NOAA Forecasts and Monitors Blooms of Toxic Cyanobacteria in Lake Erie

by Timothy T. Wynne, Timothy Davis, Ruth Kelty, Eric Anderson and Sonia Joseph Joshi

Blooms of cyanobacteria (commonly referred to as blue-green algae) have been reported in Lake Erie as far back as the 1960s and 1970s. These blooms were nearly eliminated in Lake Erie by phosphorus abatement strategies in the 1970s that were part of the Great Lakes Water Quality Agreement, but re-emerged as a major water quality issue in the mid-1990s. The re-emergence of the blooms has been hypothesized to be a result of increases in agricultural pollution (nitrogen and phosphorus) into western Lake Erie. The role of the colonization of the invasive *dreissenid* mussels (a collective term for three similar mussel species) in promoting the re-emergence of the blooms is also being investigated.

Harmful algal blooms (HABs) pose a potential human health hazard due to the production of toxins which have caused domestic and wildlife mortalities. The primary toxins produced by the cyanobacteria in Lake Erie are the microcystins. The algae can also affect the taste and odor of drinking water.

This is an overview of National Oceanic and Atmospheric Administration's (NOAA) efforts to detect, predict and mitigate the impacts of HABs in Lake Erie. The agency provides information for decision-making in the Great Lakes region in partnership with Heidelberg University, Ohio Sea Grant's Stone Laboratory, the University of Toledo, Ohio EPA, University of Michigan, Bowling Green State University, Michigan Technological University, University of Tennessee, State University of New York–College of Environmental Science and Forestry, Stony Brook University, Environment Canada, and others. This Great Lakes work is part of a larger NOAA effort to deliver ecological forecasts that support human health and well-being, coastal economies, and coastal and marine stewardship.

NOAA has been monitoring and issuing forecasts on cyanobacteria's location and concentration in the Great Lakes since 2008 *(Wynne et al., 2013a)*. There are multiple components to this effort, all of which involve many of the partners listed above.

1. A seasonal forecast gives coastal managers and drinking water facility operators a general sense of how "bad" a bloom season has the potential to be. The seasonal forecast is an ensemble of models based largely upon phosphorus discharge from the Maumee River.
2. A bulletin provides the current extent and potential trajectory of the bloom, allowing managers to determine whether to take preventative actions. It is produced multiple times a week during the bloom season, typically from June until the bloom finally dissipates, usually around mid to end of October. The forecasts are posted on the web *(http://coastalscience.noaa.gov/research/habs/forecasting)* and emailed to subscribers.
3. The HAB Tracker for Lake Erie at *http://www.glerl.noaa.gov/res/waterQuality/habsTracker.html,* combines remote sensing, field observations, and modeling to project 10-day outlooks of bloom trajectory and concentrations.
4. These forecasting efforts are complemented by on-lake monitoring of the algal bloom on a weekly basis from June - October.
5. NOAA and its partners are establishing a citizen monitoring network for Great Lakes HABs using phytoplankton monitoring protocols in communities in the region. Twenty citizen monitoring sites are to be operational this Summer 2015, providing early warning of cyanobacteria HABs spanning the western to eastern basins of Lake Erie.
6. A newly developed microcystin sensor will be deployed in western Lake Erie in 2016 on an autonomous robotic Environmental Sample Processor (ESP). The ESP and microcystin sensor will provide real-time, early warning of cyanoHAB development and toxicity to stakeholders, including drinking water facilities and public health officials.

Development of NOAA's Forecast Products

NOAA relies on satellite imagery for initial detection *(Wynne et al., 2008)*. This year, the detection algorithm is using images from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor *(Wynne et al., 2013b)*. However, MODIS is at the end of its operational lifetime and is deteriorating. The system formerly used images from the European Space Agency's MEdium Resolution Imaging Spectrometer (MERIS) sensor until operations ceased in April 2012. The European Space Agency is planning to launch a follow up to MERIS called the Ocean and Land Colour Instrument (OLCI) at the end of 2015. It will replace MODIS for the forecasting purposes in Summer 2016.

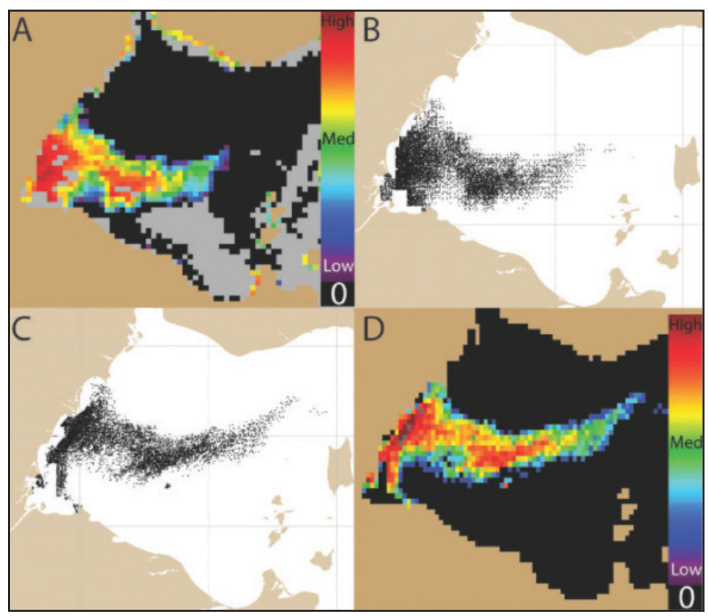

Figure 1. Shows an example of how the initial satellite image (A) is converted to passive particles (B) moved within a hydrodynamic model (C) and written back into an image (D)

With a solid detection method in place, the next step is to predict where the bloom is likely to go. The initial image and concentration is determined by satellite imagery ***(Figure 1A)***. The concentration is then read into a particle tracking software package called GNOME (General NOAA Operational Modeling Environment) and is written out into a series of passive particles, which can be thought of as a proxy for cyanobacterial cells ***(Figure 1B)***. Data on currents and winds read into GNOME move the passive particles around the lake

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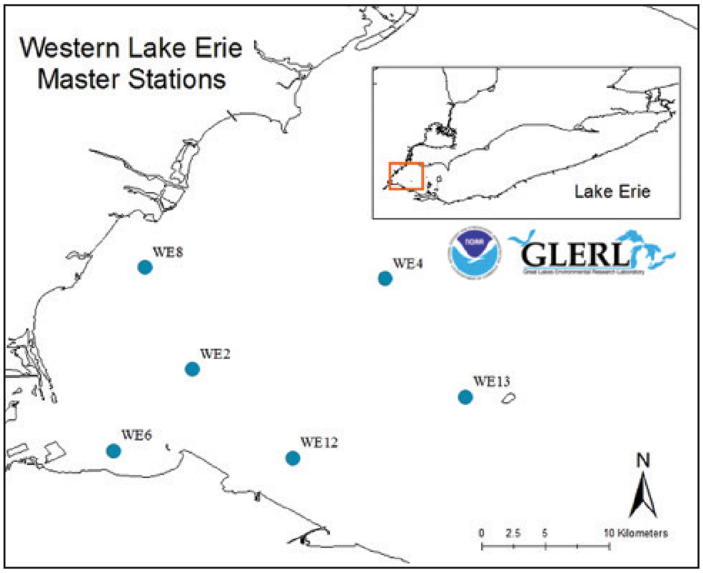
for a period of up to 72 hours from the present ***(Figure 1C)***. Finally, these particles are written back out into an image ***(Figure 1D;** Wynne et al., 2011)*.

The NOAA HAB Tracker product takes daily satellite imagery and real-time monitoring to estimate the current expanse and intensity of the bloom. NOAA uses forecasted meteorology and hydrodynamic modeling to predict where the bloom will travel and what concentrations are likely to be seen on a three-dimensional scale. These predictions can provide water intake managers timely information for public health decision-making.



NOAA/GLERL

Figure 2. Master stations sampled weekly by NOAA for harmful algal bloom toxins

NOAA Monitoring of Toxic Algae

NOAA conducts a comprehensive spatial and temporal HAB monitoring program. Every week from June – October six master stations ***(Figure 2)*** are sampled. Surface water at each location is collected and water quality parameters including, but not limited to, water temperature, dissolved oxygen, nitrogen and phosphorus concentrations, total algal biomass (measured using chlorophyll a, a pigment found in all algae) total cyanobacteria biomass (measured using phycocyanin, a pigment only found in cyanobacteria), preserved samples for microscopic identification of specific algal species, toxins (i.e., microcystins) and samples for genetic analysis are measured. Microcystin concentrations are analyzed within 48 hours and this information is uploaded to NOAA's western Lake Erie toxin tracking page *(http://www.glerl.noaa.gov/res/waterQuality/WLEMicrocystin.html)*.

NOAA also uses a sophisticated network of near-real-time water quality measurement instruments that can collect samples for many of the important parameters listed above, including dissolved phosphorus on a frequent basis in between the weekly boat samplings. These data are updated on NOAA's water quality page under the HAB Tracker images *(http://www.glerl.noaa.gov/res/waterQuality/habsTracker.html)*. In 2016, NOAA will have the capability to measure microcystins near-real-time via newly developed microcystin sensors deployed on an ESP in western Lake Erie.

This summer these efforts will be complimented by citizen monitoring at 20 sites spanning the western to eastern basins of Lake Erie. The newly established citizen monitoring network for Great Lakes HABs is part of a larger *phytoplankton monitoring network* coordinated by NOAA.

NOAA also manages the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Program *(http://coastalscience.noaa.gov/research/habs/merhab/)*, through which NOAA and other federal agencies can provide assistance for local management agencies when unexpected HAB events exceed their capacities. Potential assistance includes targeted sample efforts, analyzing toxins in water or tissue samples, and other technical expertise.

2014 HAB Impacts on Toledo, OH

During Summer 2014, municipal water supplies in Lake Erie were closed when levels of the toxin micocystin exceeded the World Health Organization's guideline level for safe drinking water (1 part per billion). On August 1, 2014, NOAA released its weekly HAB bulletin for Lake Erie. A weekly data share sent the same day reported toxicity at six sites including the Toledo drinking water intake. Both the bulletin and weekly data share warned of an intensifying cyanobacteria bloom that could introduce toxins into drinking water in the City of Toledo, OH.

The next day, the city issued a drinking water advisory, restricting drinking water access to 500,000 residents. NOAA responded to this human health crisis by increasing its bulletin production and conducting a targeted event response sampling effort to analyze samples throughout the water column around the Toledo water intake and from across western Lake Erie, for a broad suite of cyanotoxins having known human health risk but that are not routinely monitored. The agency's HAB trajectories warned of potential impacts to water suppliers in Oregon, OH and Monroe, MI. The greatly expanded information on the potential risk of the bloom directly supported state and city managers and federal agencies such as the state of Ohio's Environmental Protection Agency.

Frequency of Blooms and Their Impacts

Blooms vary from year to year ***(Figure 3)***. The 2014 bloom hit a particularly vulnerable area, but the 2013 bloom was actually bigger and had a more widespread impact. Carrol Township, Ohio, had 2,000 people that were without water in September 2013 due to elevated levels of microcystins in the finished drinking water. The bloom moved north and led to multiple beach closures in Ontario.

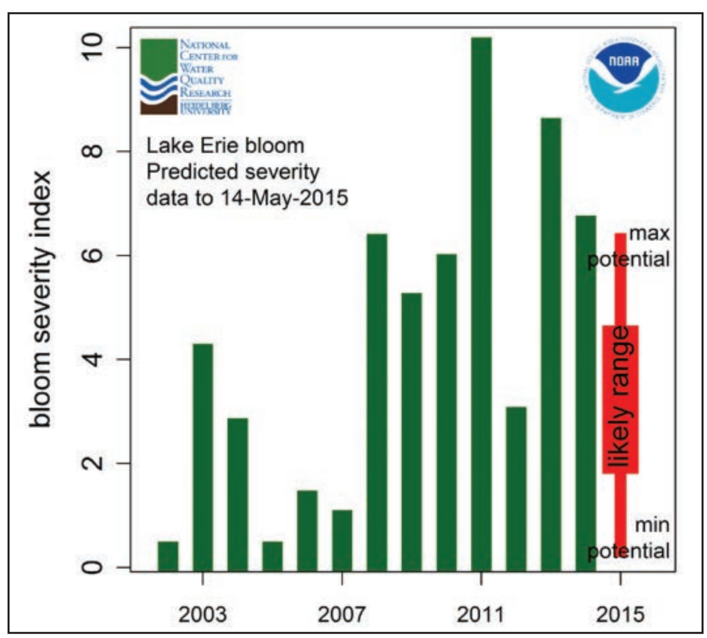


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Figure 3. Seasonal severity of Lake Erie harmful algal blooms since 2002

The 2011 bloom was the worst in recorded history with a size roughly double that of the 2013 and 2014 blooms, and with concentrations of microcystins that were many times higher than what was measured in either 2013 or 2014. The majority of bloom activity occurs within the shallow and warm western basin of Lake Erie. Central basin blooms in 2012 and 2013 may indicate that the conditions that promote bloom activity in Lake Erie are spreading. There have not been blooms in the far eastern regions of Lake Erie since the start of the forecasts in 2008. If a bloom did start in eastern Lake Erie, a forecast would be issued and the bloom would be monitored throughout its duration.

Timothy T. Wynne (timothy.wynne@noaa.gov) and Ruth Kelty work for the National Oceanic and Atmospheric Administration's National Centers for Coastal Ocean Science in Silver Spring, MD. Timothy Davis, Eric Anderson, and Sonia Joseph Joshi are with NOAA's Great Lakes Environmental Research Laboratory, Anne Arbor, MI.

References

Stumpf, R.P., T.T. Wynne, D.B. Baker, and G.L. Fahnenstiel. 2012. Interannual variability of cyanobacterial blooms in Lake Erie. *PLoS ONE*. 7(8): e42444. doi:10.1371/journal.pone.0042444.

Wynne, T.T., R.P. Stumpf, M.C. Tomlinson, G.L. Fahnensteil, D.J. Schwab, J. Dyble, S. Joshi. 2013a. Development of a cyanobacterial bloom forecast system in western Lake Erie. *Journal of Great Lakes Research*. 39:90-99.

Wynne, T.T., R.P. Stumpf, and T.O. Briggs. 2013b. Comparing the inversion of the MODIS Fluorecence Line Height with MERIS Fluorecence Line Height and applicability to cyanobacterial bloom detection. *International Journal of Remote Sensing*. 34:6668-6678.

Wynne, T.T., R.P. Stumpf, M.C. Tomlinson, D.J. Schwab, G.Y. Watabayashi and J.D. Christensen. 2011. Estimating cyanobacterial bloom transport by coupling remotely sensed imagery and a hydrodynamic model. *Ecological Applications*. Vol. 21, No. 7, pp. 2709-2721.

Wynne, T.T., R.P. Stumpf, M.C. Tomlinson, R.A. Warner, P.A. Tester, J. Dyble, and G.L. Fahnenstiel. 2008. Relating spectral shape to cyanobacterial blooms in the Laurentian Great Lakes. *International Journal of Remote Sensing*. Vol. 29 No. 12, pp 3665-3672.

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