Great Lakes HABs Collaboratory

December 15, 2015

NOAA, GLERL, Ann Arbor, MI

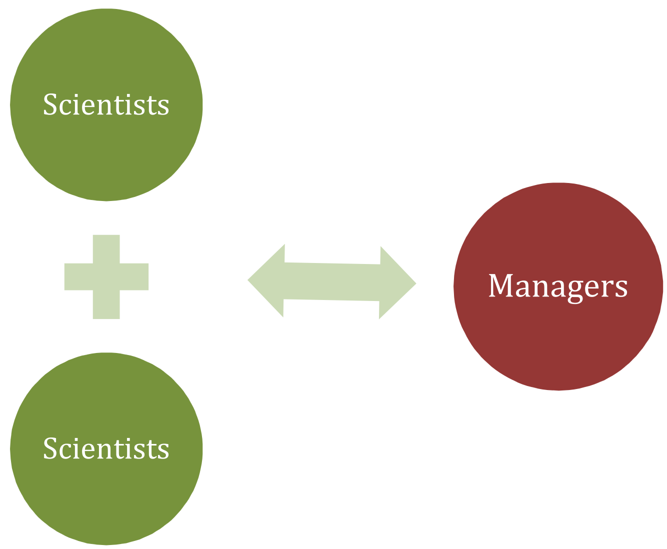
Working definition of HABs

"HABs are proliferation of microscopic algae that harm the environment by producing toxins that accumulate in shellfish or fish, or through the accumulation of biomass that in turn affects co-occuring organisms and alters food web in negative ways"

~Harmful Algal Research and Response
National Environmental Science Strategy
2005-2015

Great Lakes HABs Collaboratory is…

- *A virtual laboratory for science-based information sharing and collective action to address harmful algal blooms*



Great Lakes Commission, USGS-GLSC Partnership: Memorandum of Understanding

"to advance mutual goals and objectives related to Great Lakes conservation, protection, sustainable use and development, including activities related to invasive species prevention and control and coastal ecosystem protection and restoration."

HABs Col-laboratory with GLC as Neutral Backbone

Linking Science and Management to Reduce Harmful Algal Blooms

Regional Scientists	USGS: Science Liaison	GLC: Mgt Liaison	Regional Resource Mangers

Agenda review

Time	Item
9:00 am	Welcome and Overview • Why a HABs Collaboratory? • Great Lakes Commission, USGS-GLSC Partnership
9:30 am	Interactive Introductions
10:00 am	Overview of Interview Results
10:30	Break
10:45 am	Panel 1, Unmet Research Needs • Triggers , Nutrients
11:45 am	Networking Lunch
1:00 pm	Panel 2, Unmet Research Needs • Toxicity , Ecosystem / Food web, Management
2:15 pm	Strategic discussion
3:15	Break
3:30pm	HABHRCA session
4:30 pm	What's next?
4:45 pm	Adjourn

Objectives for the day

- What are the 2-3 top questions that can be addressed through the HABs Collaboratory?
- What are the next steps to answer those questions?
- What other questions might some people want to tackle?

Interactive Introductions

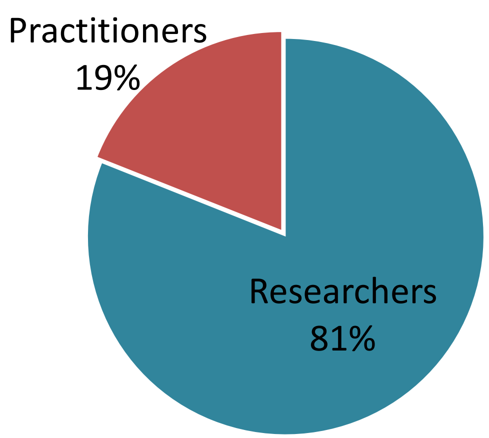
Instructions

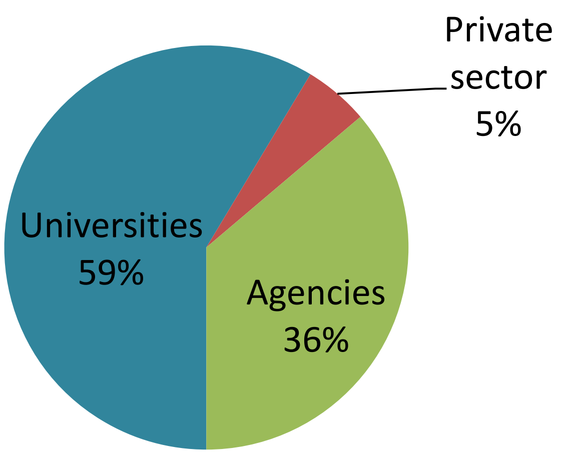
- Write on a post-it:
  - Who: *Your name*
  - What: *In **5 words or less**, what is the main topic of your research/work*
  - When: *What is the timing or seasonality of your research/work*
- *Put it where in the watershed most of your work is done on the poster*
  - *Poster 1: A to G*
  - *Poster 2: H to O*
  - *Poster 3: P to Z*

Overview of Interview Results

Who are we?

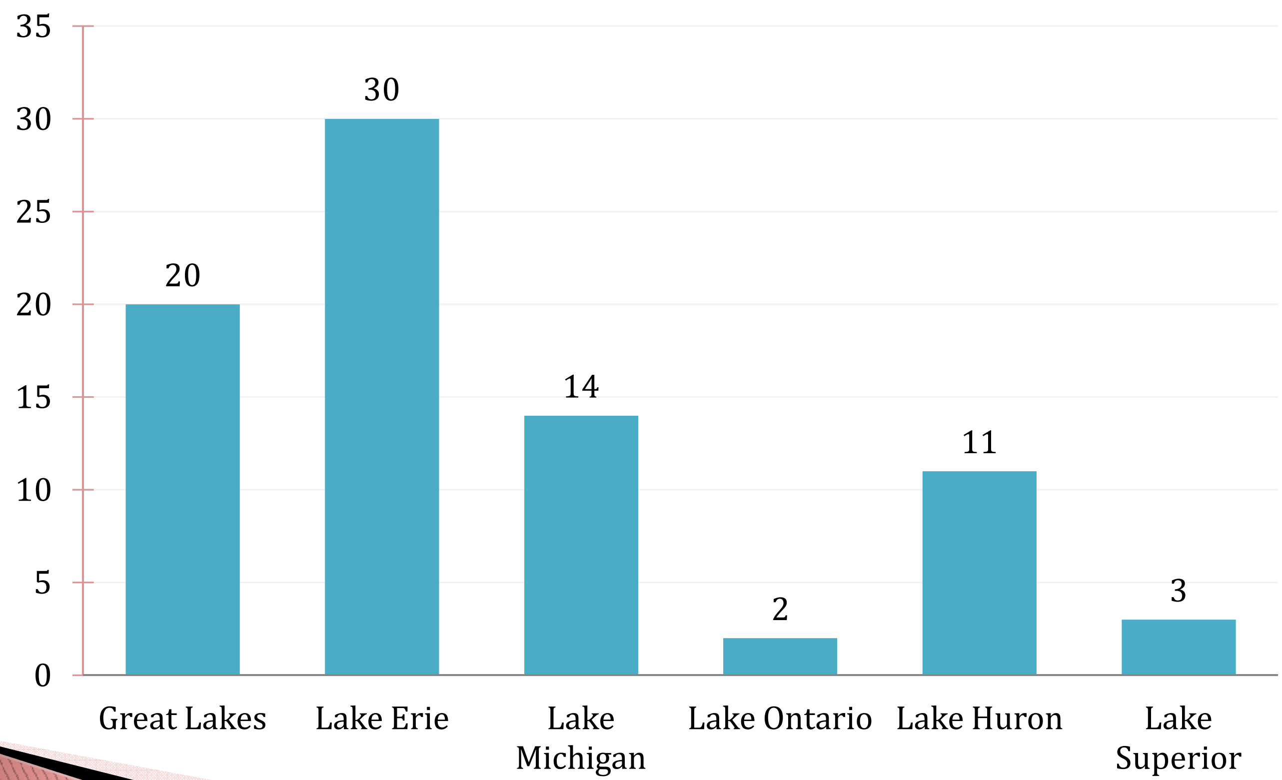
- 58 interviews
  - 47 researchers and 11 practitioners
  - 34 from universities, 3 from private sector, 21 from 5 different agencies





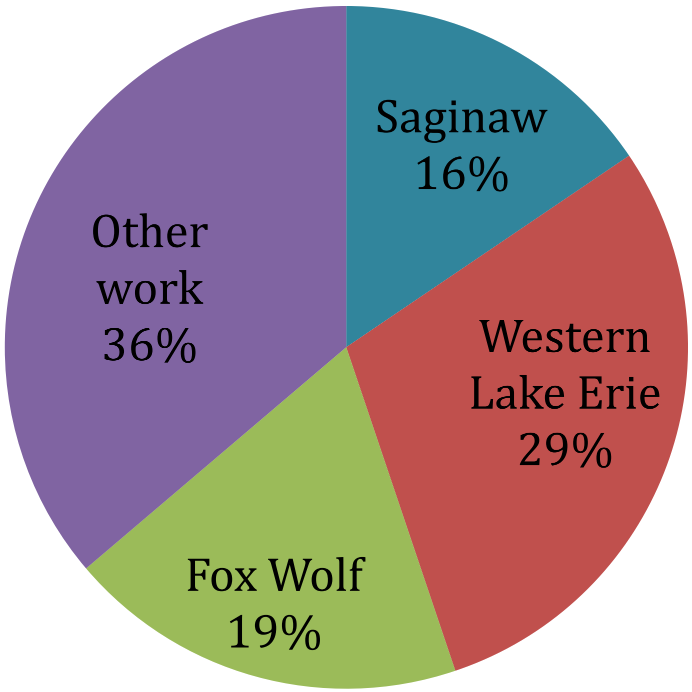
Who are we?

- Work on the Great Lakes



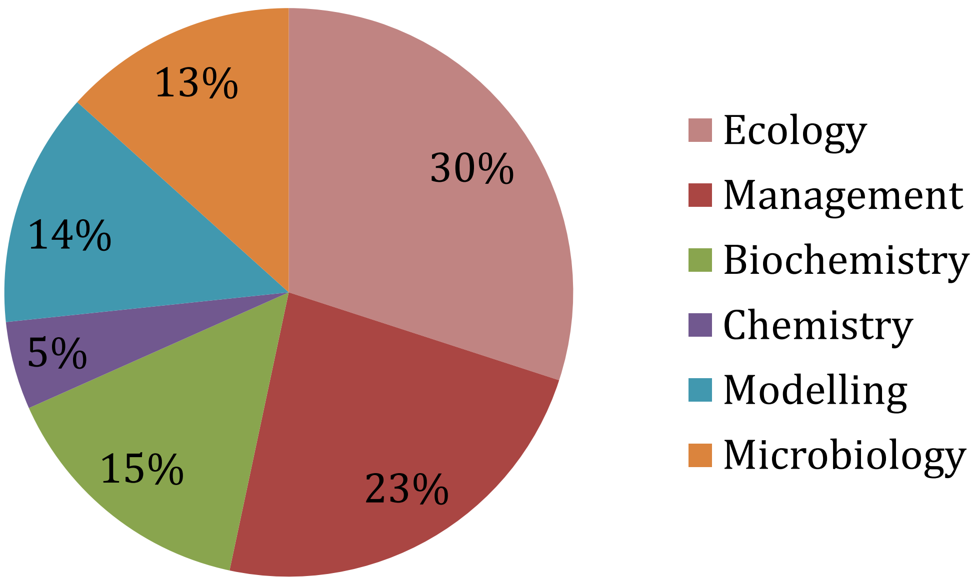
Who are we?

- Work on priority watersheds



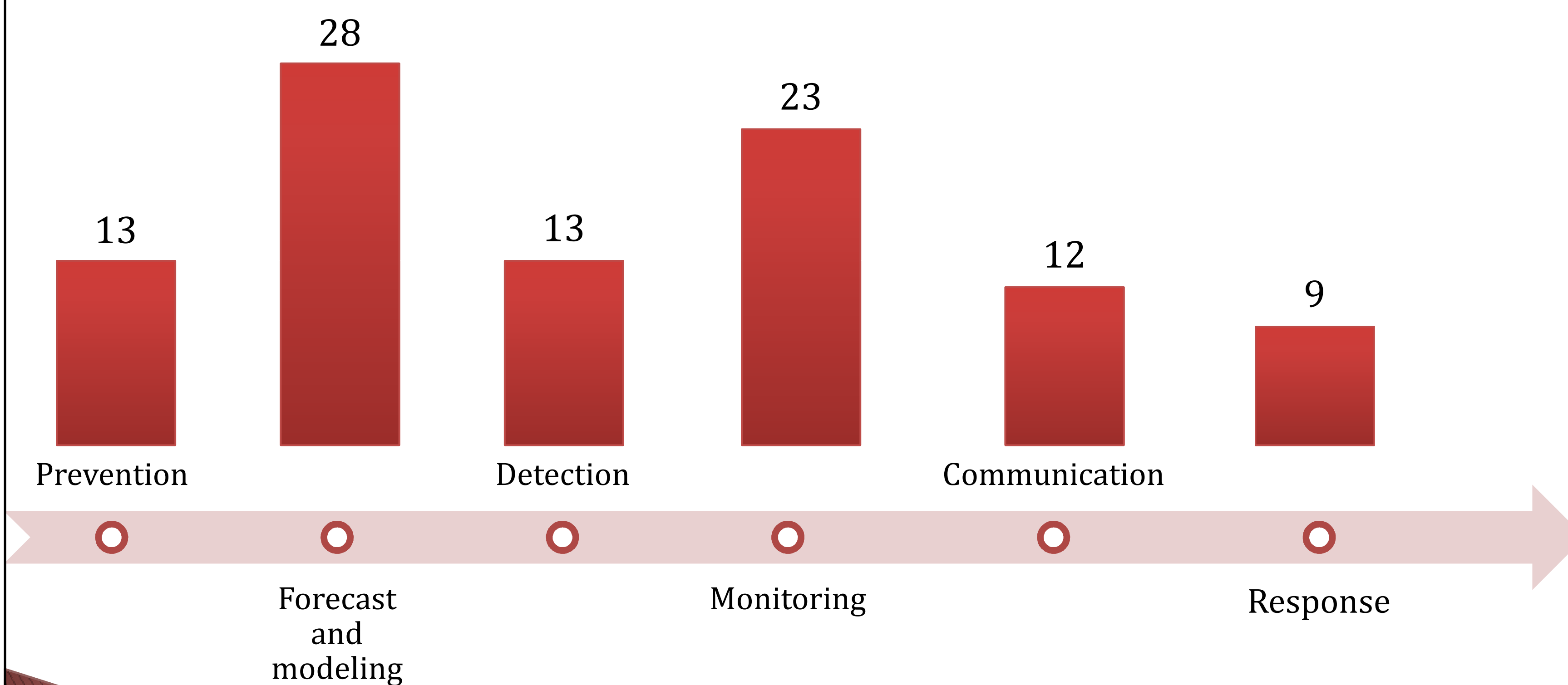
Who are we?

- Field of work



Who are we?

- Timeline of a bloom



We Are Us!

- GLC and USGS are facilitating the collaboratory. We are not the collaboratory… you are!
- Success will depend on level of individual and collective engagement
- Consider what you want to get out of it
- And what you can contribute

Top unmet research needs… for collaboration on Triggers

- What triggers and/or controls toxicity?
- What drives HABs formation/extent/size?
- What triggers HABs initiation (physical, chemical and biological triggers)?
- What conditions sustain HABs overtime?
- What environmental factors cause HABs to decline?
- What factors select for dominance by different bloom-forming and toxin-producing species?
- How is the microbial community influenced by HABs and in turn how does it influence bloom formation?

Top unmet research needs… for collaboration on Nutrients

- What is the effect of timing and pulses of nutrient input on extent and duration of HABs?
- What are the roles of other micronutrients (iron, sulfur, etc.) in toxin development?
- Are in-lake responses reflecting actions to reduce nutrients loading? Will there be a delay in the response?
- What is the drain tile effect on N:P ratio? (field base pilot project)
- What are the delivery mechanisms for land to take and how do they respond to management practices?
- What is the role of N in HABs formation and what are the synergetic effects of P and N in a freshwater system?
- What is the role of N in cyanotoxicity?
- What is the importance of external vs internal loadings?

17

Top unmet research needs… for collaboration on Toxicity

- What (environmental and biological) factors determine whether a bloom is toxic and how toxic it is? (N, micronutrients, genetics, microbial community)
- How much does toxin production per biomass vary spatially and temporally? Can consistent pattern be identified? What are the variation causes?
- What is the fate of cyanotoxins in the lakes? What factors cause degradation of toxins?
- What are the primary and secondary routes of human exposure (drinking water, recreational contact, fish consumption) and the health risks associated with each?
- What are the effects of HABs on wildlife health?

Top unmet research needs…
for collaboration on Food web and Ecosystems

- What are the microbial community interactions (effects on HABs and HABs effects on community) and how this shapes bloom development and system functions?
- How does feeding and growth of fish and zooplankton change in vs out of bloom area and before vs during vs after a HAB? Are different life stage affected differently?
- How does feeding and growth of zooplankton change in vs out of bloom area and before vs during vs after a HAB? Are different life stage affected differently?
- What is the role of dreissenids in HAB development and the tendency of a waterbody to have HABs?
- What is the relative contribution of selective grazing vs nutrient cycling pathways to dreissenids effects on HABs?

Top Management-driven unmet research needs…

- What are the best methods to diminish nutrient inputs in the Great Lakes?
- Is the HAB problem really getting worse or not?
- How can we improve modeling and prediction of spatial distribution? (we are good at "how big" but not good at "where")
- How can we manage and live with HABs? (since we are far from getting rid of them)
- What are the "early signs" of a HAB, and once we detect these signs, what management actions do we have available to prevent bloom formation?

Panel 1 presentations *Triggers*

Timothy Davis – NOAA-GLERL

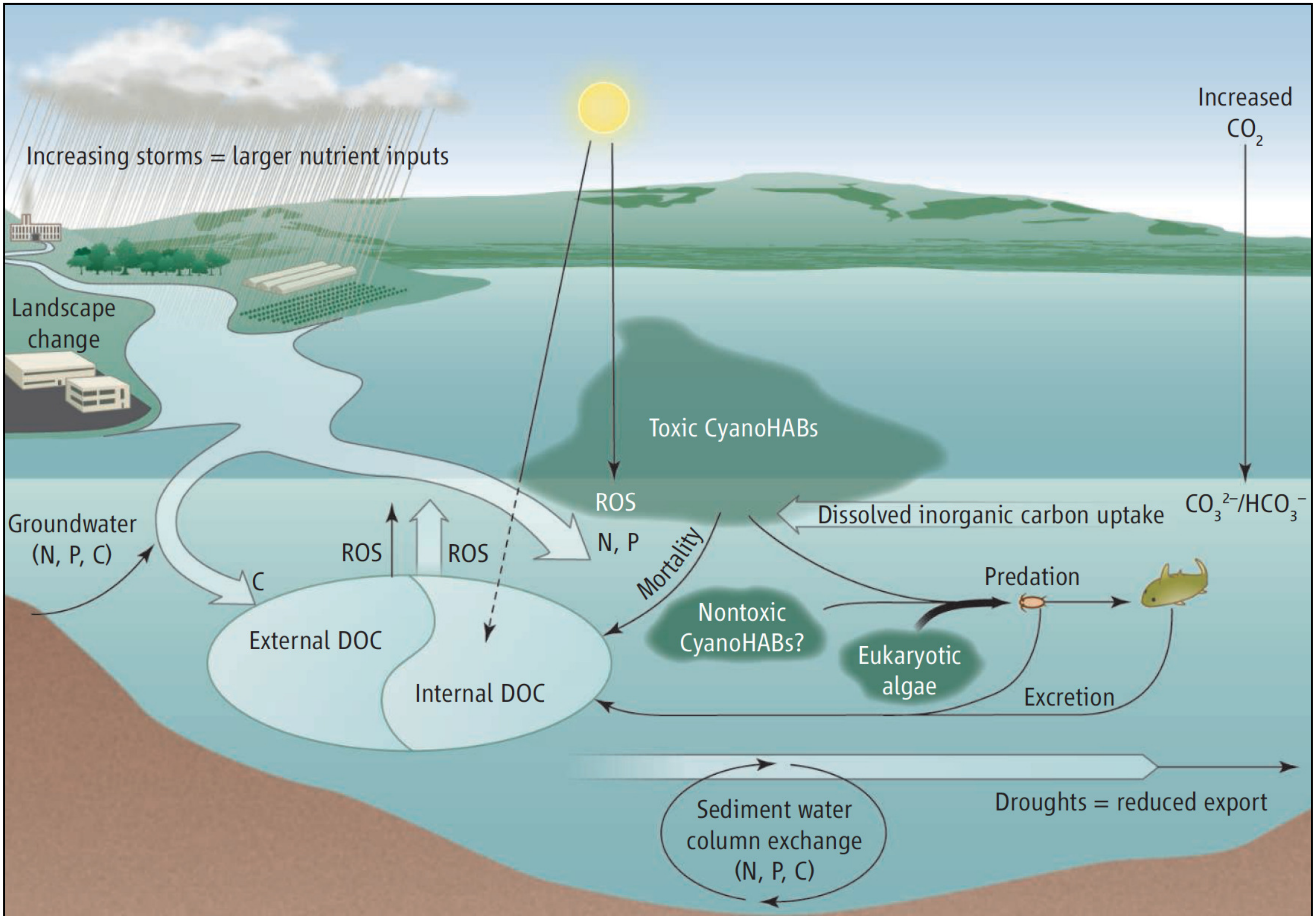
21

Future research needs for understanding the environmental drivers of bloom growth

Timothy Davis

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

GLERL
Great Lakes Environmental Research Laboratory



Paerl and Otten, *Science* 342: 433

Blooms are a visual manifestation of nutrient over-enrichment

LIMNOLOGY AND OCEANOGRAPHY

May 1979
Volume 24
Number 3

Limnol. Oceanogr., 24(3), 1979, 401–416

A relation between lake morphometry and primary productivity and its use in interpreting whole-lake eutrophication experiments

Everett J. Fee
Department of Fisheries and the Environment, Fisheries and Marine Service, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba R3T 2N6

Limnol. Oceanogr., 25(6), 1980, 1149–1152

The effect of fertilization with phosphorus and nitrogen versus phosphorus alone on eutrophication of experimental lakes

Limnol. Oceanogr., 25(6), 1980, 1152–1153

Reply to comments by Patalas and Schindler

N vs. P: The great debate continues…

Nitrogen Control Theory Resurfaces like a Phoenix in the New Millenium

Control of Lacustrine Phytoplankton by Nutrients: Erosion of the Phosphorus Paradigm. W. M. Lewis, Jr. and W. A. Wurtsbaugh 2008. Internat. Rev. Hydrobiol. 93 (4–5) 446–465.

Controlling eutrophication: Nitrogen and phosphorus. DJ Conley et al. 2009. Science 323: 1014-1015.

Algal blooms: Noteworthy nitrogen. H. Paerl et al. 2014. Nature 346: 175.

Credit: Dr. David Sch[illegible]ller, 2015 ASLO meeting, Granada, Spain

More blooms, in more places, that last longer, are bigger and more toxic

CLIMATE

Blooms Like It Hot

A link exists between global warming and the worldwide proliferation of harmful cyanobacterial blooms.

Hans W. Paerl[1] and Jef Huisman[2]

www.sciencemag.org SCIENCE VOL 320 4 APRIL 2008

Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions

Anna M. Michalak[a,1], Eric J. Anderson[b], Dmitry Beletsky[c], Steven Boland[d], Nathan S. Bosch[e], Thomas B. Bridgeman[f], Justin D. Chaffin[f], Kyunghwa Cho[g,2], Rem Confesor[h], Irem Daloğlu[g], Joseph V. DePinto[i], Mary Anne Evans[g,3], Gary L. Fahnenstiel[j], Lingli He[k], Jeff C. Ho[l], Liza Jenkins[g,j], Thomas H. Johengen[c], Kevin C. Kuo[d,m], Elizabeth LaPorte[n], Xiaojian Liu[d], Michael R. McWilliams[o], Michael R. Moore[g], Derek J. Posselt[d], R. Peter Richards[h], Donald Scavia[g], Allison L. Steiner[d], Ed Verhamme[i], David M. Wright[d], and Melissa A. Zagorski[d]

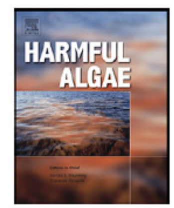
Harmful Algae 14 (2012) 313–334

ELSEVIER

Contents lists available at SciVerse ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal



The rise of harmful cyanobacteria blooms: The potential roles of eutrophication and climate change

J.M. O'Neil[a,*], T.W. Davis[b], M.A. Burford[b], C.J. Gobler[c]

Food for thought (and discussion and addition)

- One size does not fit all
  - Physiological drivers of individual species/strains vs lake specific drivers of blooms
  - Time scale is important
- Understand the effects of specific nutrient interactions, cycling, and legacy loading on bloom development
- Interactions between climate change variables and eutrophication management strategies will be important for bloom mitigation strategies
  - Most studies have looked at temperature but few have looked at CO_2
  - More rain = more nutrients but may also mean more sediment
- Interactions between light, nutrients and other variables
- Top-down constraints of bloom biomass

Panel 1 presentations *Triggers*

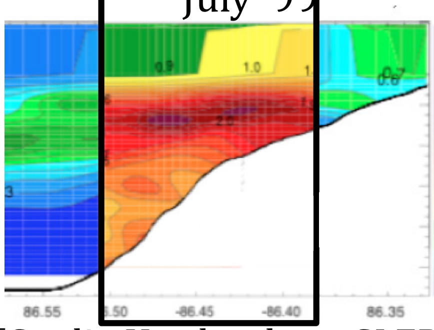
Vincent Denef – University of Michigan

1. Impacts zebra/quagga mussels on CHABs

Biota	Phytoplankton Micro/nanozooplankton	Chemotrophic bacteria	Phototrophic bacteria
Ecosystem impacts	Microbial – higher food web connectivity	Geochemical cycling (e.g. CO_2 efflux)	Harmful algal blooms (e.g., *Microcystis*)

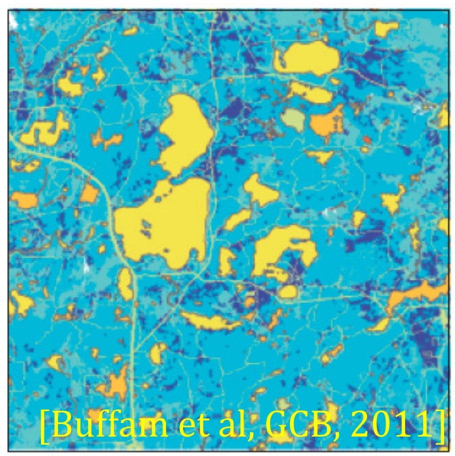
July '10

July '99



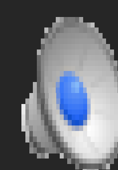
[Credit: Vanderploeg, GLERL]

Chl a conce[redacted]ion



[Buffam et al, GCB, 2011]

Annual surface-Atm. CO_2 exchange (g C m^{-2} yr^{-1})



[Credit: Vanderploeg, GLER

29

1. Impacts zebra/quagga mussels on CHABs

Zebra mussel (*Dreissena polymorpha*) selective filtration promoted toxic *Microcystis* blooms in Saginaw Bay (Lake Huron) and Lake Erie

Henry A. Vanderploeg, James R. Liebig, Wayne W. Carmichael, Megan A. Agy, Thomas H. Johengen, Gary L. Fahnenstiel, and Thomas F. Nalepa

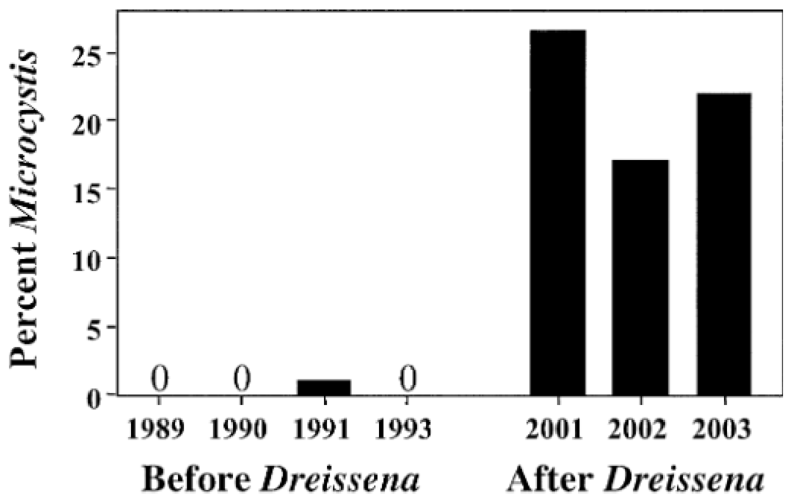
Complex interactions between the zebra mussel, *Dreissena polymorpha*, and the harmful phytoplankter, *Microcystis aeruginosa*

Orlando Sarnelle[1]
Department of Fisheries and Wildlife, Michigan State University, E

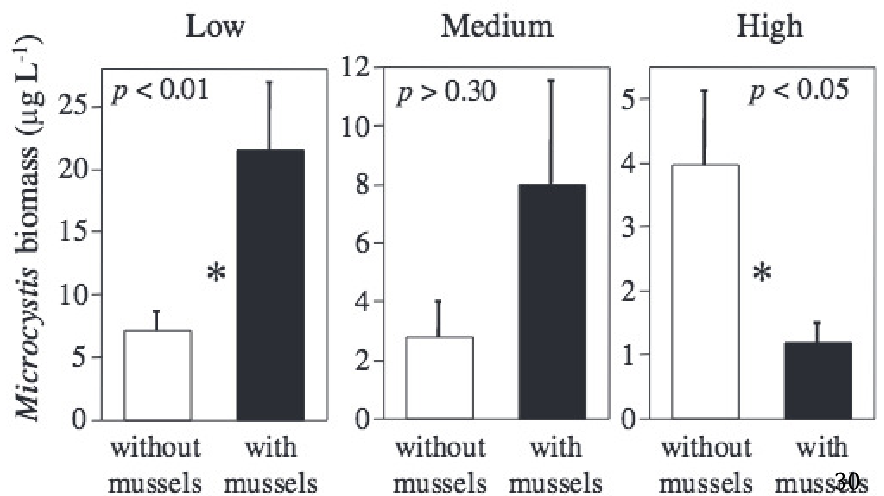
Phosphorus addition reverses the positive effect of zebra mussels (*Dreissena polymorpha*) on the toxic cyanobacterium, *Microcystis aeruginosa*

Orlando Sarnelle[a,*], *Jeffrey D. White*[a], *Geoffrey P. Horst*[a], *Stephen K. Hamilton*[b]
[a] Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA
[b] W. K. Kellogg Biological Station and Department of Zoology, Michigan State University, Hickory Corners, MI 49060, USA

Gull Lake

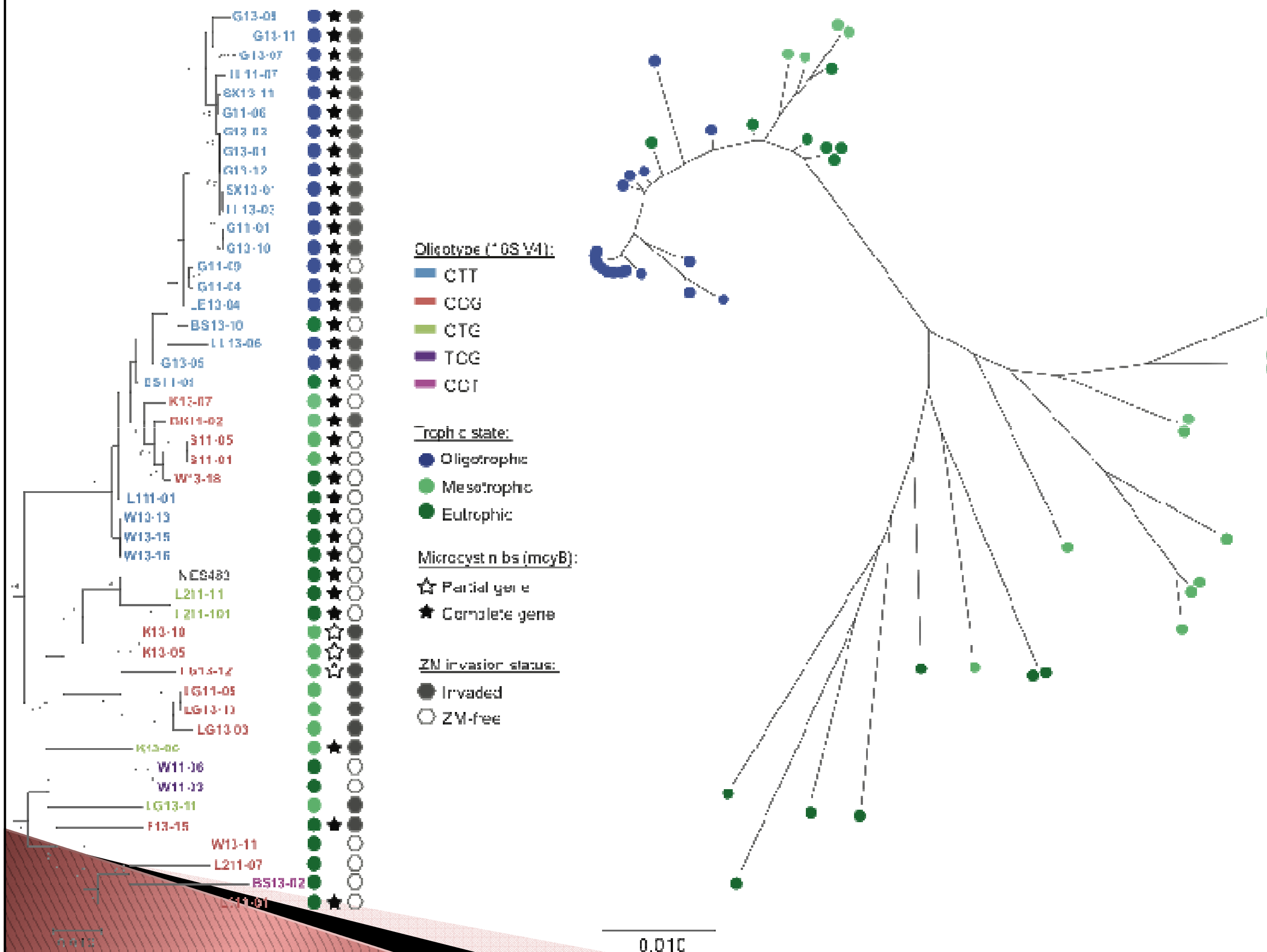


Experimental P addition (Gull Lake enclosure



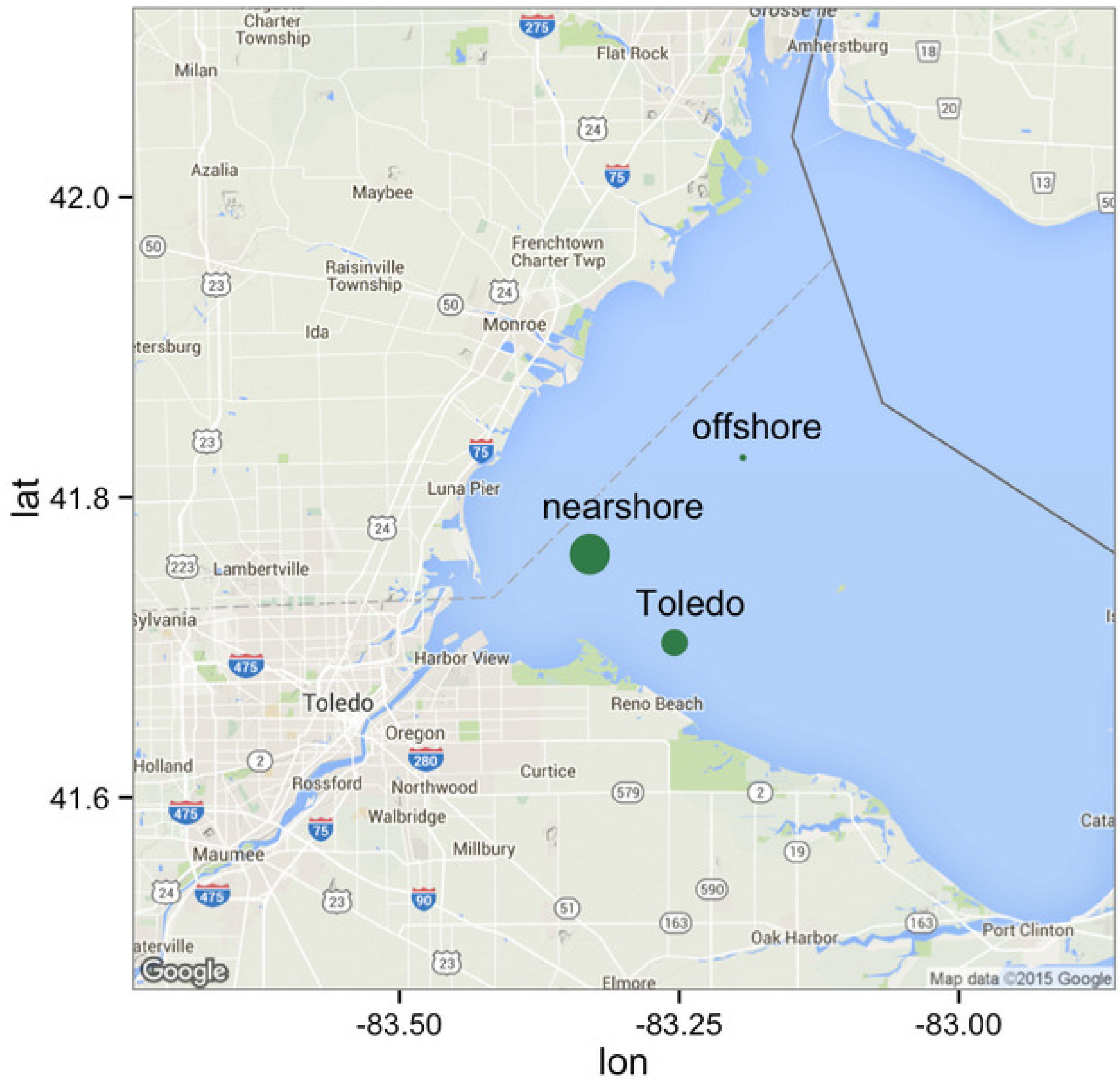

1. Impacts zebra/quagga mussels on CHABs

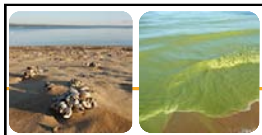
Linking genotype to ecological traits: grazing resistance



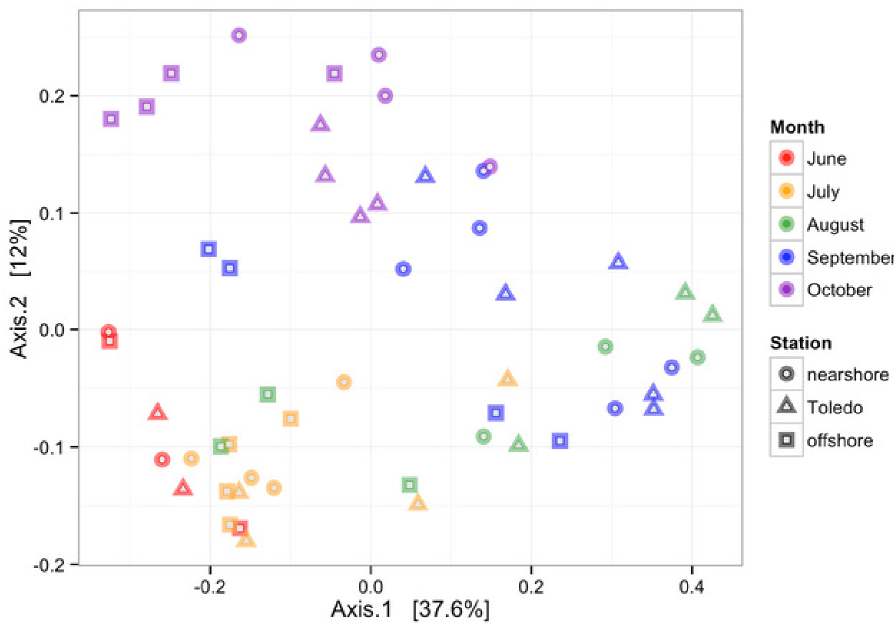
31

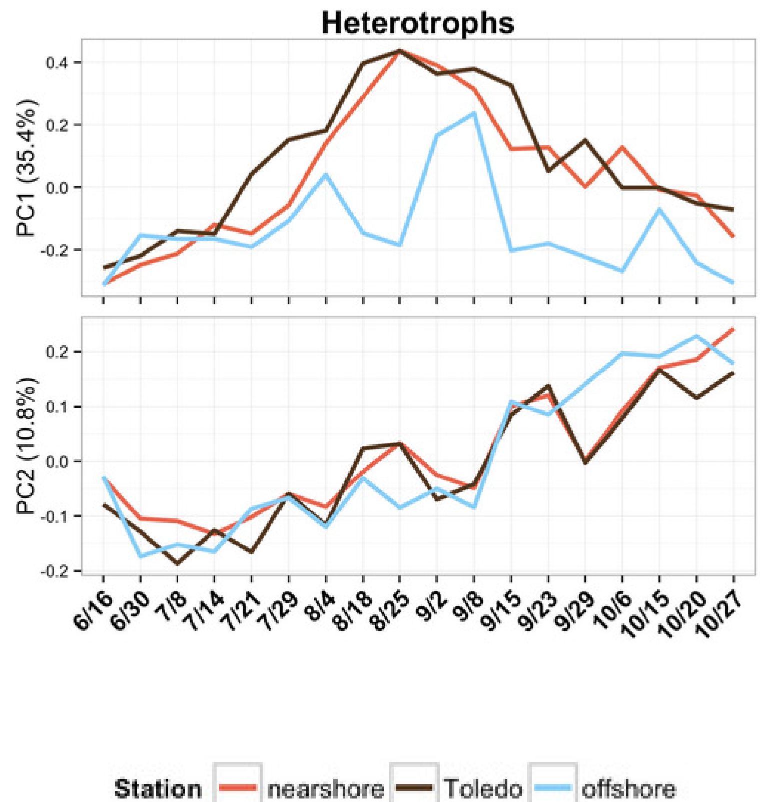
2. Role of heterotrophic community in CHABs?



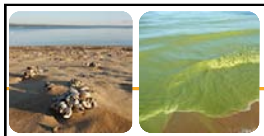


2. Role of heterotrophic community in CHABs?

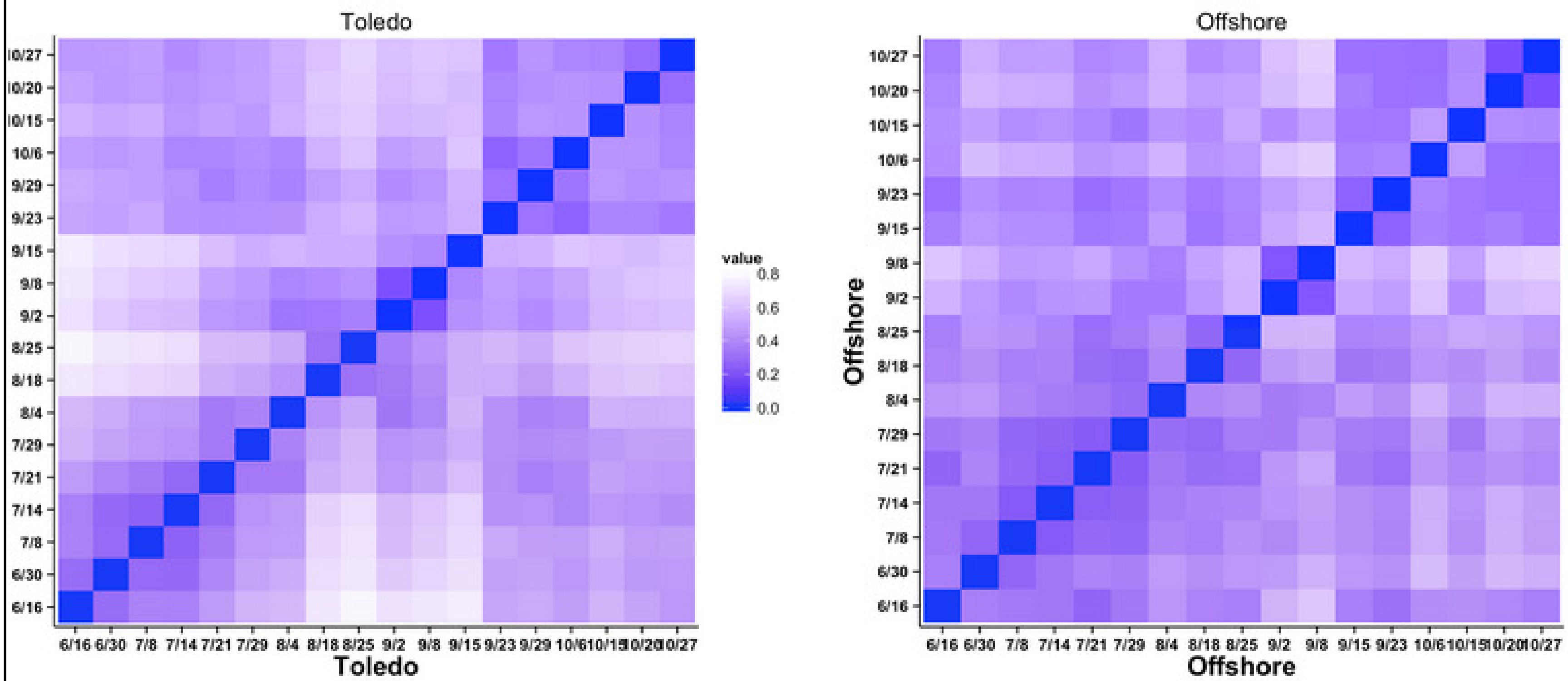




33



2. Role of heterotrophic community in CHABs?



34

2. Role of heterotrophic community in CHABs?

Assessing the role of phytoplankton–bacterioplankton coupling in the response of microbial plankton to nutrient additions

Antero Prieto[1,*], Esther Barber-Lluch[1], Marta Hernández-Ruiz[1],
Sandra Martínez-García[2], Emilio Fernández[1] and Eva Teira[1,3]
+ Author Affiliations

"…The results obtained in this study show that phytoplankton biomass and production respond only to the nutrient inputs when heterotrophic bacteria are active."

35

Panel 1 discussion

Triggers

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- Why are triggers important?
  - **Triggers of toxicity** or triggers of microcystis?
  - **Seeding from previous years**
- Do triggers differ across systems and time?
- How much do we need to reduce loadings to eliminate HABs?
  - Do legacy inputs affect results?
  - Holding of P over months—implications?
  - **Resuspension: is it a source of cells of nutrients or both (cells and nutrients)**

36

Panel 1 presentations
Nutrients

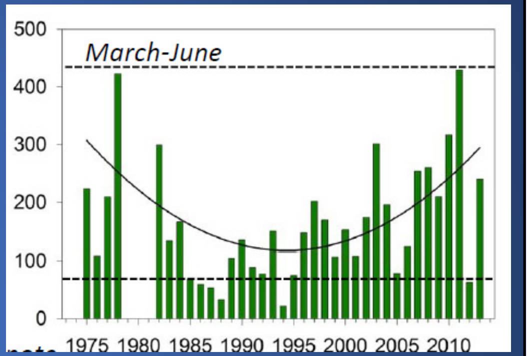
Ed Verhamme– LimnoTech

37


HABs - Nutrients
Ed Verhamme
Joe DePinto
John Bratton
Dan Rucinski
Todd Redder
Derek Schlea
GLC HABS Collaboratory
December 15, 2015
734-332-1200
38

HABs – Nutrient Concerns

- External Loads
  - Detroit River infrequent monitoring & reporting of loads (Dolan, UM WC)
  - Maumee River
    - SRP (UP) & TP (DOWN) (Heidelberg)
    - Watershed/land use changes? (LimnoTech)
- Internal Loads
  - Sediment & porewater contribution
  - Resuspension (short and long term)
  - Surface sediment P changes (increased importance?)
  - Internal processing (Mussels??)
- Role of Nitrogen
  - Very difficult to manage, but linked to <u>*toxin production*</u>



Maumee River Spring Load (source Heidelberg)

What are we doing?

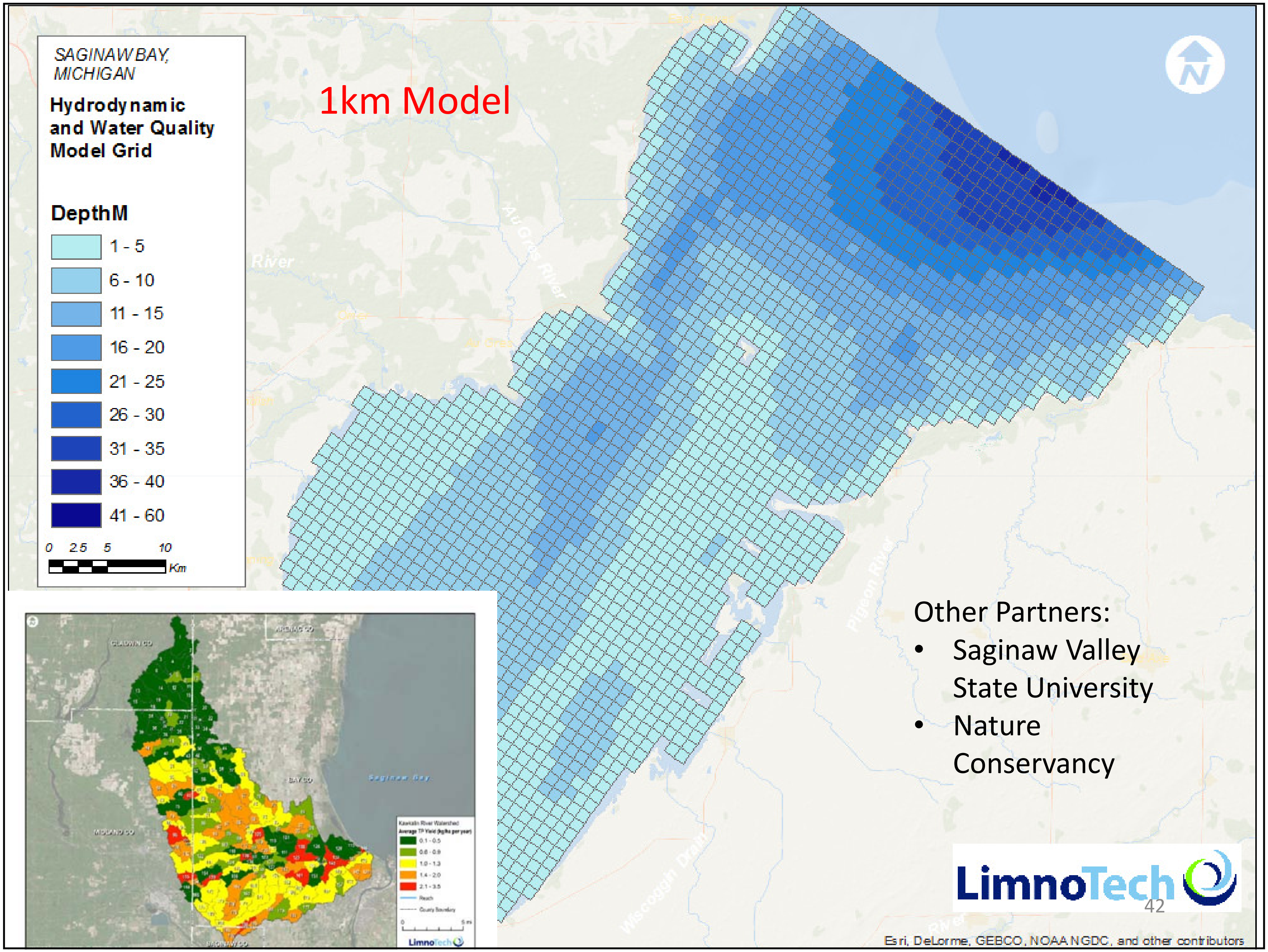
- Monitoring & Experiments
  - Loads (UM & Heidelberg)
  - Sediment flux studies (2014 GLRI)
  - Sonde network (& its real-time!!!)
  - Others?? (e.g. remote sensing, planes, auv…..)
- Modeling
  - Nutrient mass balance for all major embayments (Saginaw, Western Lake Erie, & Green Bay)
  - Watershed modeling (nutrient sources … $$$$)
  - Multi-class phytoplankton model w/focus on HABs
  - Data on loads, sediments, in-situ observations
  - Modeling forces collaboration, reflection, and brainstorming, between all disciplines
- Data Management
  - Modeling requires good data management
  - Used by other stakeholder groups (HABs forecast)
  - GLOS is providing tools and online resources for HABs

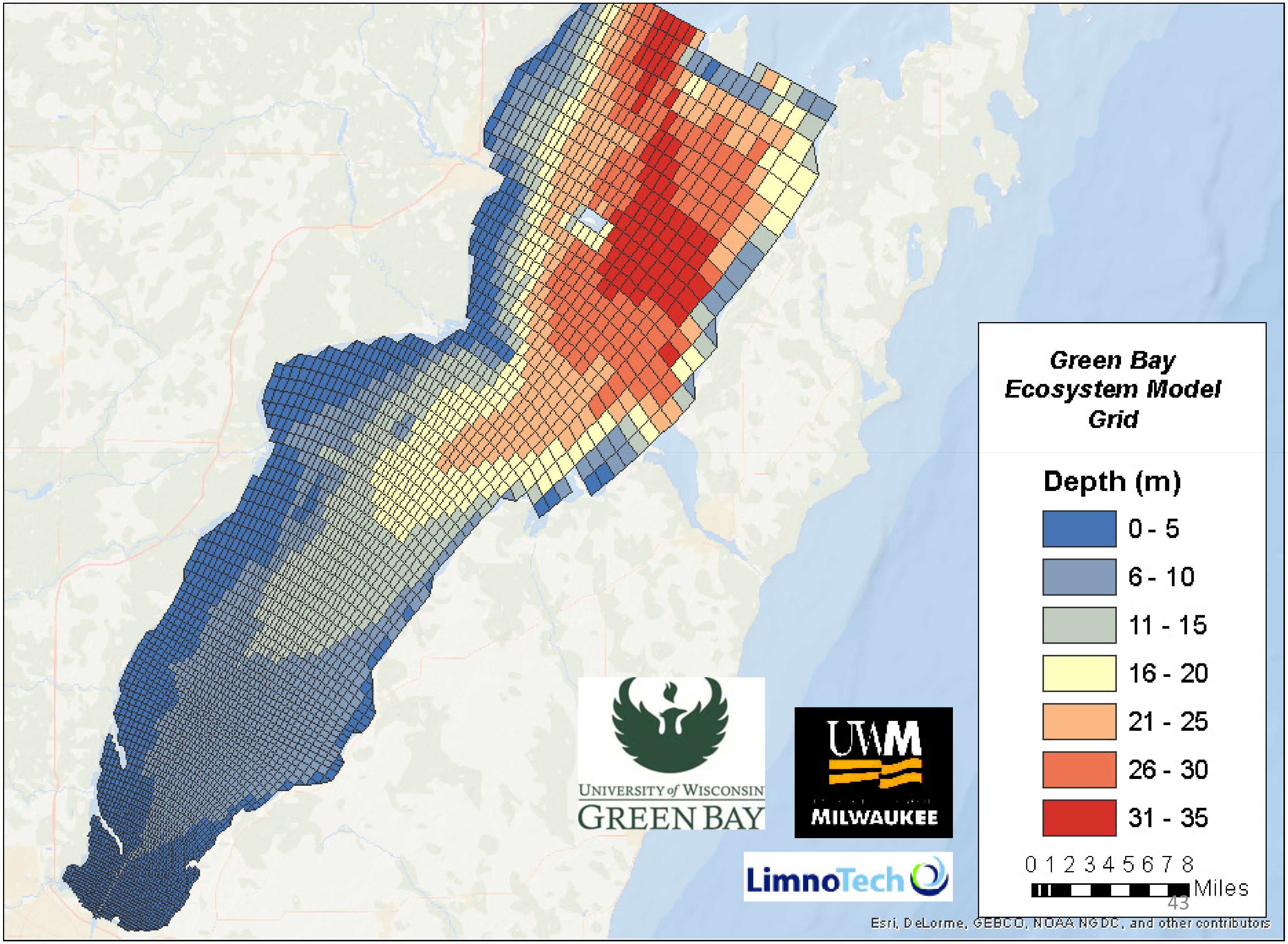
IAGLR '16 - Session 28. Big Bays Big Problems: Research and Management of Great Lake Embayments, Chaired by Ed Verhamme, Val Klump and Craig Stow

40

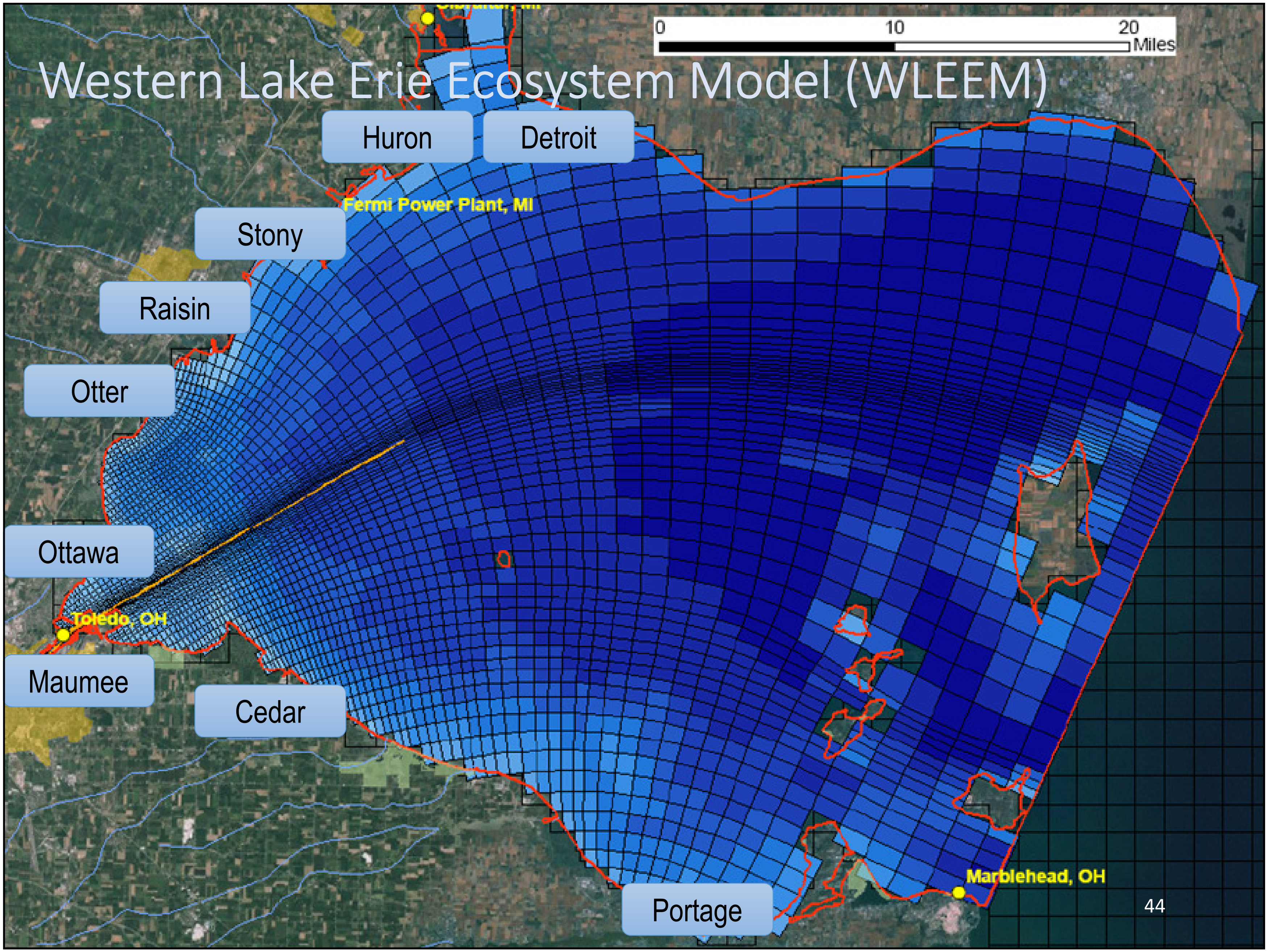
- Webinar TOMORROW
- 11am
- Over 300 registered
  - 37 states
  - 6 countries
  - 40 from USEPA
- HABs & Drinking water
- Cyanotoxin

41


SAGINAW BAY, MICHIGAN
Hydrodynamic and Water Quality Model Grid
DepthM
1 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 35
36 - 40
41 - 60
0 2.5 5 10 Km
1km Model
Other Partners:
• Saginaw Valley State University
• Nature Conservancy
LimnoTech
42
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

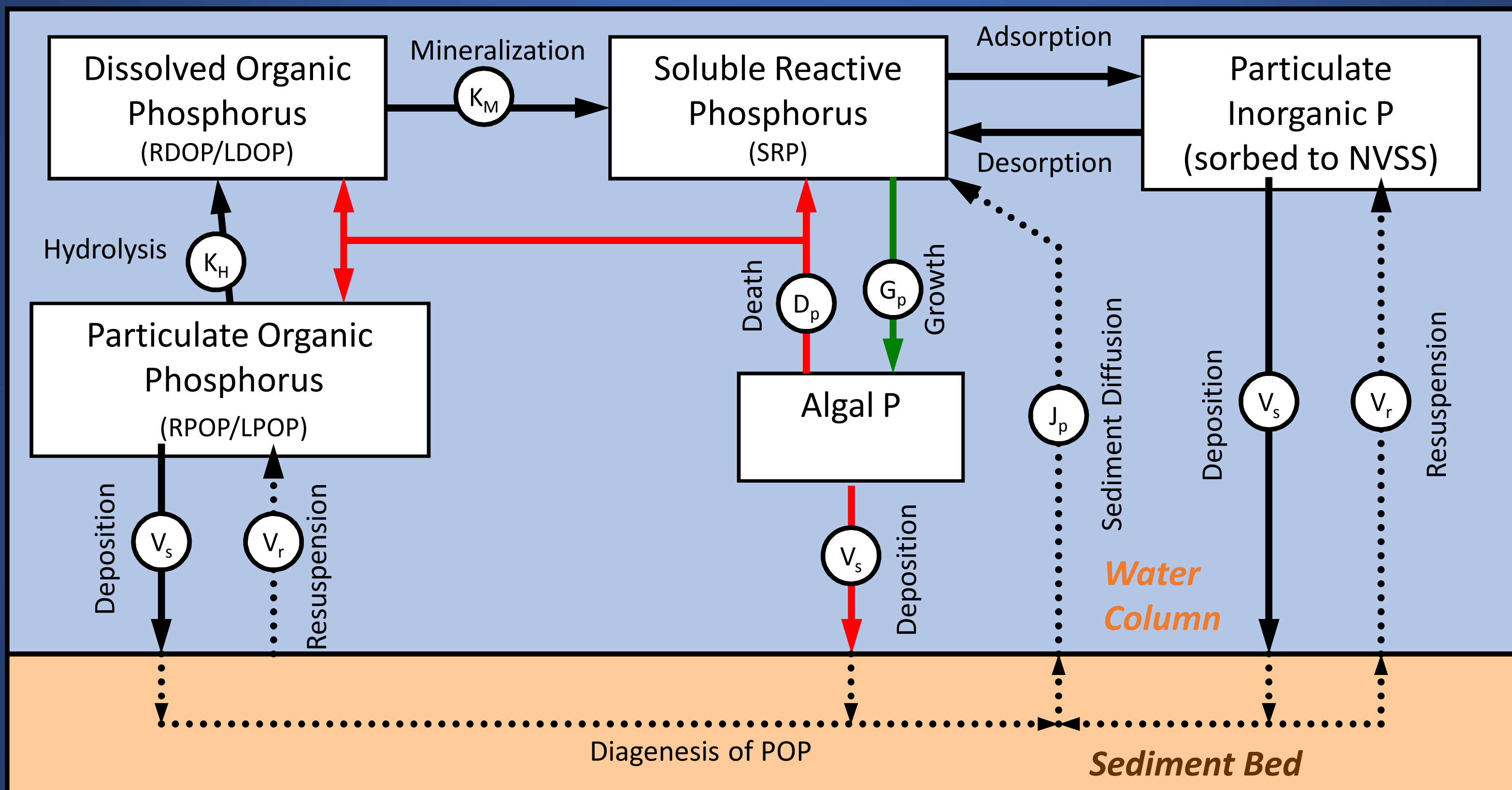

Green Bay
Ecosystem Model
Grid
Depth (m)
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 35
0 1 2 3 4 5 6 7 8
Miles
University of Wisconsin
Green Bay
UWM
Milwaukee
LimnoTech
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Western Lake Erie Ecosystem Model (WLEEM)

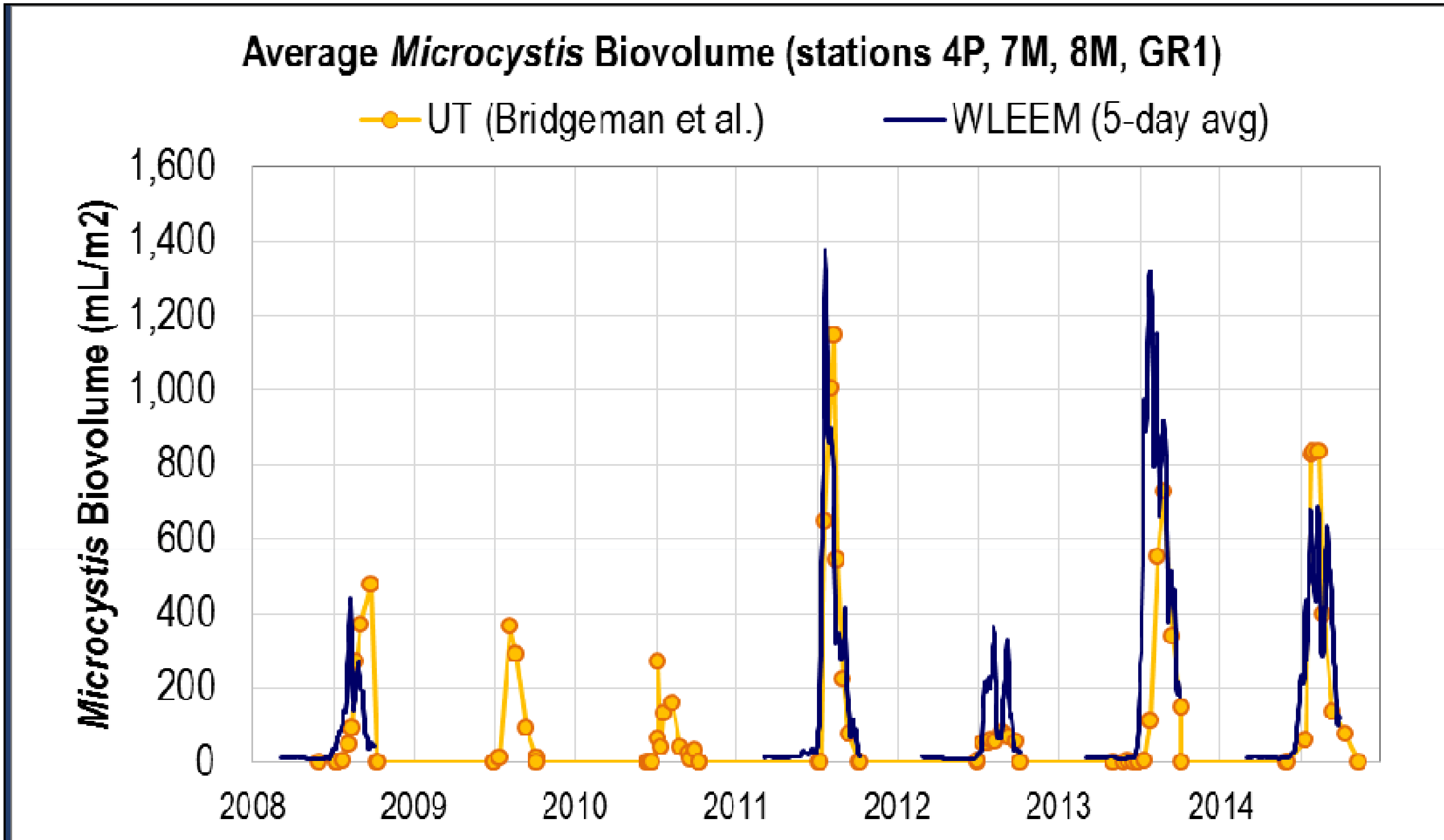


44

Phosphorus Cycling in A2EM

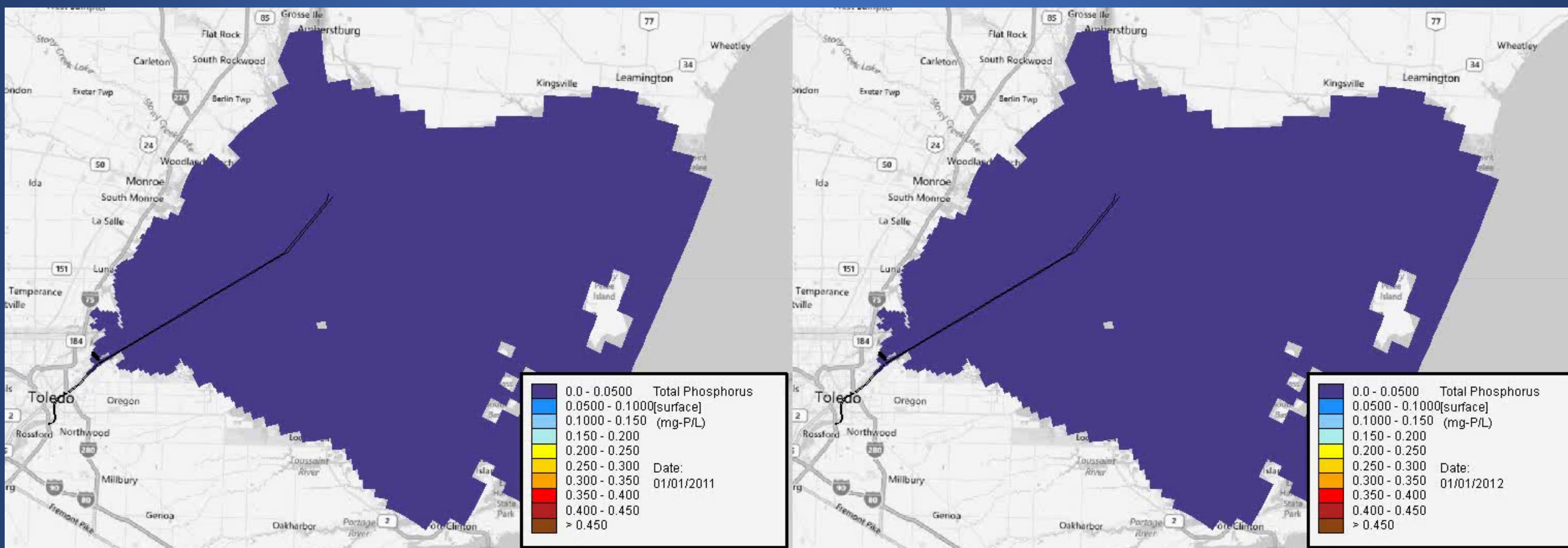


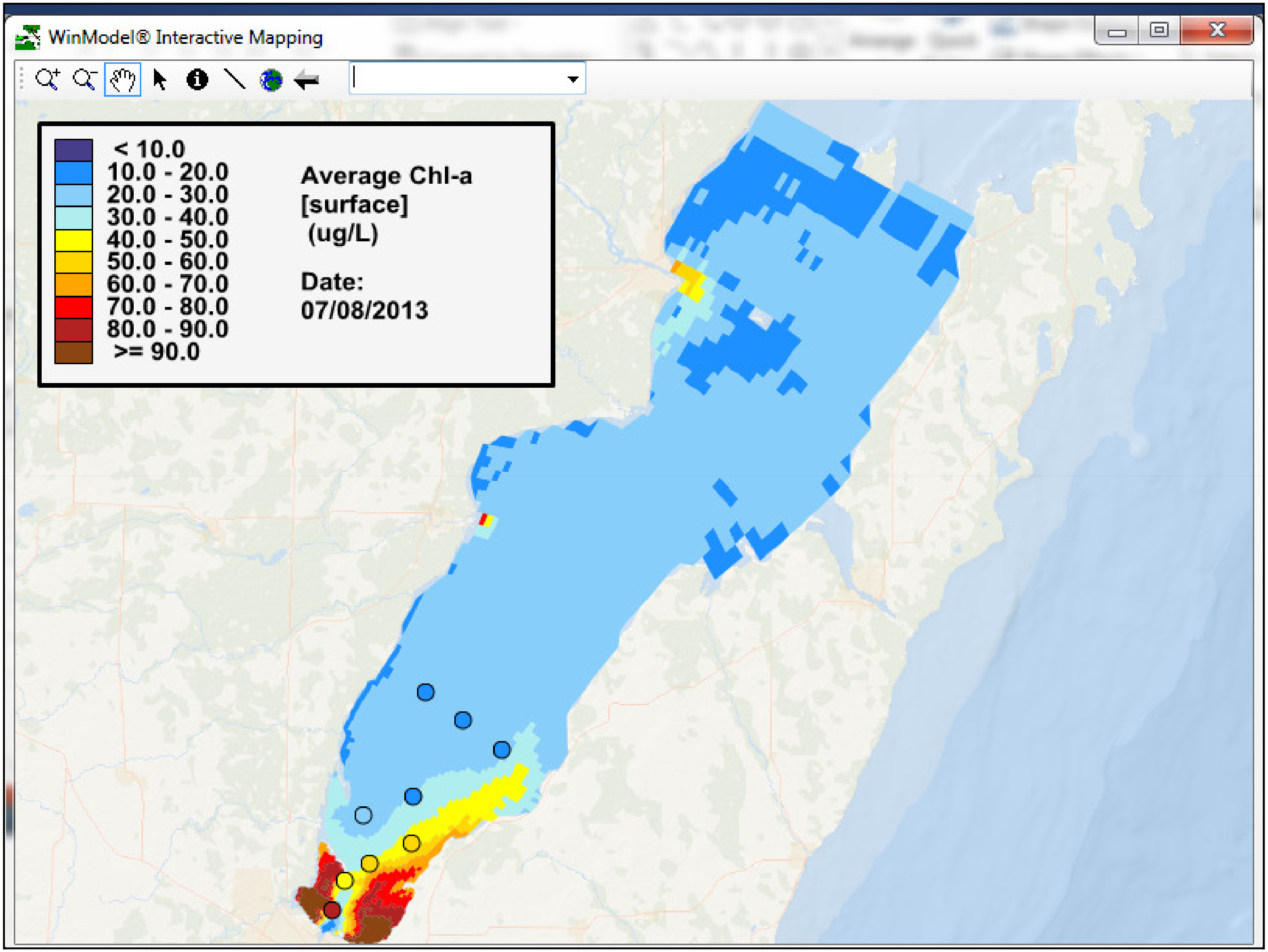
45

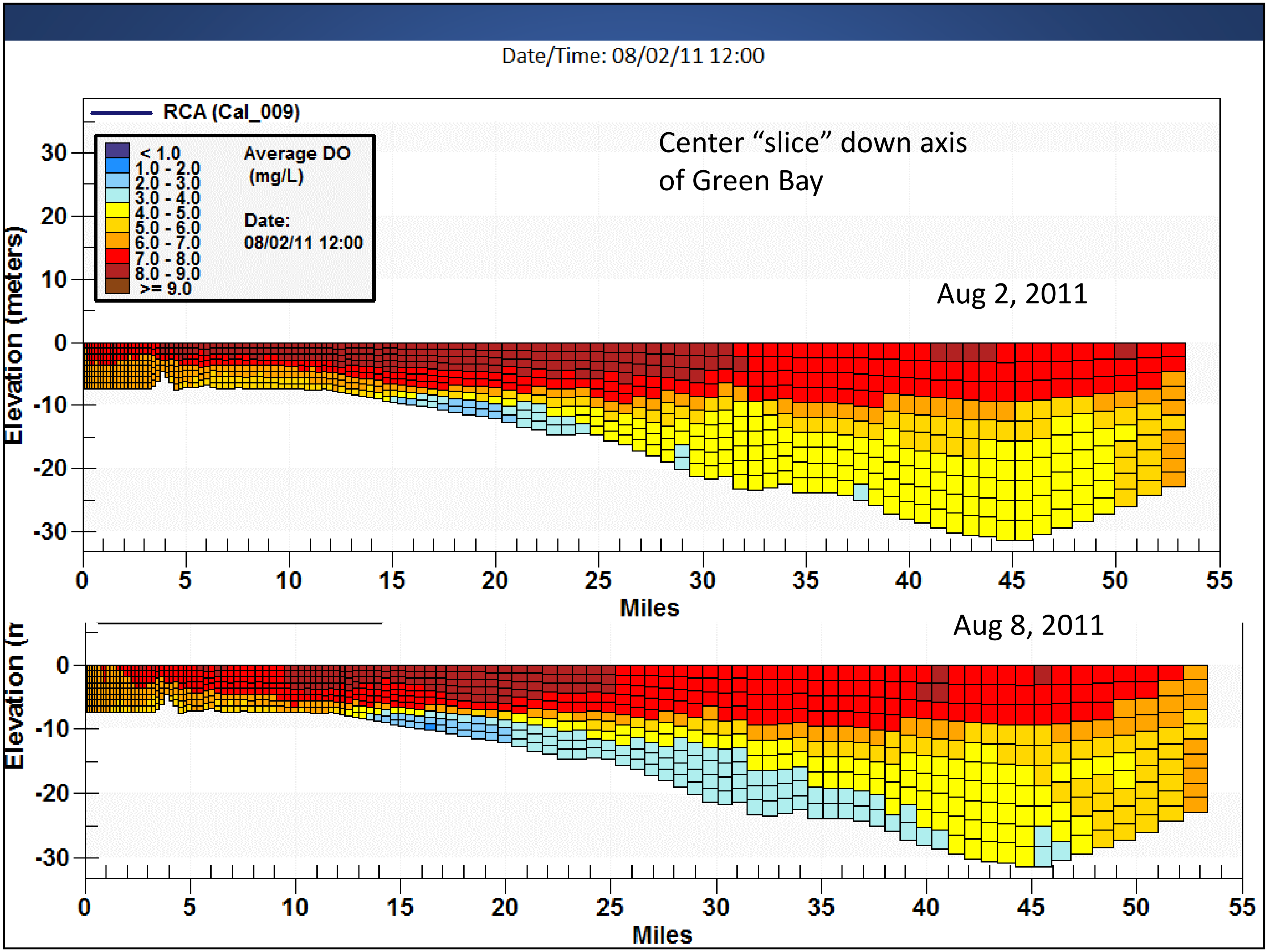


Data Credit: T. Bridgeman, University of Toledo

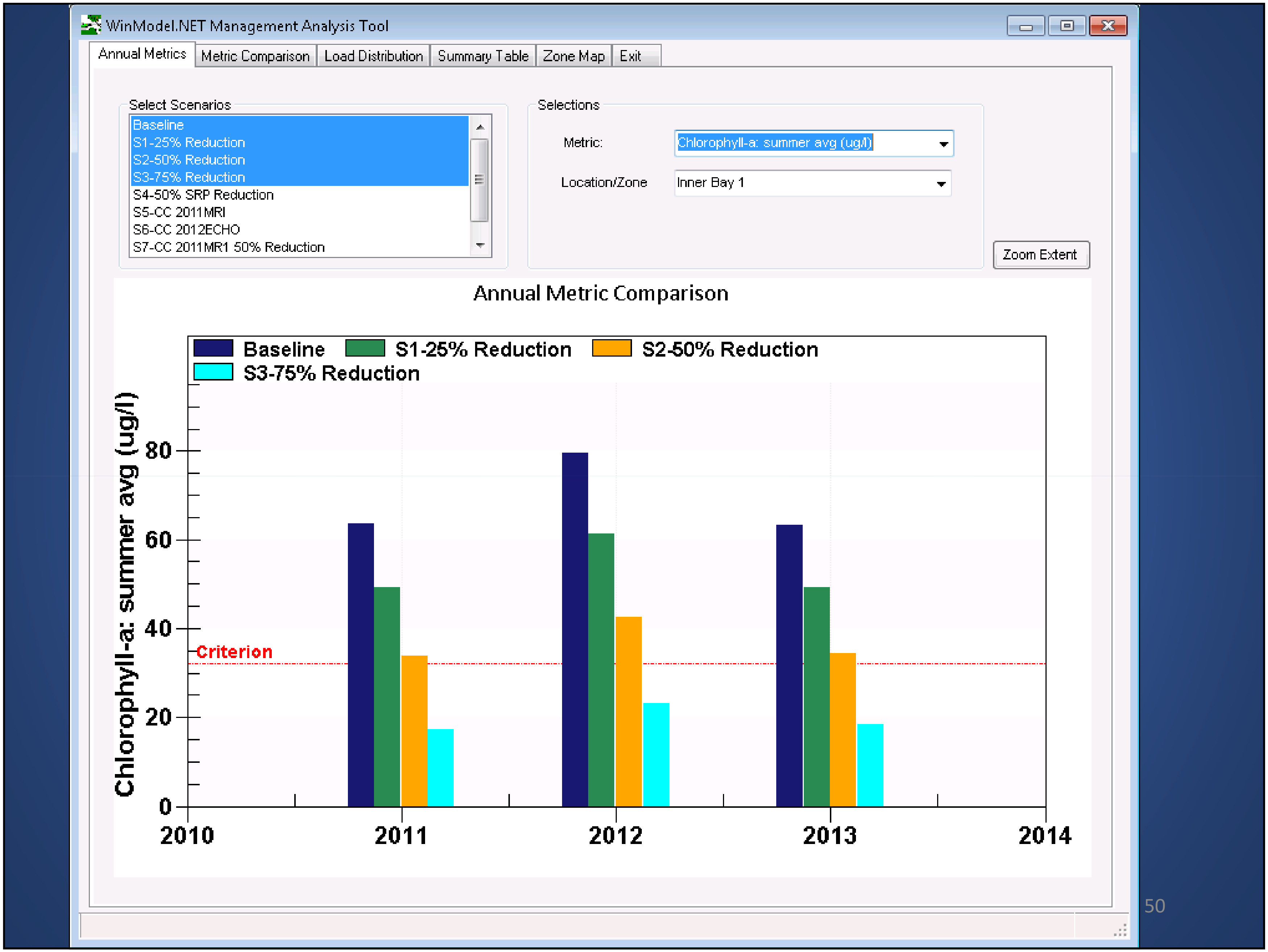
WLEEM TP Simulations (2011-12)



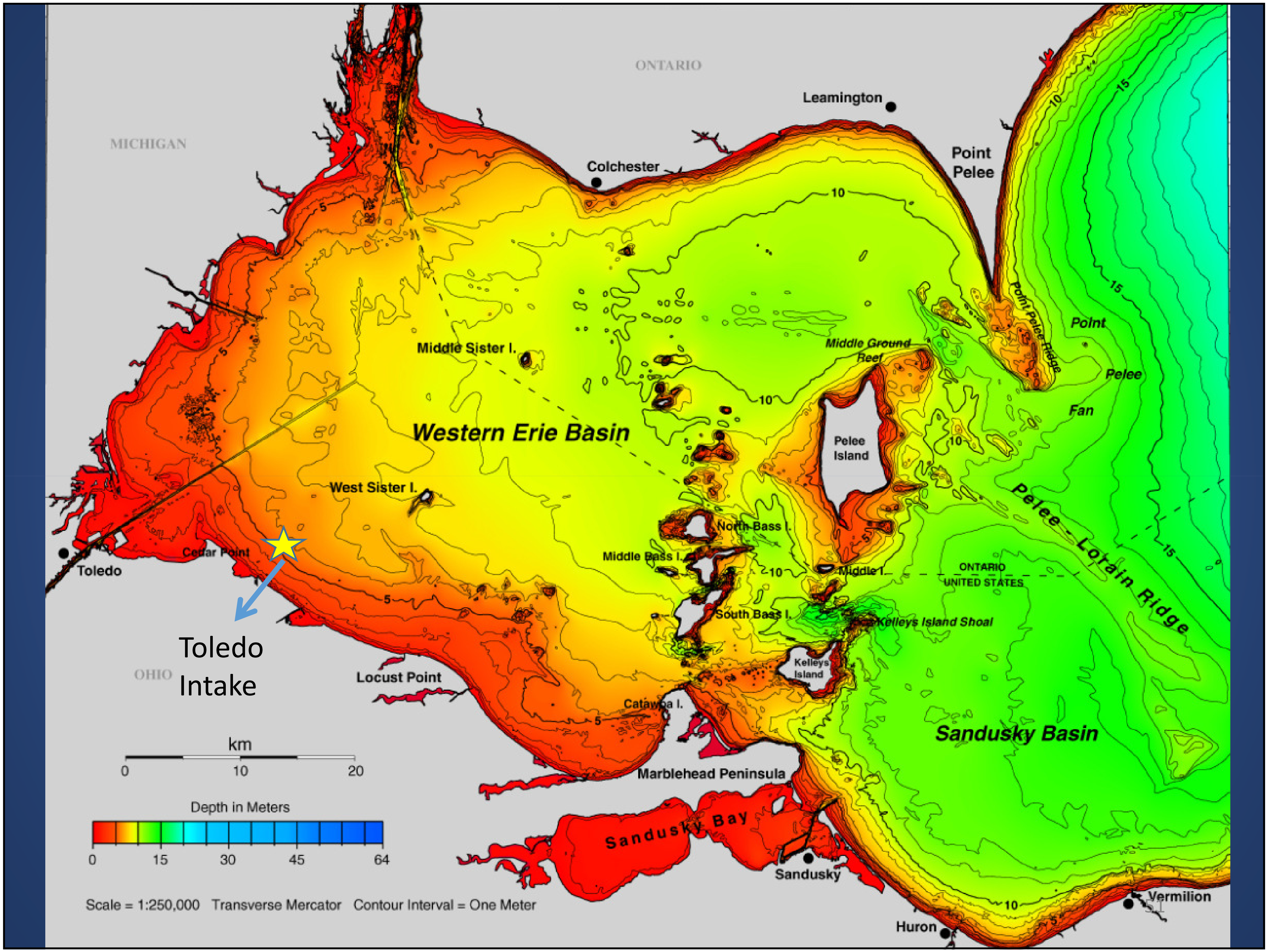

WinModel® Interactive Mapping
< 10.0
10.0 - 20.0
20.0 - 30.0
30.0 - 40.0
40.0 - 50.0
50.0 - 60.0
60.0 - 70.0
70.0 - 80.0
80.0 - 90.0
>= 90.0
Average Chl-a
[surface]
(ug/L)
Date:
07/08/2013



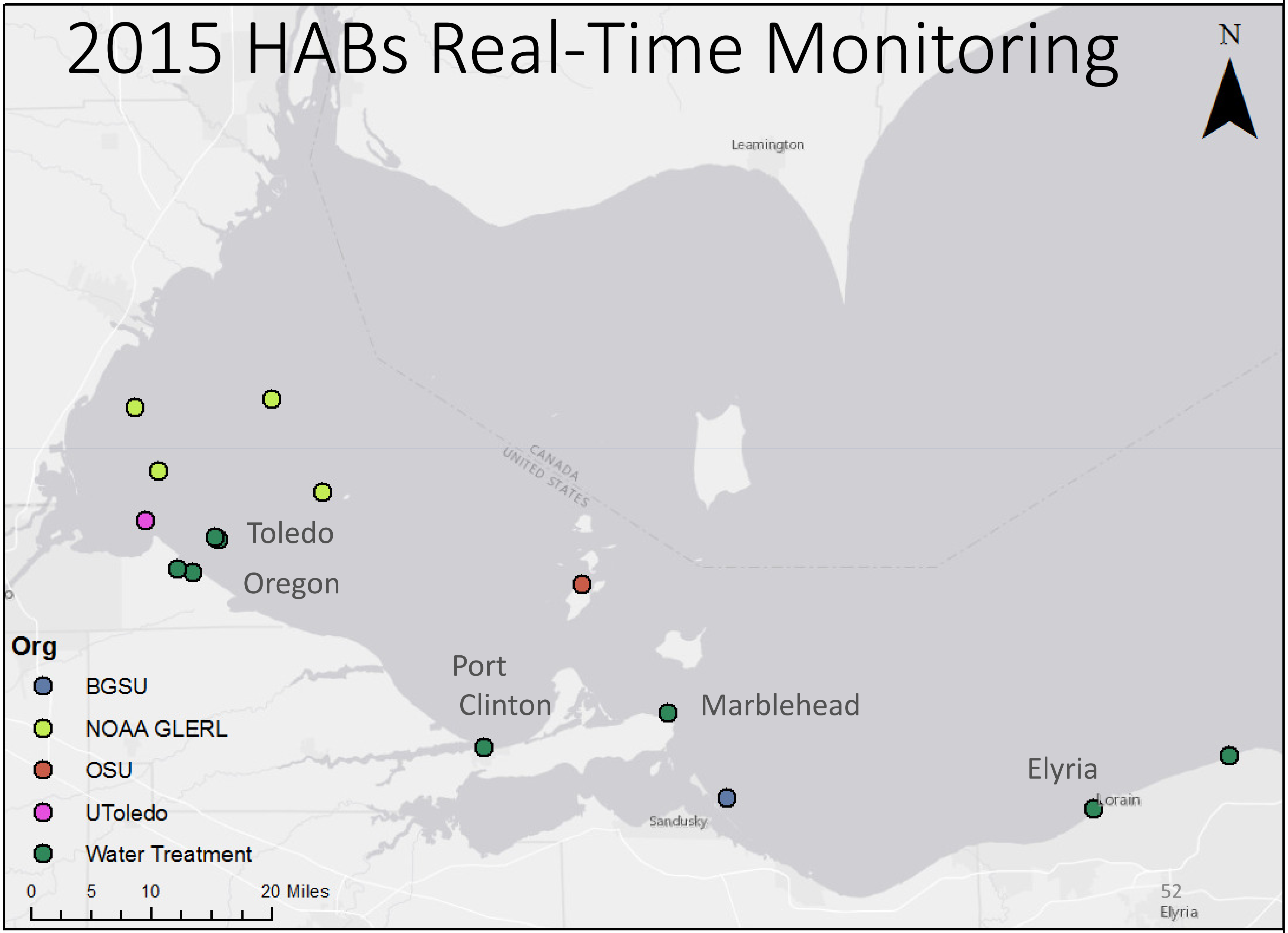
Date/Time: 08/02/11 12:00
RCA (Cal_009)
< 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
5.0 - 6.0
6.0 - 7.0
7.0 - 8.0
8.0 - 9.0
>= 9.0
Average DO (mg/L)
Date: 08/02/11 12:00
Center "slice" down axis of Green Bay
Aug 2, 2011
Elevation (meters)
Miles
Aug 8, 2011
Elevation
Miles



WinModel.NET Management Analysis Tool
Annual Metrics
Metric Comparison
Load Distribution
Summary Table
Zone Map
Exit
Select Scenarios
Baseline
S1-25% Reduction
S2-50% Reduction
S3-75% Reduction
S4-50% SRP Reduction
S5-CC 2011MRI
S6-CC 2012ECHO
S7-CC 2011MR1 50% Reduction
Selections
Metric:
Chlorophyll-a: summer avg (ug/l)
Location/Zone
Inner Bay 1
Zoom Extent
Annual Metric Comparison
Baseline
S1-25% Reduction
S2-50% Reduction
S3-75% Reduction
Chlorophyll-a: summer avg (ug/l)
Criterion
0
20
40
60
80
2010
2011
2012
2013
2014
50


ONTARIO
MICHIGAN
Leamington
Colchester
Point Pelee
Point Pelee Ridge
Point Pelee Fan
Middle Sister I.
Middle Ground Reef
Western Erie Basin
Pelee Island
West Sister I.
Pelee - Lorain Ridge
North Bass I.
Middle Bass I.
Middle I.
ONTARIO
UNITED STATES
Toledo
Cedar Point
South Bass I.
Kelleys Island Shoal
Kelleys Island
Toledo Intake
OHIO
Locust Point
Catawba I.
Sandusky Basin
km
0
10
20
Marblehead Peninsula
Depth in Meters
Sandusky Bay
0
15
30
45
64
Sandusky
Vermilion
Huron
Scale = 1:250,000 Transverse Mercator Contour Interval = One Meter

2015 HABs Real-Time Monitoring



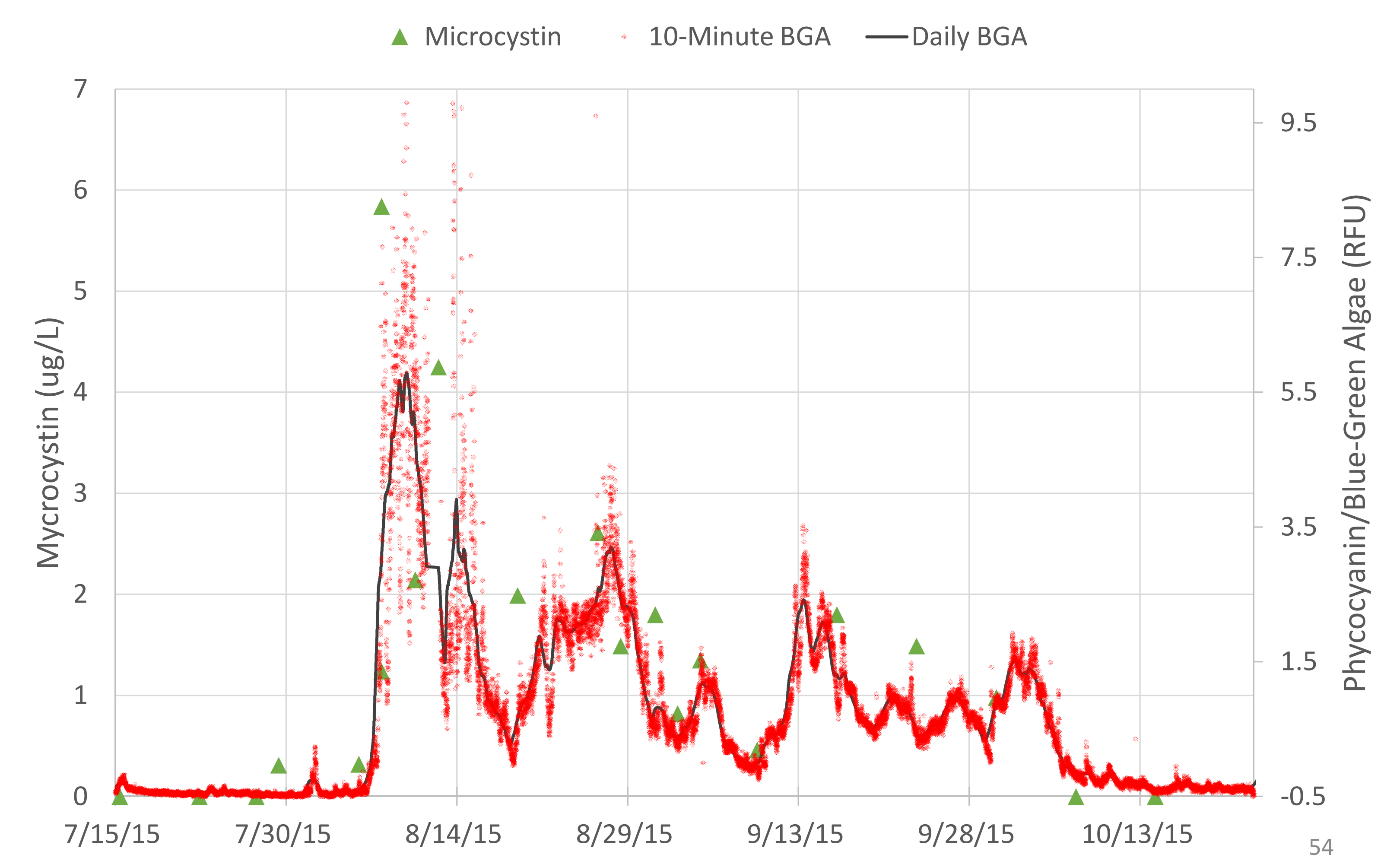
GLOS HABs Data Viewer

Share your data

53

http://habs.glos.us

Oregon Intake Microcystin



HABs Resources Tool

Lake Erie HABs Monitoring

About | HAB Monitoring | HAB Bulletin | MODIS Images | NOAA GLERL | GLOS HABs Viewer | Toledo Sondes | Sonde Stations | WQ Grab Samples

HAB Current Bulletin | HAB Bulletin Archive

Source: http://tinyurl.com/puekrgd

Experimental Lake Erie Harmful Algal Bloom Bulletin

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

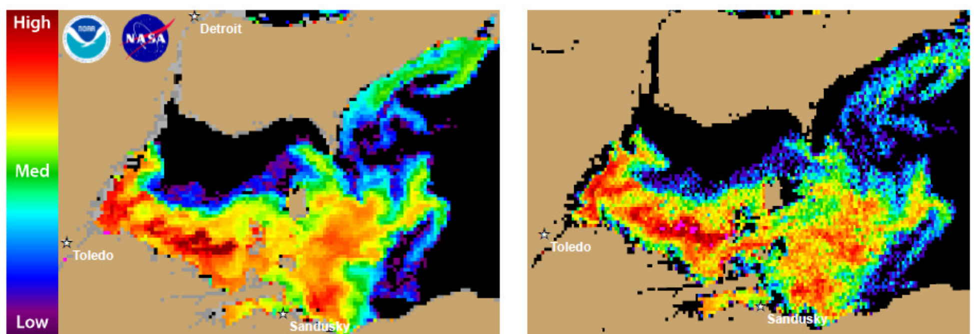
17 August, 2015, Bulletin 11

The *Microcystis* cyanobacteria bloom continues across a large part of the western basin south of West Sister Island from Michigan to the islands. Dense scums have formed in highest concentration areas, with extensive scums occuring in the red to dark red areas in the western basin. The bloom is found east of the islands, including scum patches away from shore. Moderate concentrations extend as far as Rondeau on the Ontario coast. Microcystin is present in this bloom, and the toxin levels are extremely high in scums.

Light southerly to southwesterly winds will continue today and Tuesday, gradually increasing to Thursday. Least mixing and greatest scum formation earlier in the week, and greatest mixing with passage of a cold front late Wed and Thursday. These winds will cause continued movement of the eastern edge into the central basin and also eastward on the Ontario coast.

The persistent bloom in Sandusky Bay continues. No other blooms are evident in the central and eastern basins.

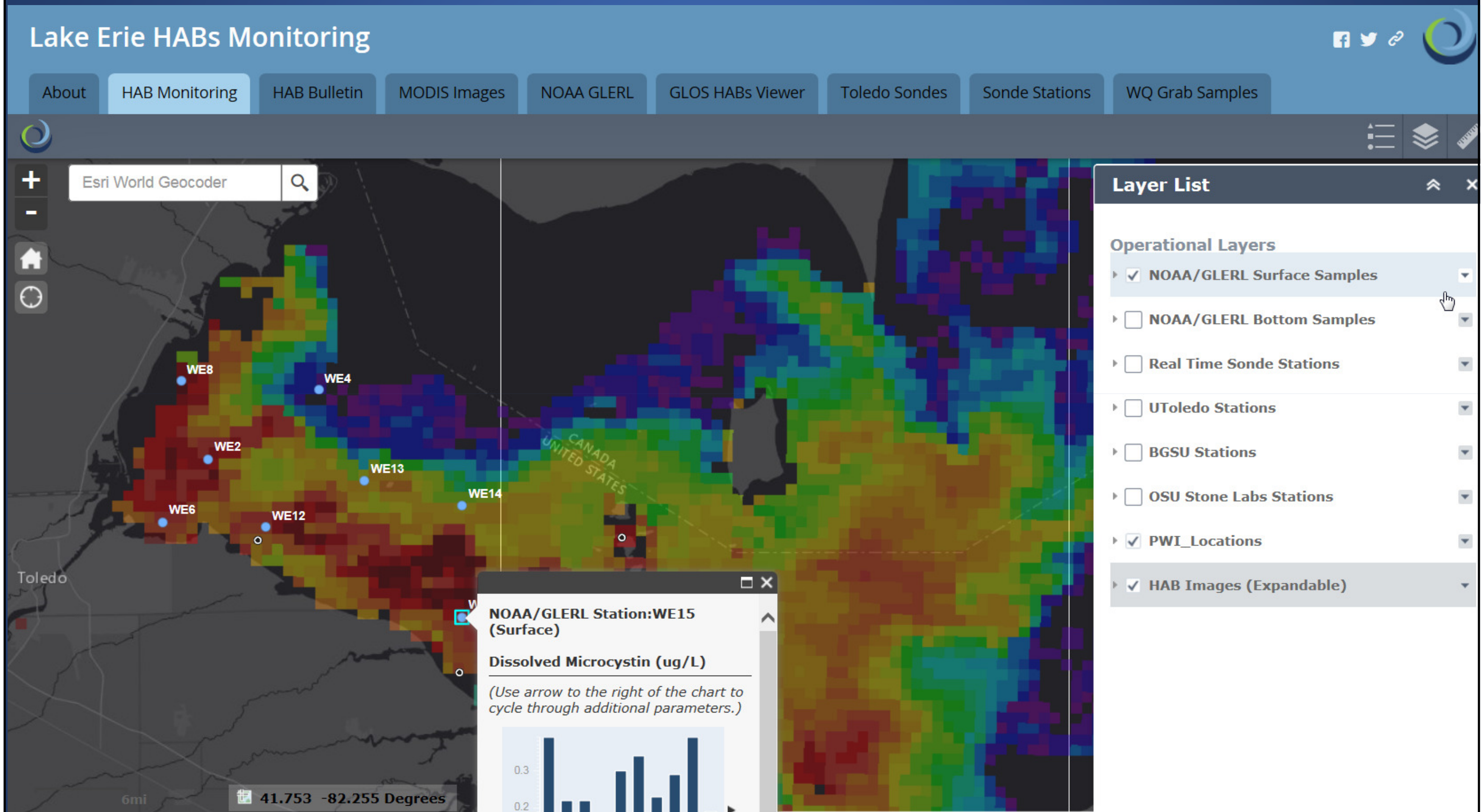
Please check Ohio EPA's site, http://epa.ohio.gov/habalgae.aspx for safety information, including updates on the State Parks. Keep your pets and yourself out of the water in areas where scum is forming. - Stumpf, Tomlinson



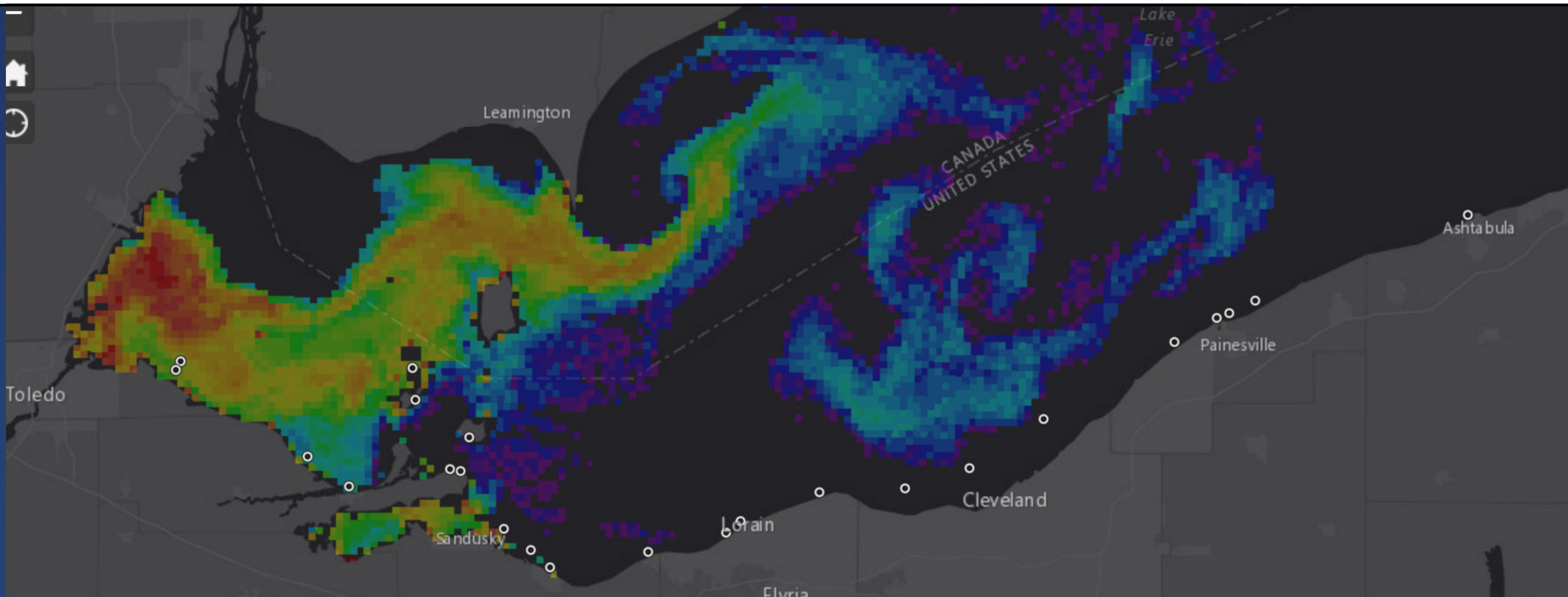
www.limno.com/beta/LakeErieHABs

55

HABs Resources Tool



Underlying Assumption: Data/product partners use some type of web service to facilitate data sharing (virtuous data management) 56

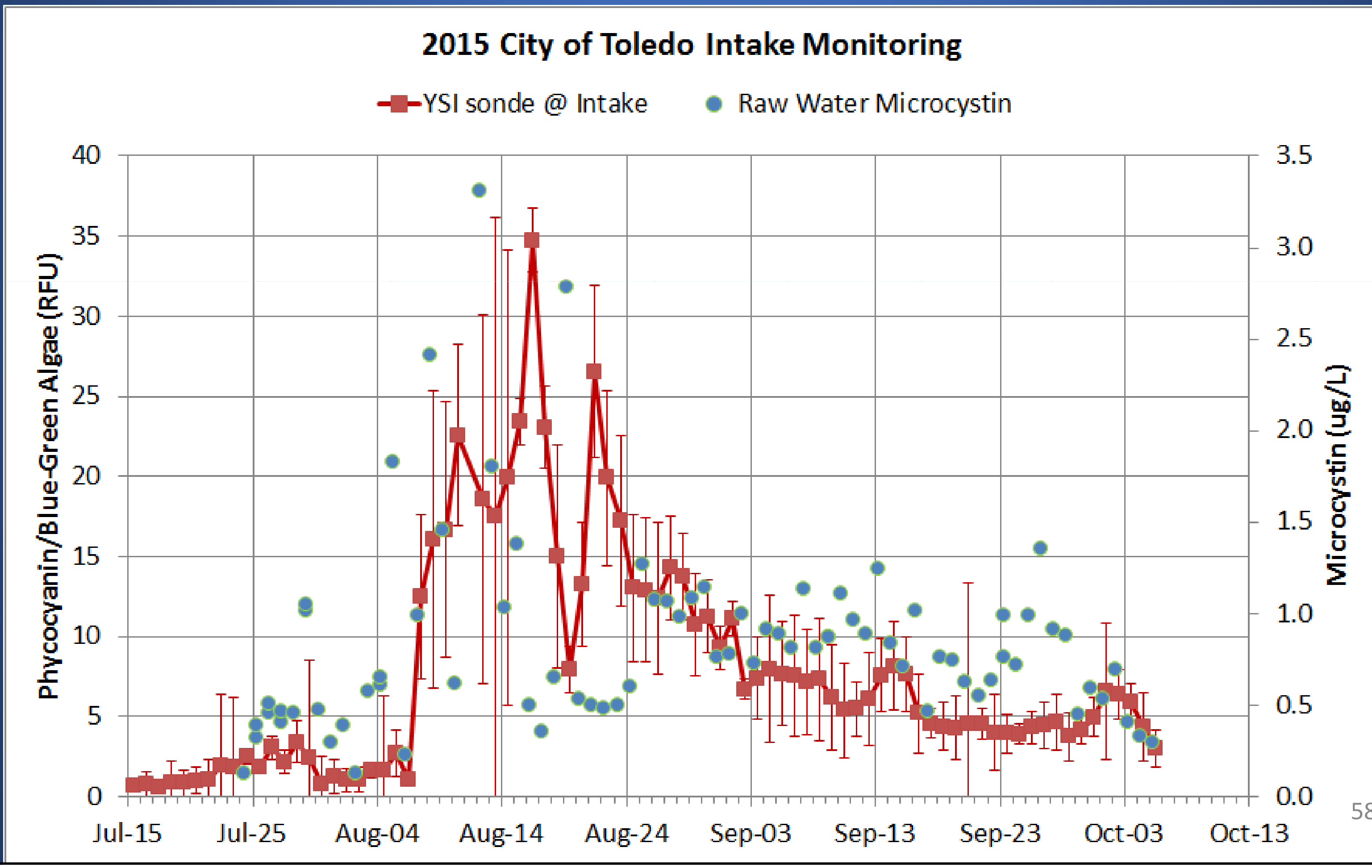


2.5 Million people drink water in Ohio

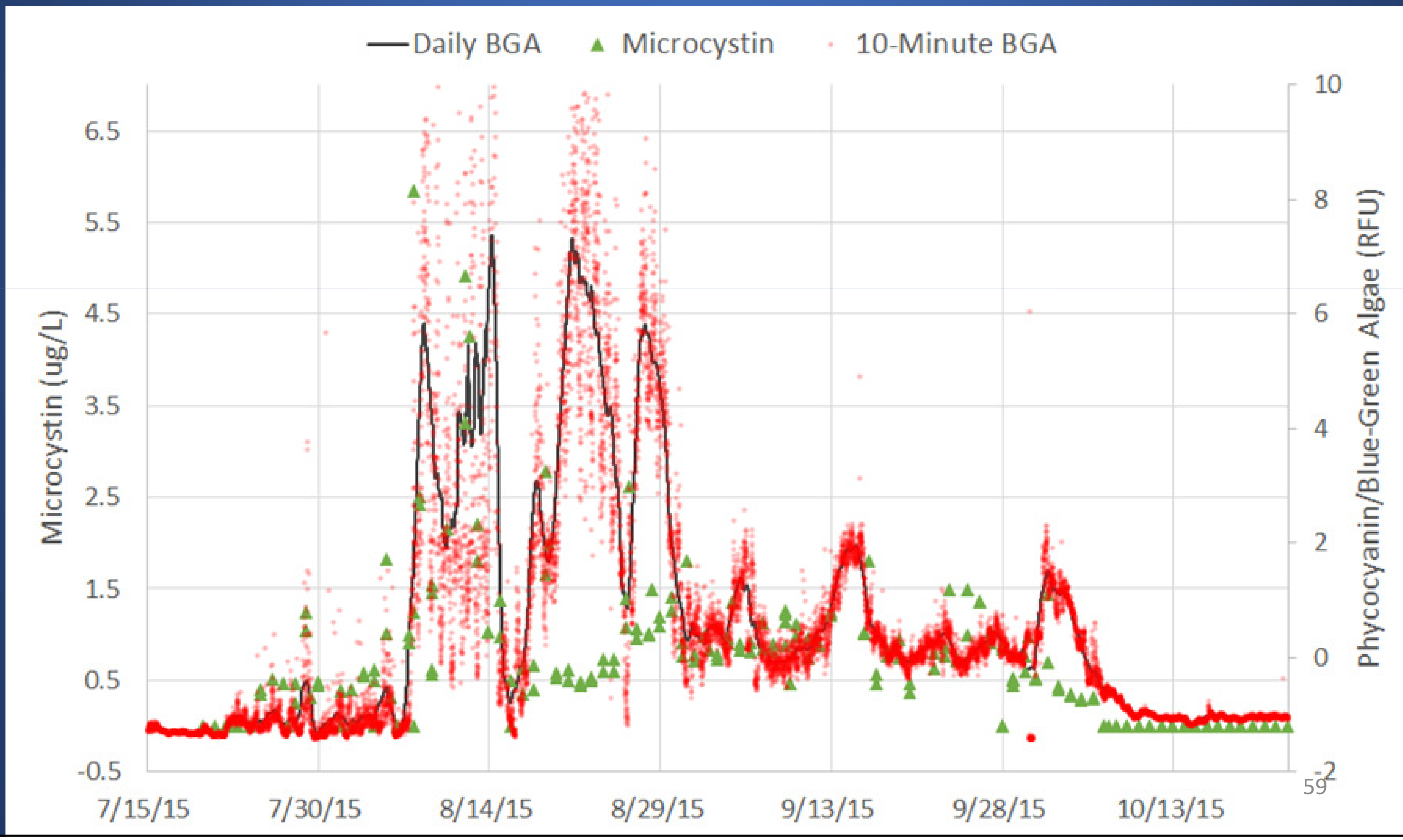
57

How can real-time data be used?

- Are HABs present in source water?
- Are HAB levels increasing or decreasing?

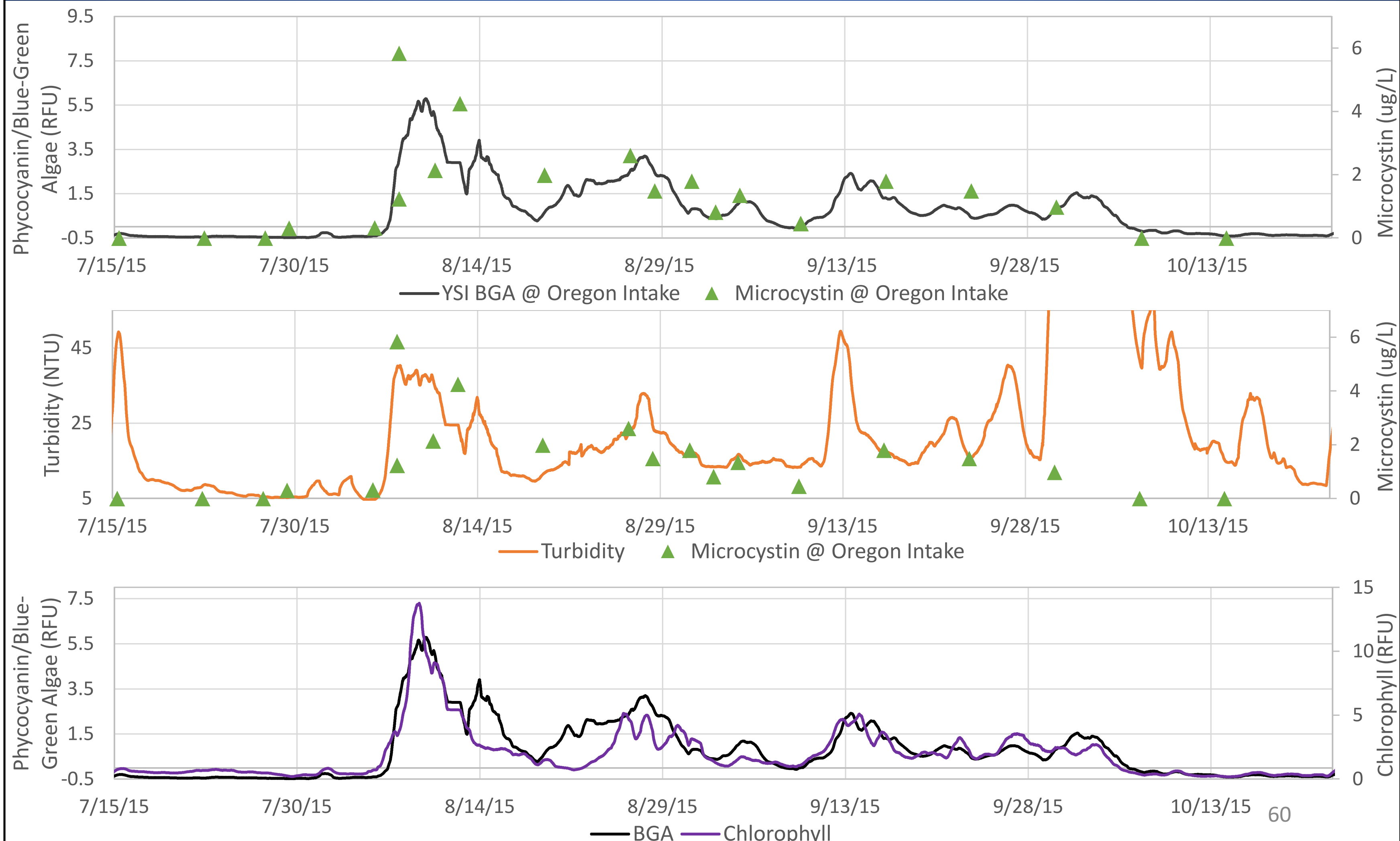


58



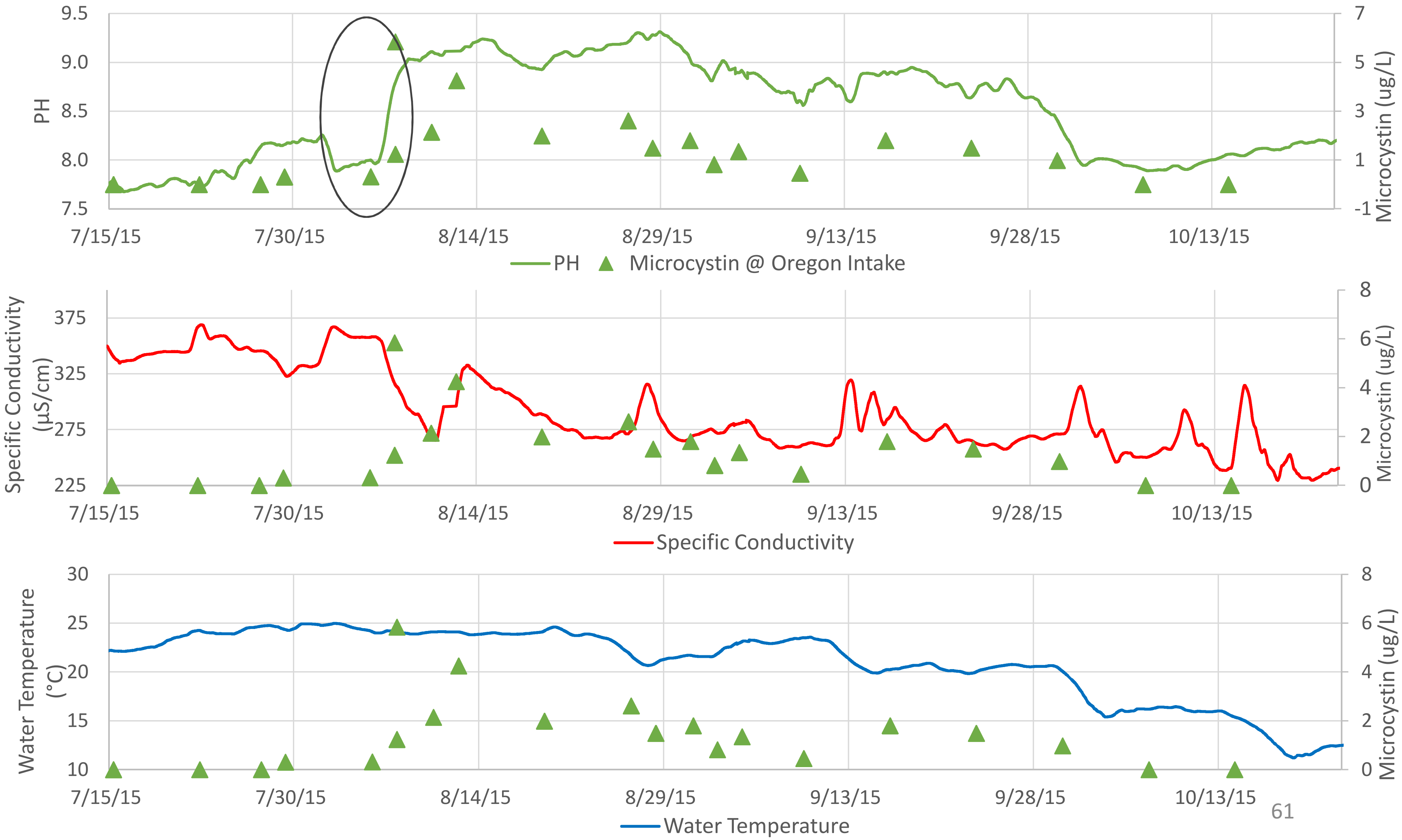
Daily BGA
Microcystin
10-Minute BGA
Microcystin (ug/L)
Phycocyanin/Blue-Green Algae (RFU)
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
10
8
6
4
2
0
-2
7/15/15
7/30/15
8/14/15
8/29/15
9/13/15
9/28/15
10/13/15
59

Oregon Intake
Real-Time Data vs Microcystin Samples



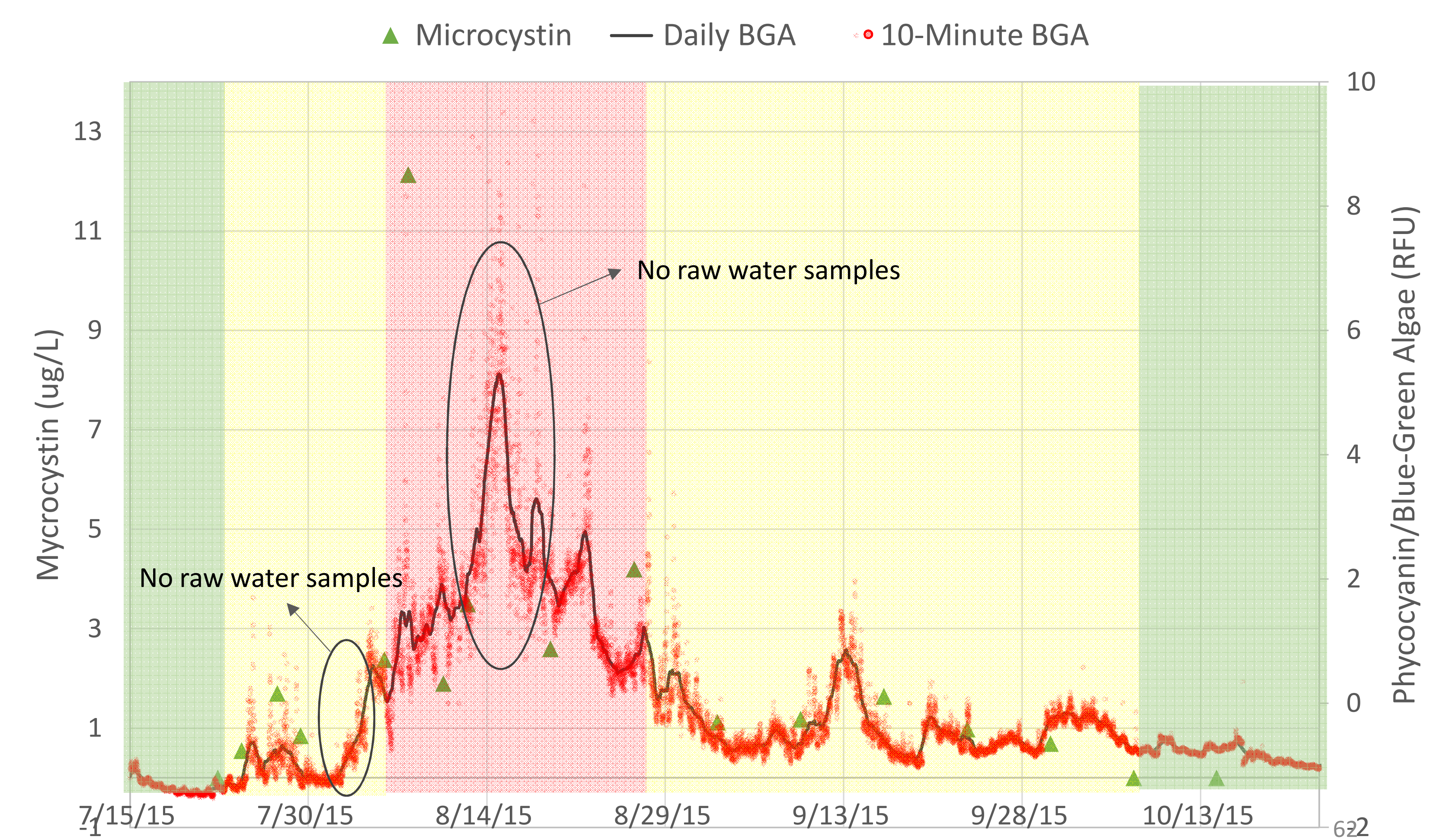
60

Oregon Intake
Real-Time Data vs Microcystin Samples

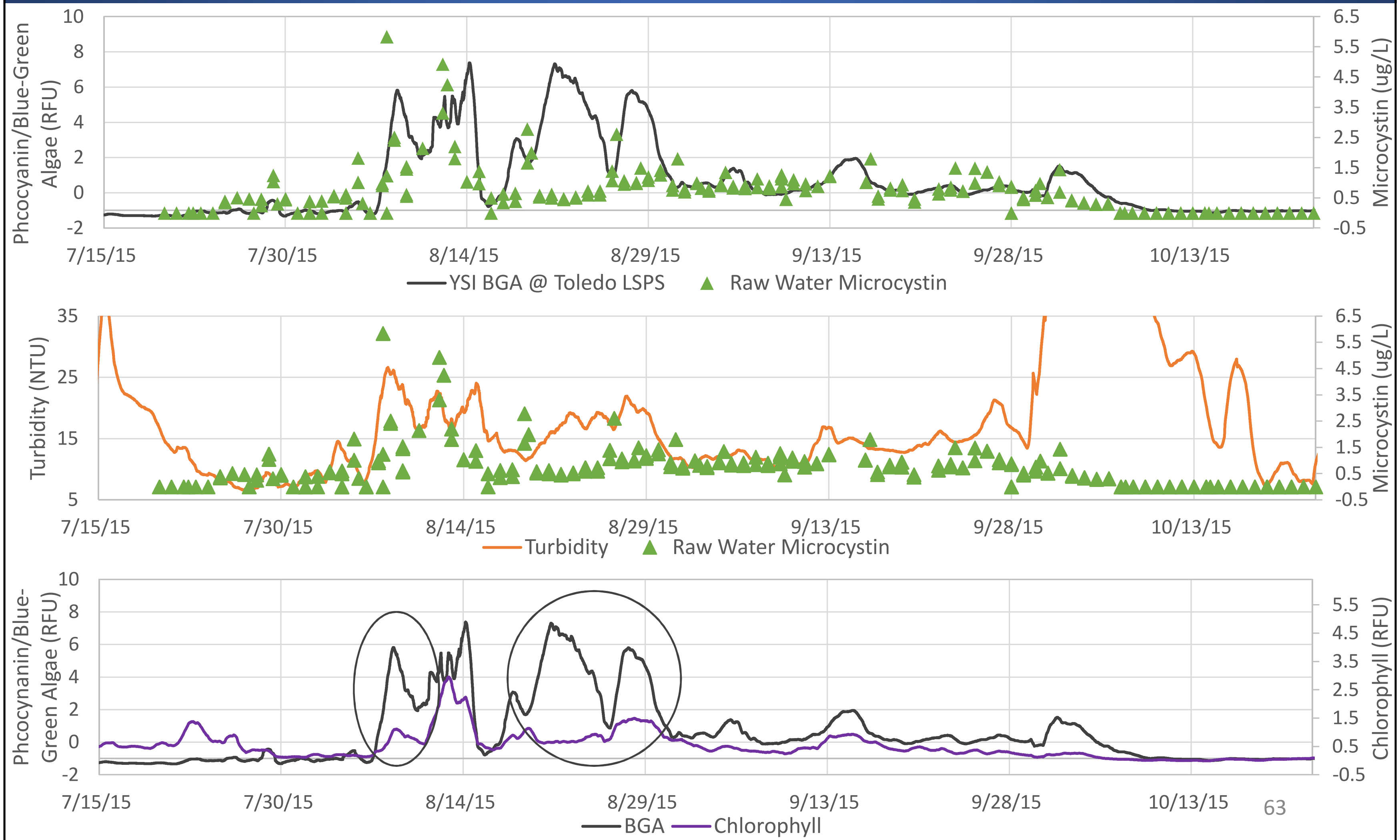


61

Near Real-Time Blue-Green Algae at the Ottawa County Intake

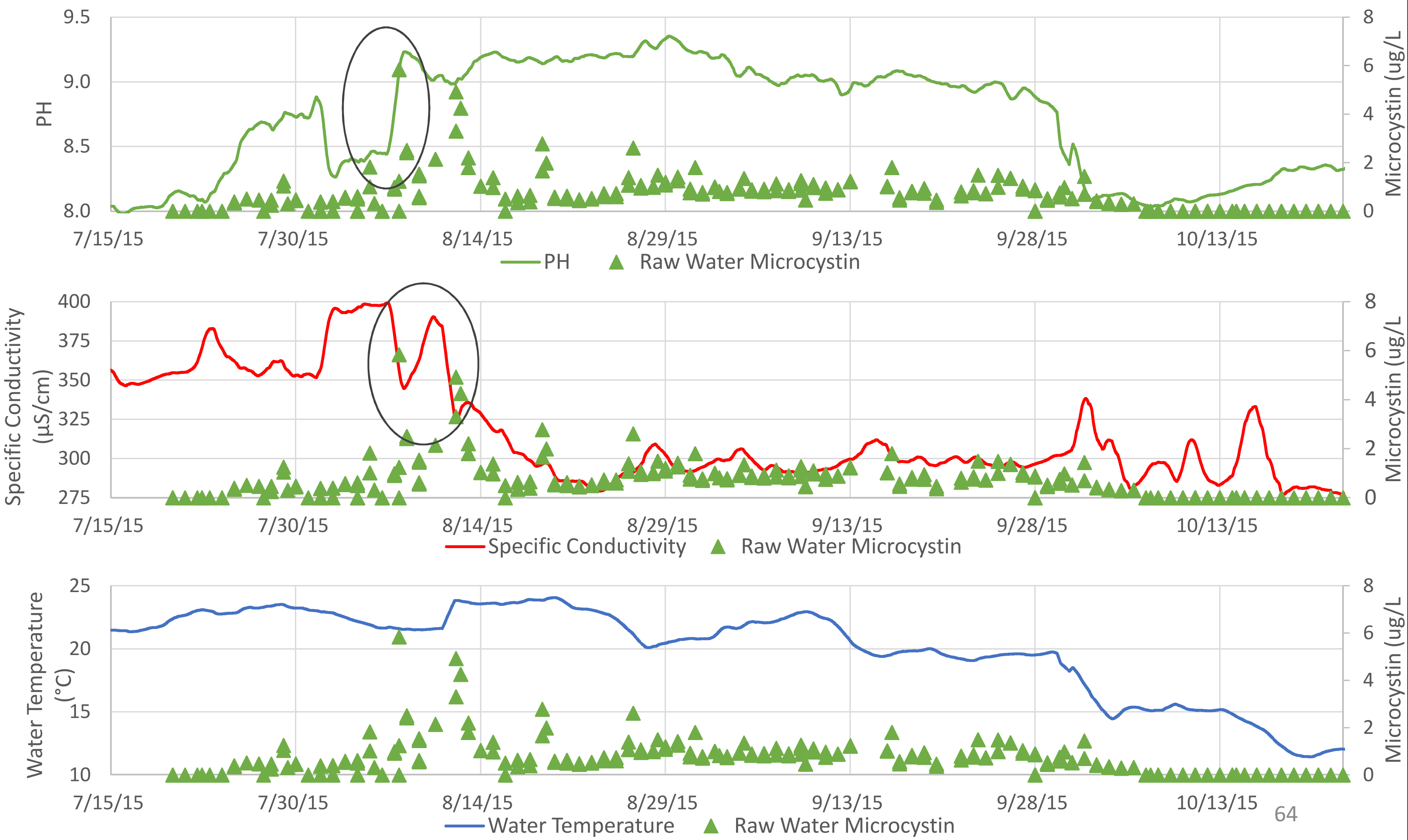


Toledo Intake
Real-Time Data vs Microcystin Samples



63

Toledo Intake
Real-Time Data vs Microcystin Samples



64

Panel 1 presentations
Nutrients

Justin Chaffin– Ohio State University

Nutrients and HABs

Justin Chaffin
Ohio State University
Stone Lab, Ohio Sea Grant
Chaffin.46@osu.edu

Images: J. Chaffin

Nutrients help us answer HABs questions

- Cyanobacteria biomass
  - External P loads and Cyanobacteria biomass in Lake Erie
  - Cyanobacteria collectively
- N-fixing genera vs. non-N-fixing genera
  - TN:TP or dissolved inorganic N concentrations
- Toxic strains vs. non-toxic strains of *Microcystis*
  - Bloom progression from toxic to non-toxic
- Why are there different genera, species, and strains occurring in different waters?

3 genera bloom forming cyanobacteria in Lake Erie

- Western basin and Sandusky Bay have similar N and P profiles (eutrophic)
  - N and/or P limited (Chaffin et al., 2013; Davis et al., 2015).
  - Different cyanobacteria… Other drivers such as light and hydrology
- Central basin low N an
  - Trace nutrient limitat
  - Evidence that HABs a

Microcystis in western basin

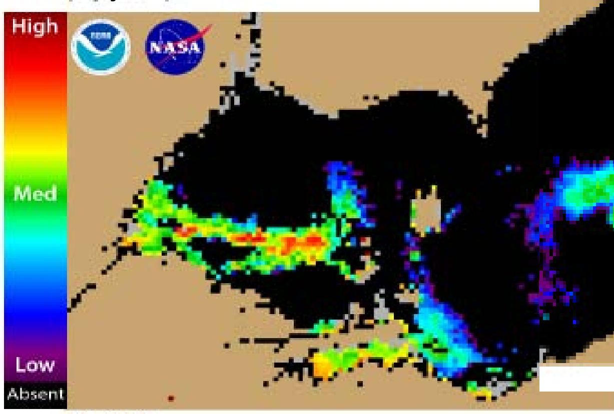
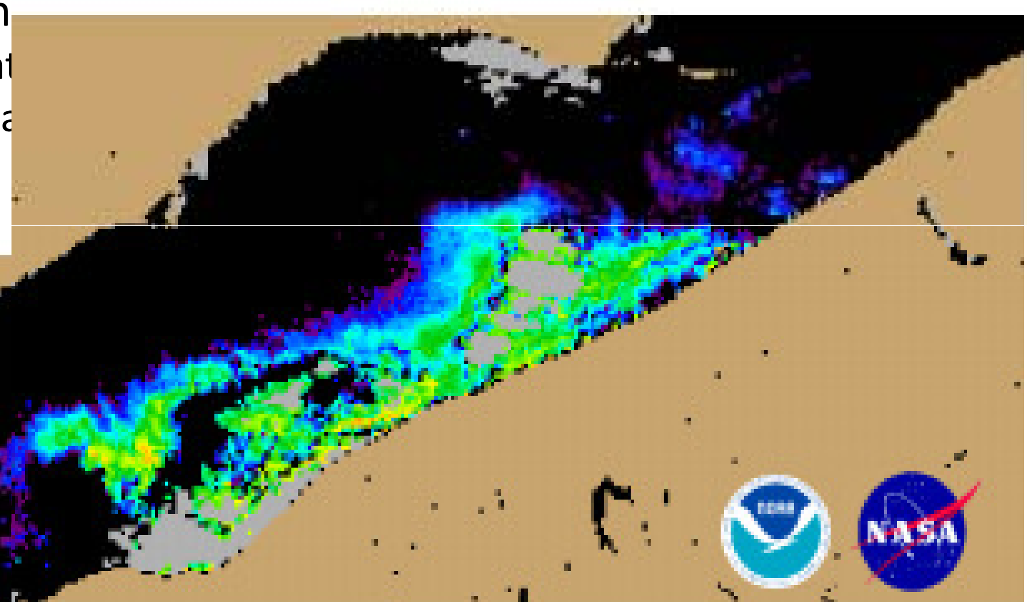


Figure 1A

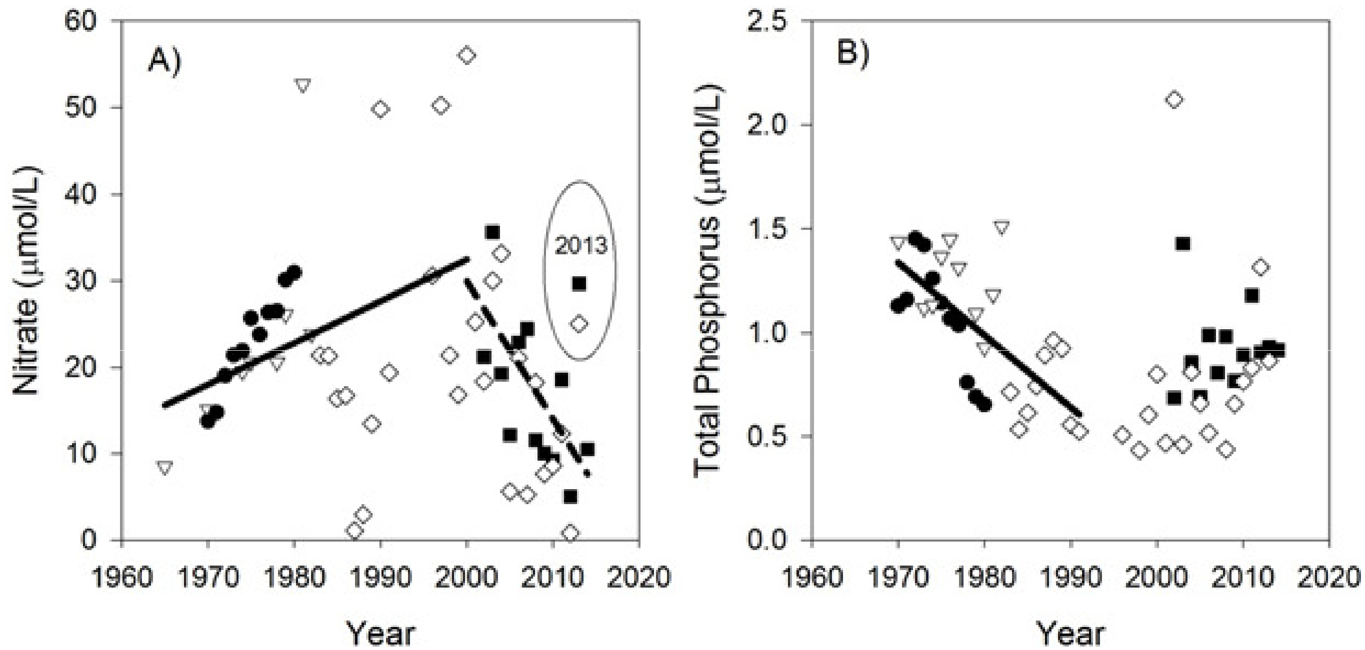
Planktothrix in Sandusky Bay



Dolichospermum (Anabaena) in central basin

NOAA HAB bulletin, July 15 2015

Long-term patterns of N and P in western LE



- Is the Lake trending towards more nitrogen limitation?
  - Impact on biomass or cyanobacteria community structure?
  - N-fixers vs non-N-fixers; Toxic vs non-toxic strains of *Microcystis*?
- July-September data from multiple sources
- Chaffin and Bridgeman unpublished

Nitrogen-HAB questions

- More forms than just nitrate
- Ammonium, organic N
  - Ammonium in lowest concentration because algae favorite N source
  - Impacts on biomass and toxin production? (Triggers, Toxicity discussions)
- Can models be used to predict N form and concentration, and ultimately microcystin production?
  - Assimilation and regeneration rates
  - River loads, Atmospheric deposition

Panel 1 discussion

Nutrients

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- **What is the contribution of nutrient cycling to bloom growth?**
  - Get at recycling rates
  - Dissimilatory processes also important
- Value in comparing different systems to understand how drivers are acting differently
  - What are the linkages between nutrients and other factors (e.g., light, temp, etc.) in HAB formation?
  - Myth: N is hard to control—
  - How are various triggers interacting within a system?
- **How do nutrients control species composition and strain?**
  - Role of oxygen /hypoxia in N and P and trace nutrient cycling
- **What is role of N in controlling Toxic vs non-toxic strains of *Microcystis*?**
- Role of carbon?
- How do we reduce the bloom and reduce the problem?

Panel 2 presentations *Toxicity*

Judy Westrick– Wayne State University

Human Health and Freshwater Cyanotoxins

Judy Westrick
Wayne State University
12/15/15
Inaugural Great Lakes HABs Collaboratory Meeting

73

Great Lake Cyanobacteria and Cyanotoxins-Knowns and Unknowns

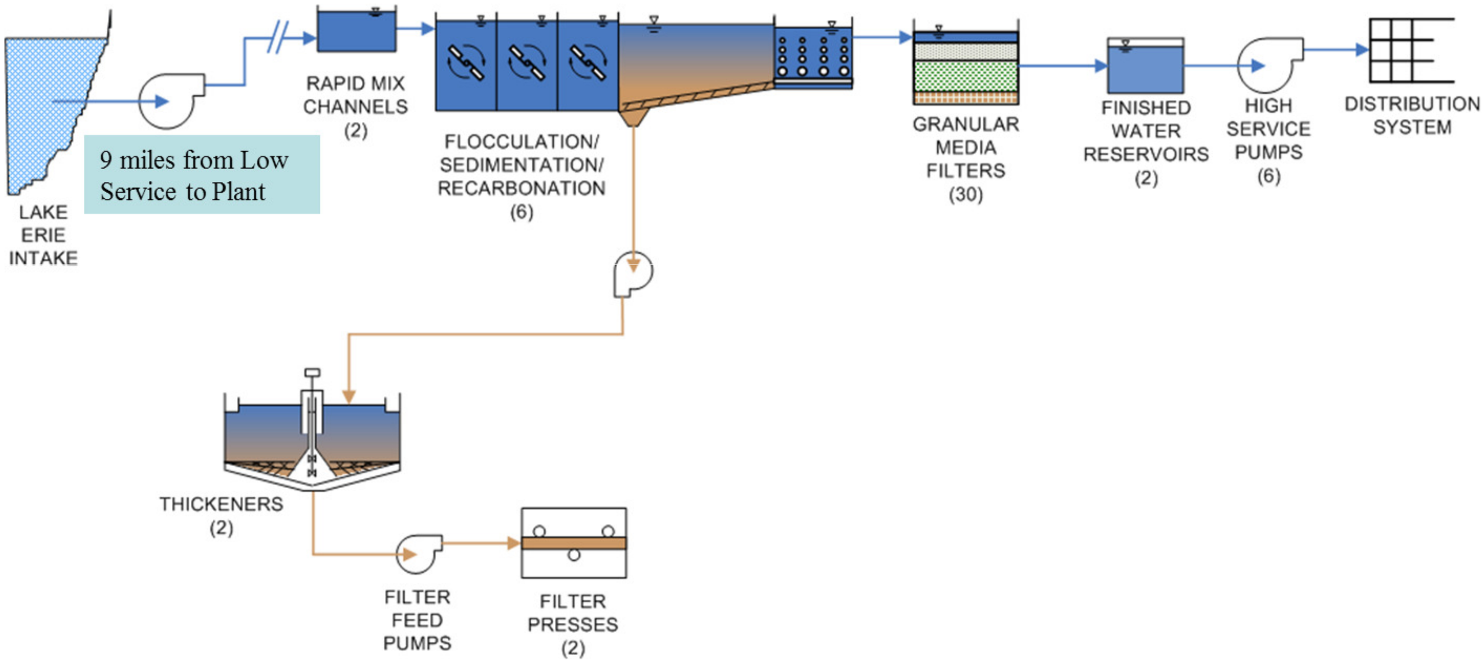
- Microcystin – yes
- Anatoxin-a – yes
- Saxitoxins – no, inland yes
- Cylindrospermopsin – no
- BMAA- ?
- Lyngbya – producing toxins?

Overview

- Great Lakes Cyanobacteria and their toxins
- Drinking water is the primary route of exposure
- US EPA Health Advisory
- Questions and Future Research

75

Drinking Water Primary Route of Exposure?



Toledo -Conflicting Clearwell Results

Microcystin ELISA (ADDA) 8/4/15	
Clear well	1.4 ppb
Plant tap	< 0.25 ppb

	RR	NOD	YR	LR	LA	LY	LW	LF
LC UPLC/High Resolution Mass Spectroscopy (method reporting limit 50 ng/L)								
Clearwell 8/3/14	nd	nd	nd	nd	nd	nd	nd	nd
Plant Tap 8/3/14	nd	nd	nd	nd	nd	nd	nd	nd
UPLC/Triple Quadrupole Mass Spectroscopy (method reporting limit 100 ng/L)								
Plant Tap	nd	nd	nd	nd	nd	nd	nd	nd

US EPA Health Advisory - 2015

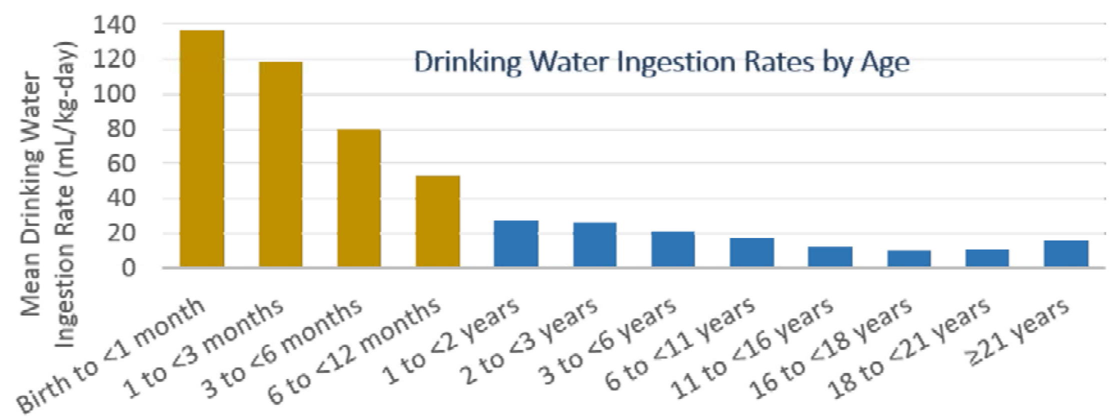
What is a Health Advisory

Infant

Safety Factors

*0.3 ug/L microcystin and 0.7 ug/L cylindrospermopin <6 years of age versus 1.6 ug/L microcystin and 3 ug/L cylindrospermopin >6 years of age

*10 days



78

Potential routes of exposure

- Dermal
- Inhalation of toxin in aerosols
- Ingestion during recreational activities
- Consumption in drinking water and food
- HEALTH EFFECTS RELATED TO EXPOSURE TO FRESHWATER CYANOTOXINS?
- EXPOSURE?
  – Not really known, preparedness and readiness.
- FATE?

Microcystin - Potential Ideas

Bioavailability/Bioaccumulation/Biomagnification

Tissue Culture - OATP

- Liver
- Blood–testis barrier
- Placenta
- Blood Brain Barrier

Classifying Groups

- LW and LF more toxic.
- OATP1B3 R(2^{nd}) /F, Y, Hty (4^{th})
- OATP1B1 L(2^{nd})

Basic Problems to Address

- Epidemiology Study – Areas with high exposure – biomarkers of exposure
- Case Study – Cyanobacteria Nutritional Supplements
- Bioavailability /bioaccumulation/ biomagnification in freshwater systems and aquaculture.
- Absorption and delivery to a target organ

Summary of Freshwater Cyanotoxins Risk Assessment

	Microcystin	Cylindrospermopsin	Anatoxin-a	Saxitoxin	Cocktail
Identify hazard	X	X	X	X	?
Dose Response	X	X	X	X	?
Exposure Assessment	/	/	/	X	?
Risk Characterization	/	/	/	/	?

Panel 2 presentations
Toxicity

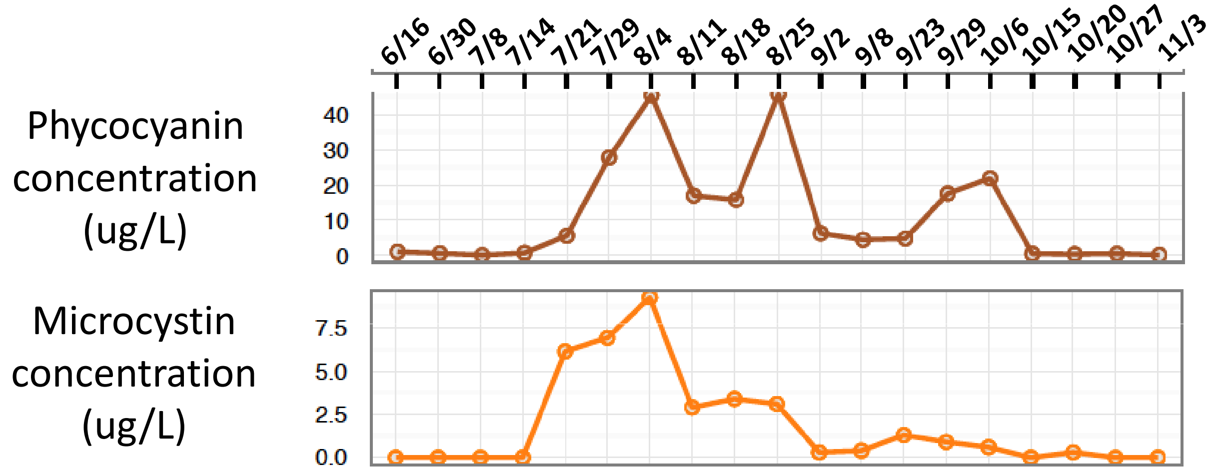
Greg Dick– University of Michigan

What are the microbial/environmental controls on toxin production?

Greg Dick
Department of Earth and Environmental Sciences
University of Michigan
gdick@umich.edu
Twitter: @umich_geomicro

What are the microbial/environmental controls on toxin production?

e.g., Lake Erie Toledo Water Intake Station (2014):



Physiological controls – environmental factors shape cellular toxin production
Ecological controls – community composition, i.e., the portion of the microbial community capable of producing the toxin.

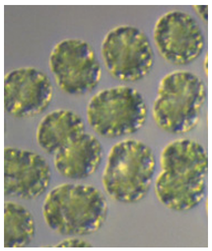
Results from Tim Davis, Tom Johengen in collaboration with Vincent Denef, Rose Cory, George Kling, Melissa Duhaime, and associated students, postdocs, and staff

1. What is the physiological/ecological function of the toxin?

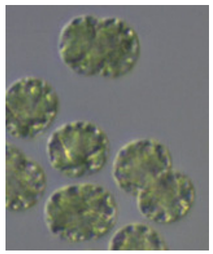
- Protection from grazing?
- Acquisition of iron (i.e., siderophore)?
- Protection from reactive oxygen species?
- What is the cellular "speciation" of the toxin (intracellular free vs. bound to protein vs. extracellular)?

→ A HABs collaboratory could help identify and link collaborators for tackling this question.

2. What controls the proportion of toxic vs. non-toxic cells in a community?

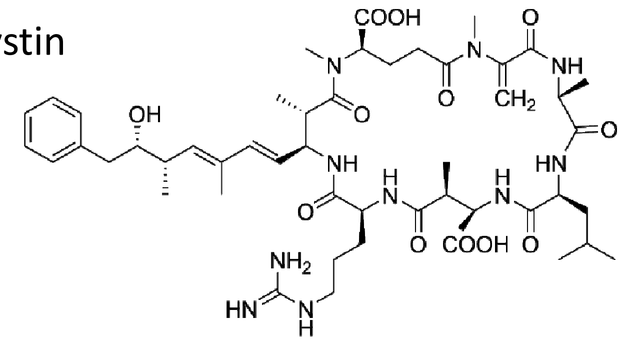


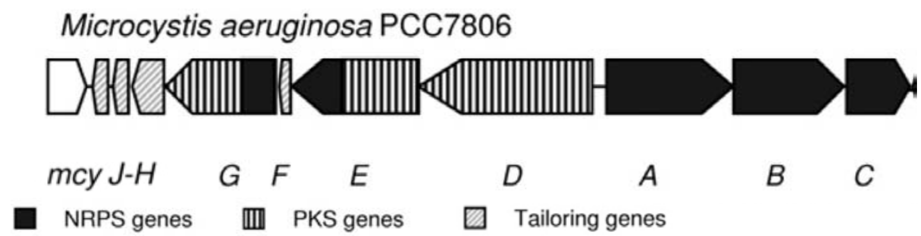
NIES1050
(toxic)



NIES44
(non-toxic)

microcystin





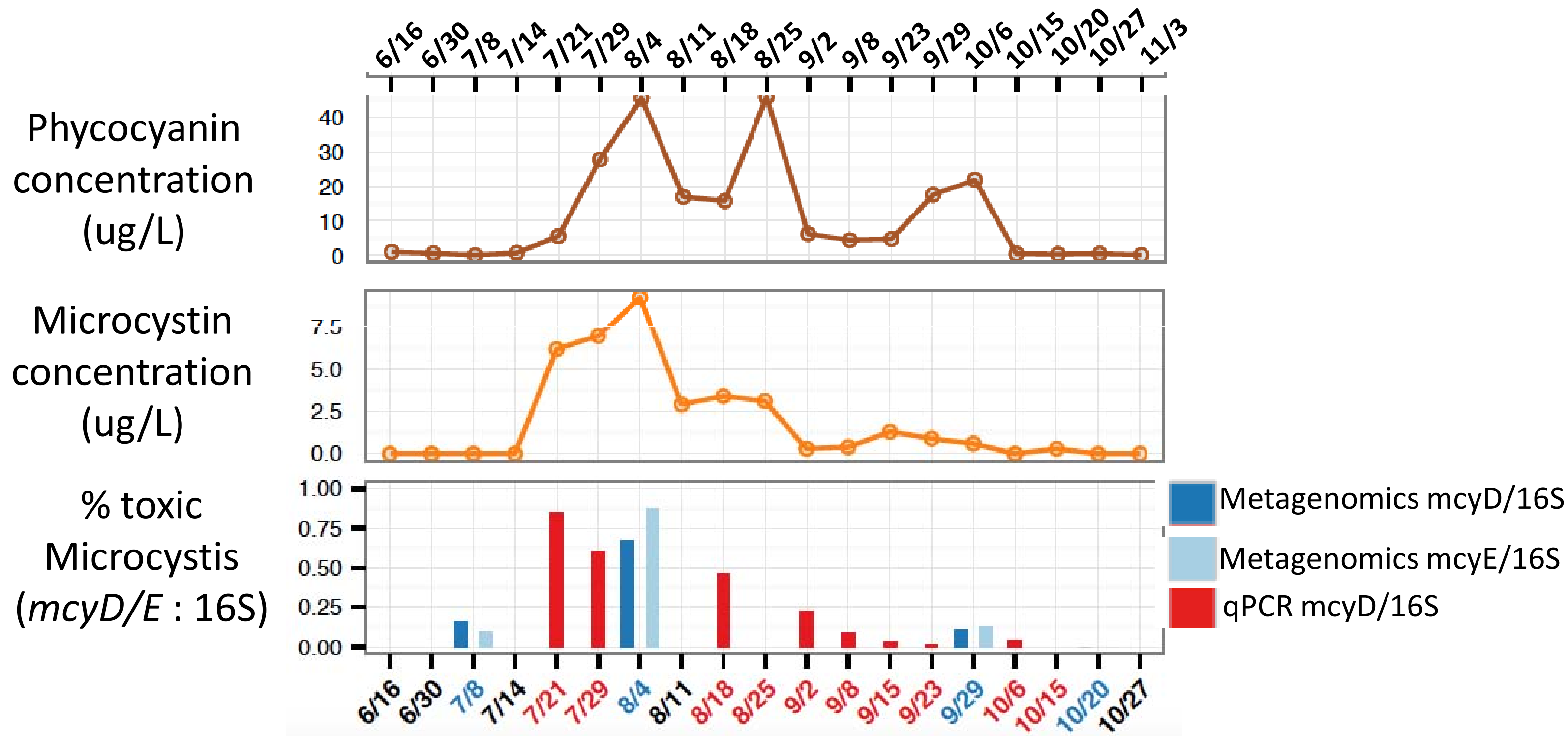
Kalaitzis et al., 2009

<u>Hypothesized factors</u>:

- Temperature
- Concentration and form of nutrients
- Light
- Reactive oxygen species (e.g., H_2O_2)

2. What controls the proportion of toxic vs. non-toxic cells in a community?

e.g., Lake Erie Toledo Water Intake Station (2014):



→ A HABs collaboratory could help to synthesize data relating environmental factors and strain abundance..

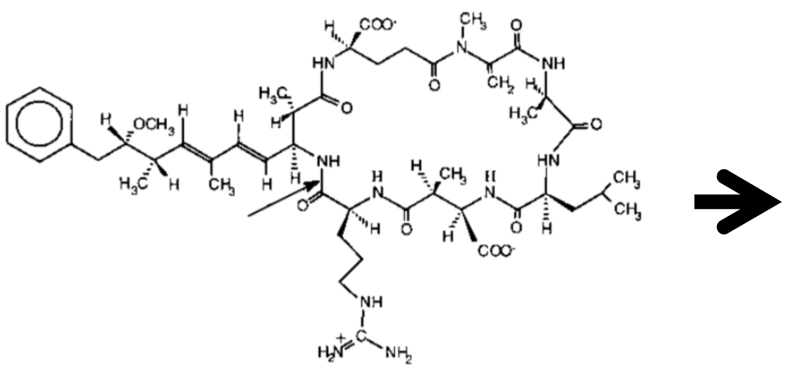
Results from Tim Davis, Tom Johengen in collaboration with Vincent Denef, Rose Cory, George Kling, Melissa Duhaime, and associated students, postdocs, and staff

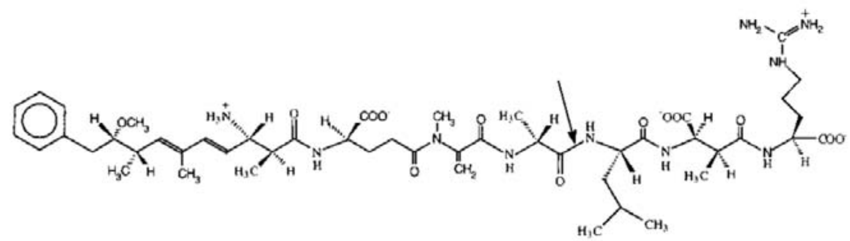
3. What is the environmental fate of the toxin?

- (Bio)chemical breakdown products
- Bacterial pathways for biodegradation
- Toxicity of breakdown products?

Enzymatic Pathway for the Bacterial Degradation of the Cyanobacterial Cyclic Peptide Toxin Microcystin LR

DAVID G. BOURNE,[1,2,3] GARY J. JONES,[2*] ROBERT L. BLAKELEY,[1] ALUN JONES,[4] ANDREW P. NEGRI,[2†] AND PETER RIDDLES[3]





Linearised Microcystin LR MW = 1012

Microcystin LR MW = 994

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Nov. 1996, p. 4086–4094

Panel 2 discussion

Toxicity

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- **Regional summary of what toxins present**
- Better human toxicology
- **Methods for toxin assessment to inform health decisions**
- What are toxin limits for chronic exposure? Risk assessment. Research for setting regulatory limits.
- Triggers for cell lysis and toxin release during drinking water treatment?
- Understanding non-drinking exposure
- Need for inter-calibration of various methods, current recommendation is to run each sample with at least 2 methods.
- What is the correct method for any given science question?
- Quantify uncertainty of any given method.
- What situations can cause a given method to give a positive result based on a non-toxic breakdown product?
- Are there modifications that will improve tests? Nested protocol.

- **Op. for within group summary and education (need people)**

Panel 2 discussion

Toxicity

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- Reason for producing toxin?
- What controls proportion of toxic to non-toxic?
- Toxin breakdown products and pathway?

Panel 2 presentations
Ecosystems / Food-webs

Joe Duris– U.S. Geological Survey

92

USGS Great Lakes Cyanobacterial Harmful Algal Bloom Research

USGS science for a changing world

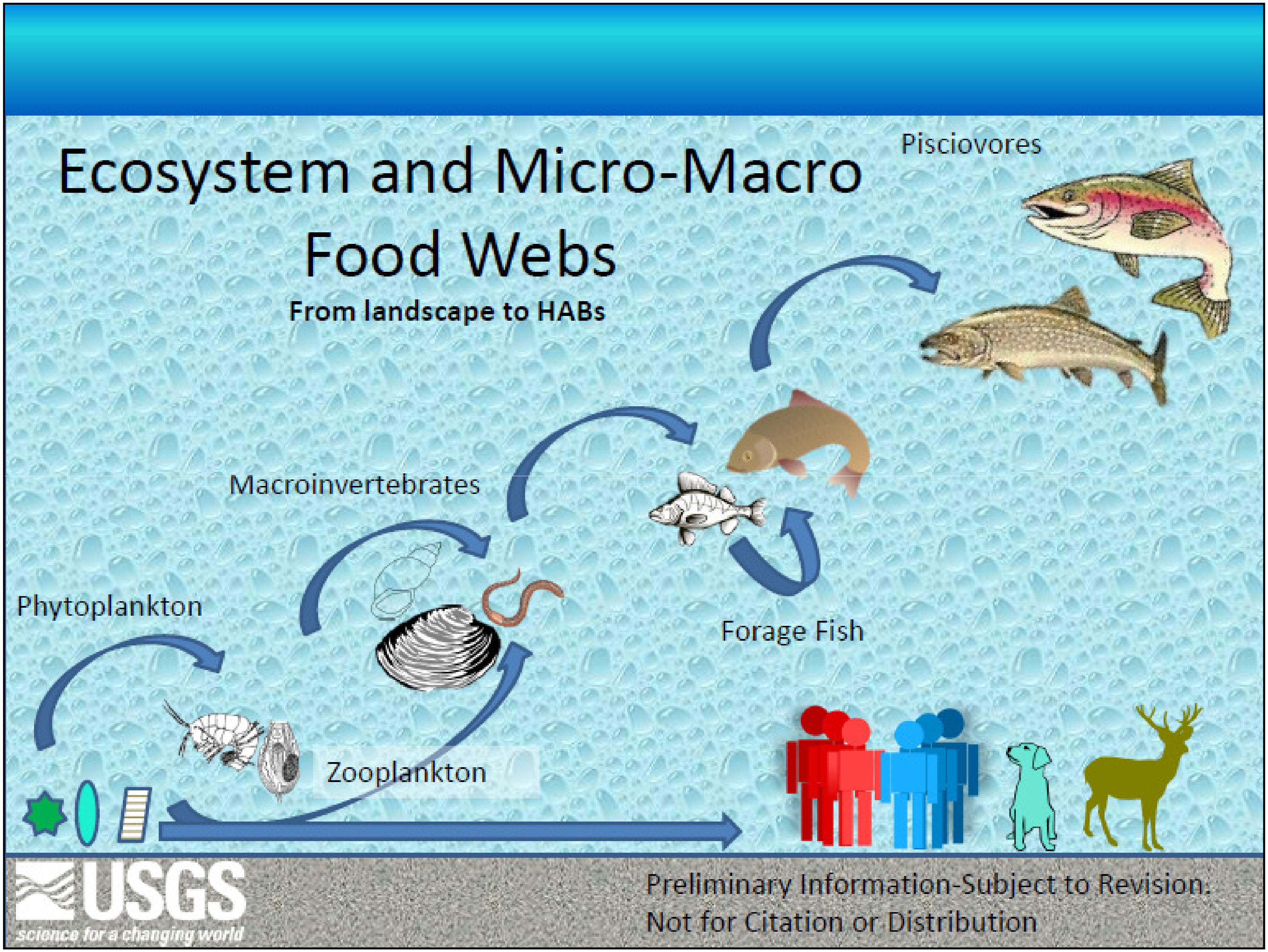
- Whole Ecosystem
  - Edge of fields and pipes
  - In stream processing
  - Accurate/rapid load estimation
  - River mouth/nearshore
  - Open lake ecology

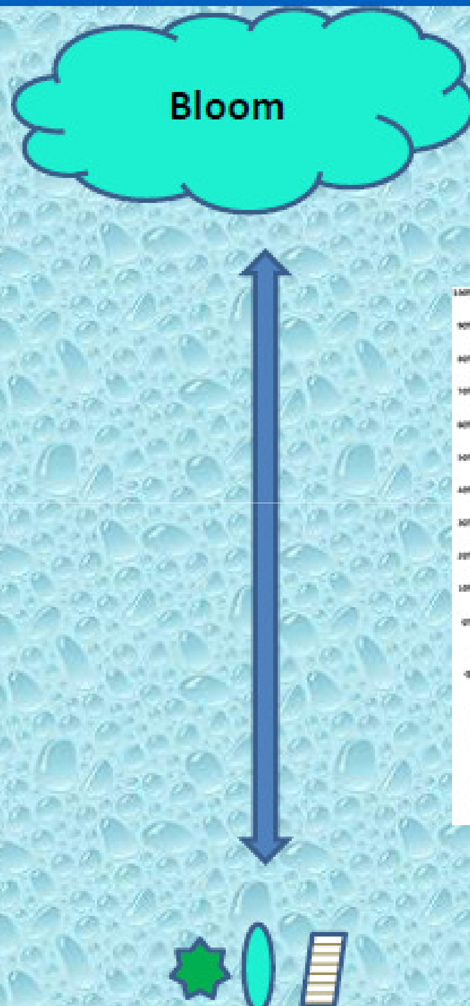
Joseph W. Duris[1], Carrie Givens[1], Erin Stelzer[2], Chris Ecker[2], James Larson[3], Keith Loftin[4], Pete Lenaker[5], Mary Anne Evans[6]

[1]USGS Michigan Water Science Center; [2]USGS Ohio Water Science Center; [3]USGS Upper Midwest Environmental Sciences Center; [4]USGS Kansas Water Science Center; [5]Wisconsin Water Science Center [6]USGS Great Lakes Science Center

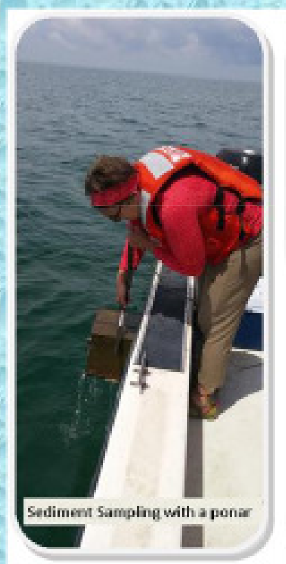
USGS

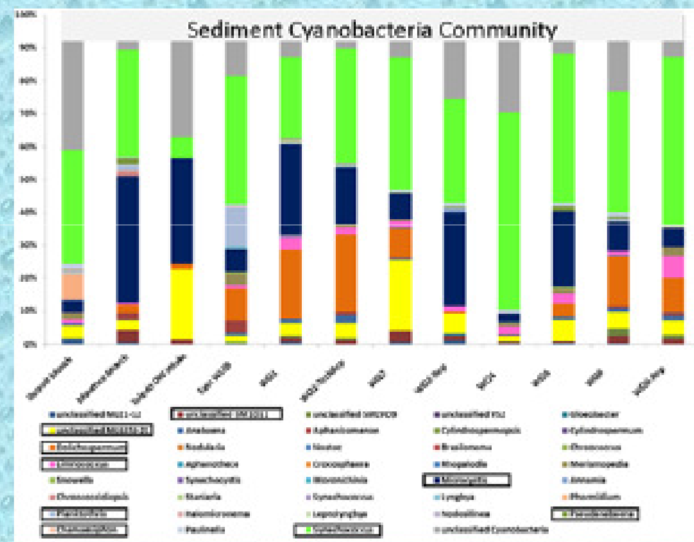
93


Ecosystem and Micro-Macro
Food Webs
From landscape to HABs
Pisciovores
Macroinvertebrates
Phytoplankton
Forage Fish
Zooplankton
USGS
science for a changing world
Preliminary Information-Subject to Revision.
Not for Citation or Distribution



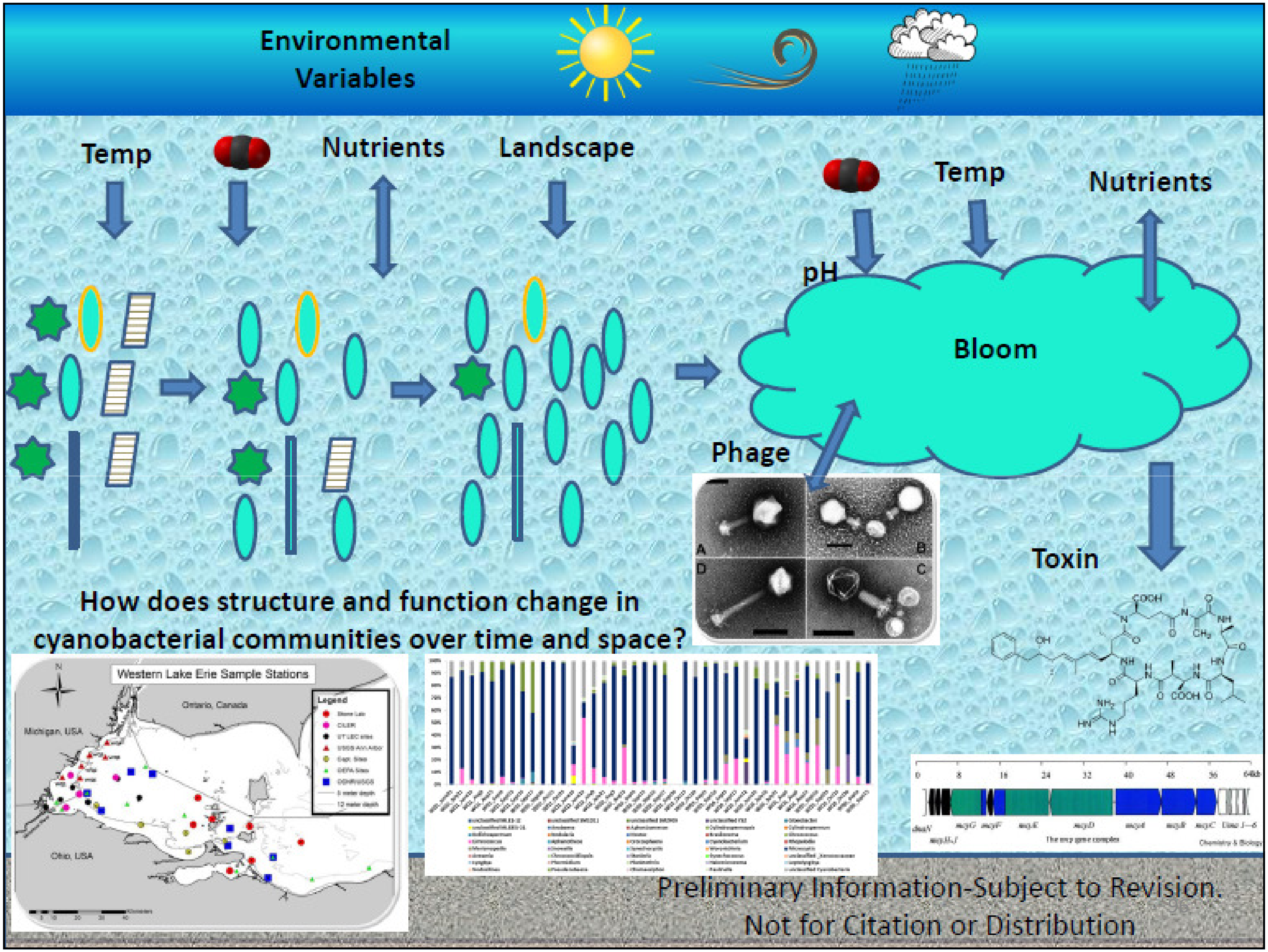
Does sediment seed next year's bloom?





USGS
science for a changing world

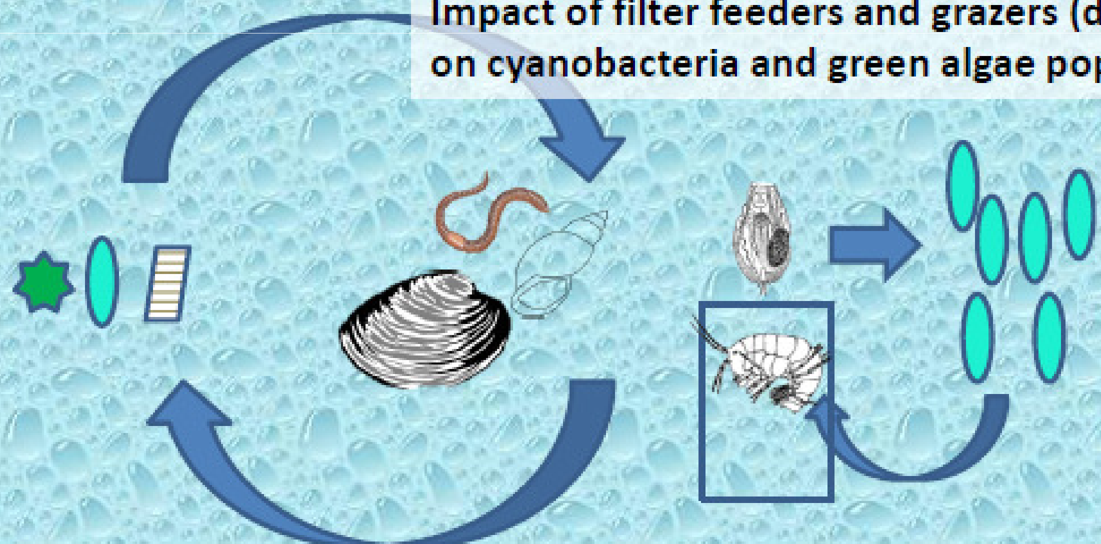
Preliminary Information-Subject to Revision.
Not for Citation or Distribution



Environmental Variables
Temp
Nutrients
Landscape
pH
Temp
Nutrients
Bloom
Phage
Toxin
How does structure and function change in cyanobacterial communities over time and space?
Western Lake Erie Sample Stations
Ontario, Canada
Michigan, USA
Ohio, USA
Legend
Preliminary Information-Subject to Revision.
Not for Citation or Distribution

Impact of cyanobacteria enrichment on primary and secondary production?

Impact of filter feeders and grazers (dreissenid mussels) on cyanobacteria and green algae populations?

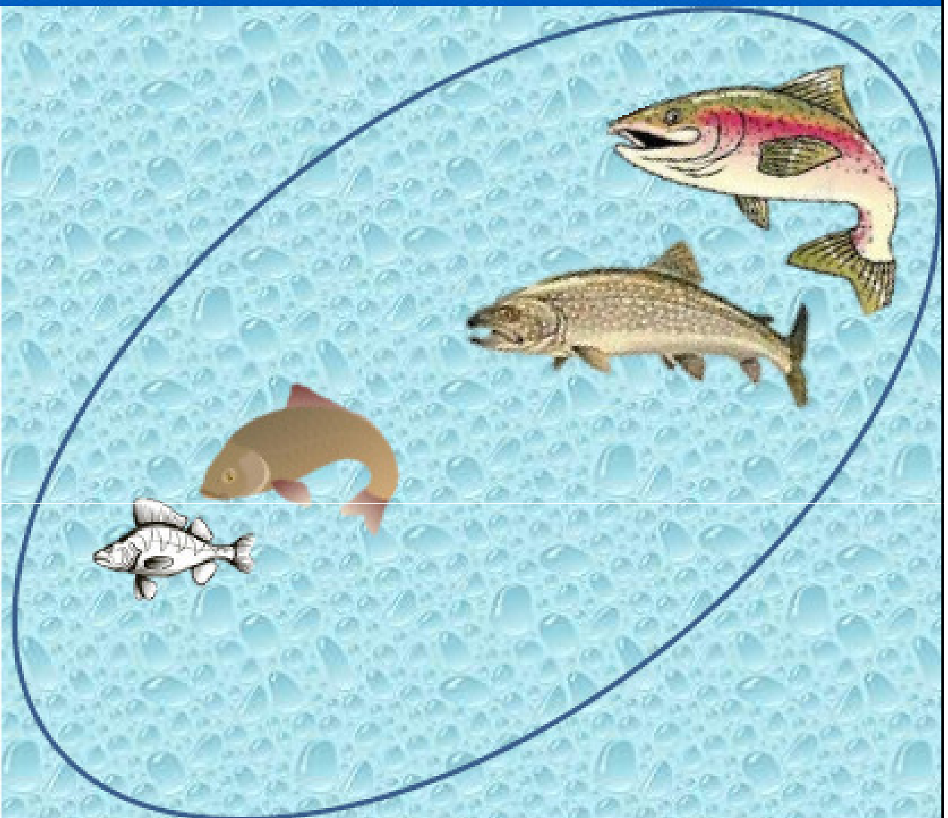


USGS
science for a changing world

Preliminary Information-Subject to Revision.
Not for Citation or Distribution

Gaps

- Relation to:
  - Fish health
  - Human health
  - Wildlife/animal health
- Climate change
- CECs/Pesticides
- Great lakes cyanobacterial sequences
- Internal loading
- Deposition loading



Preliminary Information-Subject to Revision.
Not for Citation or Distribution

Panel 2 presentations
Ecosystems / Food-webs

Tomena Scholze– Michigan State University

(No slides)

Panel 2 discussion

Ecosystems / Food webs

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- Questions?
- does the composition of one year's bloom effect next year's bloom
- **How does feeding and growth of fish and zooplankton change in vs out of bloom area and before vs during vs after a HAB? Are different life stage affected differently?**
- **Effect on secondary production**
- Fish can be a key topic for communication
- **effect of HABs on hypoxia** (*and the other way around*)
- effects of HABs on littoral zone SAV
- coupling of benthic and water column
- **shift of energy from grazing to detrital food web due to grazing resistance (not a toxin effect, turb., size)**
- Cyano blooms "attract" other microbes
- other toxins and secondary metabolites

Panel 2 presentations *Management*

Beth Hinchey Malloy– U.S. Environmental Protection Agency

101

H.R. 212

- On August 7th, 2015, the President signed H.R. 212 (Drinking Water Protection Act)
- Amends the SDWA, adding Section 1459
- Directs EPA to develop and submit a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems
- Includes steps and timelines to asses:

  Human health effects, list of algal toxins, health advisories, treatment options, analytical and monitoring approaches, causes of HABs, source water protection, and collaboration and outreach.

- Identifies information gaps and publishes information from each federal agency that has examined algal toxins.

102

H.R. 212 Strategic Plan

- *Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water*
- Developed with input from:
  - Regional offices, ORD, and OW
  - Federal partners, including the Interagency Working Group established by HABHRCA Amendments of 2014
  - Stakeholders through a listening session webinar
- Submitted to Congress Nov. 5, 2015

Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water

Strategy Submitted to Congress to Meet the Requirements of P.L. 114-45

Product of the
United States Environmental Protection Agency

November 2015

103

Management Needs

Data Sharing

- Establish a national database for freshwater HABs, cyanotoxin, and effect occurrence (e.g. fish kills) and incident reporting of illnesses or deaths in animals or humans.
- Generate commonalities among the HABs and cyanotoxin data and standardize advisories posting and notification protocols.

Cost and Resources

- Evaluation of the economic impacts, including monitoring costs, treatment and management of blooms in surface water and drinking water, and public health advisories postings.
- Status of federal initiatives and funding opportunities.

Management Needs

Research

- **Human and Ecological Health Effects:** more information on human health adverse effects from exposure to recreational and drinking water, fish consumption, and for occupational health and safety. Also, more information on the effects of cyanotoxins on aquatic animals, pets, irrigated agriculture and damage to crops and livestock.
- **Climate Change:** need to understand climate effects on HABs/cyanotoxins at a regional scale to help water systems prepare for potential blooms that could occur due to changes in regional climate.
- **Management of HABs in surface water:** evaluation of the effectiveness of current watershed protection practices (both short-term and long-term practices) that will help with the development of best management practices within a source water's watershed.
- **Drinking Water Treatment:** evaluation of the effectiveness of treatment techniques in PWS.

EPA R5 Harmful algal bloom CWA/SDWA workshop

- Spring 2016 in Chicago, IL
- Possibility of public meetings afterward (HQ sponsored)
- Contact:

Wendy Drake
US EPA Region 5
Water Division, Ground Water and Drinking Water Branch
312-886-6705
drake.wendy@epa.gov

Managing Expectations and Communicating Success

- Algal blooms could take a long time to control, a lot of variables involved (many out of our control)
- Annex 4 has updated binational P targets and is now developing Domestic Action Plans
- We have operational HABs forecasts (seasonal and weekly)
- We have greatly improved monitoring in the watersheds and in the lakes
- We have protocols in place to reduce risk to public health from exposure to cyanotoxins

Contact Information

Lesley V. D'Anglada, Dr.PH

202-566-1125

danglada.lesley@epa.gov

Beth Hinchey Malloy

312-886-3451

hinchey.elizabeth@epa.gov

EPA's CyanoHABs Website

www.epa.gov/cyanohabs

Panel 2 presentations *Management*

Sonia Joshi – CILER-University of Michigan

Identifying and Assessing Needs of Management Community

Panel 2- HABs Collaboratory meeting

Sonia Joshi
Outreach and Communications Specialist
CILER/ NOAA GLERL

110

Bridging gaps

- Missions/ priority of work differs between managers and scientists
- Takes time
- Knowledge vs. education

- Needs assessments, focus groups, surveys
- Managing expectations

GLERL Great Lakes Environmental Research Laboratory

CILER Cooperative Institute for Limnology and Ecosystems Research

111

Key Research Questions/ Needs

- Is this water toxic?
- How can we reduce blooms?
- Is it safe to eat LE fish?
- What do I do with all this data?

- Rapid test to determine toxicity: Dip stick method

GLERL Great Lakes Environmental Research Laboratory

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

CILER Cooperative Institute for Limnology and Ecosystems Research

112

Management Needs

Data Sharing and Communication

- Development of approaches for open communication and engagement between stakeholders for better cooperation and support for water quality management practices.
- Better understanding of risk communication in the context of risk management, including understanding different scenarios such as short duration exposures or low levels of exposures.
- Development of training tools to assist in answering the key questions such as cyanotoxin-producing blooms, and preventing the toxins from reaching finished water. Also, provide training on how to handle communication situations and on response measures to cyanotoxin occurrence.
- Tasking stock of lessons learned - what was tried, what worked and did not work.

GLERL Great Lakes Environmental Research Laboratory

NOAA

CILER Cooperative Institute for Limnology and Ecosystems Research

Panel 2 discussion

Management

What are the 1-3 top questions that can be worked on through the HABs Collaboratory?

- Human health effects? Exposure path?
- Climate change effects on HABs?
- What is the set of management decisions that can change the situation?
- do we have something to contribute to the 2016 workshop?
- How to best communicate both what we know and what we do not?
  - We could host an interactive web site, smart phone ap for bloom maps, maps for specific questions (eat fish, swim, etc), myth buster web site for GL HABs,
- Importance of including local experts. Clear expectations for how involved they will be?
- Monitoring and modeling for adaptive management

- Is it safe to eat the fish?
- Is water safe to drink?
- Need for a rapid test

Strategic Discussion

- Identify 2-3 top questions that can be addressed through the HABs Collaboratory
- What specific activities will the HABs Collaboratory undertake to answer those questions?
- What is the timeline to implement those activities?
- Who will participate and/or lead each activity?

Strategic discussion
Suggestions of steps

- What are the next steps to answer those questions?
  - Webinars
  - Collab papers/ posters
  - Grant proposals/funding opportunities
  - Outreach?
  - Data and analysis sharing opportunities
- Who are the champions for each question?

Top questions for each topic

Triggers

- Why are triggers important?
  - Triggers of toxicity or triggers of Microcystis?
  - Seeding from previous years
- Do triggers differ across systems and time?
- How much do we need to reduce N loadings to eliminate HABs?
  - Do legacy inputs affect results?
  - Holding of P over months—implications?
  - Resuspension: is it a source of cells of nutrients or both (cells and nutrients)

Ecosystems / Food webs

- How does feeding and growth of fish and zooplankton change in vs out of bloom area and before vs during vs after a HAB? Are different life stage affected differently?
- Effect on secondary production
- effect of HABs on hypoxia
- shift of energy from grazing to detrital food web due to grazing resistance (not a toxin effect, turb., size)

Nutrients

- What is the contribution of nutrient cycling to bloom growth?
- How do nutrients control species composition and strain?
- What is role of N in controlling Toxic vs non-toxic strains of Microcystis?

Toxicity

- Op. for within group summary and education
  - Regional summary of what toxins present
  - Methods for toxin assessment
- Reason for producing toxin?
- What controls proportion of toxic to non-toxic?
- Toxin breakdown products and pathway?

Management/ communication

117

HABHRCA Session

Timothy Davis – NOAA-GLERL

Great Lakes Plan: Tools for Engagement

- Involve wide group of stakeholders
  - Allows for inclusive input
  - Evolving process/plan
- Focus on HABs and hypoxia, through:
  - Improving scientific understanding
  - Modeling and prediction
  - Mitigating the causes/effects
  - Socioeconomics

Input opportunities:

- Annotated bibliography – *1st step*
- Webinars
- Focus on state of the science for the Great Lakes
  - Improving Scientific Understanding
  - Mitigating the Impacts of HABs and Hypoxia
  - Socioeconomics
  - Prediction and Modeling
- Fed POC, but looking for outside partners, contributors
- Email blast when ready to go
- IWG-HABHRCA@noaa.gov

120