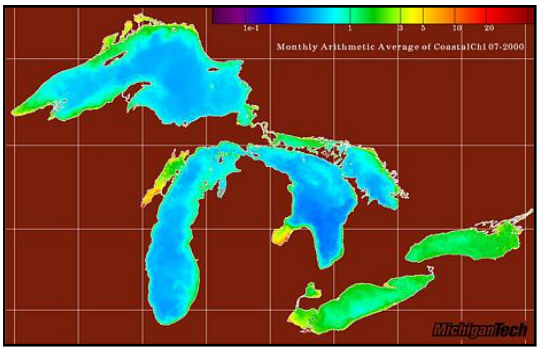
Invasive Species, Harmful Algae & Hypoxia in the Great Lakes: An Ecosystem Approach

Introduction

The Laurentian Great Lakes are a major resource to North America, containing 18% of the world's surface freshwater and 90% of the surface freshwater of the U.S. They serve as the focus for a multi-billion dollar tourist and recreation industry, supply 40 million people with drinking water, provide habitat for wildlife and fish, and support transportation and diverse agricultural production. The basin is home to 15% of the U.S. and 60% of the Canadian population.

Issues Being Addressed



In the Great Lakes the complex issue of synergistic and unexpected effects of multiple stressors is a growing concern. After a period of improving water quality during the 1980s and early 1990s, likely due to the phosphorus abatement programs that limited nutrients and reduced cyanobacterial (blue-green algae) blooms, harmful algal blooms (HABs), and low bottom water oxygen (hypoxia) have once again become important issues in the lower Great Lakes. Hypoxia has occurred frequently in the summer in western Lake Erie. HABs have been responsible for the closure of beaches, death of wildlife and contamination of drinking water supplies. HABs include cyanobacteria, especially *Microcystis*, which produce potent toxins that can contaminate drinking water and sometimes exceed safe drinking water guidelines, and macroalgae, such as *Cladophora*, that build up on beaches, impacting tourism and recreation. Although both HABs and hypoxia are naturally occurring they can also be promoted by human activities, especially those that affect nutrient availability. One potential cause for recent declines in water quality is the establishment of zebra mussels, a prolific invasive species which has fundamentally altered energy transfer and nutrient cycling. Add to this mix the impacts of local land use and climate change and the situation becomes very complex, making management and planning even more difficult.

Program Description

NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) in the National Ocean Service's National Centers for Coastal Ocean Science (NCCOS) is conducting multidisciplinary and integrated programs to study the numerous multiple stressors such as hypoxia invasive species, HABs, and climate change in the Great Lakes in order to identify the causes and develop solutions. This research is targeted to support regional ecosystem management approaches by providing predictive capabilities to evaluate alternative scenarios. Specific programs include:

Hypoxia: CSCOR is supporting research to quantify links between nutrient inputs and hypoxia in eutrophic Green Bay under potential impacts of climate change and also to assess target levels of abatement needed to meet water quality goals.

Invasive Species: CSCOR is funding a 5-year multidisciplinary regional ecosystem project to forecast the spread and economic impacts of aquatic

NOAA Programs in the Great Lakes Region

- Biotoxins
- CoastWatch
- ECOHAB
- Ecological Forecasting
- GLFS
- Hypoxia
- MERHAB
- Multiple Stressors
- Regional Ecosystem Prediction

invasive species from multiple pathways to improve management and policy in the Great Lakes. Other invasive species research has included understanding how nutrients and grazers interact to suppress or promote phytoplankton blooms and developing management protocols/practices to reduce effects of increasing cyanobacterial growth in zebra mussel-invaded lakes and to predict how future invaders (including exotic predators of zebra mussels) and changes in nutrient loading will impact HABs in the Great Lakes.

Impacts of Multiple Stressors: With a focus on Saginaw Bay, CSCOR-funded research is developing modeling tools that are adaptable across ecological systems and multiple stressors to provide managers with the means to understand and manage stressor interactions unique to their ecosystem.

Ecological Forecasting: An important regional research project is addressing the Lake Erie hypoxic or "dead" zone that has grown worse in recent years. CSCOR is funding a project to create, test and apply models to forecast how anthropogenic (land use, invasive species) and natural stresses (climatic variability) influence hypoxia formation and ecology in Lake Erie with an emphasis on fish production. In the early 1990's, CSCOR's Coastal Ocean Program made investments in the Great Lakes to develop an integrated Great Lakes Forecasting System which combines data from satellites, land, and lake-based systems with computer models for real-time prediction of the physical status of the Great Lakes. After undergoing 15 years of extensive development and testing, the system was completed and went operational in 2006 and provides output in the form of maps and data sets tailored to display specific information required by particular user groups. This system shows promise as an operational platform for HAB and hypoxia related tools and technology.

Harmful Algal Blooms: CSCOR HAB research projects inform federal and state agencies of the potential human health threat, ecosystem impacts caused by freshwater HABs and supports efforts to develop and sustain HAB monitoring and prediction in the Great Lakes. Active CSCOR research projects are identifying the roles of dissolved organic and inorganic phosphorus in regulating gene functions that promote blooms of the harmful cyanobacterium *Microcystis*. CSCOR is also identifying bacteria capable of degrading cyanotoxins for potential commercial toxin removal filtration systems to improve abilities to safeguard water for human use. Past CSCOR research developed cost effective "alert" protocols for toxic cyanobacterial blooms, improved methods of identification and response to HAB events in the Lower Great Lakes, and transitioned methods to New York and Vermont state monitoring programs. CSCOR also led NOAA and partners to complete and deliver to Congress national scientific assessment of freshwater HABs required by the Harmful Algal Bloom and Hypoxia Research and Control Act, an important driver guiding future NOAA freshwater HAB research in the Great Lakes and around the U.S.

Looking to the Future

The Great Lakes ecosystem is the most clearly bounded regional ecosystem under NOAA's purview and mission responsibilities, contains a suite of environmental stresses common to all coastal systems, and has a long history of bi-national and interagency partnerships and collaborations. Thus, the Great Lakes have a high potential for success in developing integrated ecosystem forecasting tools and having them applied to manage multiple stressors in a regional ecosystem framework.

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CSCOR Activities in the Great Lakes

From 1990 to 2012 NCCOS' Center for Sponsored Coastal Ocean Research (CSCOR) has provided over $19M for activities in the Great Lakes. The following is a list of current and past funded projects.

Current Projects

Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB)

Biological Degradation of Microcystins: A First Step Towards Biofilters for High Efficiency Toxin Removal (FY 2011-planned FY 2014). University of Tennessee, State University of New York/College of Environmental Science and Forestry. Identifying new toxin-degrading bacteria of microcystin toxins, a class of cyanotoxins detected annually in the Great Lakes --a first step for development of a commercial biological filter for toxin removal (FY 11-14: $704K planned).

Coastal Hypoxia Research Program (CHRP)

Green Bay Hypoxia: Biogeochemical Dynamics, Watershed Inputs and Climate Change (FY 2010-planned FY 2014). University of Wisconsin/Milwaukee, University of Wisconsin/Green Bay, University of Wisconsin/Madison, Green Bay Metropolitan Sewerage District, Wisconsin Dept. of Natural Resources. Quantifying link between nutrient inputs and hypoxia in eutrophic Green Bay under potential impacts of climate change and assessing target levels of abatement needed to meet water quality goals (FY 10-14: $1,367K planned).

Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

Establishing the Sources of Phosphorus Promoting Toxic Cyanobacteria Blooms in the U.S. Great Lakes Using Gene Expression Assays (FY 2010-planned FY 2013). State University of New York/Stony Brook, New York Sea Grant. Identifying role of dissolved organic and inorganic phosphorus in regulating gene functions that promote blooms of the harmful cyanobacterium *Microcystis* (FY 10-13: $461K planned).

Regional Ecosystem Prediction Program

Forecasting Spread/Bioeconomic Impacts of Aquatic Invasive Species From Multiple Pathways to Improve Management and Policy in Great Lakes (FY 2009-planned FY 2014). University of Notre Dame, University of Michigan/Ann Arbor, University of Toledo, The Nature Conservancy, Resources for the Future, University of Georgia, University of Wyoming. Forecasting the spread and economic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes (FY 09-14: $2,475K CSCOR, $1,611K EPA planned).

Multiple Stressors (MultiStress)

Adaptive Integrated Framework (AIF): A New Methodology for Managing Impacts of Multiple Stressors in Coastal Ecosystems (FY 2007-planned FY 2012). NOAA Great Lakes Environmental Research Lab, Michigan State University, University of Michigan, Western Michigan University, University of Akron, Michigan Dept. of Environmental Quality, Michigan Dept. of Natural Resources, Limno-Tech, Inc. Developing modeling tools that are adaptable across ecological systems and multiple stressors to provide managers with the means to understand and manage stressor interactions unique to their ecosystem with a focus on Saginaw Bay (FY 07-12: $4,618K planned).

Ecological Forecasting (ECOFORE)

Forecasting the Causes, Consequences, and Potential Solutions for Hypoxia in Lake Erie (FY 2006-FY 2010). University of Michigan, NOAA Great Lakes Environmental Research Lab (GLERL), E2, Inc., LimnoTech, Inc., U. Wisconsin, Western Michigan U., Heidelberg College. Creating, testing and applying models to forecast how anthropogenic (land use, invasive species) and natural stresses (climatic variability) influence hypoxia formation and ecology in Lake Erie with an emphasis on fish production (FY 06-10: $2,205K).

Past Projects

Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

Investigating Chronic Toxicity and Bioaccumulation of Microcystins in Freshwater Fish Using Toxicogenomics and Histopathology (FY 2006-2008). Univ. of Tennessee. Investigatied microcystin toxin concentrations that cause negative effects in fish during chronic low-level exposure and bioaccumulation. Determining, via biomarker gene expression, toxicogenetic & histopathological approaches used in ecological forecasting of ecosystem health (FY 06-08: $437K).

Invasive Species

Complex Interactions Between Harmful Phytoplankton and Grazers: Variation in Zebra Mussel Effects Across Nutrient Gradients (FY 2004-2007). Michigan State University, NOAA GLERL. Developed management protocols/practices to reduce effects of increasing cyanobacterial growth in zebra mussel-invaded lakes and to predict how future invaders (including exotic predators of zebra mussels) and changes in nutrient loading are going to impact harmful phytoplankton in the Great Lakes (FY 04-07: $236K).

Monitoring and Event Response for Harmful Algal Blooms (MERHAB)

Tier-Based Monitoring for Toxic Cyanobacteria in the Lower Great Lakes (FY 2002-2007). SUNY College of Environmental Science & Forestry (ESF), SUNY at Brockport, SUNY at Buffalo, Univ. of Tennessee, Univ. of Vermont, Western Michigan Univ., New York Sea Grant. Developed an integrated alert system to monitor and detect toxic cyanobacteria blooms in the lower Great Lakes (Lake Erie, Lake Ontario) and Lake Champlain (FY 02-07: $3,622K).

Oceans and Human Health Initiative (OHHI)

Predicting Pathogen Fate in the Great Lakes Coastal Environment (FY 2005-2007). Univ. of Wisconsin-Milwaukee, The Marshfield Clinic, NOAA GLERL. Determined the survival and physical transport processes that control dispersion and persistence of waterborne pathogens in the Great Lakes and develop better models predicting the fate of pathogens in aquatic systems (FY 05-07: $694K).

Identification, Characterization and Inventory of Novel Freshwater Biotoxins (FY 2005-2007). SUNY ESF, University of Tennessee. Determined the identity, distribution and occurrence on toxin-producing organisms and their toxins in Lake Erie (FY 05-07: $749K).

Episodic Events-Great Lakes Experiment (EEGLE)

Episodic Events-Great Lakes Experiment: The Impact of Episodic Events on the Nearshore-Offshore Transport and Transformation of Biogeochemically Important Materials in the Great Lakes (FY 1997-2002). Academy of Natural Sciences, Michigan Tech. U., NOAA/GLERL, Ohio State U., Rutgers U., SUNY/Buffalo, U. Georgia, U. Massachusetts U. Michigan, U. Minnesota, U. Texas, U. Wisconsin, U. Southern Mississippi, USDA/ARS, USDOE/Argonne National Lab, USEPA, USGS, et al.. Created an integrated observational program and modeling effort to identify/develop prediction tools for the winter-spring sediment re-suspension event and to assess the impact of this event on the transport and transformation of biologically important materials and ecology of Lake Michigan (FY 97-02: $4,293K).

Great Lakes Forecast System

Great Lakes Forecast System Development (FY 1993-1996): NOAA GLERL, The Ohio State Univ., NOAA National Weather Service. CSCOR/COP funded the development of the now operational Great Lakes Forecast System (GLFS), a real-time coastal prediction system developed for forecasting wind-waves, surface water level fluctuations, and the horizontal/vertical structure of temperatures and currents. The NOAA Center for Operational Oceanographic Products and Services maintains GLFS in an 24-hour operational environment providing accurate information needed by a diverse user population utilizing the lakes (FY 93-96: $687K).

Great Lakes CoastWatch

Great Lakes CoastWatch Development (FY 1990-1994): NOAA GLERL, NOAA National Environmental Satellite Data and Information Service (NESDIS). CoastWatch is a national NOAA program whose startup and development was funded by CSCOR/COP from FY 1990-94. GLERL functions as the Great Lakes regional node. NESDIS collects environmental data by NOAA satellites and CoastWatch processes this raw data and makes it available as ocean color, chlorophyll–*a* levels, and surface wind images. Products are used in a variety of applications like predicting weather, locating fishing areas, indicating harmful algal blooms, and navigation(FY 90-94: $223K).

Coastal Change Analysis Program (C-CAP)

Coastal Change Analysis for Coastal Upland and Wetland Ecosystems in the Great Lakes (FY 1992-1993). DOE Oak Ridge National Laboratory, NOAA NCCOS. Developed a prototype and operational habitat change analysis over time including landcover classification, accuracy assessment, and field validation of Landsat data for the Saint Croix River estuary, Wisconsin (FY 92-93: $90K)

WORKSHOPS

Great Lakes Issue Identification Workshop (2003). NOAA CSCOR/COP, NOAA GLERL, Cooperative Institute for Limnology and Ecosystem Research. On Jan. 20-21, 2003 the NOAA CSCOR/COP funded and co-hosted a NOAA Great Lakes Issues Identification Workshop at the University of Michigan in Ann Arbor. The focus of this workshop was to identify major issues within the Great Lakes with the results of the workshop being a brief report of recommendations for future research efforts (FY 03: $9K).

Great Lakes Environmental Evaluation Training (1993-1997). NOAA Economics Group, Univ. of Maryland Sea Grant, Northeast-Midwest Institute. Environmental valuation training was implemented to provide comprehensive information on the methods and applications of natural resource economic valuation to state/local planners, coastal zone/marine sanctuary managers, and natural resource trustees. Regional training workshops held around the country, including the Great Lakes (FY 97-98: $95K).

SPECIAL PUBLICATIONS

- **Scientific Assessment of Freshwater Harmful Algal Blooms.** 2008. U.S. Joint Subcommittee on Ocean Science and Technology.
-**Transport and Transformation of Biogeochemically Important Materials in Coastal Waters.** 2004. *Journal of Geophysical Research* 109 (C10) ($24K).
- **Special Issue on Lake Superior.** 2004. *Journal of Great Lakes Research* 30 (Sup.1): 1-491 ($10K).
- **Revealing the Economic Value of Protecting the Great Lakes.** 2001. The Northeast-Midwest Institute and the NOAA. 247 pp. (cost included in Great Lakes Environmental Evaluation Training above)

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