GLERL ECOHAB: An Integrated Approach for Monitoring and Modeling

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Overview

In the Great Lakes a resurgence of harmful algal blooms (HAB) has been noted in the last decade. These events were surprising given the success of eutrophication controls enacted during the 1970s and 1980s. These new HABs appeared to be related to the filtering activities of recently established non-indigenous mussels, genus Dreissena. The most common HAB in the Great Lakes is the cyanobacteria, *Microcystis*, which produces the hepatotoxin, microcystin. During the past few years, GLERL initiated a monitoring and event response program to *Microcystis* blooms in several areas of the Great Lakes (Saginaw Bay, western Lake Erie, Muskegon Lake, and Bear Lake). Results from this monitoring were posted on a web site at GLERL, and made available to the public. This web site was the first HAB event response site in the Great Lakes, and served as a model for the development of public response activities. This year the emphasis of the program is shifting to event response to support development and evaluation of models for forecasting *Microcystis* abundance.

Objective

Increase number of regional, coastal, and marine ecosystems delineated with approved indicators of ecological health and socioeconomic benefits that are monitored and understood.

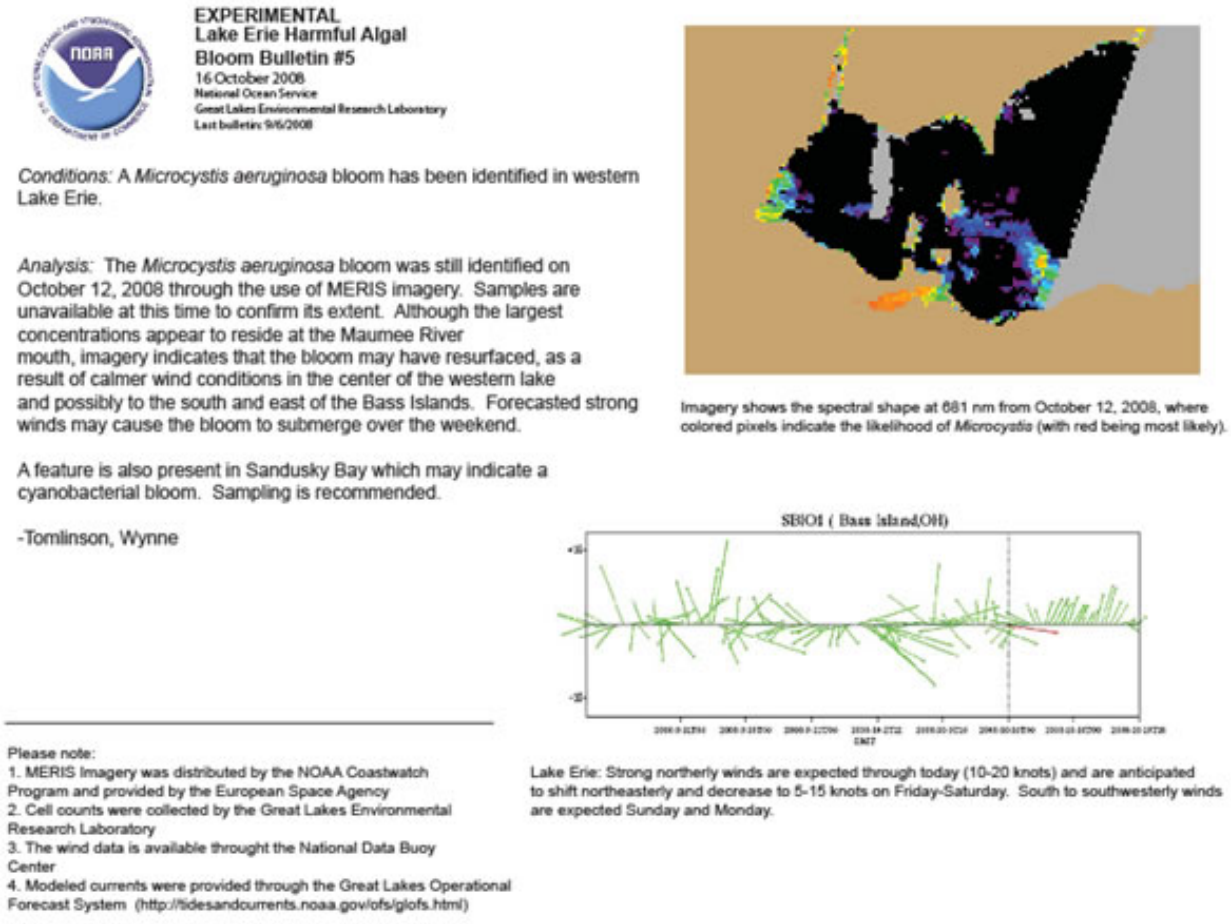
Define the primary forcing factors and time and space scales that cause HABs and anoxia for selected coastal, ocean, and Great Lakes regions.

Plans

In 2008 we initiated a student volunteer monitoring program in the Muskegon area where results were posted on the Harmful Algal Blooms website in order to facilitate public awareness of potentially high levels of microcystin in surface recreational and drinking water supplies. Local students were trained to collect water samples which were then sent to GLERL for analysis. Samples were collected on a weekly basis from June through September at Bear and Muskegon lakes. The event response website has been active for two years. This website includes data from various regions of the Great Lakes in 2008, including Saginaw Bay, western Lake Erie, and various west Michigan lakes.

For the past two years remote sensing data has been analyzed to help monitor *Microcystis* blooms in the Great Lakes. Last year we developed a method to predict *Microcystis* biomass from remote sensing data (Wynne et al. 2008). This year we developed a HABs forecasting tool, Lake Erie Harmful Algal Bloom Bulletin (Figure 1), that was distributed to users throughout the Lake Erie watershed during the bloom season. This bulletin was based on the satellite method

for determining *Microcystis* abundance (Wynne et al. 2008) and the Great Lakes Forecasting System.



EXPERIMENTAL
Lake Erie Harmful Algal Bloom Bulletin #5
16 October 2008
National Ocean Service
Great Lakes Environmental Research Laboratory
Last bulletin: 9/6/2008

Conditions: A *Microcystis aeruginosa* bloom has been identified in western Lake Erie.

Analysis: The *Microcystis aeruginosa* bloom was still identified on October 12, 2008 through the use of MERIS imagery. Samples are unavailable at this time to confirm its extent. Although the largest concentrations appear to reside at the Maumee River mouth, imagery indicates that the bloom may have resurfaced, as a result of calmer wind conditions in the center of the western lake and possibly to the south and east of the Bass Islands. Forecasted strong winds may cause the bloom to submerge over the weekend.

A feature is also present in Sandusky Bay which may indicate a cyanobacterial bloom. Sampling is recommended.

-Tomlinson, Wynne

Imagery shows the spectral shape at 681 nm from October 12, 2008, where colored pixels indicate the likelihood of *Microcystis* (with red being most likely).

SBIOI (Bass Island,OH)

Please note:
1. MERIS Imagery was distributed by the NOAA Coastwatch Program and provided by the European Space Agency
2. Cell counts were collected by the Great Lakes Environmental Research Laboratory
3. The wind data is available throught the National Data Buoy Center
4. Modeled currents were provided through the Great Lakes Operational Forecast System (http://tidesandcurrents.noaa.gov/ofs/glofs.html)

Lake Erie: Strong northerly winds are expected through today (10-20 knots) and are anticipated to shift northeasterly and decrease to 5-15 knots on Friday-Saturday. South to southwesterly winds are expected Sunday and Monday.

Figure 1: *Sample Lake Erie Harmful Algal Bloom Bulletin from October 16, 2008 at the end of the bloom season.*

Accomplishments

2006

The plan of work consists of coordinating remote sensing imagery with field sampling in order to document the extent and significance of harmful algal blooms in the Great Lakes. The GLERL Coastwatch and NOS satellite teams will provide MODIS and SEAWIFTS imagery to two summer interns, who will be responsible for field sampling. If satellite imagery indicates the presence of a cyanobacteria bloom, the interns will initiate sampling to characterize the bloom, and if a *Microcystis* bloom, determine the microcystin concentrations. One summer intern wil be responsible for coordinating, monitoring and analysis for Saginaw Bay and western Lake Erie, while the other intern will be responsible for working on a series of lakes in West Michigan (Bear Lake, Muskegon Lake, Spring Lake, etc.) where large blooms and high concentrations of microcystin have been noted. Additional routine sampling will be conducted in areas where

regular blooms have been reported, e.g., western Saginaw Bay, Maumee Bay, Sandusky Bay, etc.

2005

Time was spent coordinating activities and development of the web site. Remote sensing imagery was provided by GLERL/Coastwatch (George Leshkevich) and NOAA (Rick Stumpf). Both of these groups provided separate imaging products for chlorophyll (phytoplankton abundance) based on their specific algorithms. The GLERL/Coastwatch imagery was based on NASA products, whereas the NOAA imagery was based on ECOHAB Gulf of Mexico products. In retrospect both of these products provided similar coverage and distribution for chlorophyll in the Great Lakes. However, chlorophyll concentrations appear to be a poor indicator of cyanobacteria blooms in the Great Lakes, particularly during summer stratification.

The field sampling part was the most intensive part of this project as several new methods were used. Sampling was conducted in Saginaw Bay, western Lake Erie, Muskegon Lake and Bear Lake on a regular basis from late May through October; approximately 30 samplings were conducted during this period. For each sampling measurements of temperature, chlorophyll, water transparency, algal abundance and composition, total phosphorus, soluble reactive phosphorus, particulate phosphorus, particulate nitrogen, particulate carbon, dissolved nitrogen, DNA, intracellular and extracellular microcystin, algal pigments, and algal photosynthetic capacity were made. Since the sampling has just been completed and most of the laboratory analysis still awaits completion, only preliminary results can be presented.

Microcystin concentrations in Saginaw Bay and western Lake Erie were low (‹1 ug/L) in May and June. In July and August concentrations increased in both regions and were as high as 9 ug/l in Saginaw Bay and 4 ug/l in Lake Erie. Lower concentrations were noted in September and October.

Finally, a web page was developed that allowed the public to access the latest information on algal blooms in the Great Lakes. This web site provided basic information on algal blooms, and potential health effects, as well as the latest results of toxin concentrations associated with specific blooms. These results were generally posted within a few days of sample collection.

2004

2004 was the first year of monitoring *Microcystis* blooms and microcystin concentrations in Saginaw Bay and western Lake Erie. A synoptic cruise of Saginaw Bay and western Lake Erie was conducted in August 2004. Relatively high concentrations of microcystin (Figure 1) were found throughout Saginaw Bay even though little evidence of *Microcystis* blooms was found. Most chlorophyll concentrations in the Bay were <10 ug/l, and Secchi disk transparency averaged between 1-2 m. In western Lake Erie, where even lower chlorophyll concentrations were found, microcystin concentrations were also lower than Saginaw Bay (Figure 2, most < 1ug/l). However, one extremely high concentration of microcystin (58 ug/l) was found in the inner harbor of Put-In-Bay where surface scum of a *Microcystis* bloom was sampled.

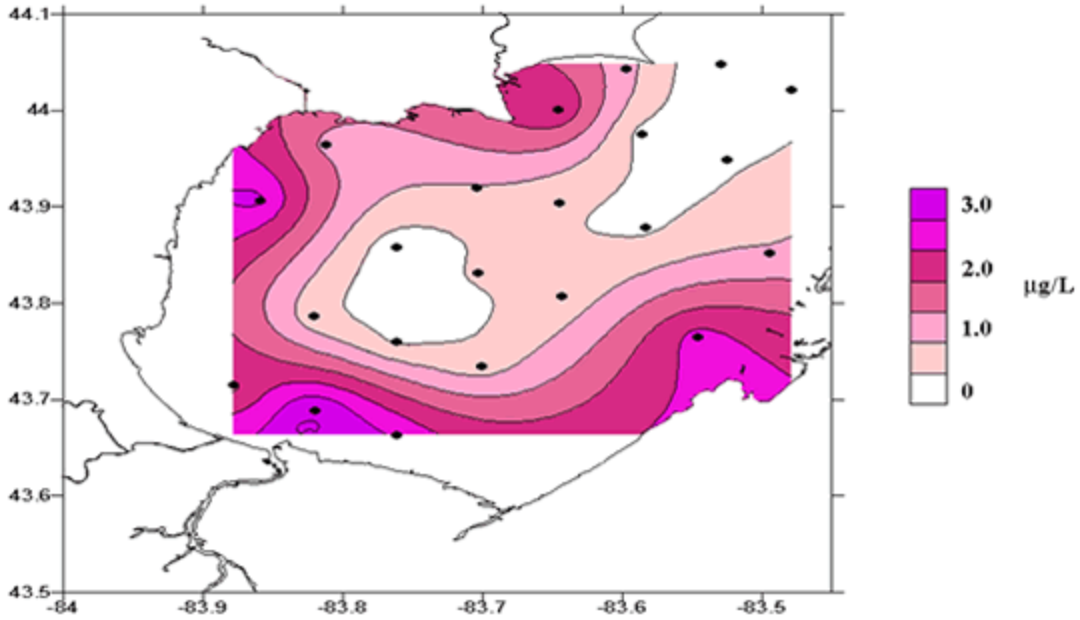


Figure 1: *Microcystin concentrations (ug/l) in Saginaw Bay, August 2004.*

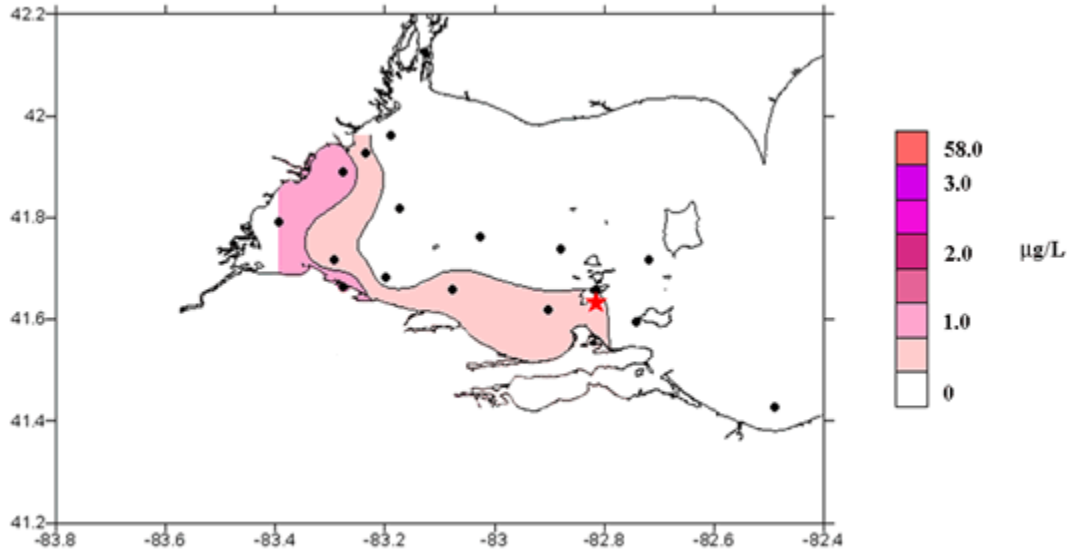


Figure 2*: Microcystin concentrations in western Lake Erie, August 20, 2004. Indicates station where high (58 ug/l) concentrations were found.*

We examined homeostatic filtering and nutrient excretion by dreissenids using a variety of state of the art tools—including direct observation techniques developed at GLERL—at different sites in Saginaw Bay and Lake Erie. Particular emphasis was placed on the Maumee region of Lake Erie. We expected this particle rich area would represent a challenge to any methods. We measured filtering, ingestion, of C, N, and P by the mussels as well as their excretion of

ammonia and phosphate, and we took sample for C:N:P ratios of the seston and algal composition.

We performed experiments at the indicated dates and sites:

Date	Mussel Species	Site
21 June 04	Zebra mussels	Erie 6L*
13 June 04	Zebra & Quagga mussels	Erie 3M**
28 July 04	Zebra & Quagga mussels	Erie 3M
8 August 04	Zebra & Quagga mussels	Erie 3M
23 August 04	Zebra & Quagga mussels	Saginaw Bay 5
20 September 04	Zebra & Quagga mussels	Erie 3M

*offshore, middle of western basin

**near Maumee Bay

We captured interesting conditions with these experiments. First, we examined filtering and nutrient excretion at times when seston quality was high and very abundant at station 3M, conditions we have never sampled in our previous work. We coordinated our work with the Fahnenstiel team for Saginaw Bay Station 5 on August 23, when there was a *Microcystis* bloom. This was an interesting bloom in that there was much *Microcystis* (the “canopy species”) plus and “understory” of edible algae that appeared to be readily ingested by the mussels. We were able to simultaneously measure response of both zebra and quagga mussels in all but one experiment to see if there are cross species differences.

Scientific Rationale

Bloom-forming, toxic cyanobacteria occur worldwide in nutrient-enriched freshwaters. Such blooms can have disastrous short- and long- term consequences for water quality and resource utilization. Consequently, cyanobacteria have been the focus of considerable research and information exists concerning the factors allowing a species to exploit environmental conditions and initiate blooms. In particular, cyanobacterial toxins are noted causative agents for human and animal illness/mortality as well as a litany of environmental-, legal-, and recreational-related problems.

Microcystis aeruginosa is the dominant bloom-forming, toxic cyanobacterium occurring in the Great Lakes. *Microcystis* has (again) become a dominant component of the summer phytoplankton in both Saginaw Bay and western Lake Erie after being a relatively minor component during the late 1980s and early 1990s. Moreover, preliminary studies have verified the presence of the cyanotoxin, microcystin, in both systems. As such, the recent blooms of *Microcystis* have caused considerable concern due to dependence on these waters as a resource and the health risks attributable to microcystins. In particular, microcystin concentrations for Saginaw Bay (2.4 g/L, Vanderploeg et al. 2001) have exceeded the

recommended limit of 1 µg/L of microcystin for drinking water (World Health Organization 1998). However, limited information concerning rates of and factors controlling microcystin production exists for the Great Lakes. In the past two years, we have regularly found concentrations of microcystin > 1ug/l in Saginaw Bay and western Lake Erie during the summer when surface scums of *Microcystis* were absent. Additionally, we have documented concentrations of microcystin in two coastal lakes on the eastern shore of Lake Michigan exceeding 200 ug/l when blooms of *Microcystis* were present.

Relevance to Ecosystem Forecasting

Improvements in ecological forecasting is a national need (NAS 2005). Much of our forecasting ability is dependent on understanding how environmental drivers change community structure and ecosystem function. Moreover, more research is needed on determining the resiliency of the ecosystem at critical temporal and spatial scales, including those related to specific ecosystem events,e.g. harmful algal blooms. It is the goal of this project to have at least one forecasting tool available for HABs this year.

The focus of this program is to increase our understanding of HABs in the Great Lakes in order to assist the development of predictive models for forecasting *Microcystis* blooms and microcystin concentrations. Monitoring and event response will be an important part of any model development and verification. In the Great Lakes limited field data exist for microcystin concentrations and *Microcystis* abundance, particularly as it is related to environmental conditions, and this project would fill this important need. It is our goal this year to have developed and tested at least one tool for forecasting HABs in the Great Lakes.

Products

Harmful Algal Blooms Website

Publications 2008

Fahnenstiel, G. L., Y. Hong, D. F. Millie, M. Doblin, D. F. Reid, and T. Johengen. Marine dinoflagellates cysts in the ballast tank sediments of ships entering the St. Lawrence Great Lakes. *Verh. Internat. Verein. Limnol*. In Press.

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Wynne, T., R. Stumpf, M. C. Tomlinson, R. A. Warner, P. A. Tester, J. Dyble, and G. Fahnenstiel. 2008. Relating spectral shape to cyanobacteria blooms in the Laurentian Great Lakes. *Int. J. Remote Sensing*. 29:3665-3672.

Millie, D. F., R. J. Pigg, G. L. Fahnenstiel, and H.J. Carrick. 2009. Algal chlorophylls: A synopsis of analytical methodologies. *American Water Works Assoc*., Manual M57. AWWA, Denver, Co. In Press

Publications 2007

Pothoven, S. A., I. A. Grigorovich, G. L. Fahnenstiel, and M. Balcer. 2007. Hemimysis anomala: the appearance of a Ponto-Caspian mysid in the Lake Michigan basin. *J. Great Lakes Res*. 33:285-292.

Publications 2006

Hong, Y., B. Biddanda, R. Rediske, A. Steinman, and G. Fahnenstiel. 2006. Occurrence of the toxin-producing cyanobacteria Cylindrospermopsis raciborskii in Mona Lake, a drowned river mouth tributary of Lake Michigan. *J. Great Lakes Res*. In Press

Millie, D. F., G. R. Weckman, H. W. Paerl, J. L. Pinckney, B. J. Bendis, R. J. Pigg, and G. L. Fahnenstiel 2006. Neural net modeling of estuarine indicators: hindcasting phytoplankton biomass and net ecosystem production in the Neuse (North Carolina) and Trout (Florida) Rivers. *Ecol. Indicators* doi:10.1016/ j.ecoind.2005.08.021.

Presentations 2007

Microcystis and Microcystins in the Great Lakes: Preliminary results from 2 coastal lakes. Presented at State of Lake Michigan Meeting, November 2005. Green Bay.

Collorators: Juli Dyble (GLERL), Patricia Tester (NOAA-Beaufort), Wayne Litaker (NOAA-Beaufort), Dave Millie (Florida Institute for Oceanography), Rick Rediske (Grand Valley State Univ.)

Presentations 2006

Microcystins in the Great Lakes. Presented at 6th Annual Surface Water Monitoring and Standards Meeting, Chicago, Il. October 2006

Marine dinoflagellates in the ballast tanks of NOBOBs ships entering the St. Lawrence Great Lakes. Presented at 30th Congress of the Int. Assoc. Theor. Appl. Limnol., Montreal.

References

Millie, D. F., G. R. Weckman, R. J. Pigg, P. A. Tester, J. Dyble, R. W. Litaker, H. J. Carrick, and G. L. Fahnenstiel. 2006. Modeling phytoplankton abundance in Saginaw Bay, Lake Huron: using artificial neural networks to discern functional influence of environmental variables and relevance to a Great Lakes Observing System. *J. Phycol*. 42:333- 349.

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