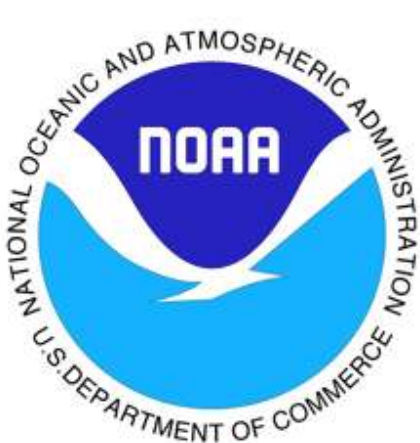


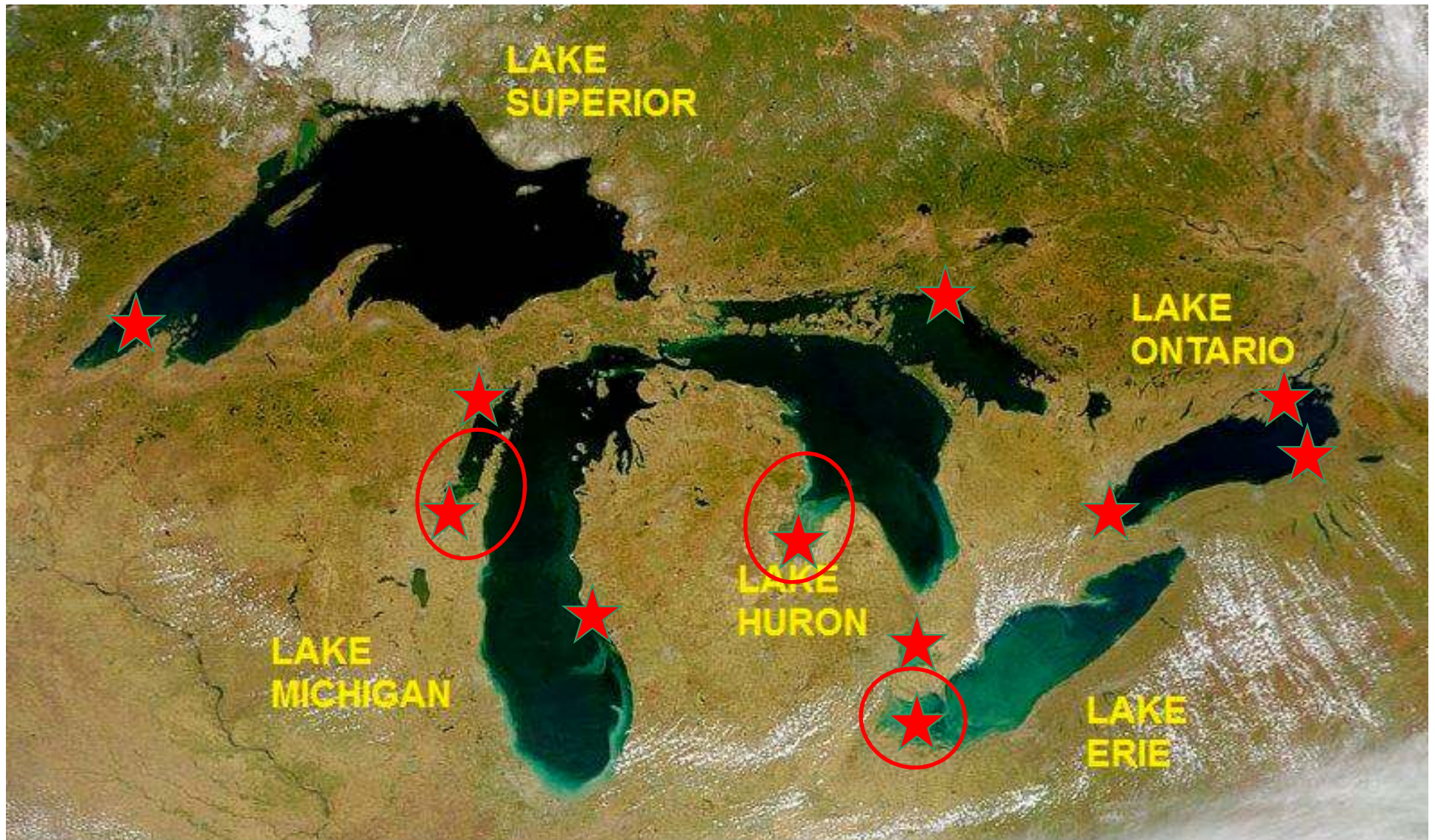
NOAA's Great Lakes harmful algal bloom program

Part 1: Prediction, monitoring and experiments

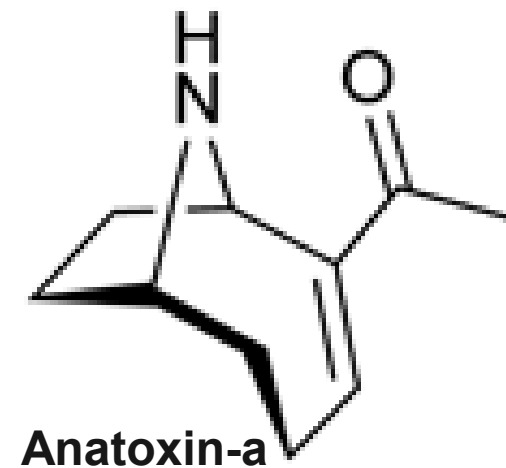
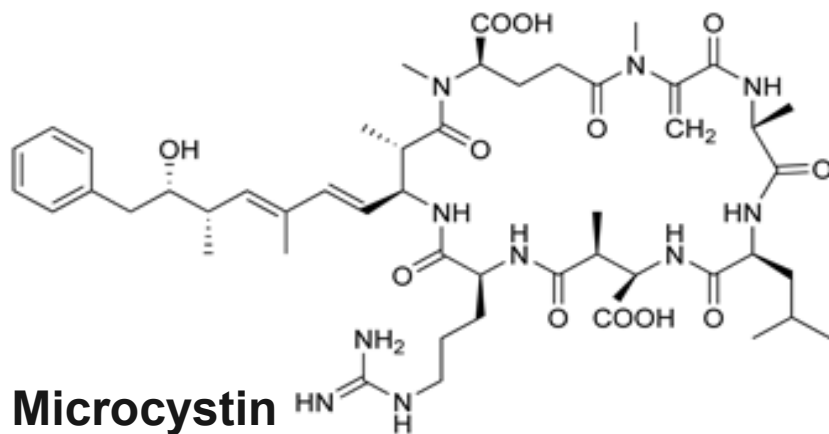
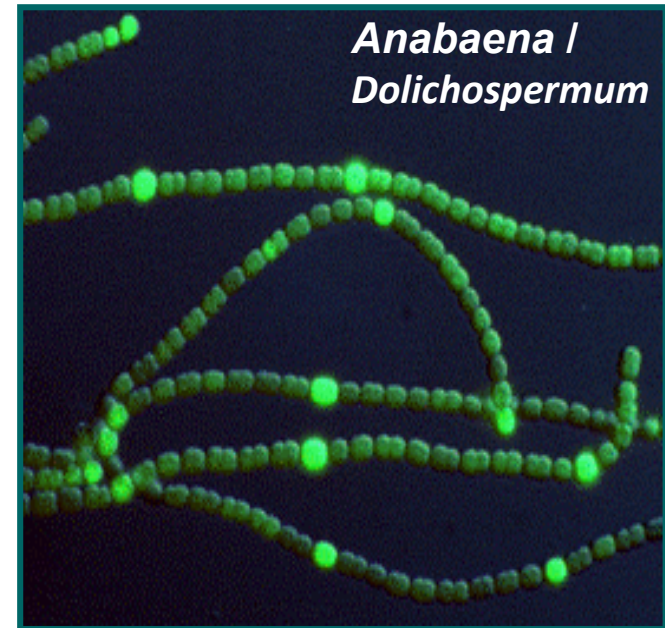
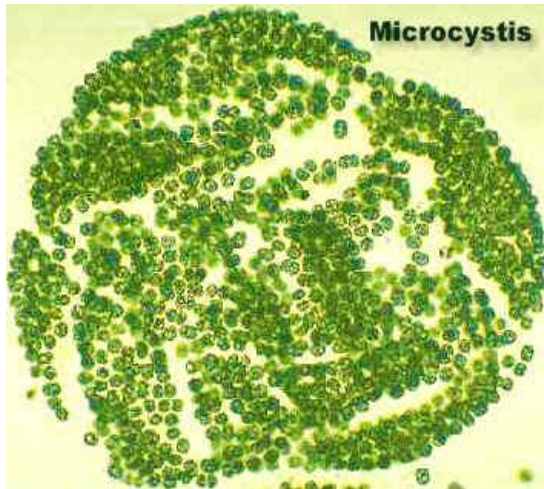
Timothy Davis



HABs occur throughout the Great Lakes basin



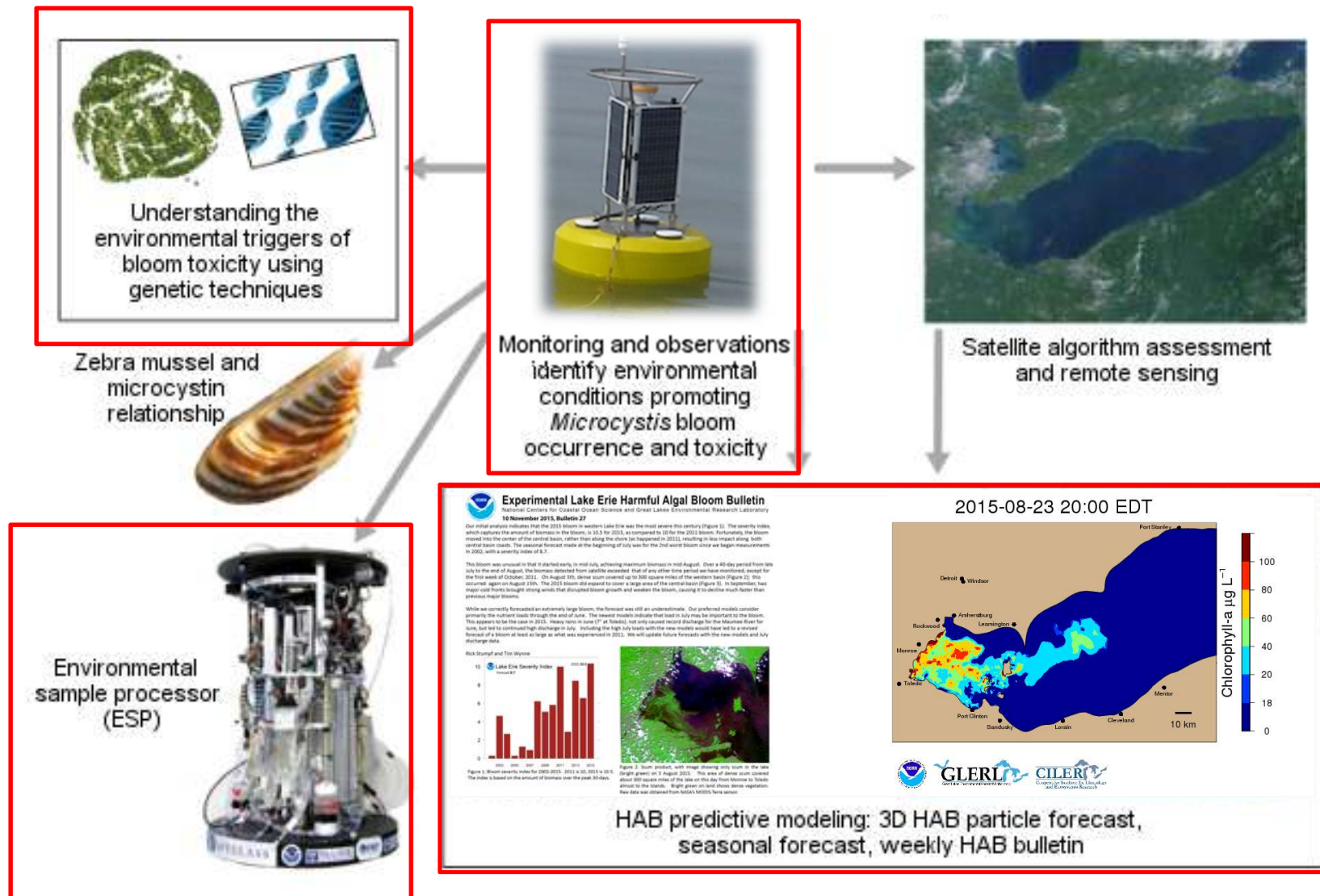
Potentially-toxic cyanobacteria of Lake Erie



Overarching research statement:

Understanding the drivers of
bloom ecology will aid in
enhancing predictive models that
forecast bloom size, location AND
toxicity

An integrated approach to studying HABs



NOAA's cross-line office CHAB team

Monitoring & Experiments

Timothy Davis

Tom Johengen*

Duane Gossiaux

Ashley Burtner*

Danna Palladino*

Heidi Purcell*

Hank Vanderploeg

Alicia Ritzenthaler*

Remote Sensing

Steve Ruberg

Richard Stumpf

Andrea Vander Woude*

Steve Constant

George Leshkevich

Ron Muzzi

Russ Miller

Modeling

Richard Stumpf

Eric Anderson

Tim Wynne

Danielle Dupuy

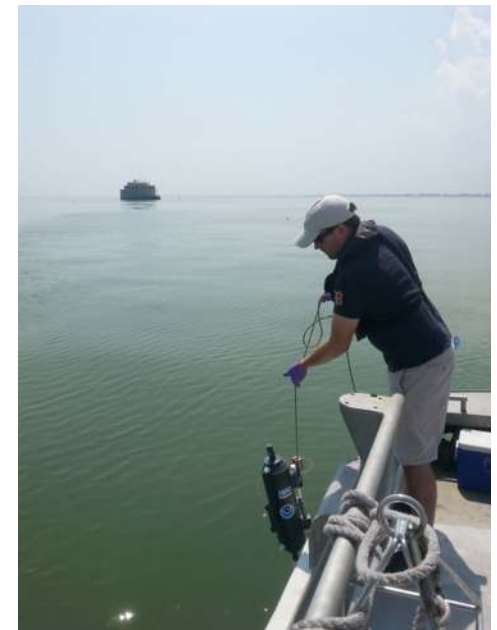
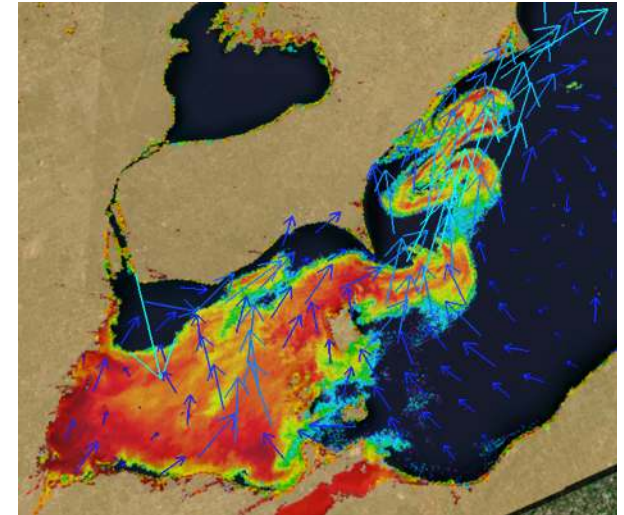
Mark Rowe*

Greg Lang

Communications

Sonia Joseph Joshi*

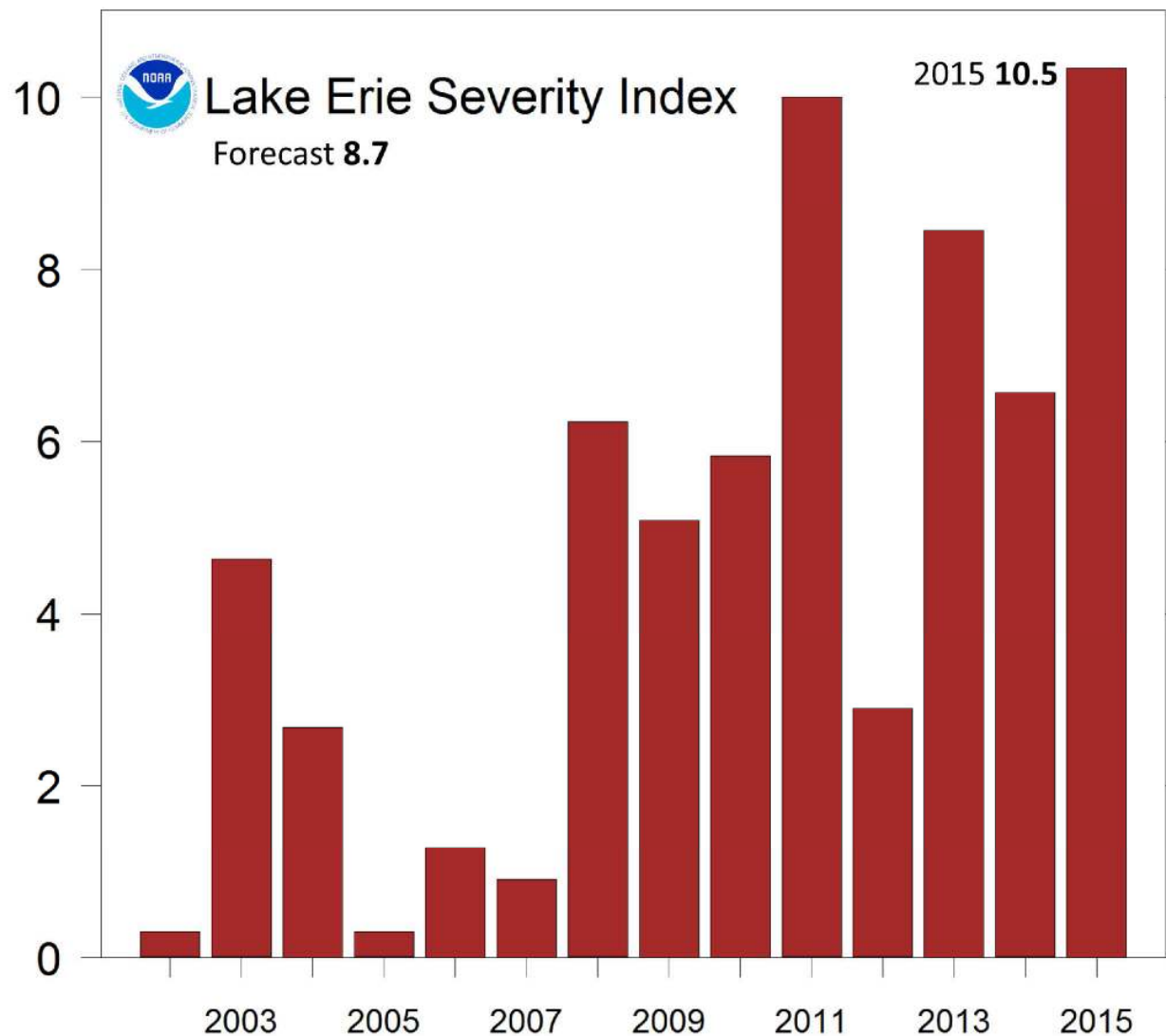
Joe Smith*



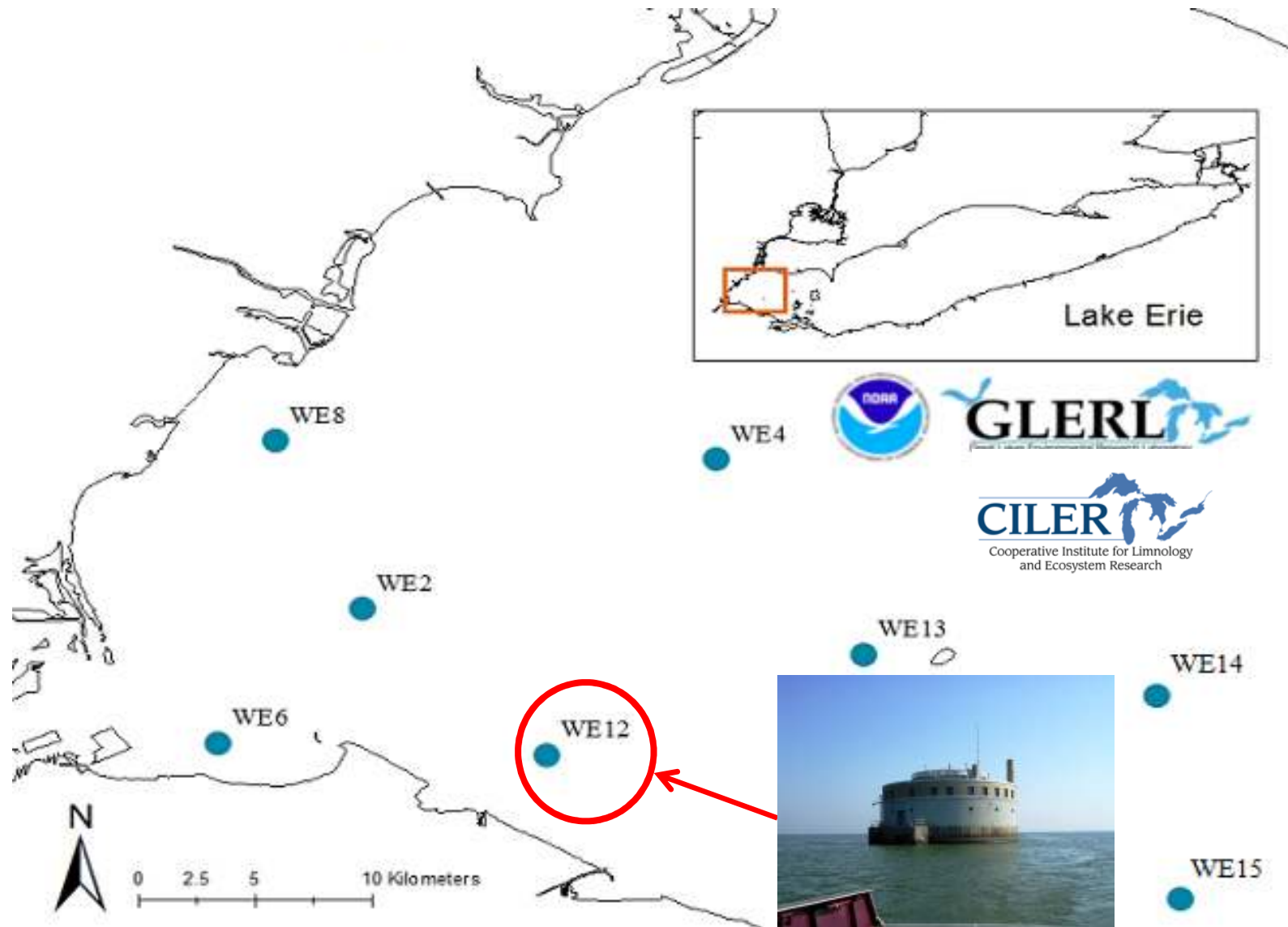
BOLD = HAB team leads
*** = CILER employees**

NOAA and academic partners predict bloom severity

2015 was the largest bloom this century



Western Lake Erie weekly sampling



NOAA GLERL HAB webpage



Enter query here...
 GLERL NOAA

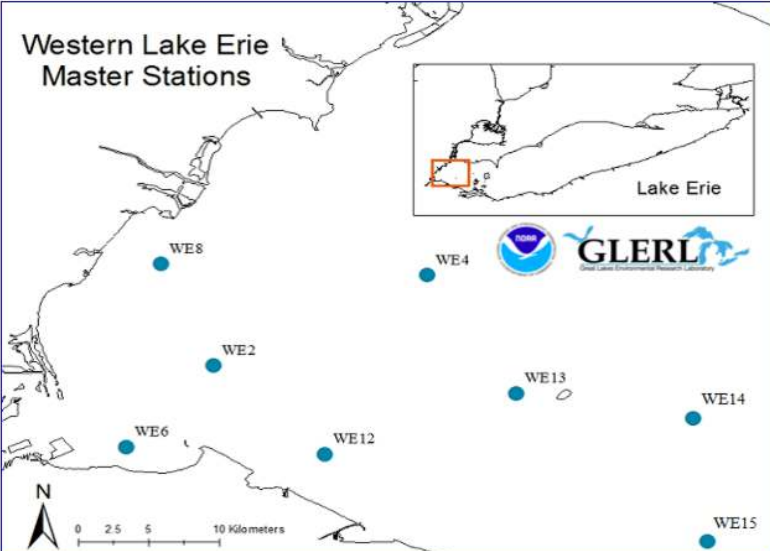


NOAA - Great Lakes Environmental Research Laboratory

[Home](#) [Quick Links](#) [About Us](#) [Research](#) [Data & Products](#) [Publications](#) [Education](#)

Monitoring of Lake Erie for the 2015 HABs and Hypoxia season has ended.

Western Lake Erie Master Stations



On a weekly basis we monitor 8 fixed sampling locations for a suite of variables that influence the growth and distribution of algal blooms. In addition we monitor algal toxin concentrations. To view our monitoring data, please [click here...](#)

Microcystin Sampling	Real-time Monitoring
HAB Tracker	Vertical Mixing Analysis
Hypoxia Monitoring	

Resources

[Experimental Lake Erie Harmful Algal Bloom Bulletin](#)

[Lake Erie HABs Bulletin \(Experimental\)](#)

- [Bulletin Sign Up](#)
- [Bulletin Archive](#)

[Overview of guidelines on algal toxins](#)

[Algal Bloom Flickr Gallery](#)

[MODIS Satellite Imagery](#)

Quick jump to Lake Erie Apps: [Microcystin Sampling](#) | [Real-time Monitoring](#) | [HAB Tracker](#) | [Vertical Mixing Analysis](#) | [Hypoxia Monitoring](#)



Experimental Lake Erie Harmful Algal Bloom Bulletin

National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory

4 August 2014, Bulletin 10

The microcystis bloom has intensified since last Thursday, and the area covered by medium to high concentrations (green to red) has increased. Calm winds have allowed the bloom to concentrate near surface; patches of scum were present in the areas of high concentration.

Today and Tuesday expect slight northeast transport (away from the Maumee Bay area). However, this pattern will change and light southward transport is expected through the end of the week. Mixing is expected to be weak.

The imagery shows the persistent bloom in Sandusky Bay is present. There are no reported harmful algal blooms or suspicious features in the Eastern Basin at this time.

-Dupuy Stumpf

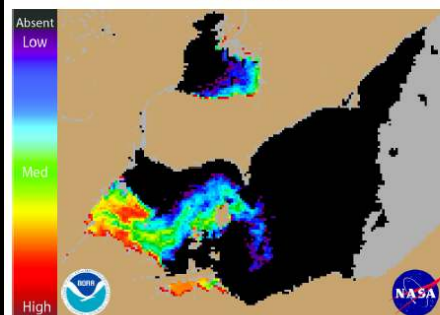


Figure 1. Cyanobacterial Index from NASA's MODIS-Aqua data collected 3 August 2014 at 1:10 pm. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 35,000 cells/mL.

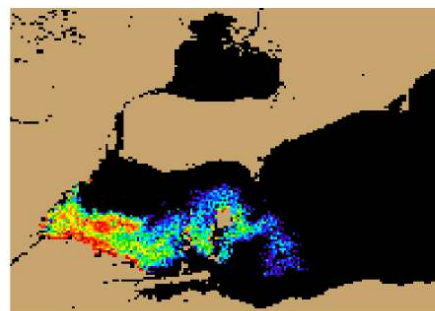
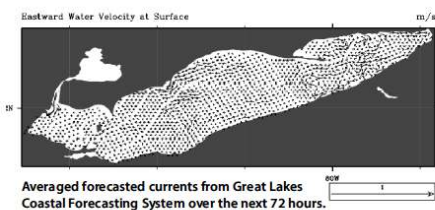


Figure 3. Forecast position of bloom for 7 August 2014 using GLCFS modeled currents to move the bloom from the 3 August 2014 image.



Supported by the NASA Applied Sciences Health and Air Quality Program.
For more information and to subscribe to this bulletin, go to:
http://www.glerl.noaa.gov/res/Centers/HABS/lake_erie_hab/lake_erie_hab.html

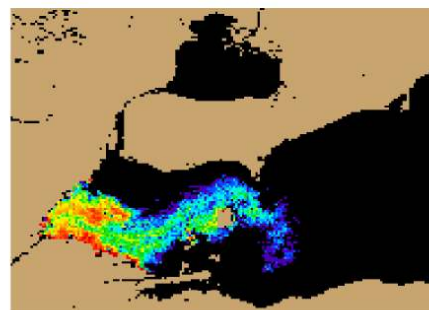
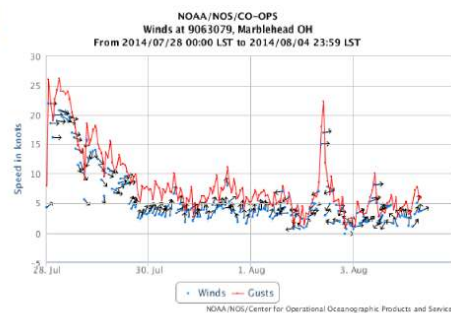
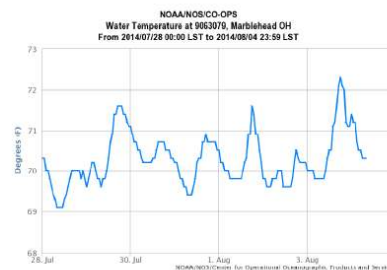


Figure 2. Nowcast position of bloom for 4 August 2014 using GLCFS modeled currents to move the bloom from the 3 August 2014 image.



Wind Speed, Gusts and Direction from Marblehead, OH. From: NOAA/Center for Operational Oceanographic Products and Services (CO-OPS). Note: 1 knot = 0.51444 m/s. Blooms mix through the water column at wind speeds greater than 7.7 m/sec (~ 15 knots).



Water Temperature from Marblehead, OH. From: NOAA/Center for Operational Oceanographic Products and Services (CO-OPS).

NOAA GLERL HAB webpage

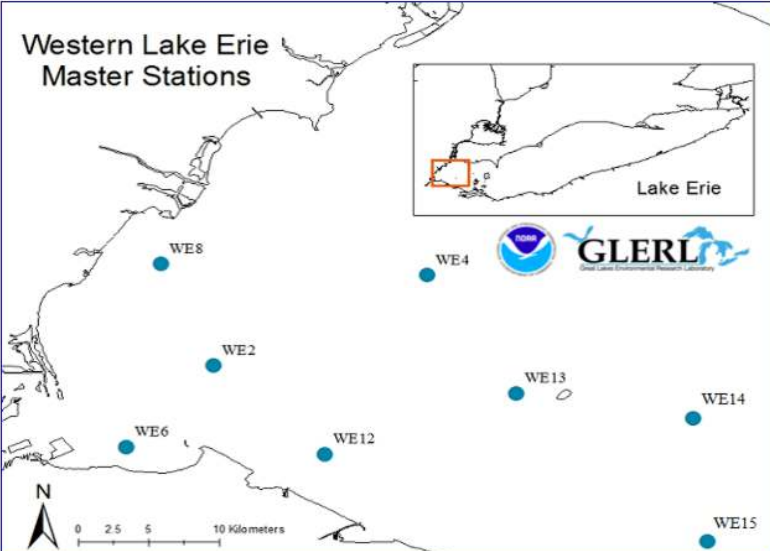


Enter query here...
[GLERL](#) [NOAA](#)



[Home](#) [Quick Links](#) [About Us](#) [Research](#) [Data & Products](#) [Publications](#) [Education](#)

Monitoring of Lake Erie for the 2015 HABs and Hypoxia season has ended.

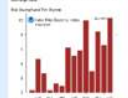


On a weekly basis we monitor 8 fixed sampling locations for a suite of variables that influence the growth and distribution of algal blooms. In addition we monitor algal toxin concentrations. To view our monitoring data, please [click here...](#)

Microcystin Sampling	Real-time Monitoring
HAB Tracker	Vertical Mixing Analysis
Hypoxia Monitoring	

Resources

[Experimental Lake Erie Harmful Algal Bloom Bulletin](#)
The Lake Erie Harmful Algal Bloom Bulletin is a weekly report that provides information on the status of algal blooms in Lake Erie. The bulletin is published every week during the growing season (May through October) and is available in both print and electronic formats. The bulletin is a key resource for the public, media, and researchers interested in the status of algal blooms in Lake Erie.



[Lake Erie HABs Bulletin \(Experimental\)](#)

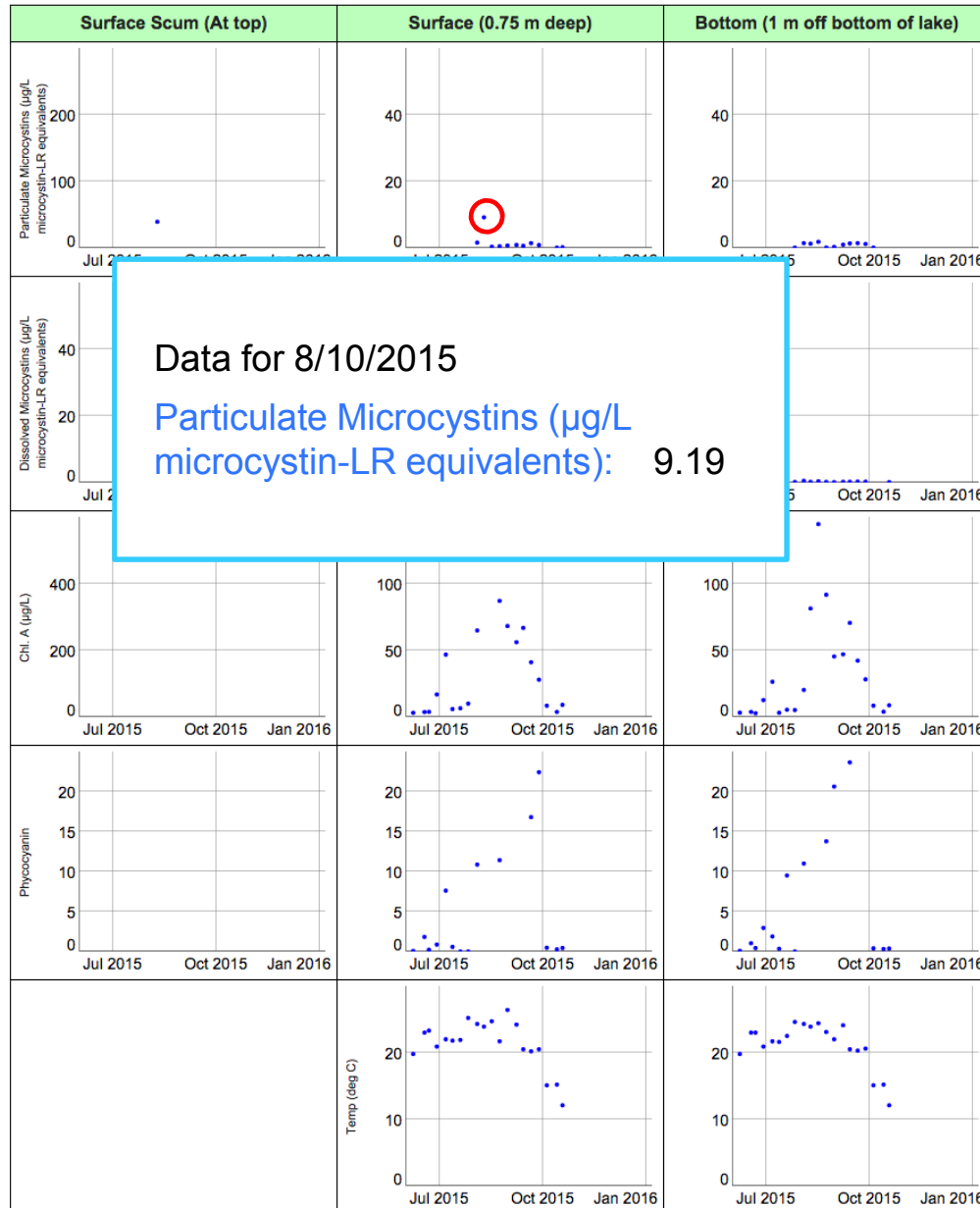
- [Bulletin Sign Up](#)
- [Bulletin Archive](#)

[Overview of guidelines on algal toxins](#)

[Algal Bloom Flickr Gallery](#)
[MODIS Satellite Imagery](#)

Quick jump to Lake Erie Apps: [Microcystin Sampling](#) | [Real-time Monitoring](#) | [HAB Tracker](#) | [Vertical Mixing Analysis](#) | [Hypoxia Monitoring](#)

Critical water quality data provided to stakeholders



- Weekly data shared with over 30 regional partners
- Allows stakeholders to view trends in bloom biomass and toxicity
- Surface and bottom measurements

NOAA GLERL HAB webpage



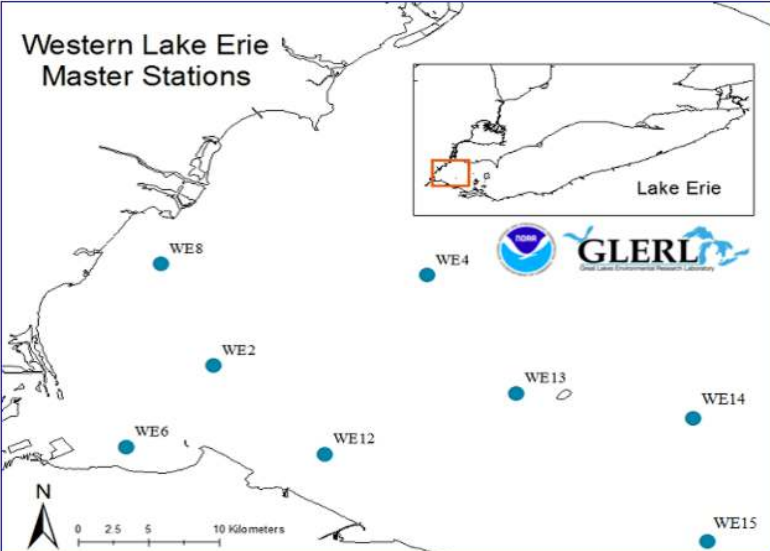
Enter query here...
[GLERL](#) [NOAA](#)

[f](#) [t](#) [in](#) [v](#)

NOAA - Great Lakes Environmental Research Laboratory

[Home](#) [Quick Links](#) [About Us](#) [Research](#) [Data & Products](#) [Publications](#) [Education](#)

Monitoring of Lake Erie for the 2015 HABs and Hypoxia season has ended.



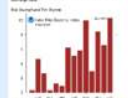
Western Lake Erie Master Stations

On a weekly basis we monitor 8 fixed sampling locations for a suite of variables that influence the growth and distribution of algal blooms. In addition we monitor algal toxin concentrations. To view our monitoring data, please [click here...](#)

Microcystin Sampling	Real-time Monitoring
HAB Tracker	Vertical Mixing Analysis
Hypoxia Monitoring	

Resources

Experimental Lake Erie Harmful Algal Bloom Bulletin
The Lake Erie Harmful Algal Bloom Bulletin is a weekly report that provides information on the status of algal blooms in Lake Erie. The bulletin is available in both print and online formats. The online format includes a map of Lake Erie showing the location of algal blooms and a table of algal bloom data. The print format includes a map of Lake Erie showing the location of algal blooms and a table of algal bloom data.



[Lake Erie HABs Bulletin \(Experimental\)](#)

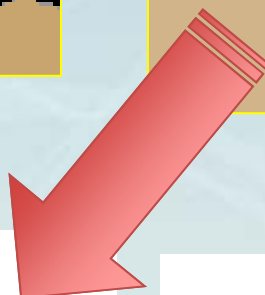
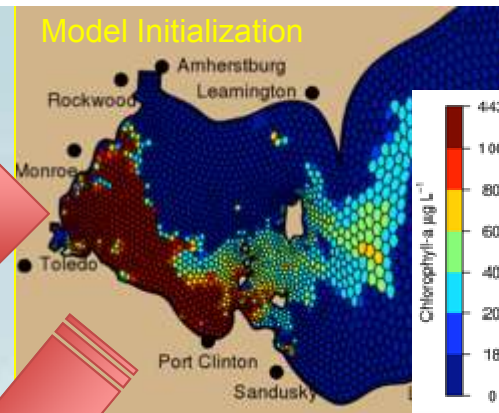
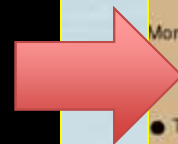
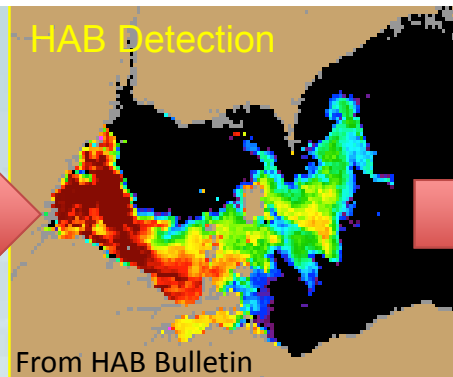
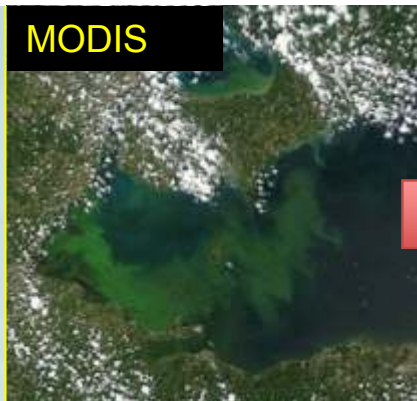
- [Bulletin Sign Up](#)
- [Bulletin Archive](#)

[Overview of guidelines on algal toxins](#)

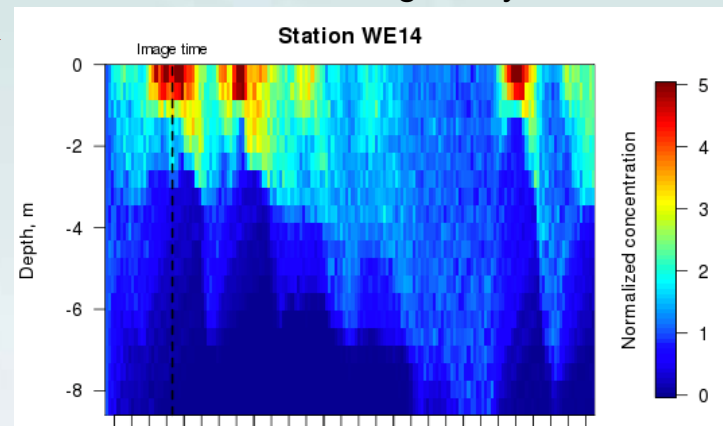
[Algal Bloom Flickr Gallery](#)

[MODIS Satellite Imagery](#)

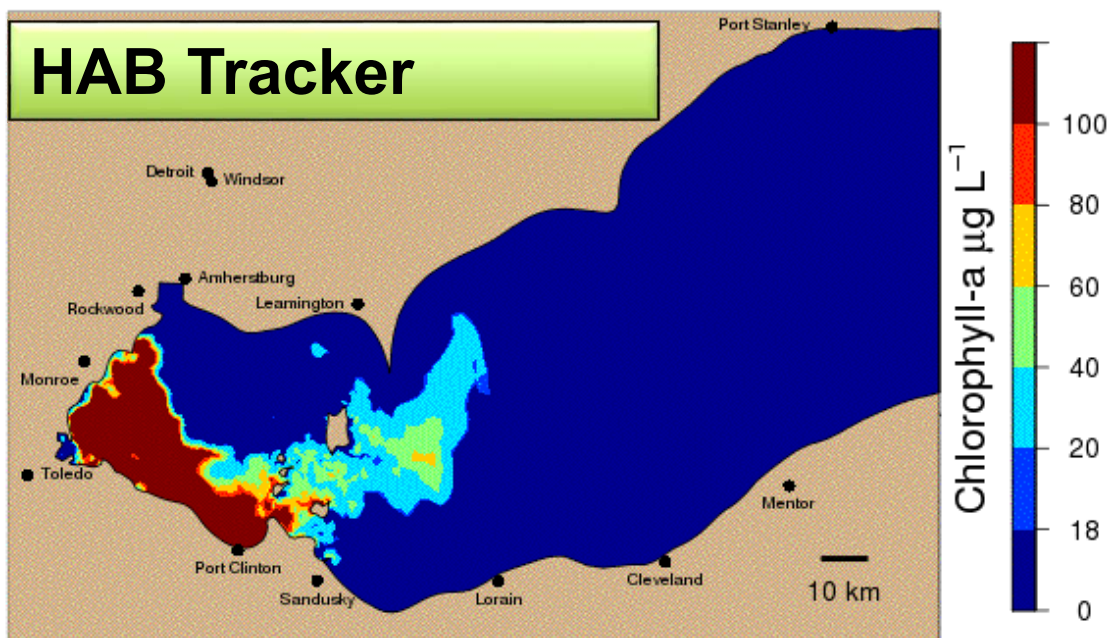
Quick jump to Lake Erie Apps: [Microcystin Sampling](#) | [Real-time Monitoring](#) | [HAB Tracker](#) | [Vertical Mixing Analysis](#) | [Hypoxia Monitoring](#)



Vertical Mixing Analysis



2015-08-05 12:00 EDT



5-day Forecast

NOAA GLERL HAB webpage

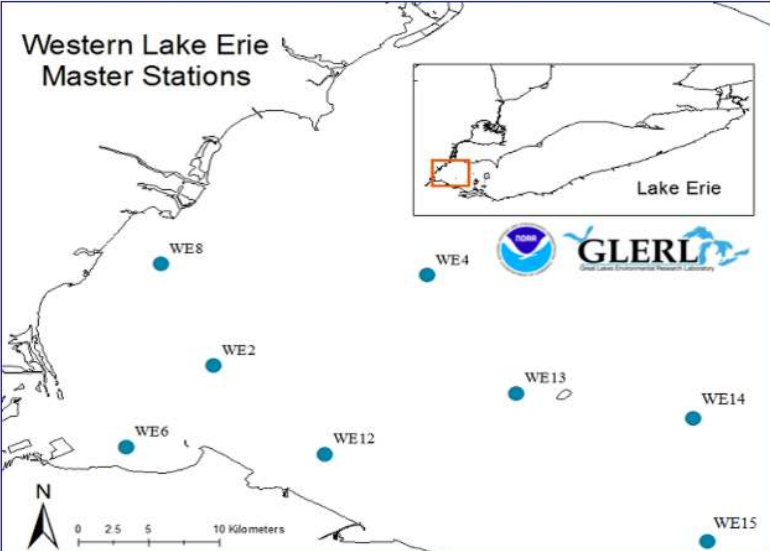


Enter query here...
[GLERL](#) [NOAA](#) [Search](#)

[f](#) [t](#) [in](#) [v](#)

[Home](#) [Quick Links](#) [About Us](#) [Research](#) [Data & Products](#) [Publications](#) [Education](#)

Monitoring of Lake Erie for the 2015 HABs and Hypoxia season has ended.



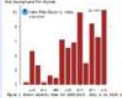
Western Lake Erie Master Stations

On a weekly basis we monitor 8 fixed sampling locations for a suite of variables that influence the growth and distribution of algal blooms. In addition we monitor algal toxin concentrations. To view our monitoring data, please [click here...](#)

Microcystin Sampling	Real-time Monitoring
HAB Tracker	Vertical Mixing Analysis
Hypoxia Monitoring	

Resources

Experimental Lake Erie Harmful Algal Bloom Bulletin
The Lake Erie Harmful Algal Bloom Bulletin is a weekly report that provides information on the status of algal blooms in Lake Erie. The bulletin is published every week during the growing season (May through October) and is available in both print and online formats. The bulletin provides information on the location, extent, and intensity of algal blooms, as well as the results of sampling and monitoring activities. The bulletin is a valuable resource for researchers, managers, and the public.



[Lake Erie HABs Bulletin \(Experimental\)](#)

- [Bulletin Sign Up](#)
- [Bulletin Archive](#)

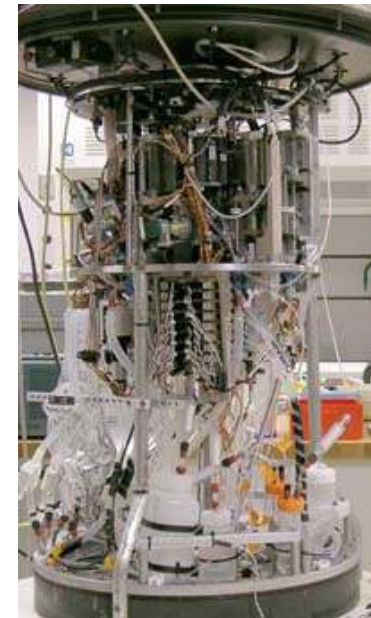
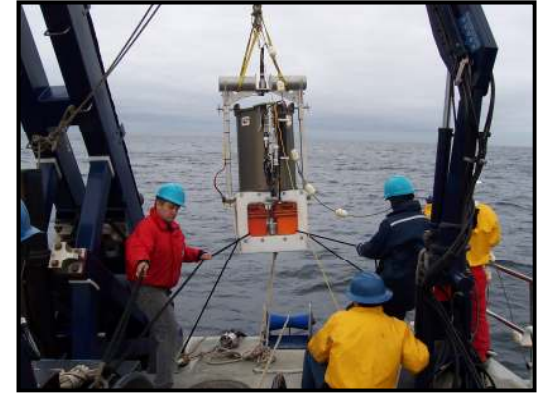
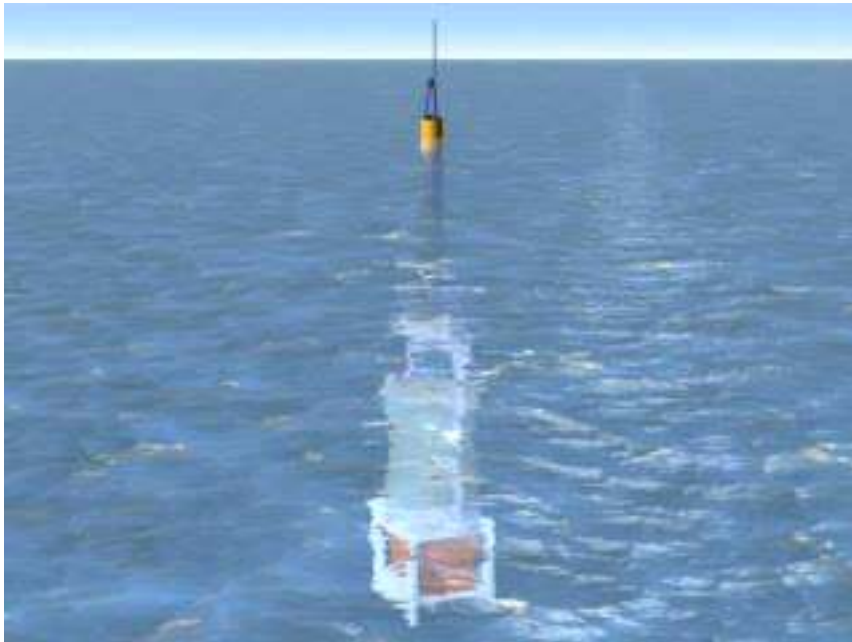
[Overview of guidelines on algal toxins](#)

[Algal Bloom Flickr Gallery](#)
[MODIS Satellite Imagery](#)

Quick jump to Lake Erie Apps: [Microcystin Sampling](#) | [Real-time Monitoring](#) | [HAB Tracker](#) | [Vertical Mixing Analysis](#) | [Hypoxia Monitoring](#)

Autonomous near real-time toxin detection for Lake Erie

Funded by EPA-GLRI



Will be extremely valuable in the development of more accurate bloom forecasting models



Deployment of ESPniagara



Pressure housing for ESP
– Rated to 48 m depth

- 5'6" tall
- 5ft x 5ft footprint
- < PSI pressure on footprint
- Deck weight ~ 1800 lbs
- In-water weight ~ 750lbs



3-way sample valve

Sampling manifold

ESP battery assemblies
(and opposite)
Each hold 200 D cell batteries

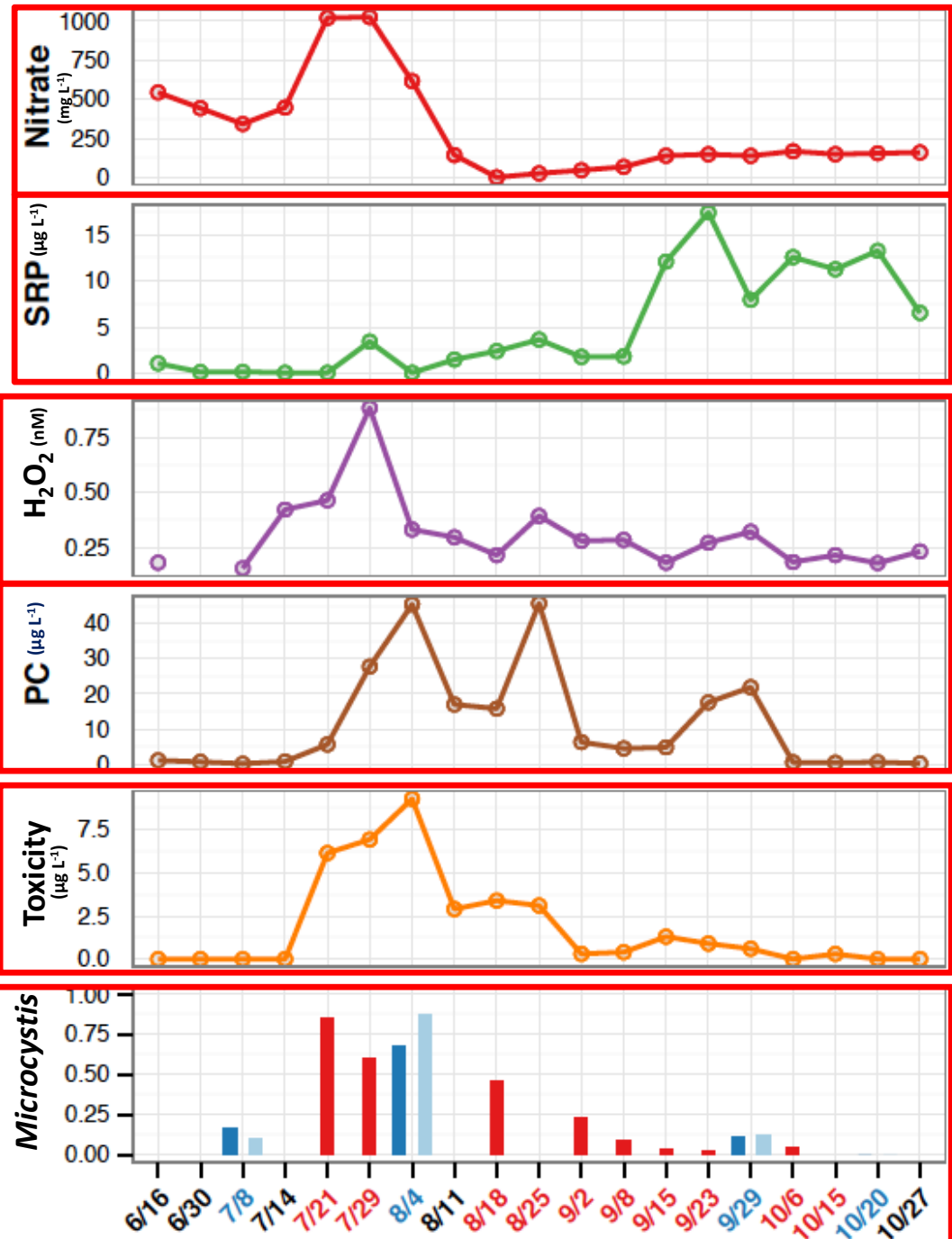
Tagline
attachment points



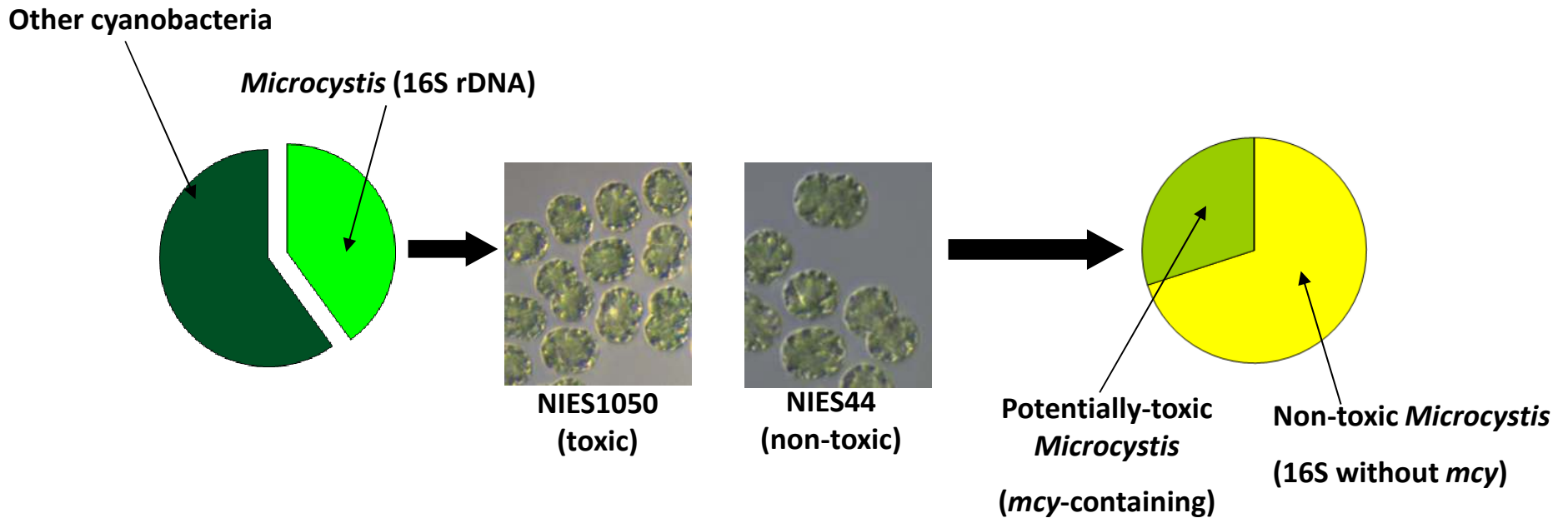
Toledo Water Intake (Station 12)

Weekly sampling reveals important trends that highlight potential environmental drivers and inform future experiments

- Toxicity changes throughout the bloom
- Relationship between nitrogen, toxicity and toxic *Microcystis*
- *Microcystis* blooms occur even when phosphorus concentrations are low
- Other factors beyond nutrients may be important in driving bloom structure and function



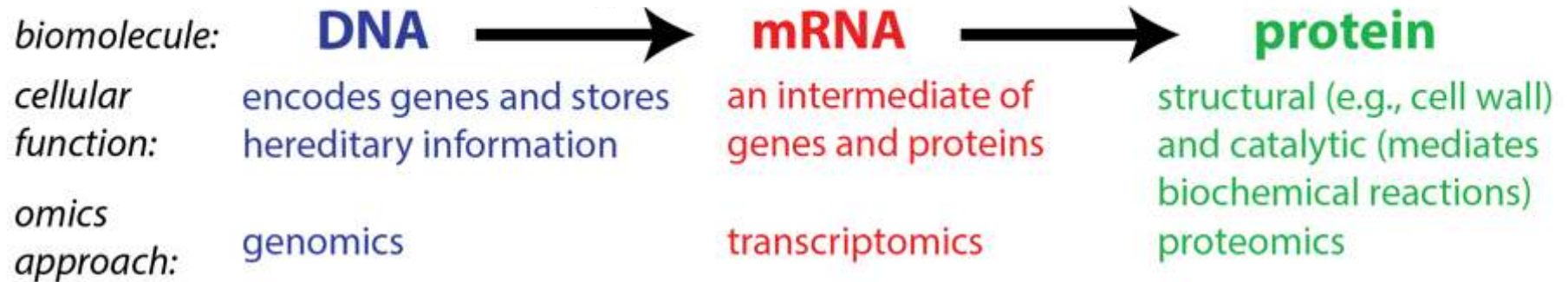
Analysis of *Microcystis* subpopulations:



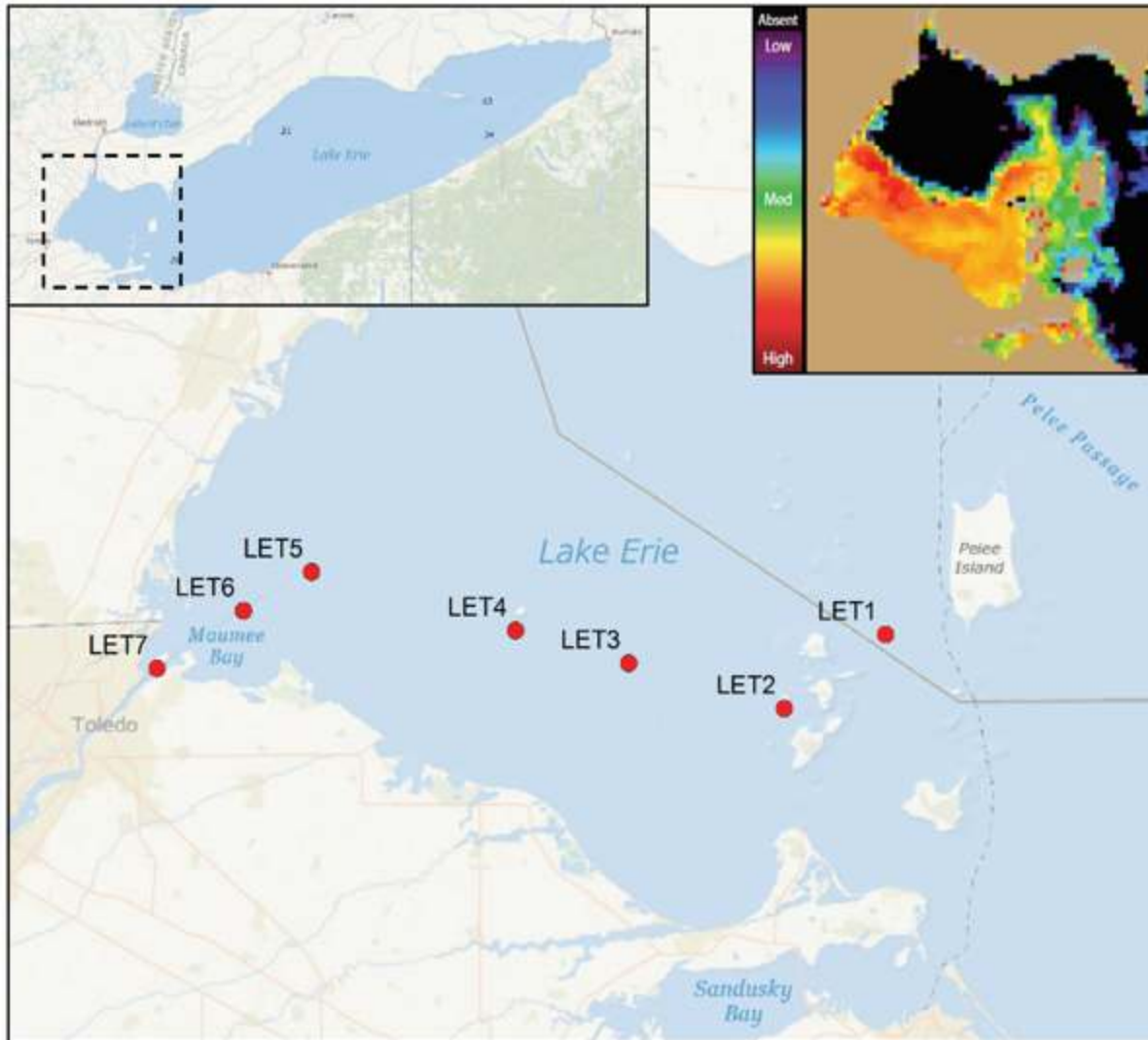
% toxic *Microcystis* = proportion of *Microcystis* cells containing the genetics to produce microcystins (*mcyD* or *E* / 16S x 100)

Determined by (1) qPCR and (2) metagenomics

What is omics?

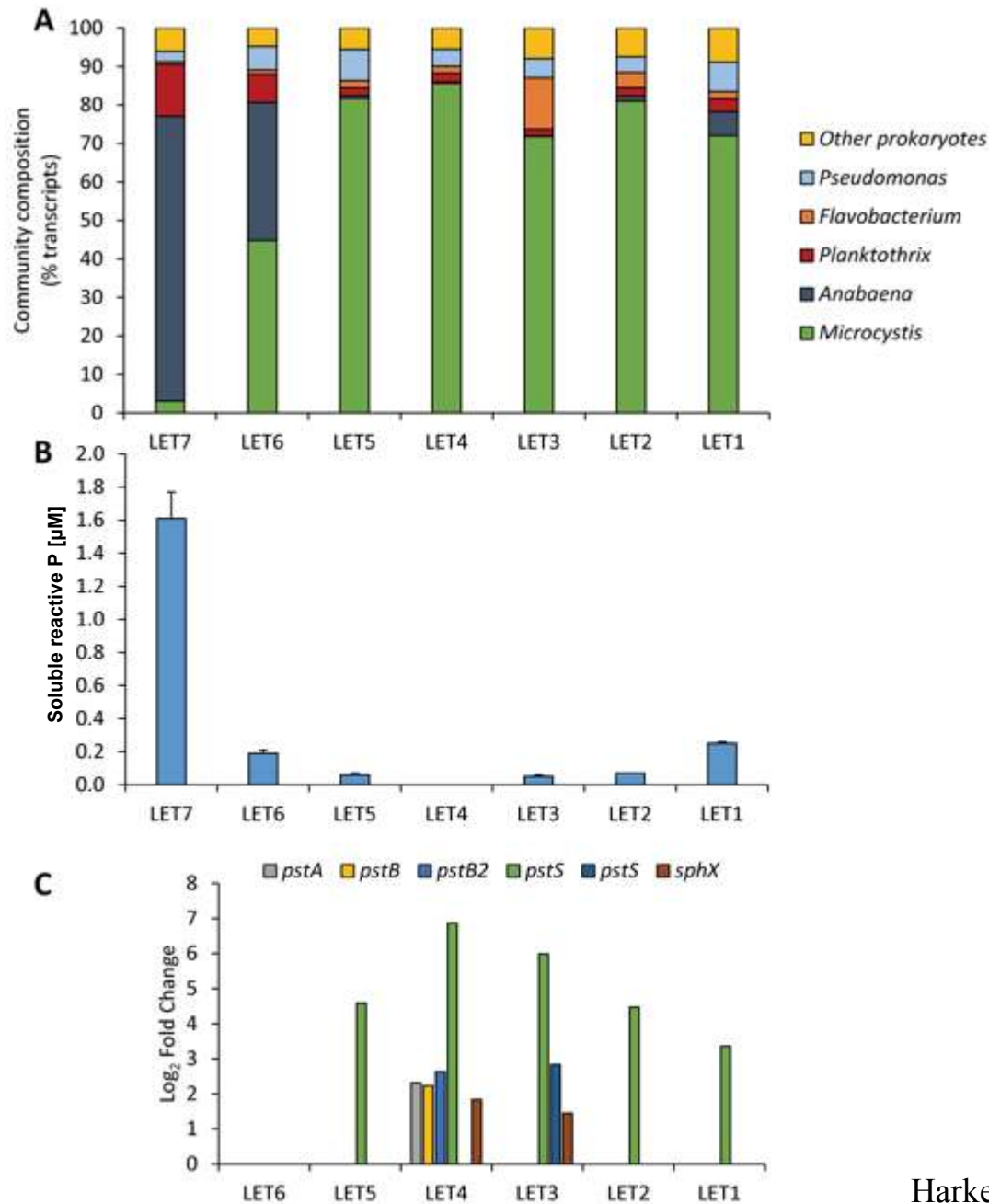


Eco-transcriptomic surveys of LE CHABs

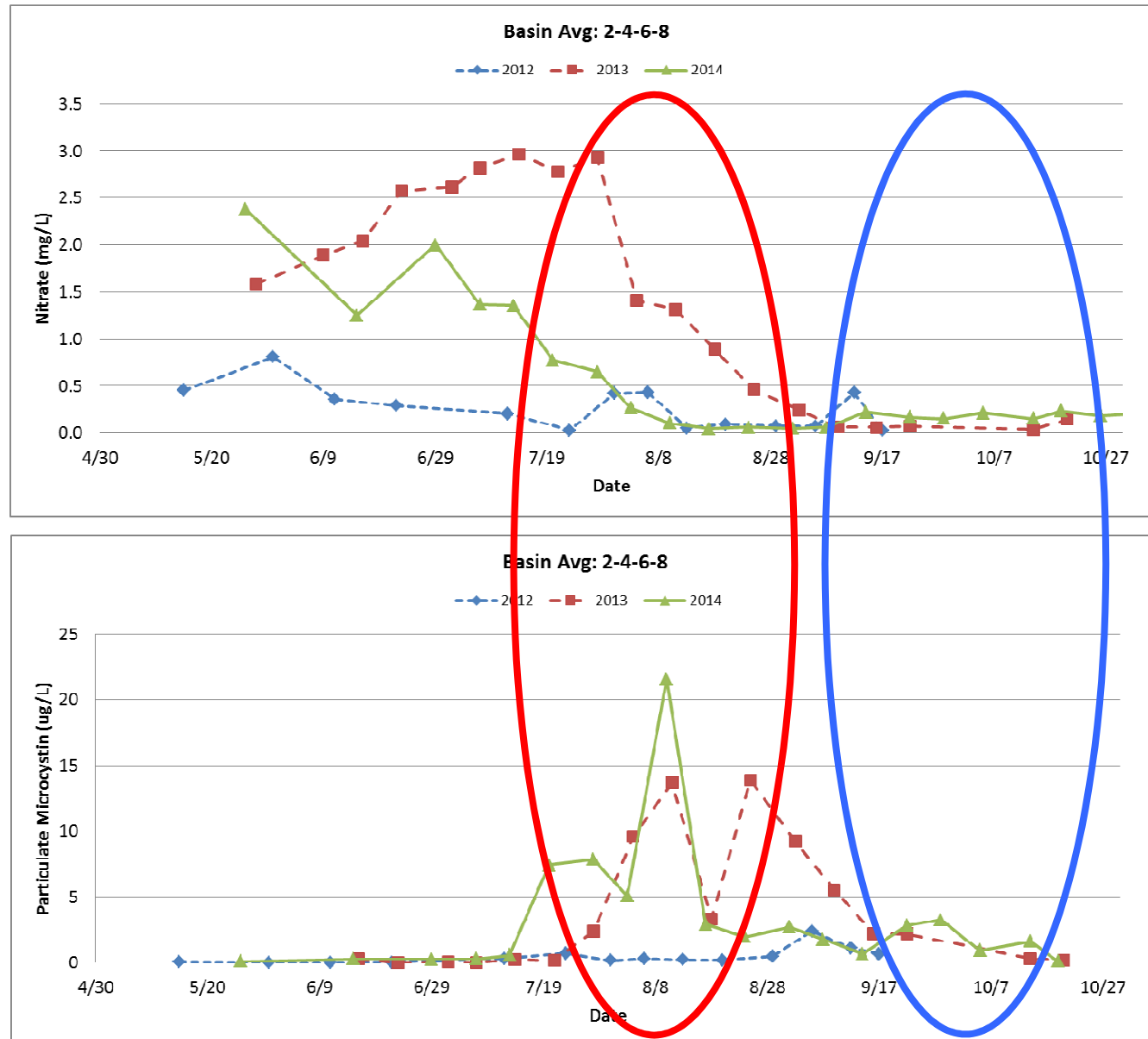


Harke, **Davis** et al., 2016; ES&T

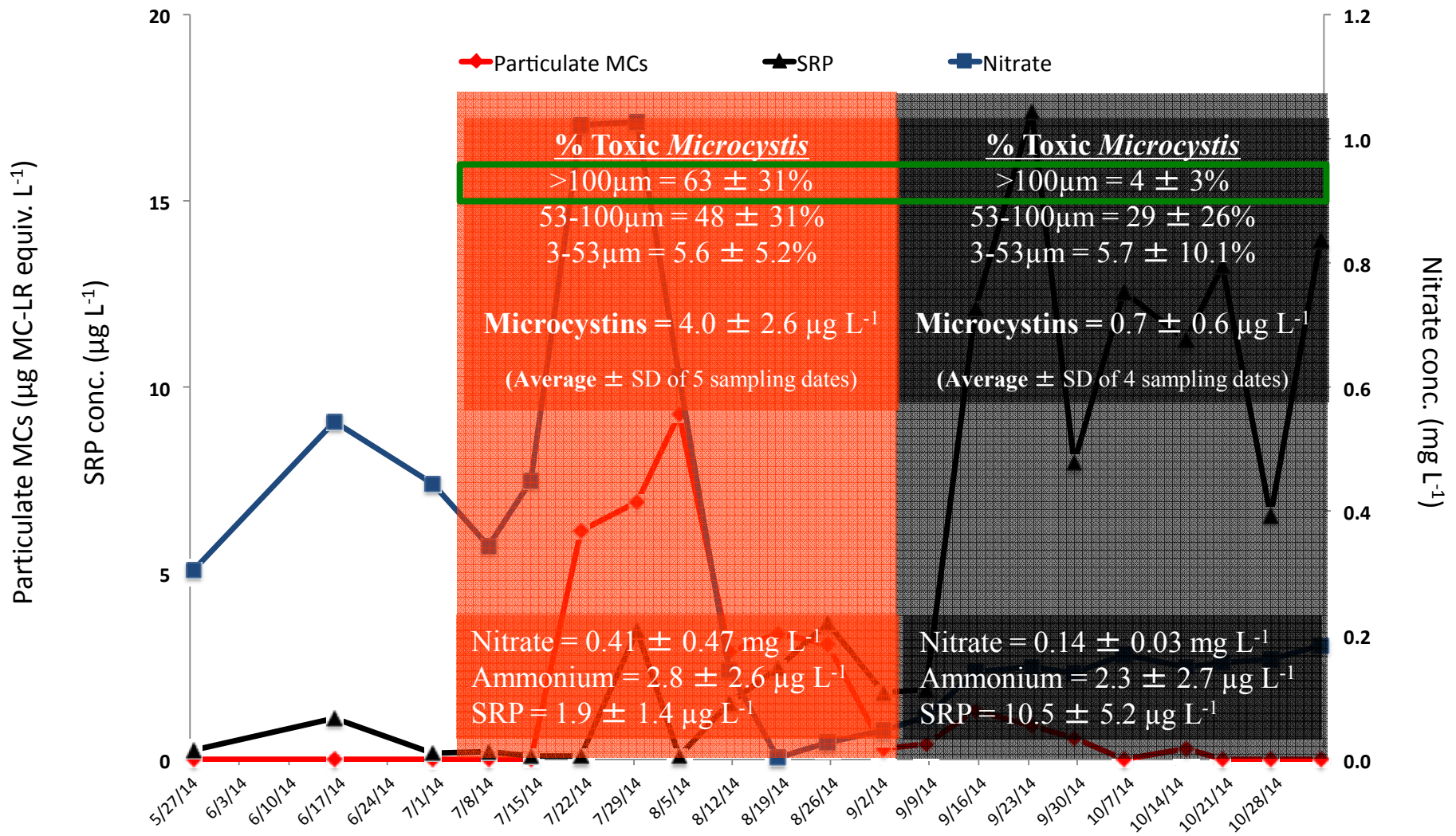
Microcystis is an excellent P scavenger



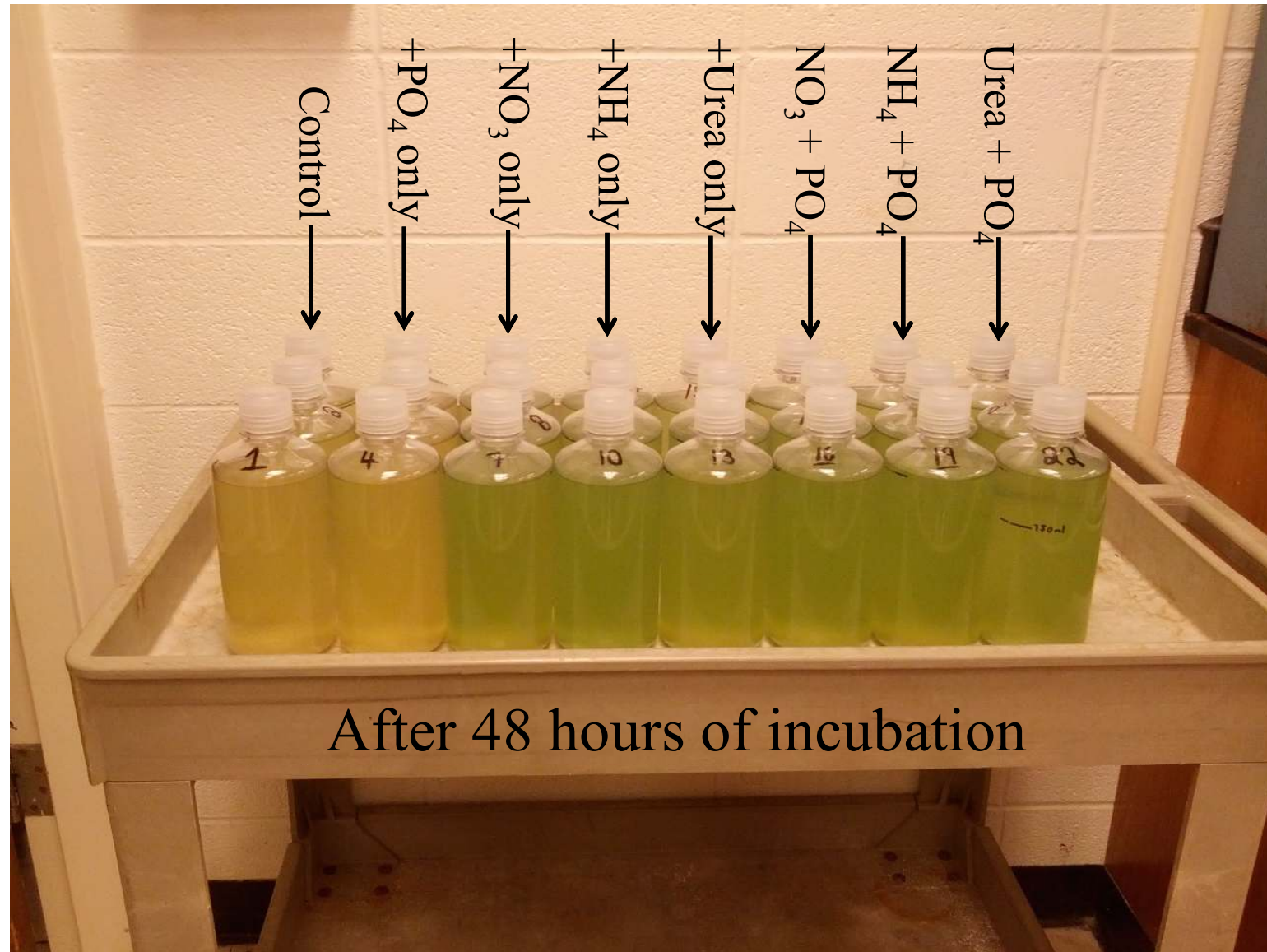
Western Lake Erie relationships

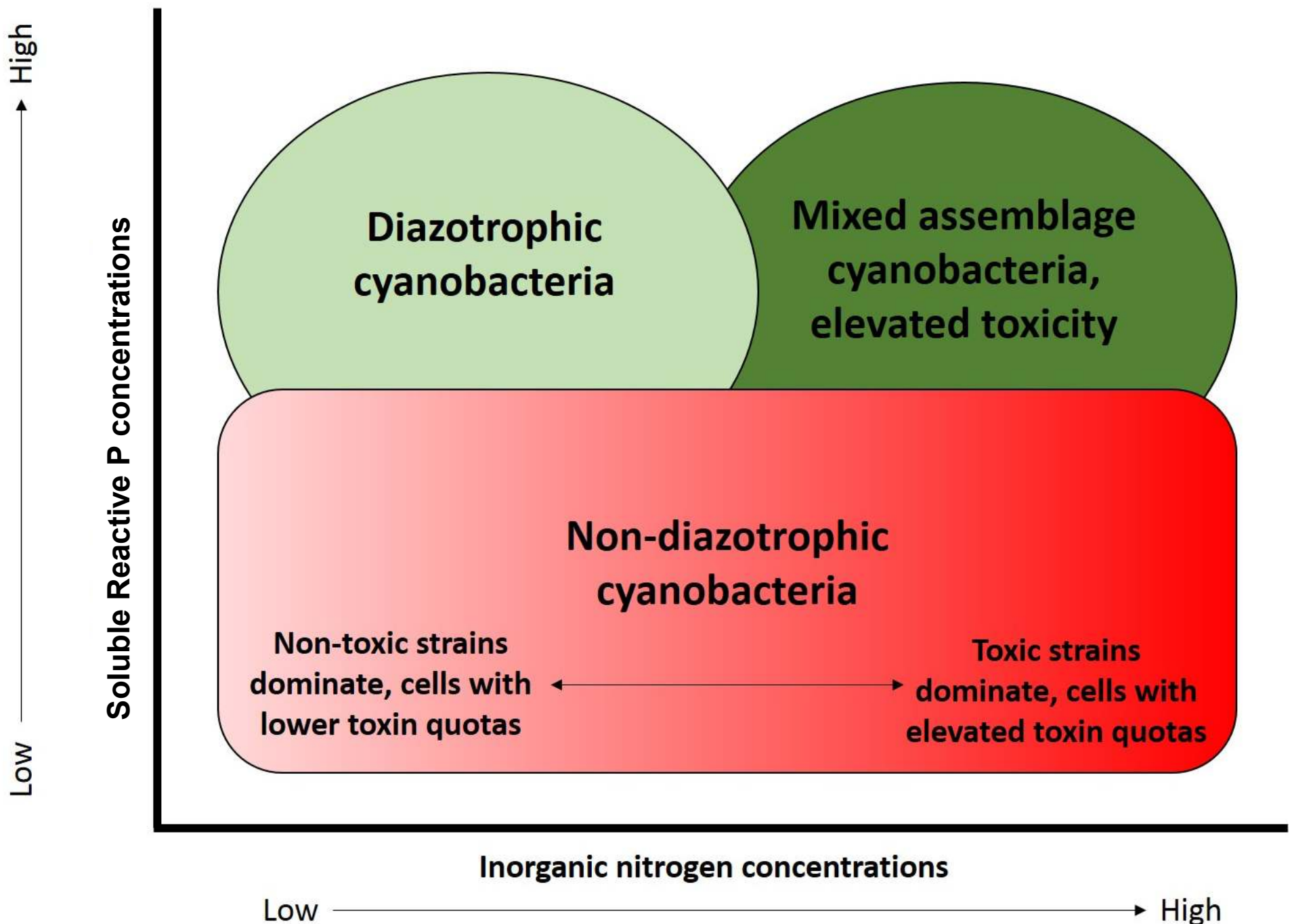


Toxic strains decline with lower N



Nitrogen constrains growth and toxicity in Sandusky Bay



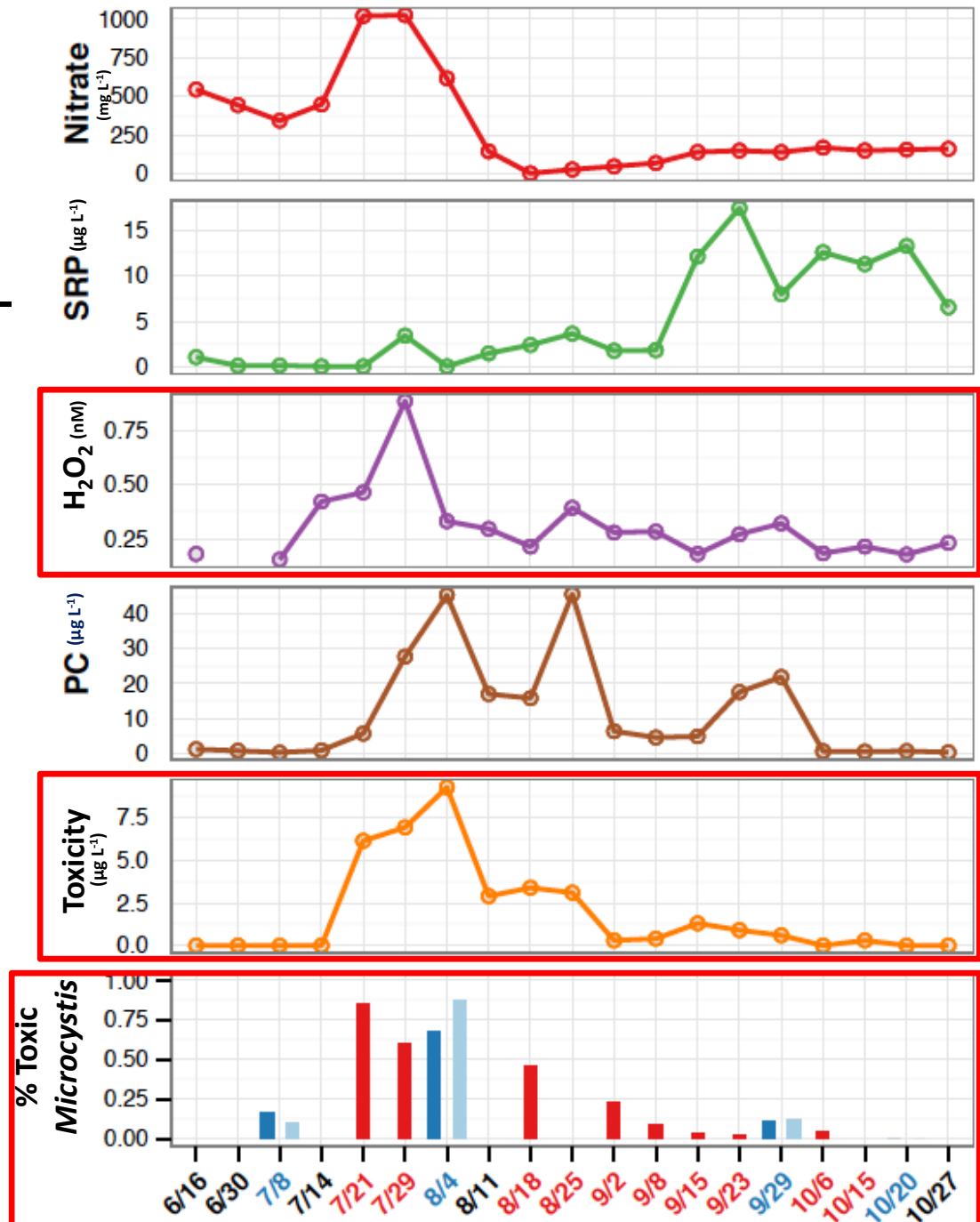


From: Gobler, Burkholder, **Davis**, et al., 2016, Harmful Algae

Weekly sampling reveals important trends that highlight potential environmental drivers and inform future experiments

- Toxicity changes throughout the bloom
- Relationship between nitrogen, toxicity and toxic *Microcystis*
- *Microcystis* blooms occur even when phosphorus concentrations are low
- Other factors beyond nutrients may be important in driving bloom structure and function

Toledo Water Intake (Station 12)

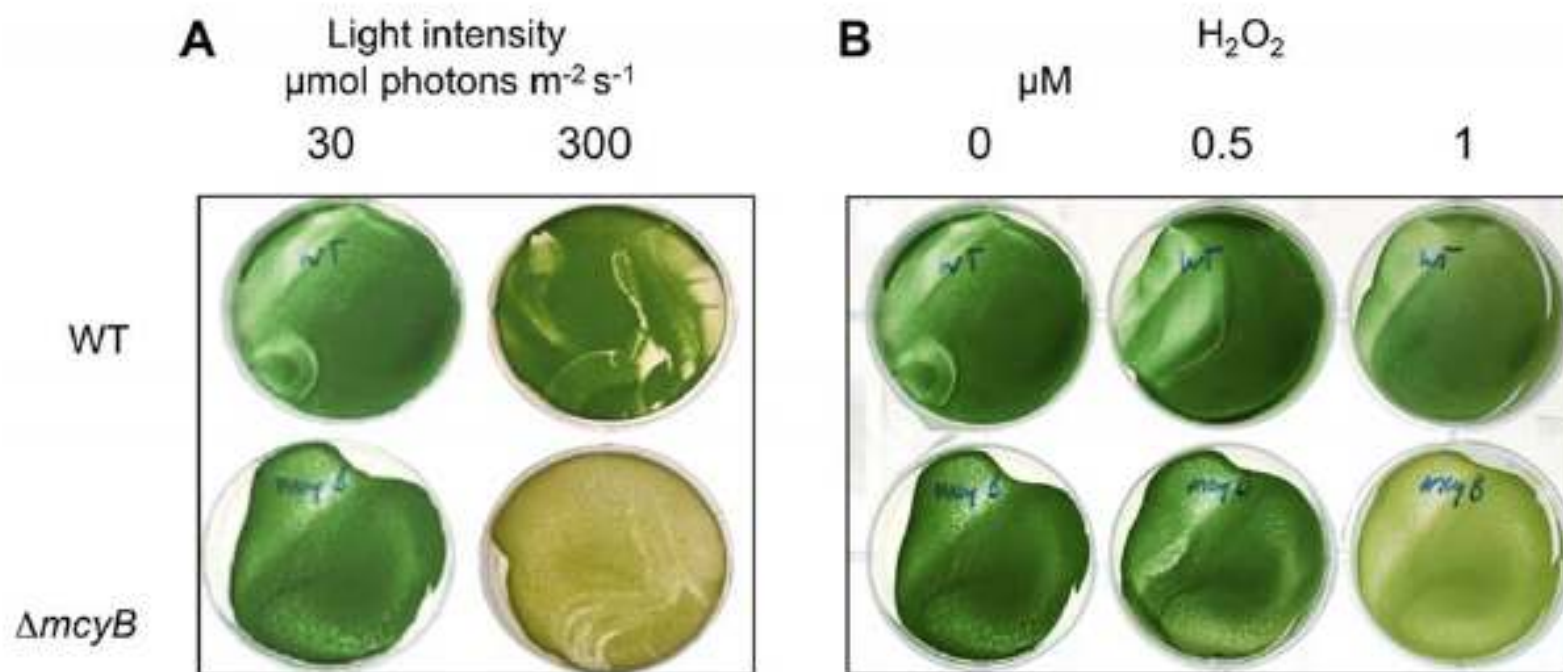


Distribution of antioxidant enzymes among select cyanobacterial genera

■ Catalase (H_2O_2)	■ KatG (H_2O_2 or ROOH)	External
■ Mn Catalase (H_2O_2)	■ cytochrome c peroxidase (H_2O_2 or ROOH)	
■ dyP-type peroxidase (H_2O_2 or ROOH)	■ Haloperoxidase (H_2O_2 or ROOH)	Internal
■ Peroxiredoxin (H_2O_2 or ROOH)	■ glutathione peroxidase (ROOH)	
■ superoxide dismutase (O_2^-)		

The Cyanobacterial Hepatotoxin Microcystin Binds to Proteins and Increases the Fitness of *Microcystis* under Oxidative Stress Conditions

Yvonne Zilliges¹, Jan-Christoph Kehr², Sven Meissner², Keishi Ishida³, Stefan Mikkat⁴, Martin Hagemann⁵, Aaron Kaplan⁶, Thomas Börner⁷, Elke Dittmann^{2*}



Microcystin production revisited: conjugate formation makes a major contribution

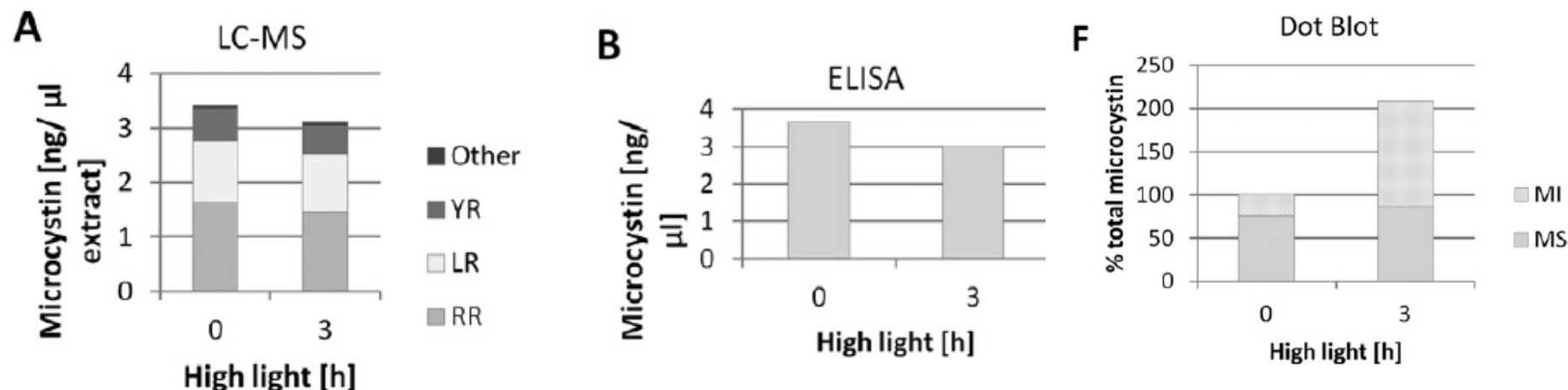
Sven Meissner,¹ Jutta Fastner² and Elke Dittmann^{1*}

¹Department of Microbiology, Institute of Biochemistry and Biology, University of Potsdam, Golm, Germany.

²Federal Environment Agency, Section Drinking Water Treatment and Resource Protection, Berlin, Germany.

MS = Methanol soluble MCs (Free)

MI = Methanol insoluble MCs (protein-bound)





ROS experimental design

Sample collection:

- Chlorophyll *a*
- Phycocyanin
- Particulate microcystins
- Dissolved microcystins
- Lugols
- DNA
- RNA
- Picoplankton
- Dissolved and total nutrients
- CDOM/FDOM
- DNA Sterivex
- RNA sterivex
- H₂O₂
- PhytoPAM



•Control

•+N_i+P (20 & 2 μM)

•+ROS (H₂O₂; 1μM)

•+N_i+P + H₂O₂

48 hours @
ambient light
and
temperature

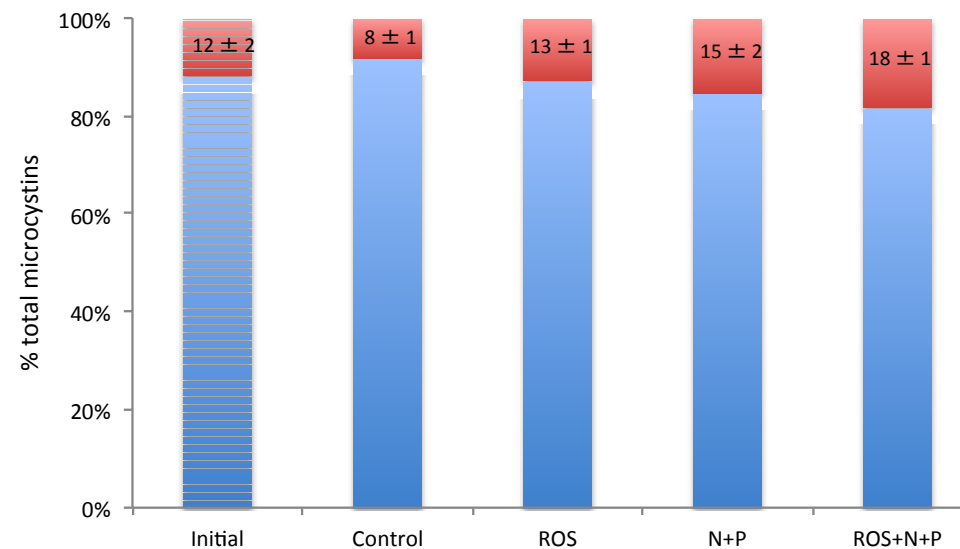
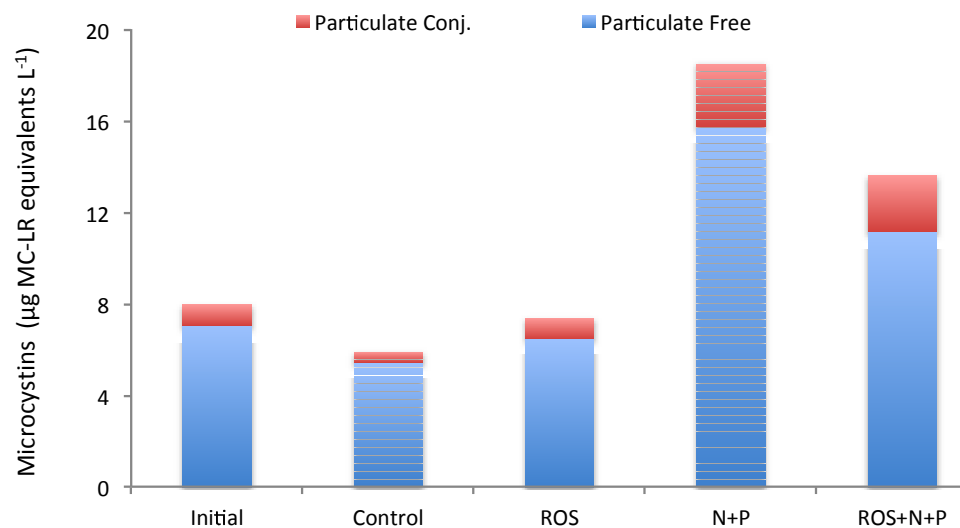
N_i = NH₄NO₃

P = KH₂PO₄

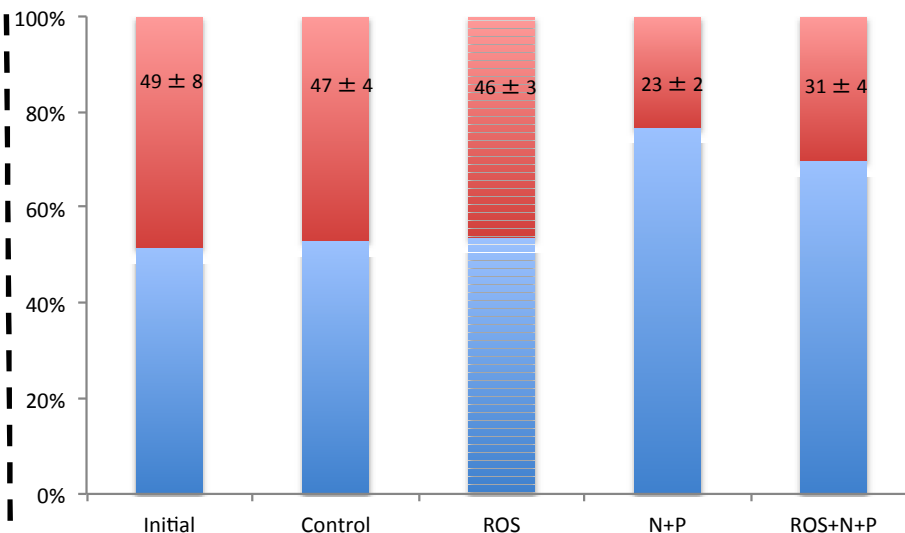
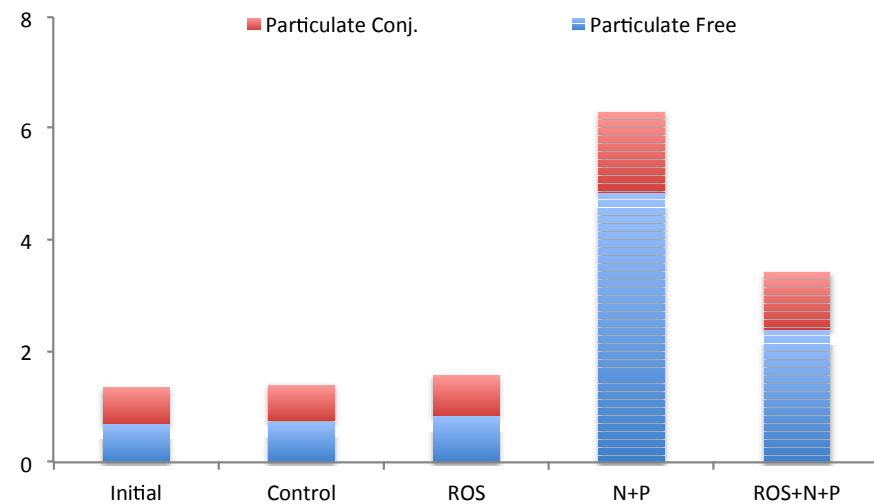
- Four experiment were conducted
- At t = 2, 4, 8, 12, 24 subsamples were collected for RNA and H₂O₂
- At t = 48 all parameters listed above were sampled (one per bottle) except for total nutrients and RNA sterivex which were omitted
- Based on calculated H₂O₂ degradation rate in LE, 500nM H₂O₂ was added every 2 hours to maintain a 1μM concentration
- Nutrients were replenished every 12 hours to maintain concentrations of 20 & 2 μM for N and P, respectively

Conjugated MCs change over time but not influenced by ROS

August 20, 2014



September 3, 2014



Microcystis protected from external ROS by synergistic relationships?

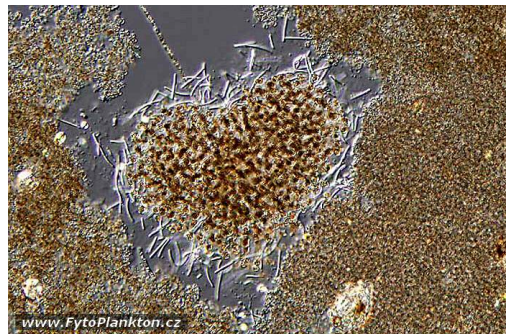
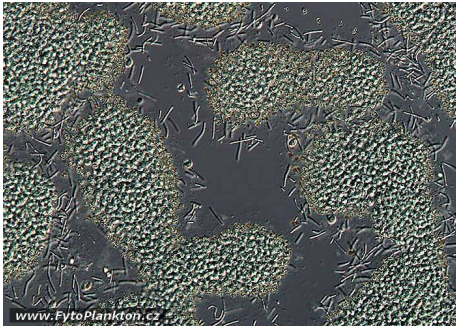
OPEN ACCESS Freely available online



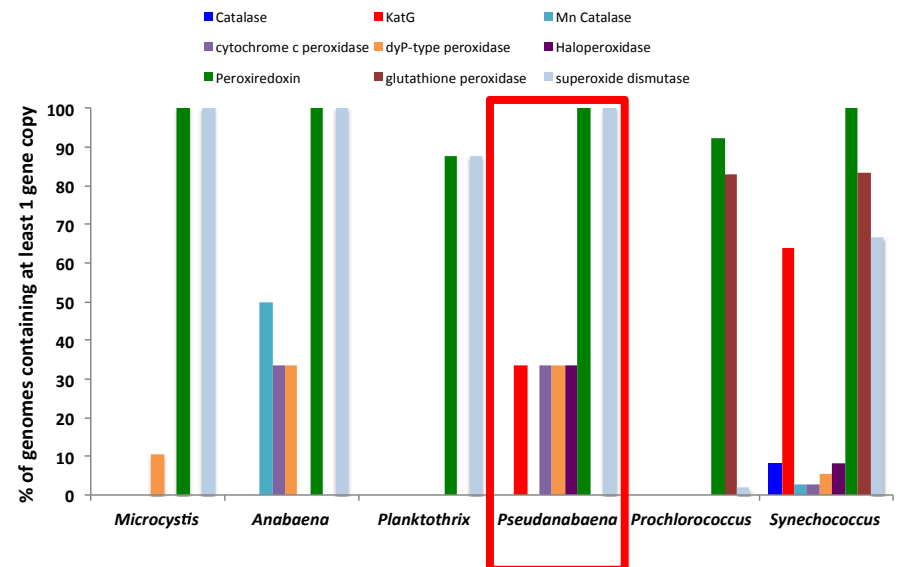
Dependence of the Cyanobacterium *Prochlorococcus* on Hydrogen Peroxide Scavenging Microbes for Growth at the Ocean's Surface

J. Jeffrey Morris¹, Zackary I. Johnson², Martin J. Szul¹, Martin Keller³, Erik R. Zinser^{1*}

¹ Department of Microbiology, University of Tennessee, Knoxville, Tennessee, United States of America, ² Nicholas School of the Environment, Duke University Marine Laboratory, Beaufort, North Carolina, United States of America, ³ Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States of America



Distribution of antioxidant enzymes among select cyanobacterial genera



Genomic database will fuel research in the Great Lakes and beyond



Cyanohub BETA

Menu

[Cyanohub Home](#)
[Query Form](#)

Table of cultured *Microcystis* strains

Strain Name	Country	Toxic	Genome Size (Mb)	NCBI Tax. ID	No. Genes (documented)
PCC 7005	USA	No	4.9	267870	5081
PCC 7806	NETHERLANDS	Yes	5.3	267872	5169
PCC 9432	CANADA	No	5	1160280	4952
PCC 7941	CANADA	Yes	4.8	213618	4646
PCC 9443	CENTRAL AFRICAN REPUBLIC	Yes	5.1	1160281	5139
PCC 9701	FRANCE	No	4.7	721123	4673
PCC 9717	FRANCE	Yes	5.2	1160286	5234
PCC 9806	USA	No	4.2	1160282	4127
PCC 9807	SOUTH AFRICA	Yes	5.1	1160283	5104

Search Database

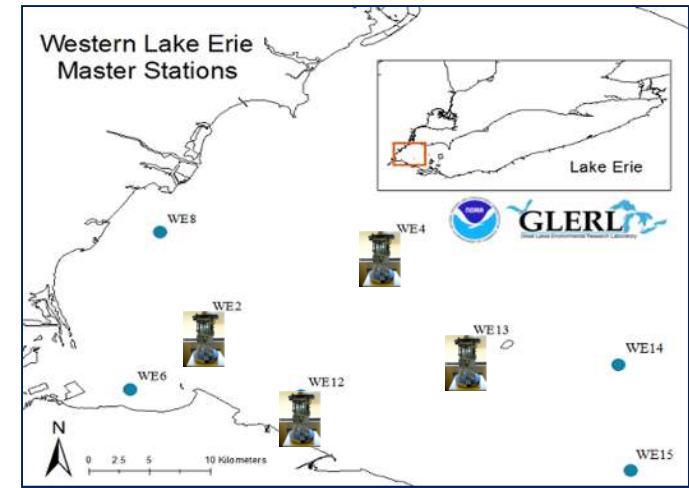
Basic Fields

Strain Name: Location:

- Searchable genomic database for CHAB genera including Great Lakes strains
- Publicly available resource
- Serves as a link between environmental and genomic data
- Critical to further understand the response of CHAB genera to environmental drivers

Future directions and challenges

- Develop an ESP network for Western Lake Erie
- Further develop the ESP capabilities
- Investigate the ecological adaptations of Great Lakes CHAB species
- Further understanding the interactive roles of light, nutrients, and temperature on toxin production and community composition
- Investigate changes in microcystin congeners over time



Microcystins

>100 congeners

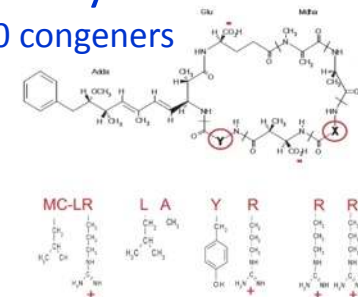


Figure 1: Structure of MC cyanotoxins. Modifications in the structure, particularly in amino acid substituents at positions X and Y, give rise to over 90 variants.

Table 1: Chemical properties and toxicity of four commonly occurring MC variants. Over 90 now identified and range in toxicity by >20-fold.

	MC-LA	MC-LR	MC-YR	MC-RR
Molecular weight	909	994	1044	1037
Amino acid substituents	Leu, Ala	Leu, Arg	Tyr, Arg	Arg, Arg
% N (mass)	10.78	14.08	13.40	17.54
Net charge (pH 7)	-2	-1	-1	0
Hydrophobicity	—	decreasing	—	— →
Toxicity (mouse bioassay LD ₅₀ µg/kg)	20 - 50	50 - 90	70 - 100	200 - 800

Questions?

