</th>
<th>Method Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Colilert</td>
</tr>
<tr>
<td>Raw Sewage</td>
<td>3</td>
<td>Yes (MSU)</td>
</tr>
<tr>
<td>Raw Sewage Spike</td>
<td>1</td>
<td>Yes (MSU)</td>
</tr>
<tr>
<td>Final Effluent</td>
<td>3</td>
<td>Yes (MSU)</td>
</tr>
<tr>
<td>Final Effluent Spike</td>
<td>1</td>
<td>Yes (MSU)</td>
</tr>
</tbody>
</table>

|                                  |                   | IMS/ATP                |
| Raw Sewage                       |                   | No                     |
| Raw Sewage Spike                 |                   | No                     |
| Final Effluent                   |                   | No                     |
| Final Effluent Spike             |                   | No                     |

|                                  |                   | qPCR                   |
| Raw Sewage                       |                   | Yes (MSU)              |
| Raw Sewage Spike                 |                   | Yes (MSU)              |
| Final Effluent                   |                   | Yes (MSU)              |
| Final Effluent Spike             |                   | Yes (MSU)              |

|                                  |                   | uidA                   |
| Raw Sewage                       |                   | Yes (MSU)              |
| Raw Sewage Spike                 |                   | Yes (MSU)              |
| Final Effluent                   |                   | Yes (MSU)              |
| Final Effluent Spike             |                   | Yes (MSU)              |

|                                  |                   | Razor EX               |
| Raw Sewage                       |                   | Yes (MSU)              |
| Raw Sewage Spike                 |                   | Yes (MSU)              |
| Final Effluent                   |                   | Yes (MSU)              |
| Final Effluent Spike             |                   | Yes (MSU)              |

Table 3. Evaluation of the Razor EX. technology for specificity to *E. coli* O157:H7

<table>
<thead>
<tr>
<th>Organism</th>
<th>Strain</th>
<th>Host</th>
<th>Class</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli</em></td>
<td>O157:H7</td>
<td>Human</td>
<td>EHEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O26:H11</td>
<td>Human</td>
<td>EHEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O45:H2</td>
<td>Human</td>
<td>STEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O103:H2</td>
<td>Human</td>
<td>EPEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O111:H2</td>
<td>Human</td>
<td>STEC/EAEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O121:H19</td>
<td>Human</td>
<td>STEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O145:H7</td>
<td>Human</td>
<td>EHEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O146:H21</td>
<td>Human</td>
<td>STEC1r3</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O156:H21</td>
<td>Cow</td>
<td>STEC</td>
<td>Razor EX</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>O174:H21</td>
<td>Cow</td>
<td>STEC</td>
<td>Razor EX</td>
</tr>
</tbody>
</table>

Results
The results of this analysis are presented in three summary tables below. Beach sample results are provided in Table 4. Information from Table 4 shows that the Colilert data correlates with the qPCR data. This correlation is shown when Colilert and qPCR data both rose together as the sample contamination increased. There were no positive results for the Razor Ex machine for the beach samples. The results for the waste water analysis are shown in Table 5. A critical
difference between the Colilert and qPCR data is present in the waste water data set. Where the Colilert data does not increase with the addition of the spike sample, the qPCR method shows a notable increase. The Razor EX machine returned an expected result showing positive when a spiked sample was present and returned negative with all other samples. The results for the specificity test are shown in Table 6. Based on these results the Razor EX machine shows a remarkable ability to not return a false positive for any of the strains other than *E. coli* O157:H7.

Table 4. Analysis of beach samples for the four study methods

<table>
<thead>
<tr>
<th>Beach Sample Location</th>
<th>Method</th>
<th>Colilert MPN/100 mL</th>
<th>qPCR <em>E. coli</em> uidA Cells/100 mL</th>
<th>IMS/ATP</th>
<th>Razor EX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Haven City</td>
<td></td>
<td>17.00</td>
<td>&lt; 1.16E+01</td>
<td>Confidential</td>
<td>Negative</td>
</tr>
<tr>
<td>Grand Haven State Park</td>
<td></td>
<td>29.00</td>
<td>4.09E+01</td>
<td>Confidential</td>
<td>Negative</td>
</tr>
<tr>
<td>Rosy Mound Recreational Area</td>
<td></td>
<td>59.50</td>
<td>6.11E+01</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Bay City Recreational Area</td>
<td></td>
<td>8.38</td>
<td>2.03E+01</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Table 5. Analysis of waste water samples for the four study methods

<table>
<thead>
<tr>
<th>Beach Sample Location</th>
<th>Method</th>
<th>Colilert MPN/100 mL</th>
<th>qPCR <em>E. coli</em> uidA Cells/100 mL</th>
<th>IMS/ATP</th>
<th>Razor EX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage 1</td>
<td></td>
<td>7.51E+01</td>
<td>1.13E+04</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Sewage 2</td>
<td></td>
<td>1.07E+02</td>
<td>1.50E+04</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Sewage 3</td>
<td></td>
<td>1.19E+02</td>
<td>1.56E+04</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Sewage Spike</td>
<td></td>
<td>1.16E+02</td>
<td>5.27E+04</td>
<td>Not Performed</td>
<td>Positive</td>
</tr>
<tr>
<td>Effluent 1</td>
<td></td>
<td>5.01E-03</td>
<td>1.14E+02</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Effluent 2</td>
<td></td>
<td>4.28E-03</td>
<td>5.80E+01</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Effluent 3</td>
<td></td>
<td>3.78E-03</td>
<td>3.25E+01</td>
<td>Not Performed</td>
<td>Negative</td>
</tr>
<tr>
<td>Effluent Spike</td>
<td></td>
<td>2.04E-03</td>
<td>1.21E+03</td>
<td>Not Performed</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Table 6. Specificity analysis for the Razor EX

<table>
<thead>
<tr>
<th>Strain Sample</th>
<th>Razor EX</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli</em> O157:H7</td>
<td>Positive</td>
</tr>
<tr>
<td><em>E. coli</em> O26:H11</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O45:H2</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O103:H2</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O111:H2</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O121:H19</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O145:H7</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O146:H21</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O156:H21</td>
<td>Negative</td>
</tr>
<tr>
<td><em>E. coli</em> O174:H21</td>
<td>Negative</td>
</tr>
</tbody>
</table>
Conclusions
The four technologies analyzed produced interesting results thus far, however until the IMS/ATP results are added a complete project conclusion cannot be made. Preliminary conclusions however can be made for the three other methods in relation to each other. The Colilert and qPCR methods are similar in terms of a related increase as the samples came from beaches that are historically more contaminated. An important difference between qPCR and Colilert is qPCR appears to be significantly more sensitive to small levels of contamination, which was shown with the waste water spiked samples. The Razor EX method performed as expected with all positive controls and spiked samples returning a positive result. None of the non-spiked environmental samples returned a positive result, which compounds the effect of the loss of the sensitivity analysis since a detection limit could not be determined. The Razor Ex technology did perform impressively in terms of the specificity analysis, where it did not return a false positive for any of the strains other than O157:H7. The specificity results indicate that the environmental samples likely did not contain O157:H7 and as a result the Razor EX returned a negative.

Future Work
Currently no future work is planned; however there are funds available for more investigation due to the unforeseen inability to purchase Razor EX strips. Any future work would have to be conducted without the Razor Ex technology.

Publications, presentations and outreach
None at this point in the project

Reference
THEME IV: PROTECTION AND RESTORATION OF RESOURCES

Projects under this theme advance restoration initiatives, including ecological priorities of Lakewide Management Plans, and Remedial Action Plans for Areas of Concern.
PROJECT TITLE: GREAT LAKES RESTORATION INITIATIVE – NOAA PROGRAM SUPPORT

Principal Investigators: Allen Burton, Tom Johengen, and Sander Robinson (CILER)
NOAA Technical Contacts: Marie Colton and Felix Martinez (NOAA)

Overview and Objectives

CILER has been assisting with the execution of NOAA and USEPA non-Federal CILER-directed GLRI grant implementation, providing evaluations of performance effectiveness of the awards, and assisting in reporting requirements. In addition, CILER has been organizing and leading workshops to facilitate information exchange across relevant GLRI projects that are important for related NOAA activities. Finally, undergraduate and graduate student fellows have been supported to assist with these GLRI projects.

In summary, the overarching objective is to provide the necessary programmatic infrastructure to support all reporting on GLRI deliverables by NOAA and participating stakeholders, and to provide data and information that are public friendly and timely.

This project addresses NOAA Strategic Plan Goal(s):
1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management, and
2) NOAA Mission support

Accomplishments

GLRI Review Update

During the last reporting period, an expert panel external to NOAA and GLRI-funded projects was assembled by CILER, and attended the review and heard summary presentations from project leads. The reviewers synthesized this information in a debriefing session during the last day of the review based on certain evaluation criteria. CILER created a draft document of the information that was sent to reviewers for comments. CILER completed the incorporation of these comments into a second draft that was sent out to the panelists for final review and editing.
During this reporting period, the report was then submitted to Marie Colton, GLERL’s Director. Since then, Dr. Colton distributed the report to project leads for consideration.

Next Step after Workshop on: Building a Community Modeling and Forecasting Framework for Lakewide Management in the Great Lakes

Based on an idea from NOAA’s Felix Martinez, planning was completed for the follow-up symposium/town hall-style conference to advertise models best suited to enhance the integrated forecasting and subsequent management of Great Lakes ecosystems. Abstracts submitted by Great Lakes modelers were evaluated and chosen for inclusion in the special session, “Integrated Modeling of Large Lake Ecosystems”, at Coastal Zone’s 2011 Chicago meeting that took place in July.

Final Report - Lake Michigan Ecosystem Modeling and Forecasting Workshop

The final version of a report summarizing the proceedings of the workshop were disseminated to the community at large through the Great Lakes Information Network (GLIN) and on the modeling page of the Great Lakes Observing System (GLOS).

Publications

None.

Presentations

None.
PROJECT TITLE: IDENTIFY LAND USE INDICATORS AND TIPPING POINTS THAT THREATEN GREAT LAKES ECOSYSTEMS

University Principal Investigators: Brian Miller (Illinois-Indiana Sea Grant); Bryan Pijanowski (Purdue Univ.); Joan Rose, David Hyndman, Jan Stevensen (Michigan State Univ.); Michael Wiley, Catherine Riseng, Sara Adlerstein (Univ. Michigan); Jeffrey Tyler (Fisheries Projections, Inc.)


Overview and Objectives:

In order for coastal communities to achieve ecosystem sustainability, they must first know what land and habitat components are necessary to sustain their ecosystems. When communities are armed with science-based environmental limits or “tipping-points”, they are able to institute land use policies and restoration plans that ensure critical green infrastructure and habitat sustaining Great Lakes ecosystems are maintained. (For example, the Sea Grant Sustainable Coastal Community Development network has used a 10% impervious cover tipping point to work with communities to measure their existing impervious surface cover, and implement land use change policies, ordinances, comprehensive plans, and smart growth strategies necessary to keep a community’s impervious surface cover below levels that impact their streams.) This project will use existing Great Lakes water quality, biological monitoring, and corresponding watershed land use data to identify tipping points that impact Great Lakes ecosystems.

1. Identify Land Use Indicators. Work will be performed by IL-IN SG extension specialists and a CILER fellow (located at Purdue University and co advised by NOAA researchers) to engage university faculty and other Great Lakes researchers in development of two new SOLEC indicator suites for Land Use Change and Agricultural Lands. These indicators will help decision makers to more completely assess the impact of coastal land and watershed impacts on both the nearshore and open waters of the Great Lakes and to make decisions that improve nearshore and open water conditions and ecosystems.

2. Develop coarse scale analysis of land use tipping points. The Purdue team (Pijanowski) will calibrate the National Land Cover Database (NLCD) to earlier land cover databases (MIRIS) at 100 m resolution so that historical data and models of stream chemistry and biology can be related to relevant coverages with more land use classifications.
The UM team (Wiley, Riseng) will rerun CART models and causal models (e.g., Structural Equation Models) using the NLCD to identify land use tipping points in Muskegon River and watersheds surrounding Grand Traverse Bay. These models will identify tipping points by relating land use indicators to hydrology, water quality, macroinvertebrates and fishes.

Tyler will finish calibration of an agent-based model of Chinook salmon, and run simulations of land-use change impacts on salmon recruitment potential in the Muskegon River. The UM team will work with Tyler to extend the analysis to the Grand Traverse Bay watershed.

3. **Compare estimates of tipping points from coarse and fine-scale analyses.** PU, UM and the GLERL team will compare predictions of land-use tipping points from the coarse-scale CART model with predictions from a calibrated, highly-mechanistic coupled modeling system for the Muskegon River estuary. Multiple land use scenarios will be evaluated with both models including varying rates of urban change, forest regeneration rates, riparian setbacks, and water recharge protection areas.

4. **Extend the Tipping Point Analysis to Include Bacterial Contaminants.** The MSU group (Dr. Joan Rose, Dr. David Hyndman) along with Dr. Bryan Pijanowski (Purdue) will develop maps of septic tank use, storm drains, CSOs, and water quality violations for the Boardman and Jordan watersheds surrounding the Grand Traverse Bay. For these watersheds, Hyndman and Rose will use hydrology and groundwater models to predict *E. coli* occurrence and transfer from septic tanks to reported TMDLs and water quality variations.

5. **Develop and apply food web modes to evaluate land use tipping points for Saginaw Bay.** Drs. Sara Adlerstein-Gonzalez (UM) and Edward Rutherford will complete development of an extant food web model (Ecopath with Ecosim - Ewe) of Saginaw Bay to simulate impacts of a land use tipping point (Phosphorus loading) on biota (phytoplankton, zooplankton, benthos, fish, birds). The EwE modeling software (Christensen et al. 2000) was applied by the investigators to analyze impacts of nutrient load reductions and Dreissena mussel invasion in the early 1990s on the Saginaw Bay food web. The Saginaw Bay EwE model will be updated to include recent species trends (through 2008) and impacts by new invasive species (round goby) on the food web and fishery.

6. **Integrate the Modeling Approaches.** We will integrate the hierarchical models (land use, hydrology, fisheries and contaminants) for the Jordan River and Boardman River watersheds. We will compare biological outcomes from our suite of models with coincident sampling and modeling of phosphorus loadings and algal blooms in Michigan’s nearshore waters of Muskegon Lake and Grand Traverse Bay by Drs.
Stevenson and colleagues on their GLRI project entitled “Nutrient management models to constrain harmful algal blooms”.

7. **Identify specific land use tipping points that change biological and/or contaminant outcomes.** We will begin to develop a web-based GIS decision support data layer that can be used by land use decision makers to determine where they are relative to these tipping points. We will initiate development of additional materials to help decision makers determine their options if they are nearing or exceeding tipping points and users will be directed to potential policies and management practices that could improve these conditions. 

8. **Conduct a Demonstration of Use.** We will travel to several locations and work directly with planners and natural resource managers in these pilot communities to demonstrate the tipping point tool. This demonstration will include a presentation and discussion regarding specific targets (i.e., tipping points) that should guide planning for their community. Feedback gained from pilot communities will be used to improve the decision support tool and associated support materials.

This project addresses NOAA’s Strategic Plan Goal to protect, restore, and manage use of coastal and ocean resources through ecosystem-based management.

**Accomplishments:**

**Obj. 1. Identify Land Use Indicators:** We held an annual project meeting March 14 2012 at Purdue University in Lafayette IN to identify land use indicators. Attendees included project investigators, US EPA representatives and Illinois-Indiana technical leads with US EPA, Sea Grant representatives from the 5 Great Lakes states, and land use planners from several counties and watersheds surrounding Lake Michigan. Several project investigators made presentations (See results below.) that clearly identified relationships between relative proportions of agriculture and urban development in the watershed and stream biota health, bacterial contamination, and nutrient loads to the nearshore zones.

**Obj. 2. Develop coarse scale analysis of land use tipping points.** (Wiley, Riseng): Wiley and Riseng completed a CART model analysis of land use thresholds (Tipping points) influencing response variables (flow, nutrient loads, and channel stability) that subsequently affect stream biotic integrity in Michigan’s lower peninsula (Figure 1). The land use tipping points were similar no matter the response variable. Preliminary work using the NLCD land cover framework for Michigan indicates a more complex response is possible. Wiley and Riseng will continue to work with Pijanowski to translate the CART models to a NLCD land cover framework.
Figure 1. Summary of analysis of land use tipping points for Great Lakes tributary biotic integrity in Michigan’s lower peninsula.

Obj. 3. **Compare estimates of tipping points from coarse and fine-scale analyses.** *(Tyler, Rutherford, Wiley, Riseng)*: Much of this past year was spent finishing model simulations of steelhead response to phosphorus loadings resulting from land use change, and developing the Chinook salmon individual based model. The Chinook salmon model is configured for habitats in the Muskegon River watershed, and includes a lake stage. The basic framework of the model is patterned after Tyler et al.’s Muskegon River steelhead model. Preliminary analyses of the Chinook model are being run to calibrate the model and begin simulations of land use change.

Obj. 4. **Extend the Tipping Point Analysis to Include Bacterial Contaminants.** *(Rose, Hyndman)*: Sampling for bacterial contamination was conducted on several Great Lakes tributaries and results were tied to land use. Results of the field surveys and modeling work indicate microbe concentrations are related to seasonal hydrologic variability. *B. theta* enters rivers through groundwater, and under baseflow conditions, *B. theta* is affected by urban land use. Watershed septic concentrations were related to spring thaw *B. theta* concentrations (*p* = .001, $R^2$=.114). The investigators found that *B. theta* is an indicator of seasonal septic usage in rural areas but not of urban land use density. *B. theta* concentrations were not different among different regions of the lower peninsula. *E. coli* contamination is most prevalent in agriculture-dominated watersheds.
(Fig. 2) where septic tanks overflow during spring flood events, discharging bacteria into tributary surface runoff. During early summer rain, *E. coli* is affected by urban land use.

![E. coli concentration range](image)

Figure 2. *E. coli* concentrations in different areas of Michigan’s lower peninsula.

**Obj. 5. Evaluate land use tipping points for the Saginaw Bay ecosystem. (Adlerstein-Gonzalez, Rutherford):** Adlerstein-Gonzalez, Ph.D student Y-C Kao, and Rutherford configured a biomass change model to simulate changes to phosphorus loading (resulting from land use change) on the Saginaw Bay food web. The Ecopath food web model was configured using data for the pre-zebra mussel invasion period of 1986-1990. They will calibrate the food web model in simulation mode (Ecosim) against phosphorus loads and biomass data for the period from 1992 to 2010. After calibrating the model to existing data, they will run simulations of various projections of land use change on the Saginaw Bay food web, with and without changes in fisheries harvest.
Obj. 6. Integrate the Hierarchical Models. Considerable integration of models occurred at the project meeting in Purdue University on March 14-15, 2012. The integration of hierarchical models is ongoing. Project investigators expect to complete this objective once all hierarchical models have been rerun using updated land use cover databases (2006 National Land Cover Database - NLCD).

Obj. 7. Identify specific land use tipping points that change biological and/or contaminant outcomes. Significant progress was made this year. Local government officials and natural resource managers were surveyed by Ph.D student Kim Robinson (Purdue Univ.) to determine what type of decision support is needed regarding water quality, ecological tipping points and agricultural indicators. The survey went to 400 individuals, and 186 responded (33% response rate) from within the 4-state region of Ohio, Indiana, Michigan and Wisconsin. Results of the survey are being analyzed. A web-based dashboard tool was developed to indicate overall watershed health, water quality index, aquatic species health and human safety indicators of each Great Lakes watershed.

Obj. 8. Conduct demonstration of use. Plans have been made to travel to several locations and work directly with planners and natural resource managers in these pilot communities to demonstrate the tipping point tool. These meetings will be held in late 2012 and early 2013. Feedback gained from pilot communities will be used to improve the decision support tool and associated support materials. Co-PI Pijanowski developed a draft web site for the Tipping Points project to provide decision support tools and associated materials (prodgis.agriculture.purdue.edu/TippingPointsMockup/index.html).

Publications:

Presentations and/or Workshops:
Marc Verhougstraete (MSU) presented a paper Oct. 14, 2011 at a conference in Manila entitled “A biogeological survey: understanding water quality using a process-based approach”. Co_investigators of the paper included Drs. Joan Rose, David Hyndman, and Anthony Kendall of MSU.

Outreach Activities: None.
PROJECT TITLE: IMPACT OF TEMPERATURE AND OXYGEN LEVEL ON GROWTH AND SURVIVAL OF FIRST FEEDING YELLOW PERCH LARVAE

University Principal Investigators: Allen Burton, CILER; Konrad Dabrowski, OSU

NOAA Technical Lead: Edward Rutherford, GLERL

Overview and Objectives:

Yellow perch is an economically important species in the Great Lakes for both sport and commercial fishing. It is important for fisheries managers to understand how hypoxia affects the larval development of yellow perch. With the temperatures of Lake Erie increasing, it is important to gain knowledge of how hypoxia may impact recruitment of yellow perch if hypoxic events occur during the early life stages.

The NOAA Strategic Plan this project addresses: 1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management

Accomplishments:

Brood stock yellow perch (n=200) we maintained in the aquaculture lab at The Ohio State University under water temperatures that followed natural temperature regimes (Fig. 1). Fish were fed 1% of their bodyweight every other day with Aqauramax Grower 500 (Purina). When females begin to ovulate, eggs will be stripped and fertilized using the dry method (Dabrowski et al. 1994). Embryos will be transferred to McDonald hatching jars and incubated in de-chlorinated city water at 15 °C. Upon hatching, approximately two weeks after fertilization, larval yellow perch will be transferred to the experimental larval-rearing system (Wojno et al. 2012). At this time, the system is undergoing repairs and modification in order to achieve optimum rearing conditions along with efficient oxygen removal. This system is a semi-recirculating system consisting of seven tanks, four of which will have nitrogen gas injected into the water to create hypoxic conditions. Dissolved oxygen in the hypoxic tanks will have a concentration of 3 mg/l and the normoxic treatment will have oxygen at 9 mg/l. Water to each tank will be delivered through a sprinkler system to break the surface tension of the water to facilitate swim bladder inflation. To prevent the larvae from clinging to the tank walls, water will have concentrated algae paste (Nannochloropsis 3600, Reed Mariculture) added to the water to create turbidity. Initially, fish will be fed with rotifers for 5 days and then Artemia naupilli will be introduced on the fourth day. In order to have larvae for multiple experiments, a group of adult yellow perch received temperature (Fig. 1) and light manipulation so that out-of-season spawning can be achieved. Photoperiod was manipulated to maintain summer lighting conditions, 14-h
light, 10-h dark until January 1. This has been done using methods described by Dabrowski et al. (1996).

**Publications:** There have been no publications to this date.

**Presentations:** There have been no presentations given about this project.

**Outreach Activities:** There have been no outreach activities about this project.

**References:**


![Temperatures 7/1 - 3/26](image)

**Figure 3.** Daily temperatures in the yellow perch brood-stock tank from July 1, 2011 to March 26, 2012. The “natural treatment” group received natural light and temperature regimes and the “manipulated” group was kept in summer temperature and day length until January 1 to have out-of-season spawning delayed until May-June.
THEME V: INTEGRATED ASSESSMENT

CILER activities that fall under the theme of Integrated Assessment include research to generate policy-relevant and synthetic efforts to help guide long-term resource use in the basin.
PROJECT TITLE: **Adaptive Integrated Framework: A New Methodology for Managing Impacts of Multiple Stressors in Coastal Ecosystems**

*Principal Investigators:* Thomas Johengen and Dima Beletsky, CILER, University of Michigan; Carlo DeMarchi, Case Western Reserve University; Tomas Hook, Purdue University; Donna Kashian, Wayne State University

*NOAA Technical Contacts:* Craig Stow and Juli Dyble Bressie, NOAA - GLERL

**Overview and Objectives:**

We proposed a novel, unique Adaptive Integrated Framework (AIF) for facilitating information collection, implementing adaptive modeling approaches, and guiding research needs to improve management decision making. This framework uses input from agency managers, researchers and modelers, including both data to characterize ecosystems and socio-economic factors to drive modeling approaches and management actions. The proposed framework is being applied to Saginaw Bay, a coastal system greatly impacted by multiple stressors such as invasive species, changing land-use patterns, and climatic change.

The program is calibrating an ensemble of ecosystem models using extensive historical data for Saginaw Bay, develop a watershed and hydrological model for the coastal ecosystem, and develop human dimensions models for evaluating resource outcomes and management plans. These efforts are being undertaken at differing scales of resolution to model and evaluate water quality, fish production and economic metrics that are of importance to management agencies and the public. The modeling efforts use an iterative process in which modeling outputs will identify knowledge gaps (i.e., drive field and experimental research) and help management agencies identify management alternatives. The results and data needs (gaps) identified by the agencies will, in turn, lead to models being re-parameterized, re-applied and re-evaluated before the next iteration of management agency input and field research.

The proposed work recognizes the crucial need for developing models that are adaptable across ecological systems and multiple stressors as well as one that provides managers with a means to understand and manage stressor interactions unique to their system. The five year project accomplishes these goals by coupling modeling, observational, and experimental studies with stakeholder workshops and socio-economic analyses. The resulting AIF approach will be broadly applicable to evaluate the nation’s coastal and estuarine ecosystems impacted by multiple stressors. This reporting period represents year 4 of the 5 year project.
Project Objectives:

- Develop the Adaptive Integrative Framework (AIF) approach to facilitate synthesis and prioritization of research and management pertaining to multiple stressors impacts on coastal ecosystems.

- Provide specific predictions regarding how fish production, human health, and regional economics, respond to multiple stressors (i.e. land use, climate change and invasive species) in Saginaw Bay, MI.

This project addresses NOAA Strategic Plan Goal(s):

1) Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management;
3) Serve society’s needs for weather and water information;

Accomplishments:

All of the field research for CILER’s component of the project has been completed and we are in the process of synthesizing the data for a series of final project reports to managers and a dedicated Journal issue. However, final modeling scenarios and synthesis will still be taking place over the course of the next year or so. The following text represents a basic synthesis of findings that are being addressed in these summary publications. We have been working closely with Great Lakes resource managers and project collaborators as to the best way to the form and content for these reports.

Ecosystem Stressors

Phosphorus Inputs

Following initial decreases in the late 80’s and early 90’s, total phosphorus loads to Saginaw Bay have stabilized. However, the target load of 440 tonnes per year established in the Great Lakes Water Quality Agreement is not being met, even when only the Saginaw River is considered. Initial decreases in loading were confirmed to have resulted from declining TP concentrations, mostly in the Saginaw River. The uncertainty of the annual Saginaw River TP load estimates is relatively high due to sparse monitoring of TP concentrations. TP loads from the smaller tributaries are not well-monitored for either flow or TP concentration – tributary data collected during this project do not indicate local hotspots, but these data are extremely limited. Current annual load fluctuations result mostly from differences in river flow. River flow fluctuates yearly but shows no long-term trend – seasonal changes may be occurring with declining early spring flow. The wetland and marshes around the National
Wildlife Refuge just south-west of Saginaw have a strong effect on the loads produced in the Flint River, Shiawassee River, and other smaller tributaries, with an average reduction of around 13%. A spatial analysis of the TP load entering the bay reveals the following sources of the P inputs (when the effect of the NWR is taken in consideration): Tittabawassee River, 21%; Shiawassee River, 5%; Flint River, 19-20%; Cass River, 9%; Bad River, Marsh Creek, Birch Run, Bear Creek, 5%; Saginaw/Bay, 14%; Kawkawlin-Pine, 4-5%; Pigeon-Wiscoggin, 8-9%; AuGres-Riffle, 5%; and atmospheric deposition, 8-9%. Urban and industrial point sources emissions accounted for 145 and 146 mtP/y in 2004 and 2005, two average years, 158 mtP/y in 2009, an exceptionally wet year, and just 109 mtP/y in 2010, a very dry year. The contribution of Retention Treatment Basins (RTB) in these four years was relatively stable around 14-16 mtP/y. Based on the ratio between emissions and summer low flow river load, it seems that 80% of this load is exported to the bay. Thus, the contribution of point sources to the total load to the bay should vary between 18% in wet years to 33% in dry years. Contributions of RTBs vary between 2 and 6% of the TP total load. The main point sources WWTPs (Saginaw, Bay City, Bay County WWTPs) are already at best available technology. The only main source that could be substantially improved is the Flint WWTP. However, the fact that the Flint River discharges upstream, the NWR may diminish the impact of technological changes to this WWTP. A possible decrease of point sources load to the bay could be achieved by rerouting all or part of the Saginaw City WWTP discharge from the main river to the adjacent Crow Park State Game area, which is a wetland (that could also be expanded) as well as the output of the Bay City WWTPs to some nearby wetland area. Retention treatment basins (RTB) represent around 2-6% of the Saginaw River load. The quality of water coming out from the RTBs is comparable to that coming out from WWTPs, but worse than the typical stormwater.

Implications – Our knowledge of the phosphorus load to Saginaw Bay is based almost completely on Saginaw River data. The relatively high uncertainty of these estimates, resulting from limited TP concentration data collection, combined with fluctuating river flows, will make it difficult to discern any future trends in the TP load into the Bay.

Invasives

Overall, mussel densities are down from the 1990s, and populations have shifted from initially just zebra mussels to about 80% quagga mussels. Experiments on mussel feeding and nutrient cycling reveal that feeding and excretion rates are highly variable over time and reflect both changes in temperature and metabolic responses as well as changes in food quality as reflected by phytoplankton composition and nutrient stoichiometry. Experimentally determined rates can be used to better inform the ecosystem models being applied. Mass balance modeling indicates that the proportion of influent TP retained in the sediments increased when the mussels arrived but
because TP loads were decreasing the annual TP mass retained has been relatively stable. While Dreissenid density in the bay seems to be lower than was observed in the 1990’s, the composition is largely quaggas and there is still evidence of their influence on altering phosphorus dynamics and light conditions in the bay. And they still have an influence on Cladophora production and Microcystis bloom formation. The model suggests that increasing Dreissenid density will increase both Cladophora and Microcystis production problems in the bay.

**Implications** – The shift from zebra to quagga mussels is similar to what is being observed throughout the Great Lakes. Mussel densities are down from the 1990s. Whether current densities are relatively stable or represent short-term fluctuations is unclear due to the eleven year monitoring gap from 1996 to 2008. Although there is evidence that mussels have increased the net phosphorus sedimentation in Saginaw Bay, ambient concentrations of TP and other monitored water quality characteristics exhibit no clear patterns over time.

**Ecosystem Responses**

**Water Quality/HABS**

Prior to this study the inner Saginaw Bay was generally thought to be vertically well-mixed. However, temperature profiles at several locations around the inner bay indicate periodic, short-lived stratification. Dissolved oxygen measurements at station 10 (the deep hole ~ 11 meters) indicate regular, rapid dips in the dissolved oxygen concentration near the bottom. The development of hypoxic conditions is of concern based on experimental findings that cores from this site incubated under low oxygen conditions exhibited very high phosphorus flux to the water column. Temperature measurements at station 10 indicate periodic pulses of cold water periodically move into the inner bay, so the exact extent of hypoxic development is unclear.

It was also found that some existing maps (e.g. IJC, 1977) inaccurately depict circulation in the outer bay. Hydrodynamic model results for 1991-1996 and 2008-2010 show a persistent anti-cyclonic gyre (instead of a cyclonic one) near the mouth of the outer bay, impacting water and constituents exchange with Lake Huron. Riverine flushing time of the inner bay was estimated to be about 1.8 years. Previous studies (Dolan, 1975) showed that water exchange driven by lake circulation substantially decreases this time, down to 3.7 months. New model results (based on a 2D particle transport model that was run from spring to late summer for the above mentioned 9 years) revealed considerably longer flushing times. The minimum flushing time for the inner bay was about 5 months (in mid and late summer) and exceeded 7 months in the spring.

Inner Bay TP concentrations declined with the decreasing loads and have been fairly stable since the late 1980s. Similarly, inner Bay chlorophyll a concentrations
declined with decreasing TP and have been fairly stable since the late 1980s. Neither TP nor chlorophyll \( a \) show any clear patterns, on an annual basis, since the mussel invasion. Neither the 15ug/L target TP concentration nor the 3.6 ug/L target chlorophyll \( a \) concentration are consistently met in the inner Bay. Wind-driven resuspension in the shallower areas of the inner bay contributes significantly to water column total phosphorus concentration on an event basis. Simulation of total phosphorus in the bay would not match observations very well if sediment resuspension was not included in the simulation. However, it is not clear that sediment resuspension of particulate phosphorus contributes significantly to algal growth. Other water quality characteristics including total dissolved phosphorus, nitrate and secchi depth show no clear patterns from 1991-2010 (the mussel era), though soluble reactive phosphorus extremes have declined. Most soluble reactive measurements are currently very near the practical detection limit. Phytoplankton biovolume measures show a mix of diatoms and cyanobacteria. On a cell density basis cyanobacteria are dominant at most times of the year. Cyanobacteria composition is mixed, with a lot of Microcystis and Merisomopedia. Ambient microcystin concentrations were variable; approximately 19% of the 145 measurements exceeded the 1 ug/L recommended limit on drinking water concentration, mostly in the late summer. A well-defined relationship between chlorophyll \( a \) and total phosphorus implies that phytoplankton are phosphorus limited. Late summer Microcystis blooms continue to occur in inner Saginaw Bay. These blooms are driven by a combination of elevated water column temperature and elevated levels of available phosphorus in the bay from both external loads and phosphorus recycling from Dreissenids and internal sediment diffusive fluxes.

**Implications** – There is a potential for sediment phosphorus release in the region where bottom water oxygen is rapidly depleted. The spatial extent of this region is unclear as is the relative importance of this release with respect to the annual phosphorus budget or the promotion of algal growth. Though there are no current standards, the measured phytoplankton levels are not particularly high compared with other systems. Although the drinking water microcystin criterion is periodically exceeded the standard is applicable to treated drinking water, not the raw water measured. Identifying the phytoplankton group responsible for recent taste and odor problems at drinking water taps requires further investigation.

**Beach Issues/Muck**

Park ranger logs from the Bay City Recreation Area indicate that muck on the beaches was a nearly continuous, regular problem during the 1980s and early 90s. This period follows the establishment of phosphorus regulations and precedes the mussel invasion and, within the Great Lakes region, is generally regarded as an era when declining phosphorus levels led to reduced Cladophora growth with a resultant
reduction in nuisance algal deposits. Muck composition differs across the summer season and between years. Cladophora, Spirogyra, macrophytes, and wood chips have all been observed. “Fresh” muck deposition (i.e. identifiable composition) occurs early in the season and only occasionally later in the season. More often, the muck is so badly decomposed that the composition is indeterminate. The general direction of the muck movement is from north to south along the coastline. Fine-scale circulation models confirm this pattern and indicate regular pulses converging near the river mouth, with north winds.

Algal muck precursors are both light and phosphorus limited and appear to grow in the southwestern zone of Saginaw Bay between the Saginaw River and Au Gris, MI. Conditions for Cladophora production in the inner bay seem to be optimum in the shallow (≤2 m depth) areas of the west and southeast portions of the inner bay. There seems to be a relationship between Cladophora production and muck production, but there also seem to be several other constituents of muck that contribute to this problem. It is not clear that eliminating Cladophora growth will eliminate the muck problem.

There is no question that phosphorus is the limiting nutrient for primary production in Saginaw Bay. It is also clear that reduction in phosphorus loads from the watershed will reduce nuisance and harmful algal growth. However, the model has not been explored via diagnostic scenarios yet to be able to recommend optimal spatial and temporal strategies (i.e., focus on Saginaw River or minor tributaries directly feeding into nearshore zones of the bay) for this load reduction. Nor has the model been exercised to develop a quantitative load response relationship for these lower food web ecological response endpoints. Both of these issues are in our plans. Muck appears to collect most heavily in inlets and coves along the shoreline; areas protected from heavy wind and wave scour. Lastly, microbial analyses have shown that the muck harbors high levels of fecal indicator bacteria.

Implications – While dreissenid mussels are generally believed responsible for the reappearance of beach muck around the Great Lakes, the situation in Saginaw Bay appears more complicated. There is insufficient data to document whether the muck composition varies systematically or randomly over time, and further the composition of the muck prior to the mussel invasion is unclear. These facts make it difficult to ascertain the importance of mussels in muck promotion currently. It is likely that the failure to attain target TP loads and ambient TP concentrations contributed to regular muck problems before the mussel invasion, and evidence that the algal muck precursors are phosphorus limited suggests that further phosphorus reductions will reduce the muck that results from decaying benthic algae. However, the deposition of decaying macrophytes may still occur, at times, even if benthic algal growth is reduced.
Fishery

Based on analyses of long-term MI-DNR trawling surveys, recruitment of walleye in Saginaw Bay appears to be set by fall of age-0, while recruitment of yellow perch appears to be set by fall of age-1. While past analyses suggest that walleye recruitment was historically controlled by alewife, historical controls on yellow perch recruitment are less clear. The yellow perch stock-recruitment relationship from 1970-2008 appears to be non-stationary. Moreover, current spawning stock biomass is very low relative to this period of record. Based on multiple re-sampling and multivariate analyses, from 1970 to 2008 the Saginaw Bay fish assemblage changed with a) increased richness, b) decreased prevalence of eutrophic-tolerant species, and c) increased relative abundance of many moderately tolerant species.

An increase in large cladocerans (i.e. *Daphnia*) since the 1990s appears related to the decline of alewife, nevertheless, small cladocerans still account for 80% of the cladocerans, reflecting high planktivory pressures in the bay. The plankton ratio (i.e. calanoid/(cyclopoid+cladoceran)) increased from 0.06 in the 1990s to 0.22 in 2009-2010, reflecting a more oligotrophic system.

The invasive predatory cladoceran *Bythotrephes* appeared early in the year, and persisted into the fall at relatively high densities (> 100/m²), although peak areal densities were lower than those observed in other Great Lakes. While still relatively rare in Saginaw Bay, mayflies (including *Hexagenia*) were collected in benthic samples and in diets of various fish species. In addition, numerous *Hexagenia* exuvia were collected in horizontal plankton tows.

Age-0 yellow perch grew relatively fast during larval and early juvenile stages. However, growth slowed by late summer. Many age-0 yellow perch did not undertake an ontogenetic diet switch from zooplankton to benthic macroinvertebrates and instead continued to consume zooplankton throughout their first year of life. Slow growth by young yellow perch may have impacted survival as a) small age-0 yellow perch were more likely to be consumed by walleye than large age-0 yellow perch and b) yellow perch lost significant energy during winter and smaller individuals may have been more likely to experience overwinter mortality. Recently emerged larval walleye were initially collected by the mouth of the Saginaw River, but were subsequently collected throughout the bay, suggesting that successful spawning took place in multiple habitats. During the first year of life, walleye transitioned from feeding entirely on zooplankton as larvae to benthic invertebrates and then fish, and by late fall age-0 walleye were almost entirely piscivorous, consuming small round goby, rainbow smelt and shiners. Most age-1+ walleye ate fish, although a few ate macroinvertebrates. Yellow perch (mostly age-1) accounted for 42% of the fish eaten, round goby 26%, gizzard shad 14%, shiners 10% and rainbow smelt 7%. Most age-0 lake whitefish ate cladoceran zooplankton in June, but by July-September, most fish were eating benthos (chironomids, amphipods, ostracods, sphaerid clams). The main zooplankton eaten (by
number) were *Bosmina* in June, *Diaphanosoma* in July, and Chydoridae in August and September. Most age-0 white perch ate mainly zooplankton (*Daphnia*) in July. During August-November, increasing numbers of fish incorporated benthos (chironomids, amphipods, ostracods) into their diets, but most fish still ate zooplankton as well (*Daphnia* in August and September, chydorids and *Diaphanosoma* in October and November).

Evidence regarding the role of round gobies contributing to declines of dreissenid mussels from 1990s to 2008-2010 is equivocal. Dreissenid size distributions are indicative of predatory control, while bioenergetics analyses suggest that round gobies cannot consume sufficient numbers of dreissenids to impact the population. Results to date from our fine-scale inner bay particle tracking model indicate that the Saginaw River can be a source of larval fish to areas in the bay where they have been observed.

**Publications:**


**Presentations:**

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.


**Outreach Activities:**

Project PI’s held a workshop at NOAA-GLERL in December 2011 for the Great Lakes water quality managers, updating them of our preliminary results.

Project PI’s held a workshop at NOAA-GLERL in October 2011 for the Great Lakes fishery managers.

A meeting between project researchers and Michigan DNR management was conducted in August 2011 to discuss the overall state of the project and to help develop approaches and content for disseminating project final results.
PROJECT TITLE:   ECOFORE - FORECASTING THE CAUSES, CONSEQUENCES AND REMEDIES FOR HYPOXIA IN LAKE ERIE

University Principal Investigators:
Allen Burton, Donald Scavia, J. David Allan, Dmitry Beletsky, Thomas Johengen, Hongyan Zhang, Mary Anne Evans (University of Michigan); Tomas Höök (Purdue), Steven Bartell (E2, Inc.); Joseph DePinto (LimnoTech, Inc.); David Dolan (University of Wisconsin – Green Bay); Chansheng He (Western Michigan University); Roger Knight (Ohio DNR); Peter Richards (Heidelberg College); Stephen Brandt (Oregon State University); Stuart Ludsin (Ohio State University); Nate Bosch (Grace College)

NOAA Technical Leads:
Doran Mason, Edward Rutherford, Steven Ruberg, David Schwab, Henry Vanderploeg (NOAA-GLERL)

Overview and Objectives:
The overall objective of this project is to create, test, and apply models to forecast how multiple stresses influence hypoxia formation and ecology of Lake Erie’s Central Basin, with an emphasis on fish production potential. These models integrate the multiple factors that interact to create hypoxia on Lake Erie, such as surface water flow, phosphorus input, lake dynamics, climate variation, fish movement patterns and fish and Dreissenid biology and physiology. The forecasts are conducted within an Integrated Assessment (IA) framework, which is a formal approach to synthesizing existing natural and social scientific information in the context of a natural resources policy or management question.

This project addresses two of NOAA Strategic Plan Goals: 1) to protect, restore, and manage use of coastal and ocean resources through ecosystem-based management, and 2) to understand climate variability and change to enhance society’s ability to plan and respond.

Accomplishments:
This is a year of project extension without cost, and the major focus is to finalize research, disseminate results, and intensively collaborate/interact among teams (watershed, hydrodynamics, and food web teams).
Remaining data compatibility issues were resolved such that models can interact more effectively. A project team meeting was held and a timeline developed for project completion. We have met both of our March timeline objectives, producing lake thermo regimes under climate change scenarios and refining sediment oxygen demand (SOD) functionality in the level 2 hypoxia model to accommodate climate scenarios, and are on course to meet the remaining time points.

**WATERSHED TEAM**

Many activities in the Watershed Team are being conducted and completed concurrently. Nutrient (TP, NO₂+NO₃, TKN, TN, TSS, and SRP) loading data are being compiled and summarized to be used as model inputs for the Hypoxia Team. Watershed nitrogen (N) and phosphorus (P) budgets are being created to better understand N and P sources over time as well as to aid in forecasting scenarios. The Distributed Large Basin Runoff Model (DLBRM) and the Soil and Water Assessment Tool (SWAT) are being parameterized and calibrated to be used in climate and land management practice change forecasting scenarios.

**Nutrient loading efforts**

Monthly and daily river export load series for the Raisin, Maumee, Sandusky, Vermilion, Cuyahoga, and Grand Rivers have been completed for the period of record. Missing data have been filled in, and the complete time series have been posted to the project website.

Richards and several EcoFore colleagues are working on a critique of the USGS Great Lakes SPARROW model, for publication in JAWRA. The critique is currently undergoing revision.

**Watershed models**

Multiple databases of land use, soil, digital elevation model (DEM), hydrography, and agricultural management practices have been acquired, processed, and analyzed to develop dynamic input parameters for the DLBRM and the revised universal soil loss equation (version 2) (RUSLE2) for the 6 watersheds on the U.S. side (Grand-OH, Cuyahoga, Sandusky, Maumee, Huron-MI, and Raisin). We have acquired and processed multiple databases of land use, soil, digital elevation model (DEM), and hydrography for the Grand River –Ontario. A computer program was written to spatially link the Ontario soil attribute database with the polygon database for extracting the soil input parameters. Input parameters for the DLBRM were derived.
We have also built basic model application databases (daily meteorology, land use, soils, elevation, and hydrography) for all 17 U.S. Lake Erie watersheds, and we completed DLBRM daily calibrations for five Lake Erie watersheds: Huron, Raisin, Maumee, Sandusky, and Grand (Ohio). We are now calibrating the DLBRM for the remaining 12 U.S. Lake Erie watersheds. We estimated sediment and nutrient transport for two non-Erie watersheds and are doing the same now for the Maumee watershed on Lake Erie. We are now adding transport mechanics to the DLBRM. We developed automatic near real time "Resource Shed" processing for 18 watersheds, including the five Erie watersheds mentioned previously. Resource shed maps for the last 31 days are available daily and will soon be accessible via the internet.

SWAT models have been developed, calibrated, and validated for the same 6 Lake Erie watersheds on the U.S. side being modeled by DLBRM – Huron, Raisin, Maumee, Sandusky, Cuyahoga, and Grand. Overall, the SWAT models' performance is strong when compared to observed stream discharge, sediment loads, and nutrient loads (total phosphorus, soluble reactive phosphorus, total nitrogen, and nitrate). Currently, agricultural best management practice scenarios are being simulated. Preliminary results are showing that implementation of cover crops are most effective at reducing river nutrient export loads to Lake Erie for agricultural watersheds. A first paper describing its parameterization and testing model performance has been published (See below). A second paper is now underway to evaluate the effectiveness of BMPs vs source reductions to reduce nutrient and sediment loads to Lake Erie. A third paper is also in preparation which focuses on climate change.

Nutrient budget analyses to evaluate spatial and temporal patterns in phosphorus loading are largely complete. A first paper has been published (See below). A second paper about historical trends in phosphorus loading to watersheds of the Lake Erie and Lake Michigan basins is in press (See below).

HYPOXIA TEAM

The Hypoxia Team is developing four levels of models, representing a range of complexity, intended to relate the attributes (magnitude, duration, spatial extent) of hypoxia in the central basin of Lake Erie to a range of stressors (physical conditions, external loadings of nutrients, and Dreissenid densities). The four models in order of increasing complexity are the following:
Level 1 – one-dimensional model of the central basin with 1D thermal model and simple first-order deoxygenation rate in water column and zero-order SOD, forced by meteorological input alone;

Level 2 – one-dimensional model of the central basin with 1D thermal model and simple phosphorus-chlorophyll-DO process model, forced by meteorological input and external phosphorus and organic carbon loading;

Level 3a – Three-dimensional model composed of a 3D hydrodynamic – temperature model linked to the level two simple phosphorus-chlorophyll-DO process model, forced by hydrological and meteorological input and external phosphorus loading; and

Level 3b – Three-dimensional model composed of a 3D hydrodynamic – temperature model linked to an advanced eutrophication model (including Dreissenids and Cladophora), forced by hydrological and meteorological input, external nutrient and organic carbon loading, and Dreissenid density.

Hydrodynamic Modeling

A three-dimensional, 2 km grid hydrodynamic model of Lake Erie was developed (based on the Princeton Ocean Model) with a goal to calculate lake-wide circulation and thermal structure. Daily inflows at 22 major tributaries and hourly meteorological data at 12 land stations and 3 meteorological buoys were assembled, edited and interpolated to create gridded forcing functions for the hydrodynamic model for 2004, 2005, 2007 and 1976. Complete 3D hydrodynamic model simulations were accomplished for all four years and results compared with observations. Alternative forcing functions (surface wind fields) were developed for 2004, 2005 and 2007 (not available for 1976). They are based on the 3-hourly output of the Canadian regional meteorological model GEM which employs 15 km grid and appear to be superior to mostly land-based meteorological observations normally used by POM in the Great Lakes. New model results (for 2004, 2005 and 2007) showed improvements in modeled thermocline shape and anti-cyclonic circulation pattern in the central basin.

The 1D hydrodynamic model was run for with scaled (relative to 1987-2007 period) air temperature for low change and high change scenarios, representing climates in mid- and late 21 century. Results showed warmer lake with somewhat shallower thermocline because of decreased wind stress (due to increased stability of atmospheric boundary layer).

This modeling work has also demonstrated the potential importance of nearshore-offshore gradients of important biogeochemical materials, making the exchange of
material between the nearshore and offshore an important aspect to be considered in our level 3 modeling.

**Water Quality Modeling**

The level 2 hypoxia model (extended to be used for climate and nutrient load scenario modeling). To capture the sediment oxygen demand (SOD) response to differing nutrient loads, it was necessary to incorporate an equation to calculate SOD internally in the model. A saturation equation was developed to estimate SOD based on total annual phosphorus loads to the central and western basins of Lake Erie. Additionally, we have developed a method for varying the ratio of SRP to TP in the model, to investigate potential changes in the phosphorus distribution.

Dozens of combinations of loading scenarios and high- and low-change climate scenarios are now being simulated by the level 2 hypoxia model. The goal of this approach is develop a predictor of hypoxia, or hypoxic days, based on delivered total phosphorus and soluble reactive phosphorus loads to the lake.

Development of the level 3a and 3b models has also continued in order to incorporate the 3-dimensional aspects of the problem as well as two different levels of process complexity. The level 3a model is intended to assess how the food web impacts on dissolved oxygen resources vary spatially, particularly in near shore regions. This model uses a three dimensional spatial domain, and a simplified limnology kinetic framework, driven by SRP and TP loads from the major tributaries in Lake Erie. The model has also been dynamically linked to the Lake Erie 3D hydrodynamic model at the same spatial resolution to utilize the hourly hydrodynamic transport and temperature regime from that model. New 3D hydrodynamic model output was generated to reproduce anti-cyclonic circulation patterns in the lake. This output has recently been applied to the previously calibrated simulation for 2005, and we are continuing to investigate the implications of the altered transport regime.

Our level 3b model, which will be a complex hypoxia model, incorporating Dreissenids and nearshore lower food web dynamics that may be different from offshore dynamics has been developed and initial calibration efforts are continuing. This model is linked to the same 3D hydrodynamic model being used for the level 3A model. We have compiled forcing function data (including loads of all state variables from all main tributaries) for the four master years to which this model will be calibrated and confirmed.
ECOLOGICAL EFFECTS TEAM

The Ecological Effects Team is developing a suite of models to explore how hypolimnetic hypoxia impacts ecological interactions and fisheries production in the central basin of Lake Erie. We are using a parallel modeling approach including: 1) Empirical, statistical models; 2) Bioenergetics models (Growth rate potential models [GRP] and Individual-based models [IBM]); and 3) Foodweb models (Ecopath with Ecosim) and CASM [Comprehensive Aquatic Simulation Model]). Our ultimate goal is to apply these models to forecast how fish production in Lake Erie would be affected by potential, future nutrient loading scenarios and hypoxia dynamics.

During the initial phase of the project, we primarily work to develop and parameterize ecological models. To accomplish this goal, we rely on a variety of existing data: physical measures (temperature, water clarity, oxygen concentration), fisheries harvest data, annual fisheries-independent stock assessments, hydro-acoustic estimates of fish biomass, benthic macroinvertebrate surveys, zooplankton surveys (from optical plankton counter, net collections and pump samples), and fish samples (midwater and bottom trawl caught fish allowing for quantification of species-specific vertical distributions and diet contents). Most of these data were collected through the IFYLE (International Field Years on Lake Erie) program and state/provincial agency-based monitoring efforts. Most of the data which we use for model development and parameterization have been previously collected and analyzed (primarily through IFYLE-related efforts). However, some previously collected data required compilation, processing and analyses before they can be used for model development and parameterization. To this end, we analyzed biological data (zooplankton, benthic macro-invertebrate, and fish) and compiled historical fisheries and fisheries-independent data (including manual data entry from paper copies).

In applying our models, we build directly on the efforts of other project components (i.e., we use output from Watershed and Hypoxia forecasting models as input for our models). As these other project components have realized model outputs, our modeling efforts have ramped up. During 2008, we hired three postdoctoral research associates (Arend [Purdue; Bioenergetics modeling and CASM], Hosack [Ohio State; Empirical analyses], and Zhang [NOAA-GLERL and U. Michigan; EcoPath]). Arend and Hosack subsequently moved on to other positions and two other postdoctoral research associates were hired in 2009 (Pangle, Ohio State University; Bioenergetics and Empirical modeling) and 2010 (Goto, Purdue University; Bioenergetics modeling). During the past year, Daisuke Goto completed his postdoctoral position, and Tim Sesterhenn joined the project as a postdoctoral researcher.
Empirical analyses

We have explored the effects of hypoxia on commercial catch rates of walleye using both commercial and fishery independent data in Lake Erie. Hypoxia, as estimated by the 1-D model, positively correlates with annual catch rates of walleye. Monthly analyses, however, show that catch rate and harvest response to hypoxia varies by region. Spatial data available from IFYLE 2005 shows that hypoxia is constrained to the central basin, and fishery independent survey data suggests that the probability of walleye occurrence exhibits unimodal relationships with respect to bottom dissolved oxygen and temperature. Ongoing work investigates how spatial IFYLE abiotic data relates to walleye distribution and the distribution of a primary prey species, rainbow smelt.

Bioenergetic models

To date, we have developed bioenergetics growth rate potential models for emerald shiner, rainbow smelt, round goby, yellow perch, and walleye. We have applied these models 1) using physical, chemical and biological data collected during 2005/2007 IFYLE cruises in central Lake Erie and 2) using output from 1-dimensional hypoxia models. Analyses based on output from 1-dimensional hypoxia models suggest that hypoxia effects on habitat quality vary inter-annually and differentially affect various species and life-stages. Analyses based on measured temperatures, oxygen concentrations and prey distributions suggest that hypoxia may affect habitat quality in unexpected ways. For example, while growth rate potential modeling suggests that hypoxia will limit the availability of hypolimnetic habitat for walleye, overall walleye habitat quality may ultimately benefit as both walleye and their prey are constricted into a narrow depth range just above the hypoxic hypolimnion. Growth rate potential results have been synthesized and manuscripts have been drafted and submitted for publication.

Currently, our bioenergetics modeling efforts focus on dynamic individual-based models. We have incorporated dynamic behavior and movement into growth rate potential models. Development of the multispecies spatially-explicit individual-based model (SE-IBM) has been completed using IDL (modeling and visualization software). At present, we are fine-tuning parameters of the SE-IBM and will soon run final 1D simulations for both the hindcasting and land use/climate scenario forecasting applications of the model. The SE-IBM currently consists of 8 age classes of walleye, 7 age classes of yellow perch, 2 age classes of rainbow smelt and emerald shiner, as well as zooplankton (from the water quality model outputs) and benthic macroinvertebrates (modeled using detrital carbon outputs from the water quality model outputs) as prey.
All trophic groups in the model (invertebrate prey, benthivores, planktivores, and piscivores) are linked through predator-prey relationships. Initial simulations of the model are being conducted using central basin outputs from the Level 3a hydrodynamic-water quality model that was calibrated with the 2005 field data. These simulations are in agreement with some results from the other ecological models (e.g., walleye benefits from hypolimnetic hypoxia to some extent, while rainbow smelt suffer). We are using a 10-minute time step to compromise between the desired detail of physiological (e.g., acclimation to ambient temperature and DO) and behavioral (e.g., vertical movement) responses to hypoxia, and the computation time associated with the complexity of the model. This time step duration, along with use of superindividuals (a collection of individuals), has decreased computation times while still capturing important details. We also are working with Purdue University’s Rosen Center for Advanced Computing to run simulations in a cluster environment, in order to complete all required simulation replicates most efficiently. Additionally, visualizations of model outputs using IDL and ArcGIS are being refined that show impacts of hypoxia on fish movement (vertical and horizontal), inter- /intra- specific interactions among fish populations, and population-level responses (survival and growth). These visualizations permit comparison of the model processes (e.g., locations of fish in the model space) to the natural world, enabling accurate calibration, and will be used in future presentations and publications.

**Foodweb models**

CASM is a bioenergetics-based foodweb model used to estimate ecological risks posed by various physical, chemical, or biological stressors in aquatic systems. Risks include direct impacts on individual modeled populations of primary producers or consumers, as well as indirect effects that result from alterations of grazing or predator-prey interactions. The CASM Lake Erie (CASM-LE) is being developed and applied to evaluate how hypoxia impacts may cascade through the foodweb of Lake Erie’s central basin. The foodweb represented in the CASM-LE was developed in coordination with the project investigators (Zhang et al.) who are developing the Lake Erie EcoPath and EcoSim. The foodweb in the CASM-LE consists of four broadly defined taxonomic groups of phytoplankton, six populations of herbivorous and carnivorous zooplankton, five benthic invertebrate populations (including Dreissenids), and 16 different taxonomically defined fish populations. Rainbow smelt, yellow perch, and walleye are represented by juvenile and adult populations. Consistency in food web structure will facilitate the comparison of CASM-LE with results from the Ecopath and EcoSim for similar hypoxia scenarios and provide multiple-model projections of potential impacts of hypoxia. Various sources of data and information have been used to define foodweb interactions, initial population biomass values, bioenergetics parameters, and physio-
chemical conditions in CASM-LE (e.g., physical, chemical and biological data from IFYLE; literature values; agency reports). Estimation of bioenergetic parameters in the CASM-LE is based in part on other bioenergetics work being performed as part of the Ecofore Project. The overall CASM-LE has been re-programmed to include 3-layer vertical structure that permits certain invertebrate and fish populations to move vertically in relation to food availability and oxygen concentration. The direct effect on the annual production of each modeled population is determined by functional relationships between daily changes in dissolved oxygen concentration (in each vertical layer) on population respiration and mortality rates. Direct effects on prey populations can cascade throughout the foodweb in terms of alterations in prey availability. The CASM-LE includes a nearshore and offshore modeled locations that permit horizontal migration in response to oxygen concentrations. The major development within 2010 for the CASM-LE has been the reprogramming of the model using a Monte Carlo framework. This approach directly evaluates the effects of parameter uncertainty on modeled impacts of hypoxia. Importantly, this approach also permits modeled effects of hypoxia to be characterized as probable impacts (i.e., ecological risks). The Monte Carlo version of the CASM-LE is currently being debugged using IFYLE physical-chemical data from 2005.

Ecopath with Ecosim (EwE) is a suite of food web models that is designed to address ecological questions, to evaluate ecosystem effects of fishery management, to explore management policy options, and to evaluate effect of environmental changes, etc. Our Ecopath model focuses on the central basin of Lake Erie, and aims to evaluate the impacts of hypoxia on the lake ecosystem structure and function, and to explore water quality management and fisheries management scenarios. Our EwE team has been compiling and analyzing data since December 2008 to modify an existing Ecopath model for Lake Erie developed by Johnson and Zhu to investigate the effects of invasive species on the Lake Erie food web. Our EwE team has consulted lower trophic level experts regarding merging taxa into functional trophic groups in Ecopath. We estimated biomass of the lower trophic-level groups based on literature review and data sources including IFYLE field studies and the LEPAS (Lake Erie Plankton Abundance Study at Ohio State University). We are modeling 41 age/size groups of fish in our Ecopath model: biomass estimated from IFYLE trawl and acoustic data, and from surveys by state and provincial agencies. Our EwE team also is working with Lake Erie fisheries managers to design relevant management simulations and to ensure the final EwE model is a useful management tool. The inputs of EwE have been carefully checked and verified and the team is drafting a manuscript on the model and findings.

Ed Rutherford and Hongyan Zhang worked on the Ecopath with Ecosim model for the Lake Erie central basin. They have been actively involved in a formation of a Great
Lakes EwE modeling group which includes modelers from NOAA/GLERL, CILER/UM, USGS, the Institute of Fisheries Research at University of Michigan, and Michigan State University. This EwE modeling group will produce guidelines for ecosystem modeling efforts in the Great Lakes and compile a list of data sources used for model development. They participated the first workshop on Feb. 28-Mar.1, 2011 and the second workshop on July 12-13, 2011 at Kellogg Biological Station (KBS), MI.

**Coordination and application**

We have worked to ensure that our models and simulations are highly relevant for Lake Erie fisheries managers and that our collective analyses provide insight regarding tradeoffs between nutrient loading and fisheries production. We are engaged with managers via presentations at stakeholder meetings, personal conversations, and distribution of project literature (including series of questions for managers). While we have developed a multitude of models which have unique advantages and disadvantages, an ultimate goal of our efforts is to be able to compare model predictions. While this may not always be feasible (given the differential forms of our models), when possible we are facilitating model comparisons by initially structuring models in a similar manner.

**Publications:**


Han H., N.S. Bosch, and J.D. Allan. 2011. Spatial and temporal variation in phosphorus budgets for 24 watersheds in the Lake Erie and Lake Michigan basins. Biogeochemistry 102:45-58. This is publication 09-007 supported by NOAA Center for Sponsored Coastal Ocean Research grant NA07OAR432000.

Han H., N.S. Bosch, and J.D. Allan. 2012. Historical Pattern of Phosphorus Loading to Lake Erie Watersheds. Journal of Great Lakes Research, (*in press*). This is
publication 11-001 supported by NOAA Center for Sponsored Coastal Ocean Research grant NA07OAR432000.


Presentations:

DePinto, J.V. 2011. Using the LMR-MB model to understand the 2011 Microcystis bloom in the Western Basin of Lake Erie. Invited talk at the Western Lake Erie Basin Partnership Leadership Team meeting, Perrysburg, OH. December 12, 2011.


**Outreach Activities:**


J. DePinto gave an invited talk (listed above) at the annual meeting of the Lake Erie Improvement Forum, a group of stakeholders with the mission of improving the Lake Erie ecosystem.
J. DePinto gave an invited talk (listed above) at the annual meeting of the Western Lake Erie Basin Partnership leadership team in Perrysburg, OH.

J. DePinto worked on an IJC workgroup to write a report on “Nuisance and Harmful Algae” in the Great Lakes that was released to the general public at the 2011 IJC Biennial Meeting.

The watershed and lake hypoxia teams collaborated to provide several years of tributary-specific phosphorus loading and concentration maps of Lake Erie to the Lake Erie LaMP work group and forum.

Scavia, D. In addition to the talks listed above, has provided routine consulting advise to the International Joint Commission, the Healing our Waters Great Lakes Coalition, the National Wildlife Federation, and the Environmental Law and Policy center on a range of issues related to non-point source pollution impacts on the Great Lakes.
CILER activities that fall under the theme of Education and Outreach focus on facilitating education and outreach activities for NOAA in the Great Lakes region.
**Project Title:** CLIMATE CHANGE IMPACTS INFORMATION AND OUTREACH

*Principal Investigators: Allen Burton and Brent Schleck - University of Michigan - CILER*

*NOAA Lead: Heather Stirratt – NOAA / National Ocean Service / Coastal Services Center*

**Overview and Objectives:**

The overall objective of this CILER fellowship with NOAA’s National Ocean Service is to build, support, and strengthen climate partnerships in the Great Lakes region to ensure effective and timely delivery of NOAA products and services. To that end, this fellowship position has provided resources facilitating, participating in, and delivering regional climate workshops and coastal projects to ensure better coordination across NOAA and GLRI efforts. These provided resources include regular partner interaction and support, as well as developing high level plans and documents to inform regional policy, funding, and science decisions.

**Objective:** To ensure effective delivery of NOAA products and services by building, supporting, and strengthening Great Lakes regional partnerships.

Given this objective, this position addresses the following NOAA strategic plan goals: Understand climate variability and change to enhance society’s ability to plan and respond, serve society’s needs for weather and water information, and NOAA Mission support

**Accomplishments:**

- Completed and distributed the “Climate Funding Opportunities” document to NOAA partners around the nation. Document provided a snapshot of available, climate-related funding opportunities with detailed information on application processes. (January 2012)

- Completed an inventory of organizations involved in climate-related activities. Document recommendation led to a $25,000 partner project with The Nature Conservancy involving climate-related, Great Lakes case studies and outreach videos (YouTube) – (ongoing)
• Worked with Heather Elmer of Old Woman’s Creek NERR to compile a prioritized list of ten needs for the Great Lakes region, to inform future climate work (currently in press) (ongoing)

• Attended and participated in two regional meetings (Coastal Habitat Conservation in a Changing Climate – Ypsilanti, MI; FY11 GLRI Climate Project Coordination Meeting – Lansing, MI) (September 2011, November 2011)

• Currently drafting a NOAA Climate Science Plan (mandated by the EPA) to inform policy and funding decisions regarding future climate science in the Great Lakes region. (ongoing)

Publications:

Climate Funding Opportunities
January 15, 2012
Published online on the University of Notre Dame “Collaboratory” website http://adapt.nd.edu/resources/243/download/Climate_Funding_Opportunities_Jan2012.pdf

Compilation of Top Ten Prioritized Needs (based on NOAA Technical Memorandum GLERL-153)
(In Press)

Presentations:

CILER summer fellowship presentation
Authors: Brent Schleck
Date Given: Sept. 21, 2011
Title: CILER Fellow 2011: Strategic Climate Partnerships
Venue Title: CILER fellow presentations
Venue location: GLERL, Ann Arbor, MI
Source of Support: CILER fellowship

Outreach Activities:

September 2011 – Scribe for National Climate Assessment break-out session at Ypsilanti, MI Habitat Conservation workshop
November 2011 – Scribe for FY11 GLRI Climate Project Coordination Meeting, Lansing, MI
Overview and Objectives:

As part of the NOAA Oceans and Human Health Initiative, the Center of Excellence for Great Lakes and Human Health (CEGLHH) is required to engage public health and natural resource managers and decision-makers in order to develop and deliver useful products and services. Ensuring the development of useful and timely products, tools, and services requires involving stakeholders in determining research priorities. Through a partnership with Michigan Sea Grant Extension, outreach programming for CEGLHH is conducted by a Michigan Sea Grant Outreach Specialist. One of the responsibilities of the Michigan Sea Grant Outreach Specialist is to translate CEGLHH materials into a concise, easily understood format and identify community needs. In addition, the Michigan Sea Grant Outreach Specialist serves as a liaison to the Great Lakes Sea Grant Network to connect with end users throughout the Great Lakes. CEGLHH’s Outreach Coordination serves two roles, identifying and assessing user needs (related to Great Lakes and human health) and disseminating scientific information, technology, and research materials to aid health officials, local governments, and communities in making sound environmental decisions. Michigan Sea Grant Extension’s outreach uses a multidisciplinary approach to translate the scientific information and research.

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:

Ottawa County and Muskegon County Harmful Algal Bloom Volunteer Monitoring Program

Seven Michigan volunteers trained and collected samples weekly for 9 weeks throughout the summer of 2011. In conjunction with our volunteer monitoring, Hope College was conducting extensive research in the watershed to determine nutrients...
sources that may be contributing to the growth of algae in Lake Macatawa. The microcystin concentration data was shared with Hope College to assist in their research on determining causal linkages between nutrients and algae and bacteria growth.

**Lake Erie Harmful Algal Bloom Experimental Forecast Weekly Distribution**
Repeated the electronic distribution of the Lake Erie Harmful Algal Bloom Experimental Forecast Bulletin (developed by the NOAA Center of Excellence for Great Lakes and Human Health) for summer 2011. The subscribership for the Bulletin increased from 185 at the beginning of the field year to 474 subscribers in 2011. The Lake Erie HAB Bulletin predicted one of the worst blooms in Lake Erie in recent decades and due to the severity of the 2011 bloom in Lake Erie, interest in information on Lake Erie’s algae problem escalated, which led to the surge in subscribership to the Weekly Forecast Bulletin.

**6th Annual Ottawa County Water Quality Forum**
Served on planning committee for the Annual Ottawa County Water Quality Forum, which serves to educate environmental health and natural resource staff and professionals based in western Michigan on water quality research conducted in Ottawa County. Topics and presentations were focused on watershed issues influencing the Grand River as well as microbial source tracking of contaminated beaches on Lake Michigan.

**Michigan Water Quality Survey**
Conducted a statewide knowledge assessment survey to obtain a baseline of information on existing knowledge of algae and causes and consequences of algae blooms in the state. In addition the survey was structured to identify the various types of economic, recreational, and social issues related to algae in Michigan waters. According to our respondents algal blooms are having negative economic impacts on selling lakefront homes and are deterring tourists from recreating on the Great Lakes. This information has been used to help in directing and targeting outreach programs for CEGLHH.

**Publications:**
Presentations:

* Presentations being reported for this Annual Report are the presentations that have been funded through NOAA’s Great Lakes Restoration Initiative Project # 2011-214: Developing Predictive Models for Improving Coastal and Human Health and Beach Forecasting

Joseph Joshi, S., D. O’Keefe. 4/19/11. Water Quality and Invasive Species in the Great Lakes, American Water Works Association Regional Chapter Meeting. Ann Arbor, MI. Presentation as part of a series that Dan O’Keefe gave. I created my own presentation and presented at the Ann Arbor location of this meeting.

Joseph Joshi, S., C. Sotka, J. Trtanj, D. Schwab. 5/20/11, NOAA’s Oceans and Human Health Initiative: Links to One Health in the Great Lakes, One Health Convening. Shedd Aquarium, Chicago, IL.


Joseph Joshi, S. 7/25/11. NOAA’s Oceans and Human Health Initiative and One Health in the Great Lakes. IJC’s Council of Great Lakes Research Managers and Health Professionals Task Force Joint Meeting. Concordia University- University School of Pharmacy. Milwaukee, WI.


Joseph Joshi, S., G. Fahnenstiel, R. Stumpf. 3/30/12. Tracking western Lake Erie’s Toxic Algae. Lake Erie WaterKeepers Annual Conference. Toledo, OH.

Outreach Activities:


University of Brasilia tour at the NOAA Great Lakes Environmental Research Laboratory and the Center of Excellence for Great Lakes and Human Health’s research programs. Eastern Michigan University, University of Brasilia


Joseph Joshi, S. 11/10/11. Toward a 120 hour Beach Decision Support System. LimnoTech. Ann Arbor, MI

Joseph Joshi, S. 12/16/11. The Great Lakes and Your Health: Is There a Relationship? Harper Woods Middle School presentation

Michigan Water Quality survey (See above.)

Lake Erie HAB Forecast Bulletin Feedback survey- conducted a survey of all recipients of the Lake Erie HAB Forecast Bulletin to solicit feedback on the accuracy, value, usability, and format of the Forecast Bulletin in order to further improve this tool for 2012.
APPENDIX 1: Publication Count by year and Grand Total to date for current CA

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Totals: 2007-2012

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APPENDIX 2: Employee Count.

Summary of Joint Institute Staff by Head Count 2011-2012 (Includes subcontracts)

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