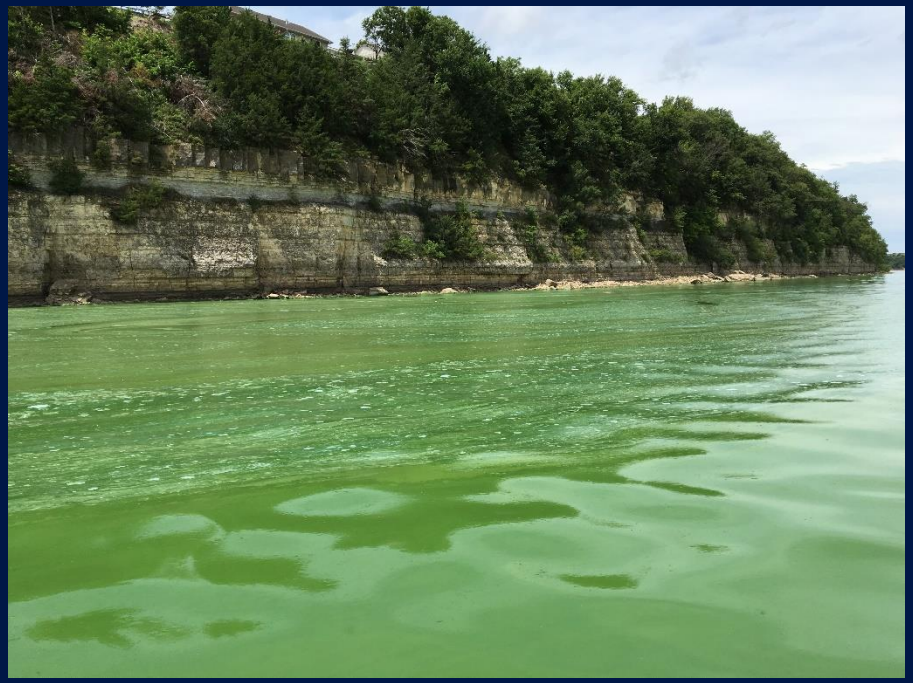
Cyanotoxins: Advancing Drinking Water Science to Protect Human Health



Jennifer L. Graham and Keith A. Loftin

U.S. Geological Survey

Ruth Briland

Ohio Environmental Protection Agency

ASDWA 2018 Webinar Series

July 2, 2018

OBJECTIVES

- Provide background information on cyanotoxins.
- Describe approaches used to study cyanotoxins to better understand occurrence, risks to human health, and development of tools to guide decision making.
- Discuss prevalence of cyanotoxins in surface waters and potential for exposure.
- Identify technologies that may enhance source-water monitoring programs.

We need a common language when communicating about harmful algal bloom science

- What puts the "H" in HAB?
  - Algae and cyanobacteria cause human, ecosystem, and economic health concerns but "harm" is often not quantified
  - Abundant algae and cyanobacteria are not inherently harmful – adverse impacts must be carefully defined
- What are Algae?
  - "Algae" no longer has any real taxonomic meaning
- What is a Bloom?
  - Rapid increase in biomass
  - Extremely high cell densities
  - Dominance
  - Visual accumulation

We need to learn to be as specific as possible in our communications

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Biological phenomena in surface waters, such as cyanobacteria, can cause drinking-water treatment challenges

Changes in Water Quality

- Increased biomass
- Elevated pH
- Diurnal swings in pH and dissolved oxygen
- Increased turbidity

Metabolites and Degradates

- Taste-and-odor causing compounds
- CYANOTOXINS
- Degradation by-products (DBPs)

Economics

Treatment Concerns

- Filter clogging
- Increased carbon feed
- Increased oxidant demand
- Blending or switching sources
- Providing an alternate supply

Human-Health Concerns

- Exposure to cyanotoxins
- Exposure to DBPs

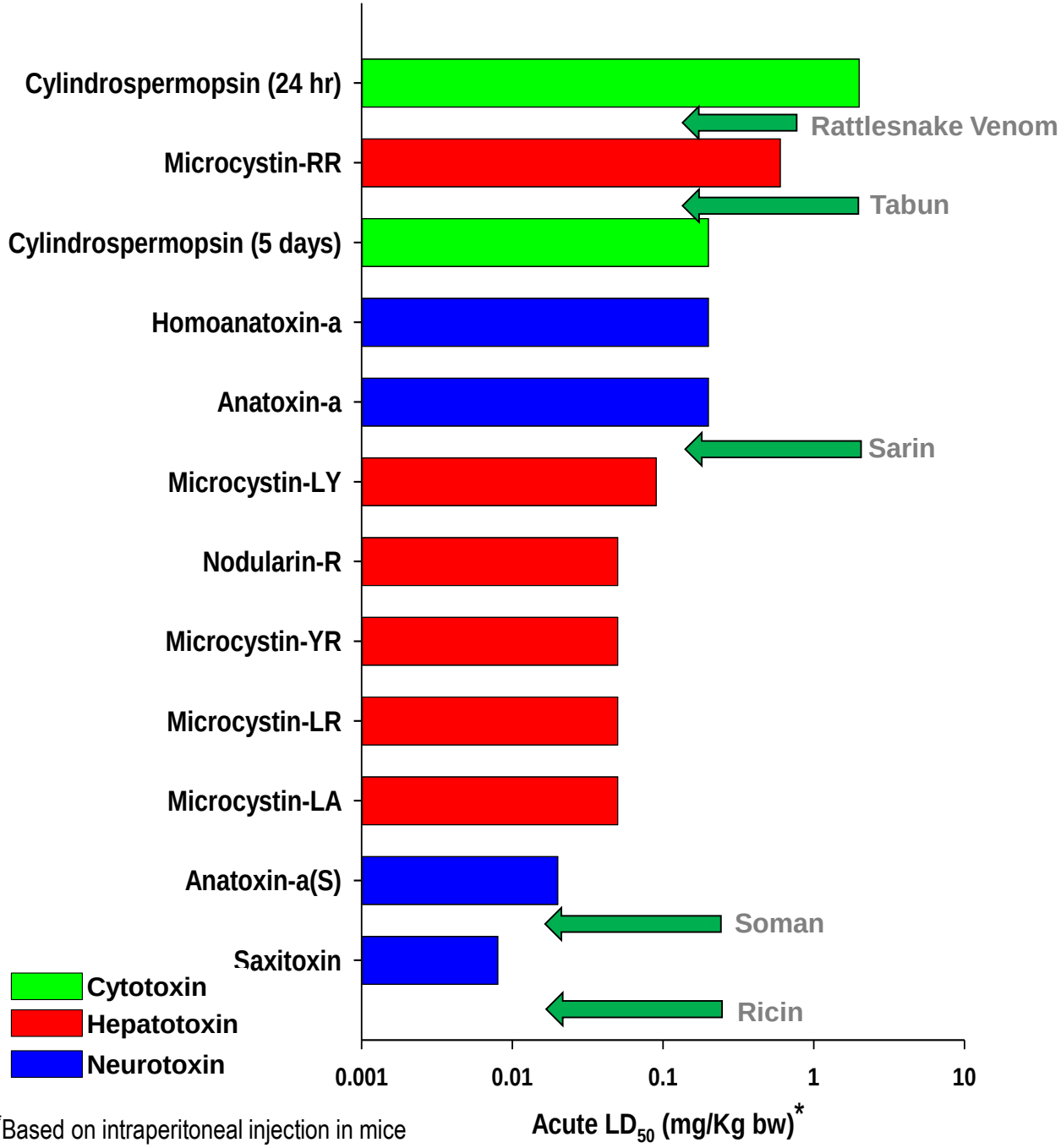
Toxicity of known cyanotoxins

Acute Toxicity

- Cytotoxic
- Neurotoxic
- Hepatotoxic
- Dermatoxic
- Respiratory Distress

Chronic Toxicity

- Carcinogen
- Tumor Promotion
- Mutagen
- Teratogen
- Embryolethality



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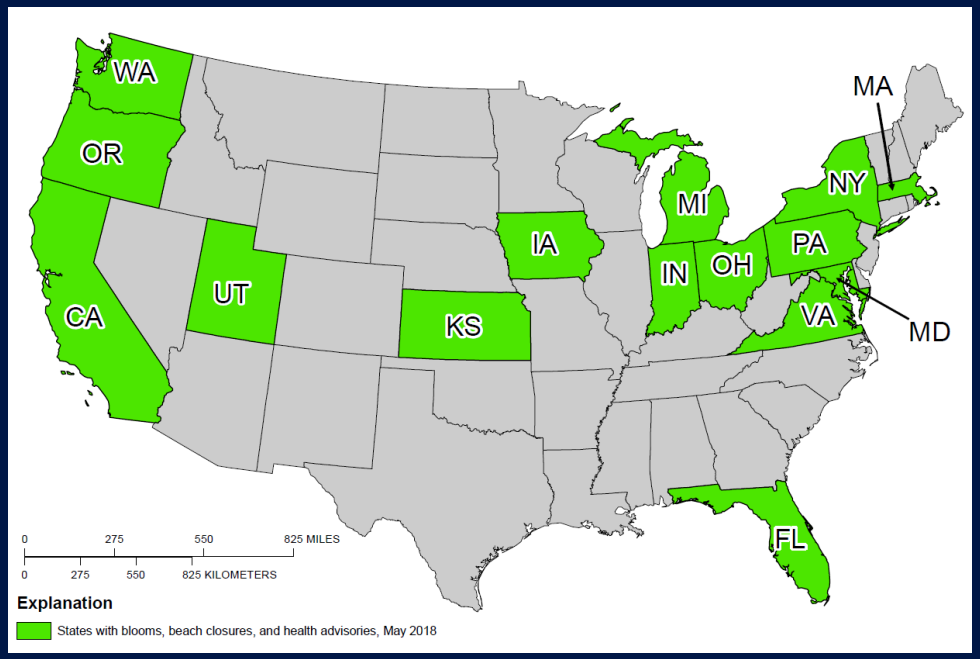
2015 USEPA health advisory values for microcystin and cylindrospermopsin in finished drinking water

Cyanotoxin Health Advisory Levels - 10 Day Average Exposure

	Bottle-fed infants and pre-school kids	School-age kids and adults
Microcystins	0.3 ug/L	1.6 ug/L
Cylindrospermopsin	0.7 ug/L	3.0 ug/L

https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations#what2
https://www.epa.gov/sites/production/files/2017-06/documents/cyanotoxin-management-drinking-water.pdf

Data to quantify cyanotoxin exposures and human health effects through drinking water are sparse



In May 2018, at least 15 states had recreational beach closures or health advisories associated with cyanotoxins in lakes and rivers.

Cyanotoxin breakthrough in DWTP (* - denotes an advisory)

- Toledo, OH (2014) *
- Ingelside, Texas (Jan/Feb 2016)
- Des Moines, IA (Aug 2016) *
- Cayuga County, NY (Sept/Oct 2016)
- Salem, OR (May 2018)*

Cyanobacteria bloom entered DWTP

- Norton, KS (June 2018) – resulted in switch to GW (toxin results pending)

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After USEPA Freshwater HAB News, May 2018
Personal Communication, Lesley D'Anglada, US EPA 6/20/2018

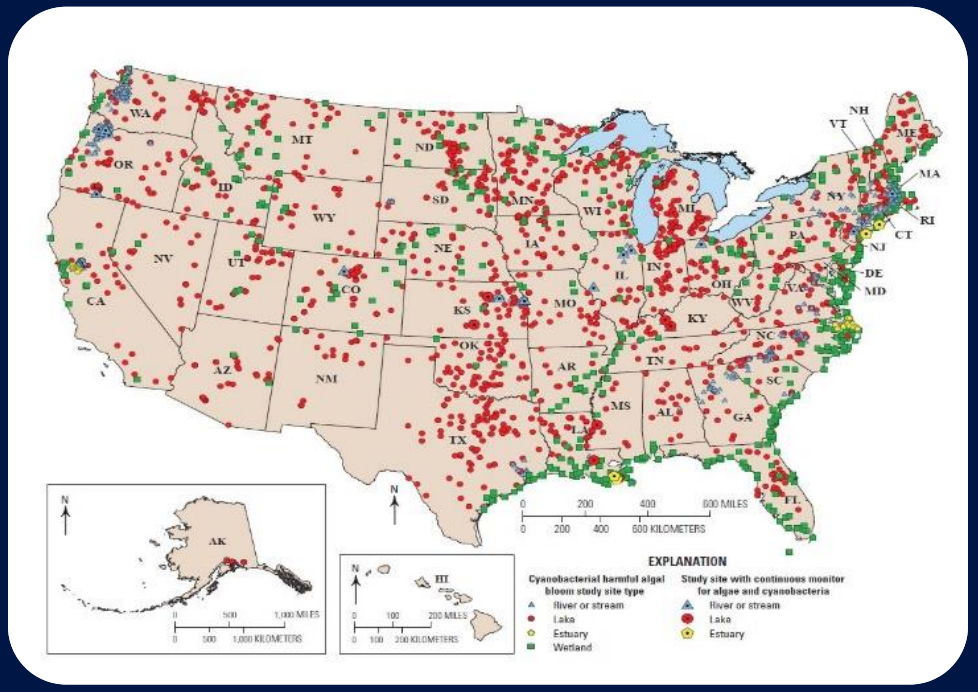
USGS cyanotoxin occurrence collaborations

Lakes and Reservoirs

- 2006 USGS Midwestern Lake Reconnaissance
- 2006, 2017-2018 USGS Texas Reconnaissance
- 2007 EPA National Lakes Assessment
- 2012 USGS Illinois Reconnaissance
- 2014-2017 USGS GLRI Lake Erie
- 2015 EPA National Coastal Assessment (Great Lakes)

Wetlands

- 2011 EPA National Wetlands Assessment
- 2016 EPA National Wetlands Assessment



Graham and others, 2016, USGS OFR 2016-1174
http://dx.doi.org/10.3133/ofr20161174

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USGS cyanotoxin occurrence collaborations (cont.)

Estuaries

- 2012-2014, 2017 USGS Albemarle Sound, NC
- 2015 EPA National Coastal Assessment
- 2016 - 2019 NOAA MERHAB

Wadeable Streams

- 2013/2016 USGS Midwestern Stream Quality Assessment
- 2014 USGS Southeastern Stream Quality Assessment
- 2015 USGS Pacific Northwest Stream Quality Assessment
- 2016 USGS Northeastern Stream Quality Assessment
- 2017 USGS California Stream Quality Assessment

Rivers

- 2017-2018 NAWQA Fixed Site Pilot Study

USGS capabilities: field and laboratory methods

- Guidelines for Nationally Consistent Science
  https://water.usgs.gov/owq/FieldManual/Chapter7/7.5.html
- Robust and Quantitative Analytical Methods for Cyanotoxins in Water, Tissues, and Sediment
  https://pubs.usgs.gov/of/2008/1341/
  https://pubs.er.usgs.gov/publication/ofr20101289
- Morphological Taxonomy
  https://pubs.er.usgs.gov/publication/ofr20151164
- Molecular Methods
  https://doi.org/10.3133/sir20135189
- Other Developing Approaches

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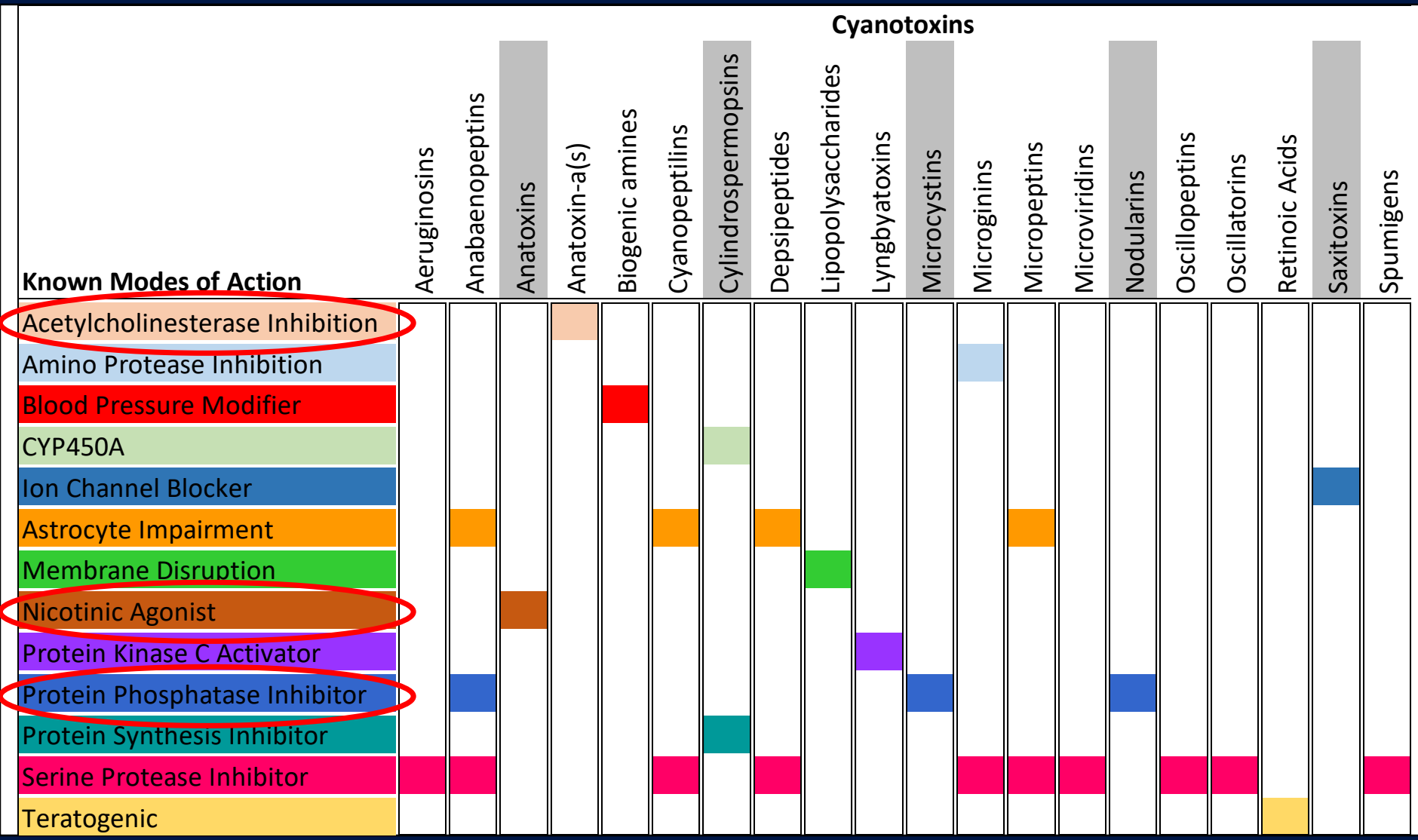
USGS capabilities: laboratory methods based on cyanotoxin mode of action



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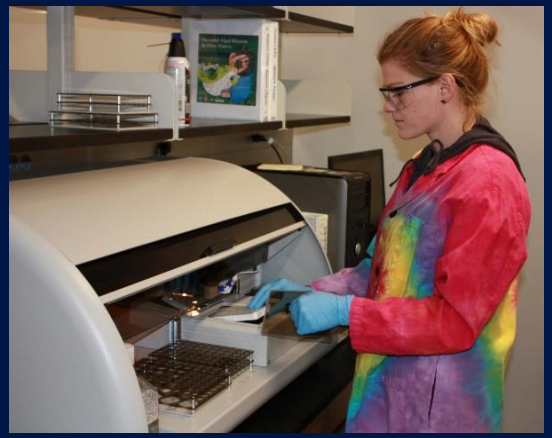
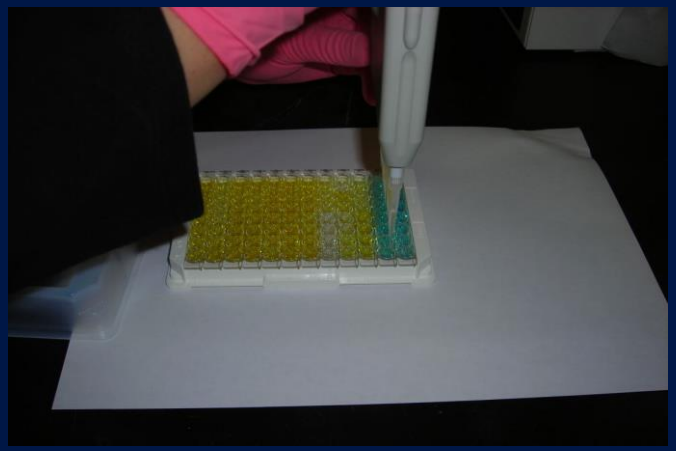
Summarized from Handbook of Cyanobacterial Monitoring and Cyanotoxin Analysis (2017)

USGS capabilities: targeted versus non-targeted cyanotoxin analyses





Non- Target Mode of Action Screening

- PP2A Inhibition
- AChE Inhibition
- Nicotinic Acetylcholine RBA

Targeted Screening

ELISAs

- Anabaenapeptins
- Anatoxins
- Cylindrospermpsin
- Microcystins/Nodularins
- Saxitoxins

Targeted Quantitative Analysis

- Anatoxins
- Cylindrospermopsins
- Microcystins
- Nodularins
- Saxitoxins

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USGS capabilities: bioaccessibility of cyanotoxins

Human Exposure = Recreation + Drinking Water + Food

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USGS capabilities: environmental effects of exposure

Microcystin may affect juvenile recruitment of endangered suckers in Upper Klamath Lake, Oregon.

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Health and Condition of Endangered Juvenile Lost River and Shortnose Suckers Relative to Water Quality in Upper Klamath Lake, Oregon and Clear Lake, California

Summer Burdick, Diane Elliott, Carl Ostberg, Carla Conway, Amari Dolan-Caret, Kevin Feltz, Marshal Hoy, James Carter, and Kathy Echols

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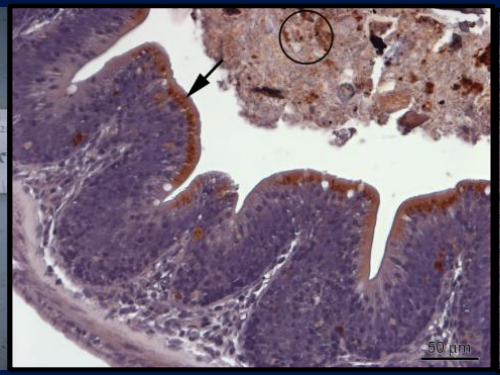
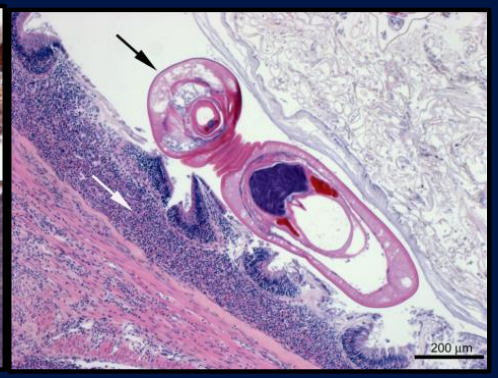
Effects of Microcystin on Juvenile Lost River Suckers

Barbara A. Martin[1], Kathy R. Echols[2], Kevin Feltz[2], Diane G. Elliott[3], and Carla M. Conway[3]
[1]USGS, Western Fisheries Research Center, Klamath Falls Field Station, 2795 Anderson Avenue Suite 106
[2]USGS Columbia Environmental Research Center, [3]USGS Western Fisheries Research Center





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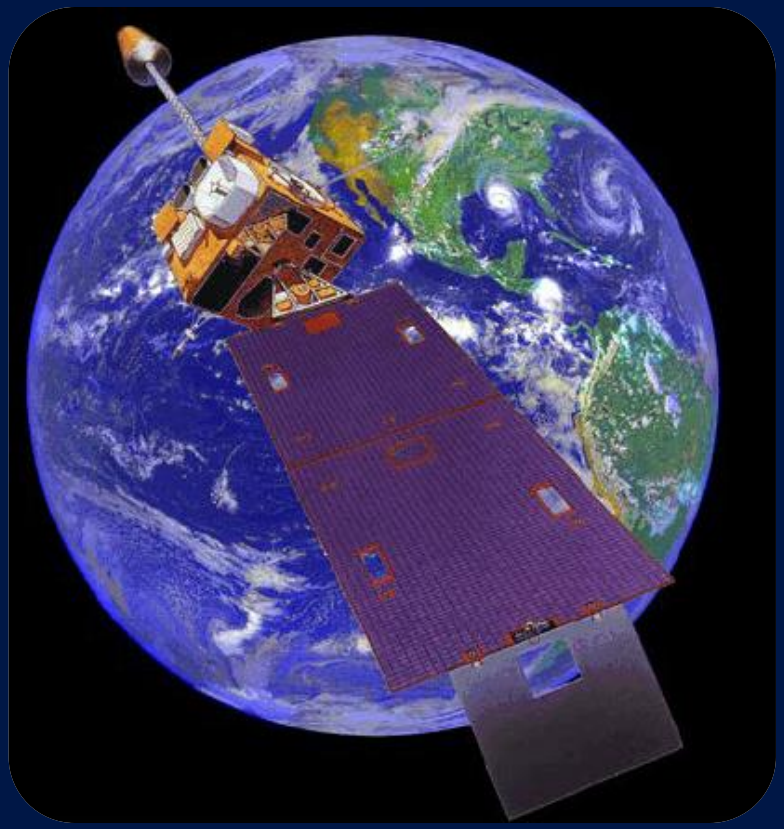
USGS capabilities: near-real time data acquisition and delivery through a variety of platforms



Remote Sensors

Cameras

In Situ Sensors

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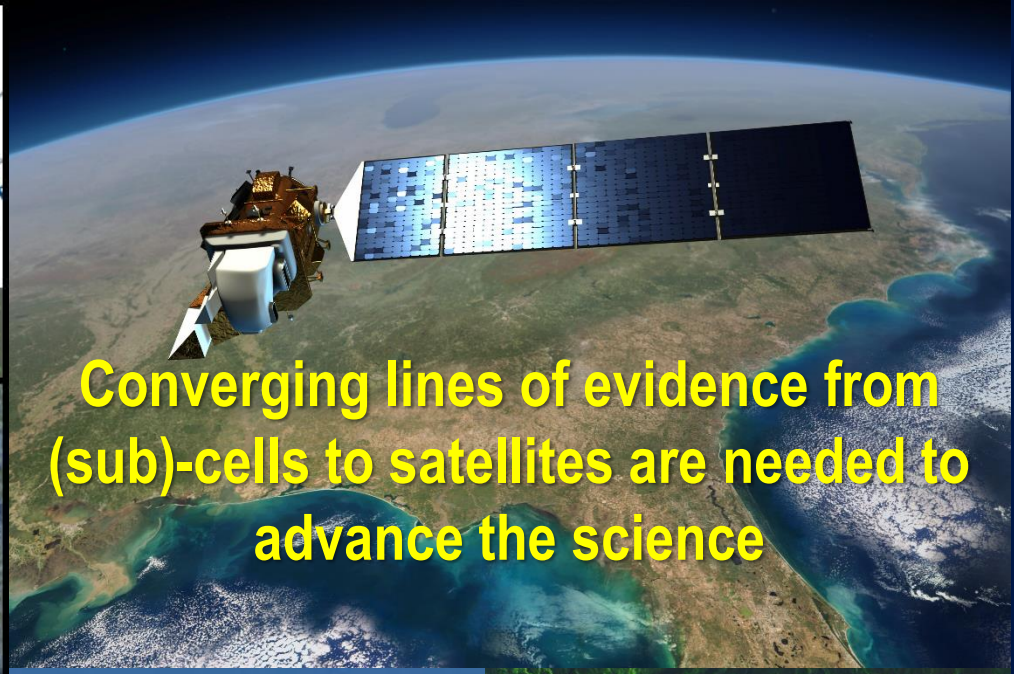
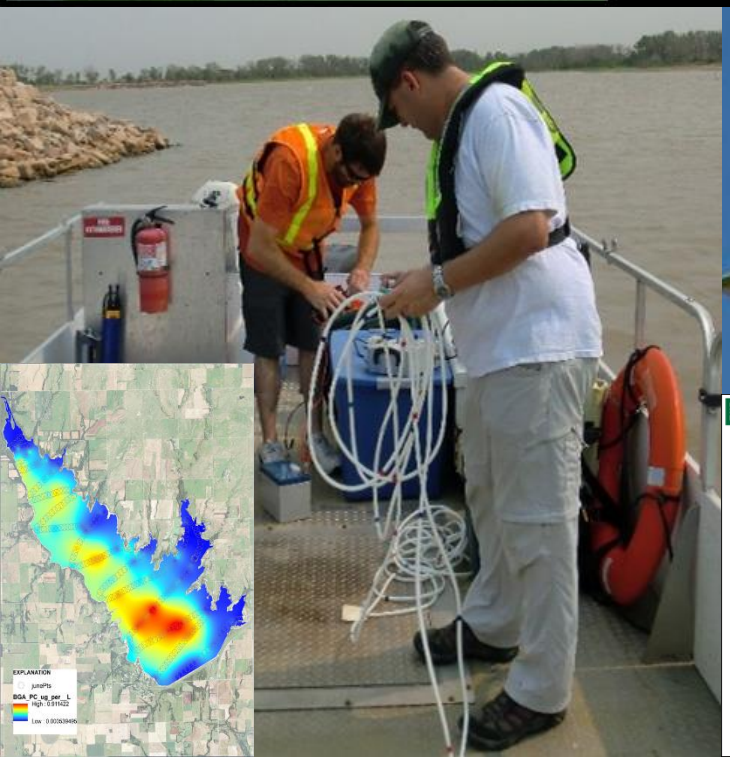
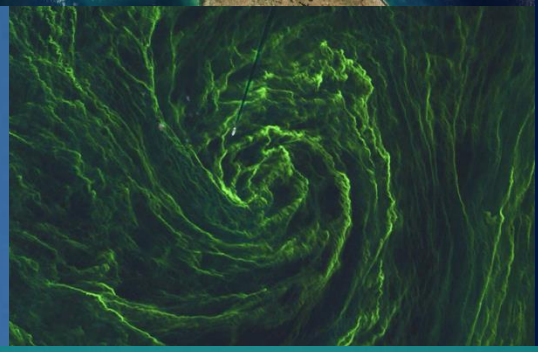
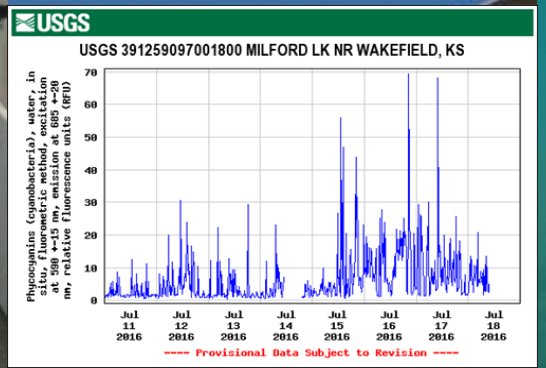
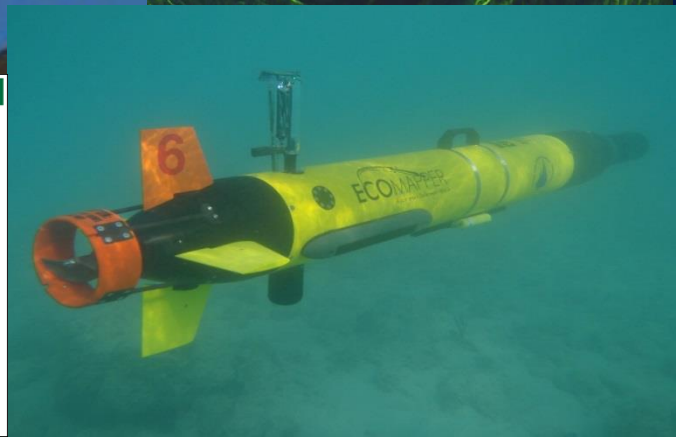


Converging lines of evidence from (sub)-cells to satellites are needed to advance the science

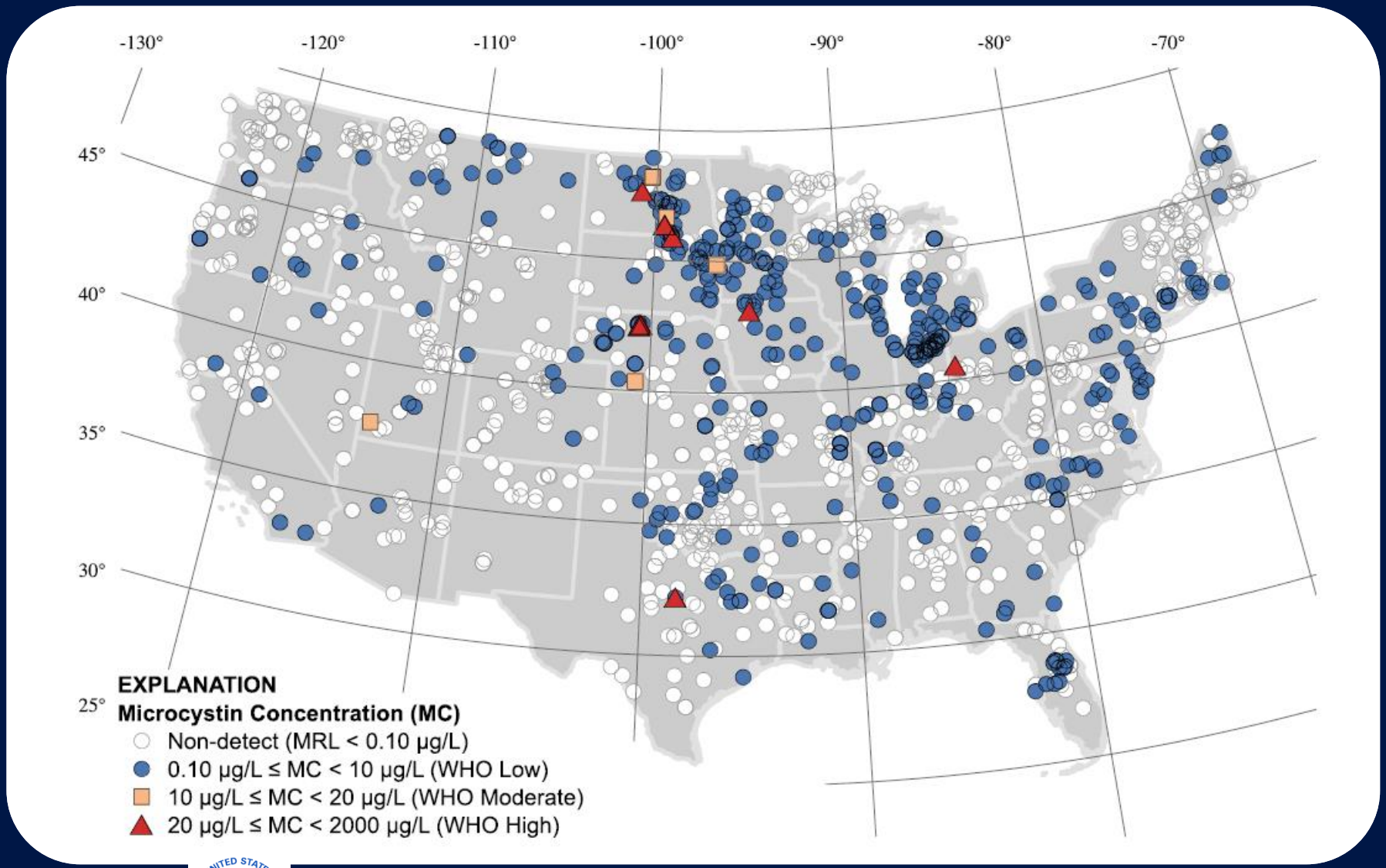








In the 2007 National Lakes Assessment, microcystins were detected by ELISA in about 32% (n=1252) of analyzed samples



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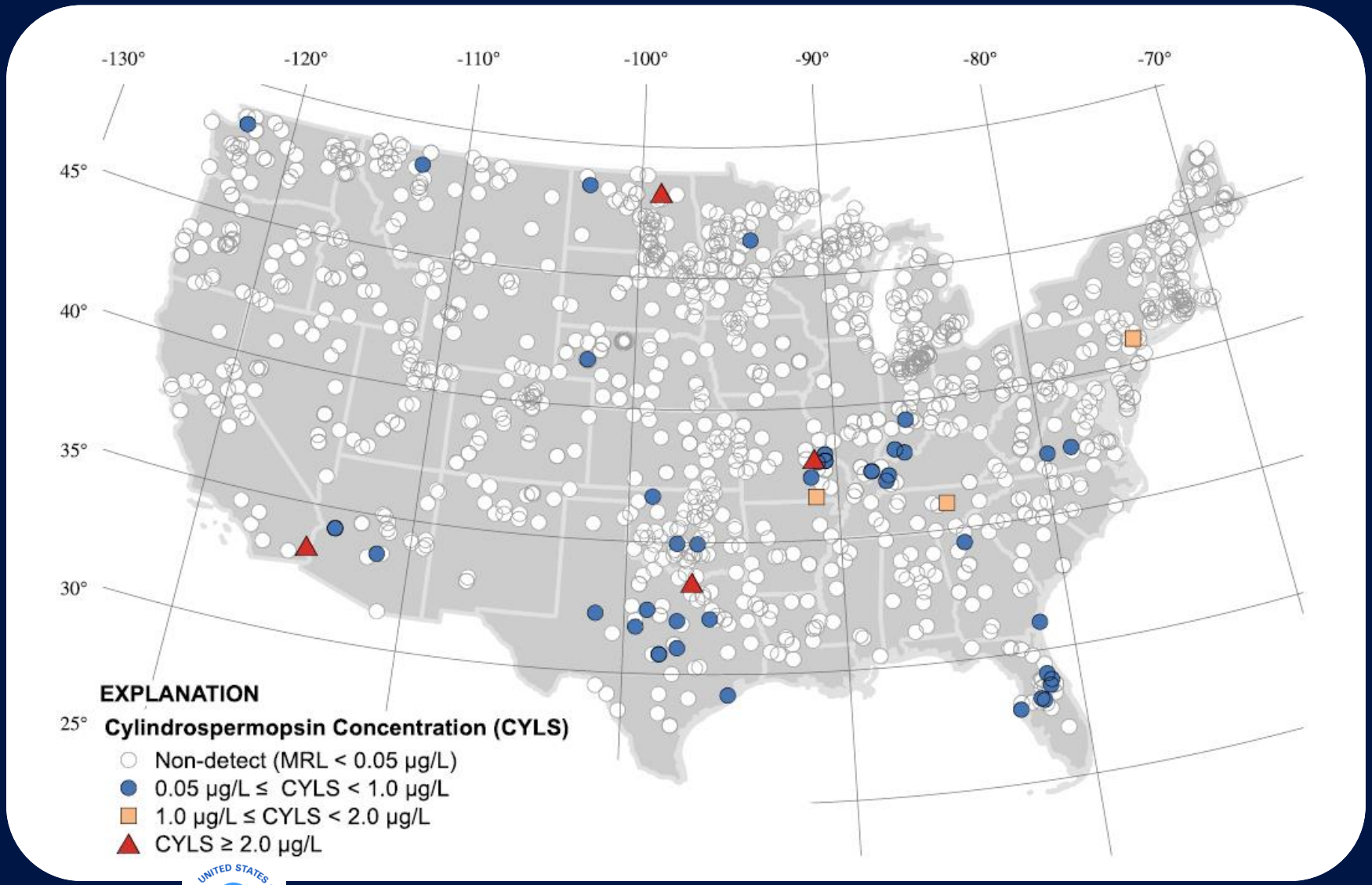
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Loftin and others, 2016, Harmful Algae

In the 2007 National Lakes Assessment, cylindrospermopsins were detected by ELISA in about 4% (n=1252) of analyzed samples



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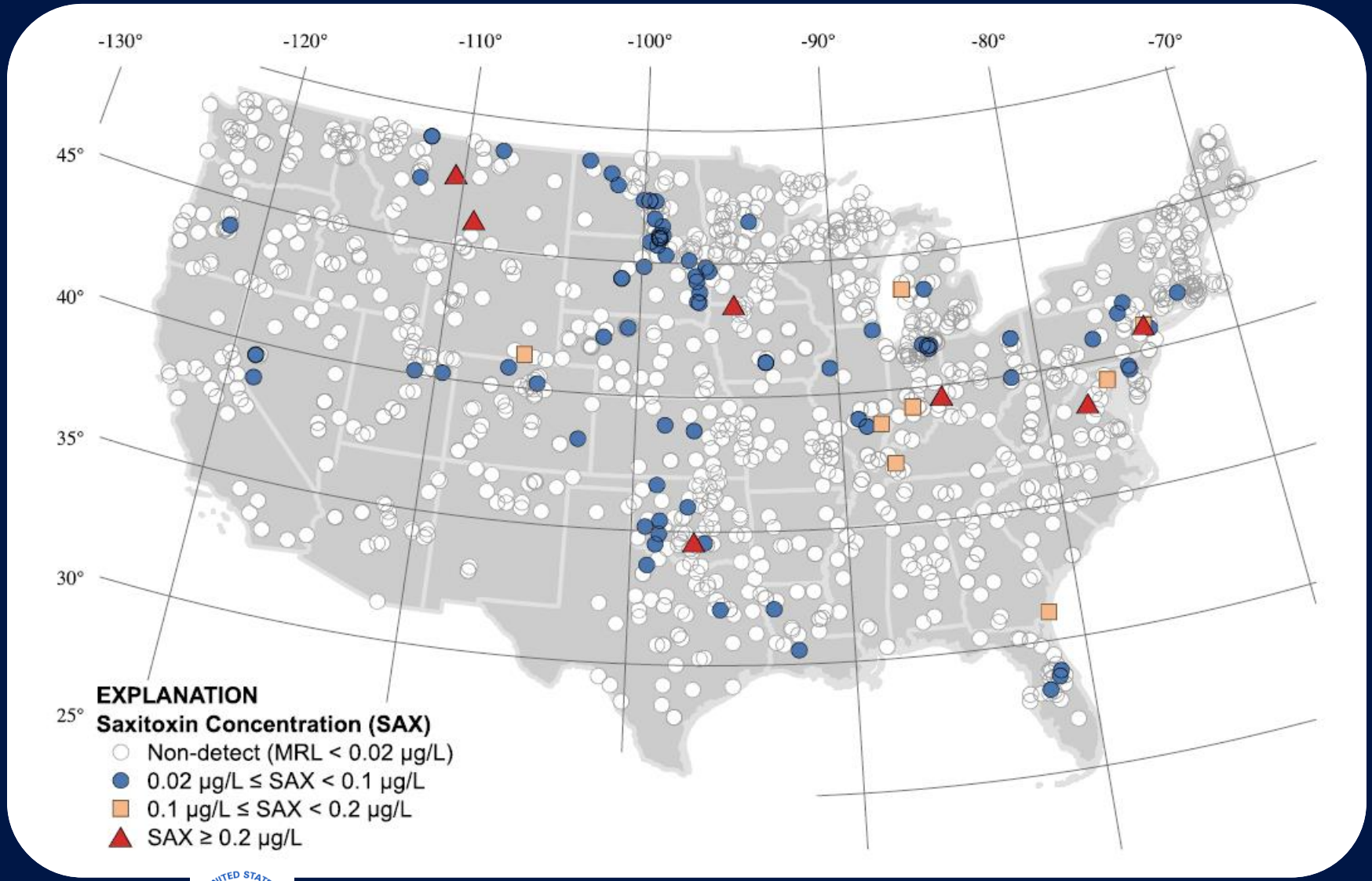
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Loftin et al., 2016, Harmful Algae

In the 2007 National Lakes Assessment, saxitoxins were detected by ELISA in about 8% (n=678) of analyzed samples



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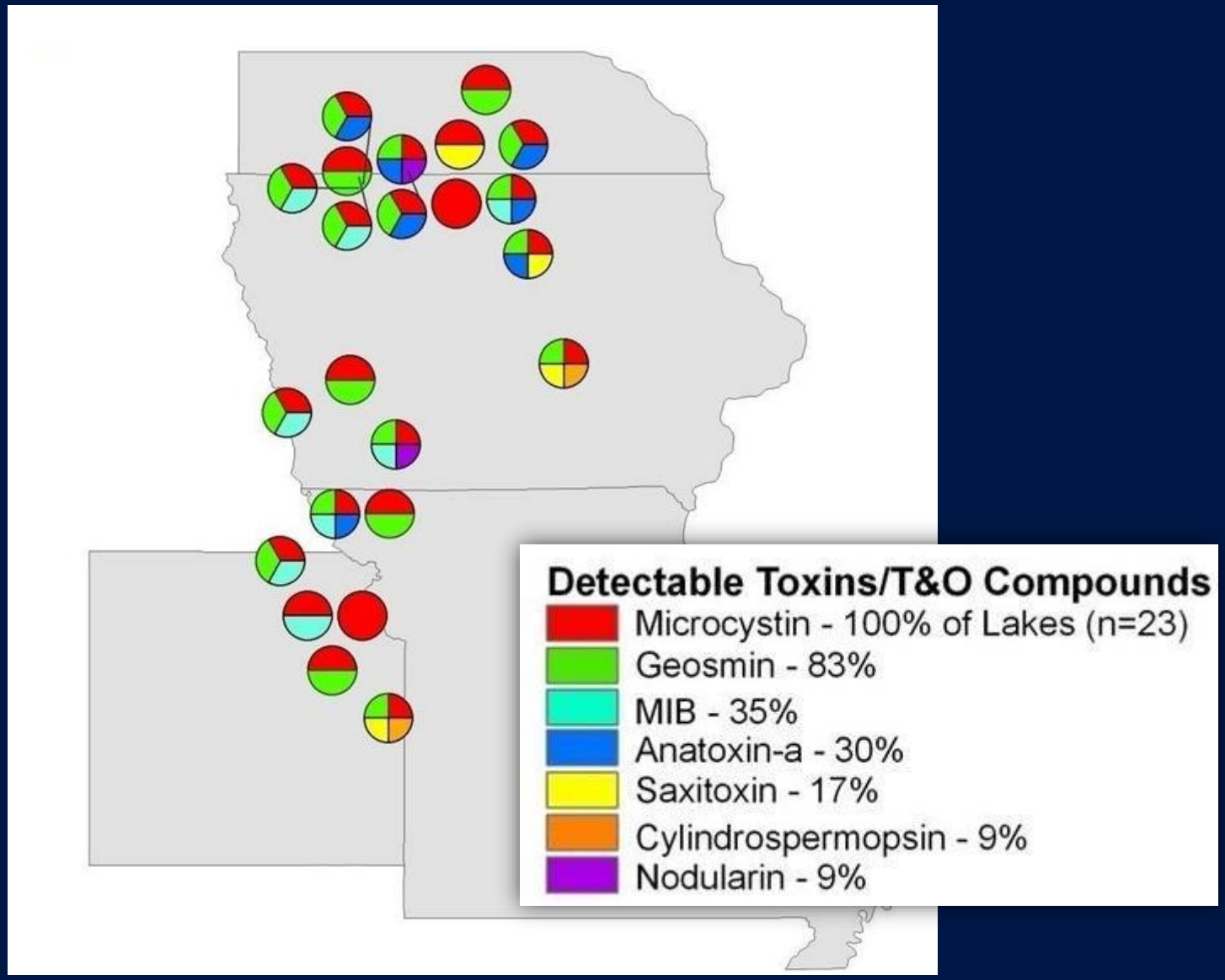
Loftin et al., 2016, Harmful Algae

Multiple toxins and taste-and-odor compounds frequently co-occur in cyanobacterial accumulations



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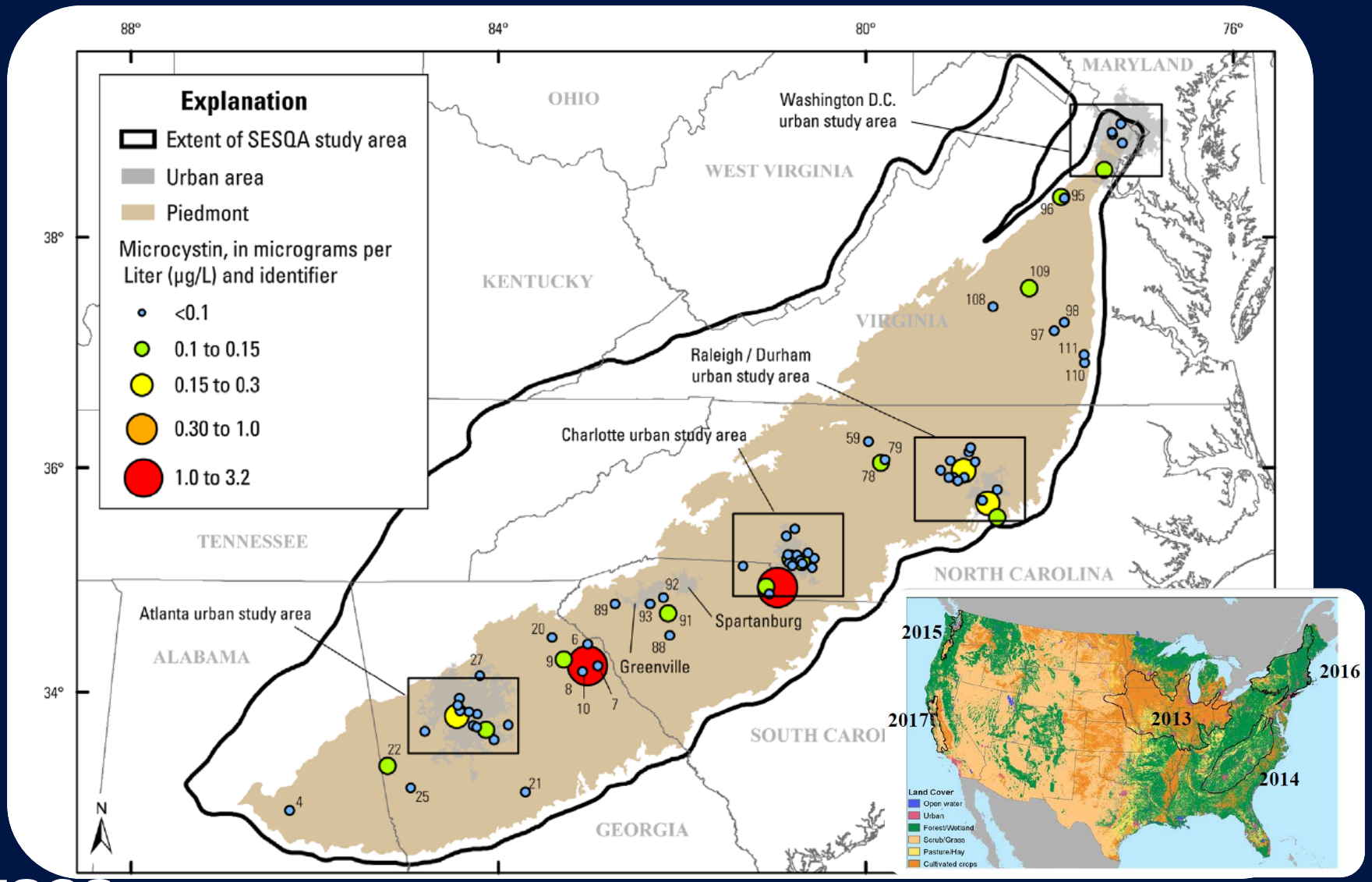
Graham and others, 2010, ES&T

During summer 2014, microcystins occurred in 39% of small stream sites sampled in the southeastern United States



Loftin and others, 2016, Environmental Toxicology and Chemistry

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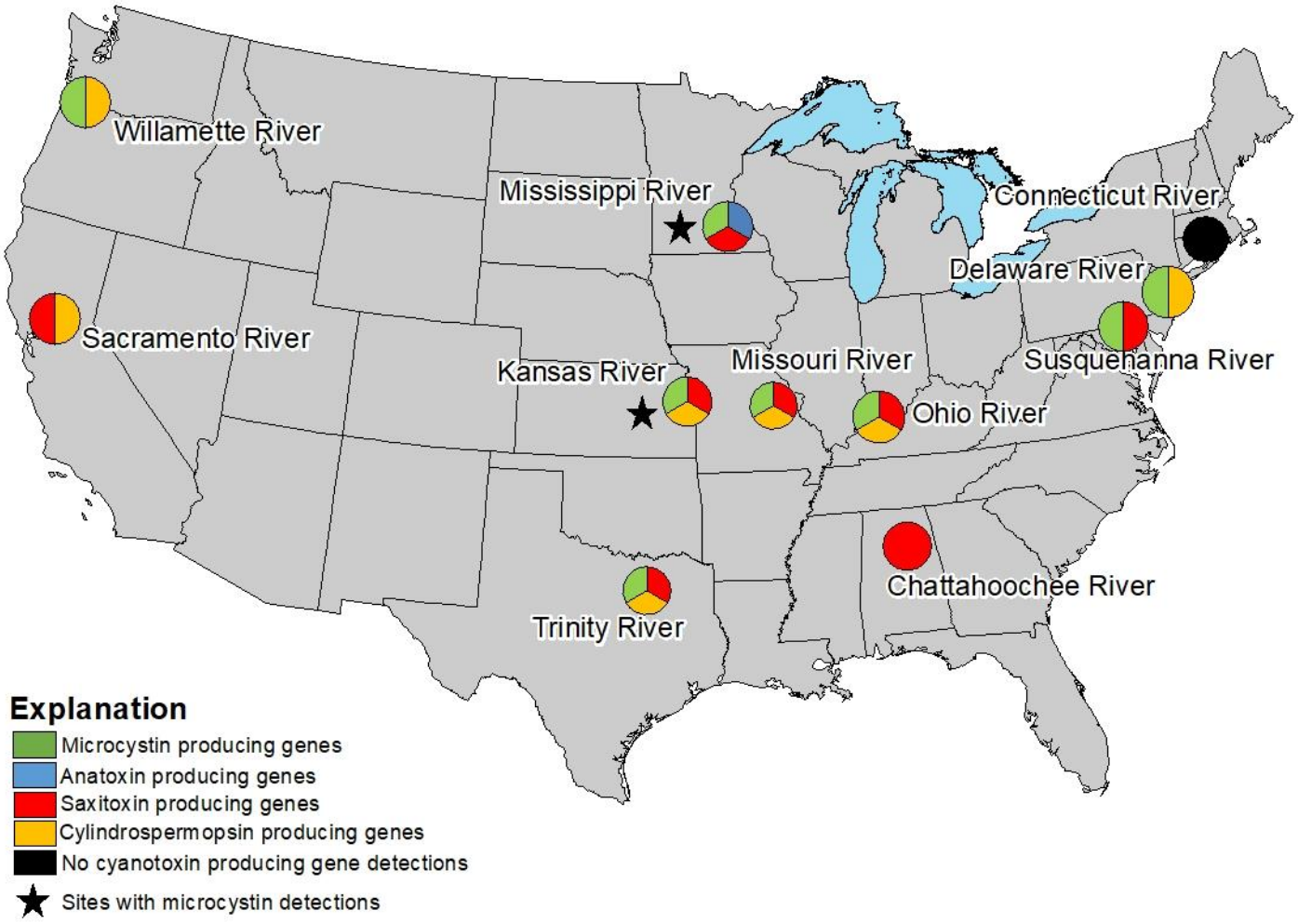
The *potential* for cyanotoxin production was detected at all large river sites except one during June-September 2017



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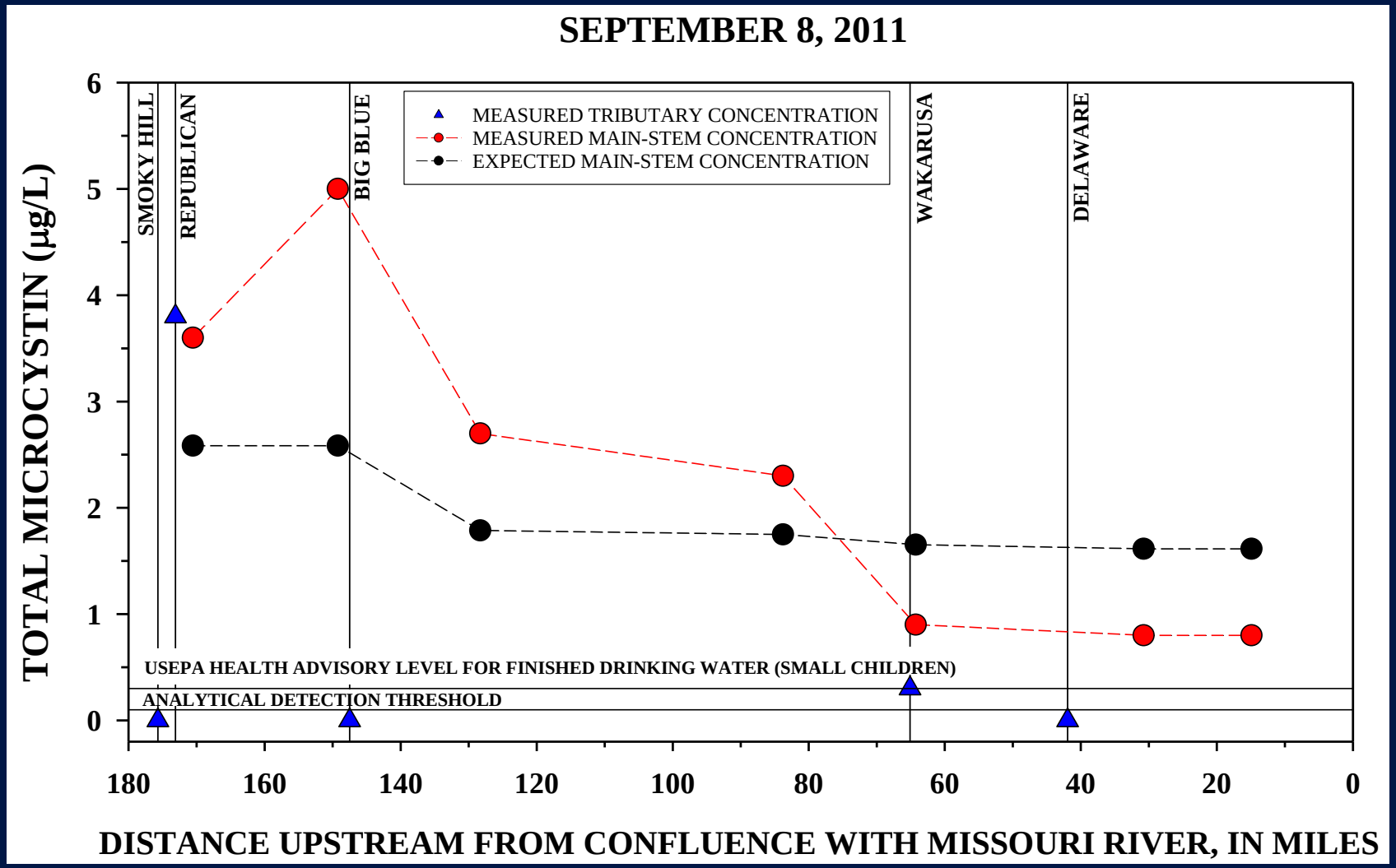
Graham and others, in preparation

Cyanobacteria and associated compounds may be transported for relatively long distances downstream from lakes and reservoirs



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Graham and others, 2012, USGS SIR 2012-5129

2017 tapwater exposure & effects pilot study

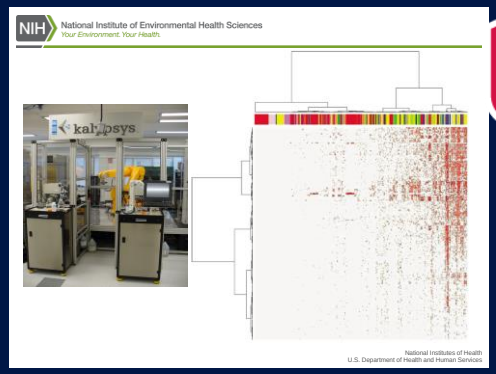
Systematic assessment of correlation between **residential human exposure at the tap, biomarkers of exposure, and human health metrics.**

Analytes

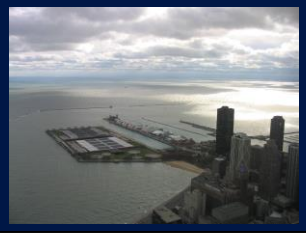
- **PESTS** designed-bioactive
- **PHARMS** designed bioactive
- DBPs
- **Anions/Cations (metals)**
- PFAS
- VOCs
- Hormones
- **Nutrients**
- Pathogens
- **CYANOTOXINS**

Screening tools

- Bioassays USGS/EPA/NIEHS
- Non-target (Q-TOF)
  - **Human Health Metrics**
- UIC PMI: biomarkers…
- NIEHS/CDC Human Databases



"Understanding chemical and microbial contaminants in drinking water: raw, treated, and tap water", ASDWA Webinar, Date: TBD in August



Point of use water treatment assessment study

Current focus on personal, mobile POU DW treatment.

To assist outdoor community and evaluate as an alternative to bottled water during emergency do not drink orders.

Working on:

- Review of treatment options
- Development of standardized testing approach
- Study design

If you have source waters you would like us to consider, please let us know

"Now just hold your horses, everyone. … Let's let it run for a minute or so and see if it gets any colder."

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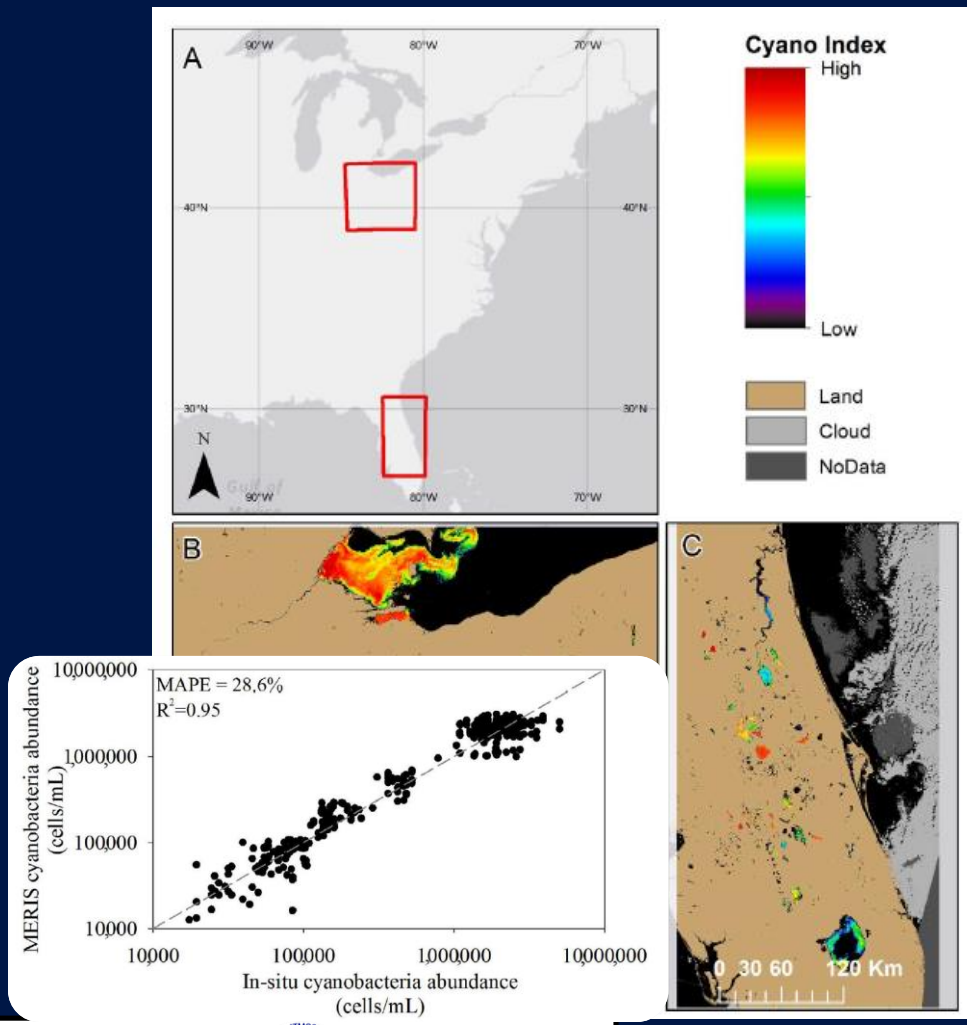
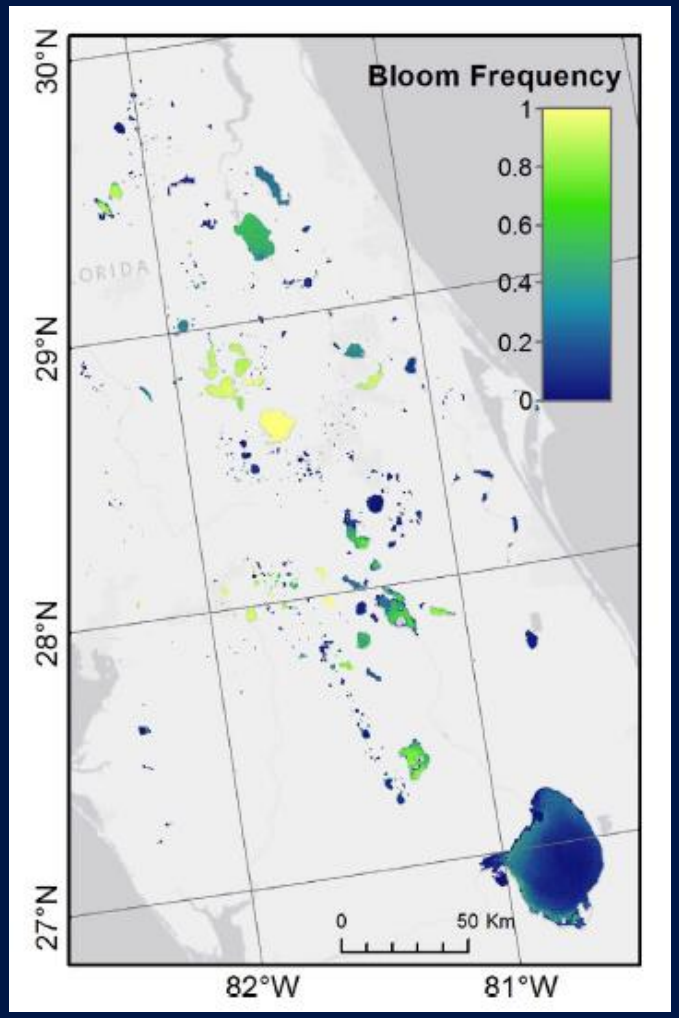
Satellite imagery may capture spatial and temporal variability across a regional scale

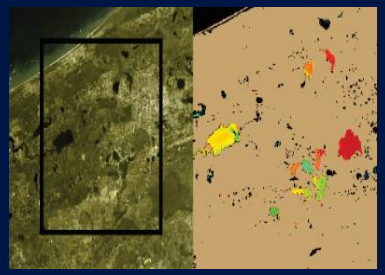




After Clark and others, 2017
http://dx.doi.org/10.1016/j.ecolind.2017.04.046

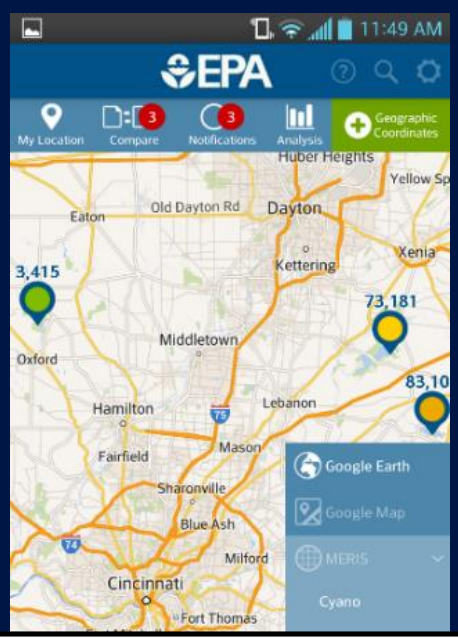
Tools to utilize satellites for inland monitoring of cyanobacteria are being developed

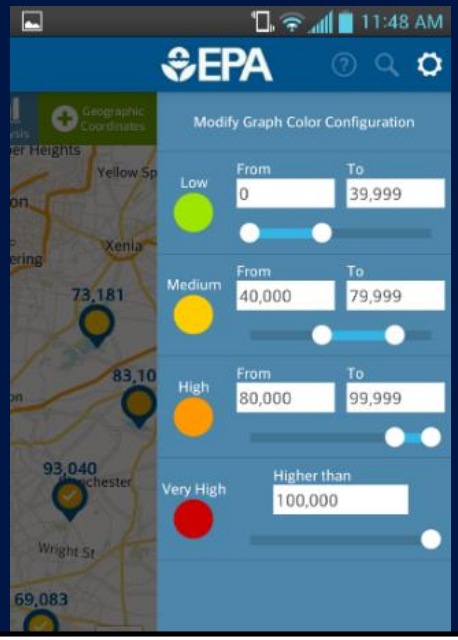
Cyanobacteria Assessment Network (CyAN) Project



Remote Sensing

Field Data





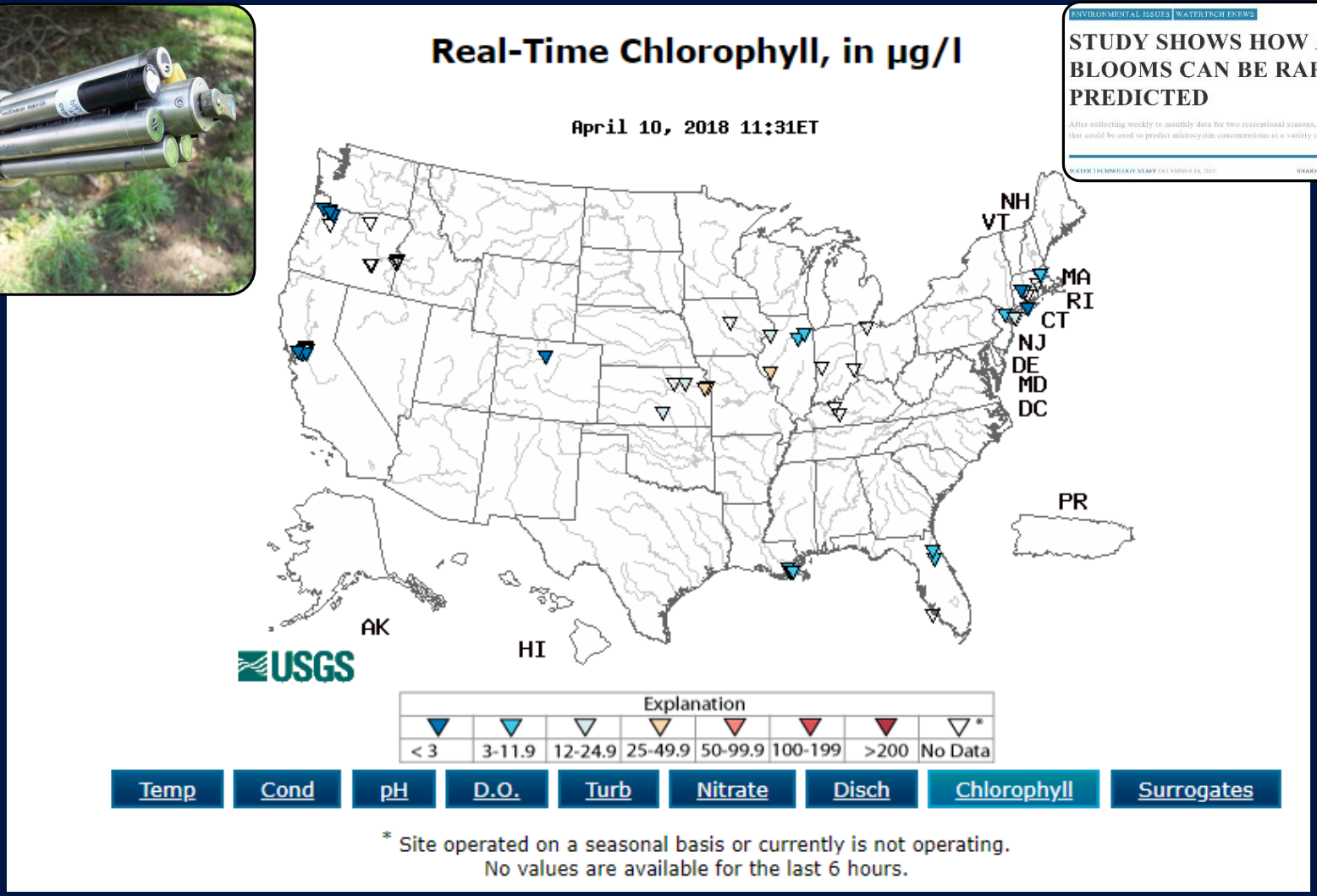
Water-quality sensors show promise as early warning tools

ENVIRONMENTAL ISSUES | WATERTECH ENEWS

STUDY SHOWS HOW ALGAL BLOOMS CAN BE RAPIDLY PREDICTED

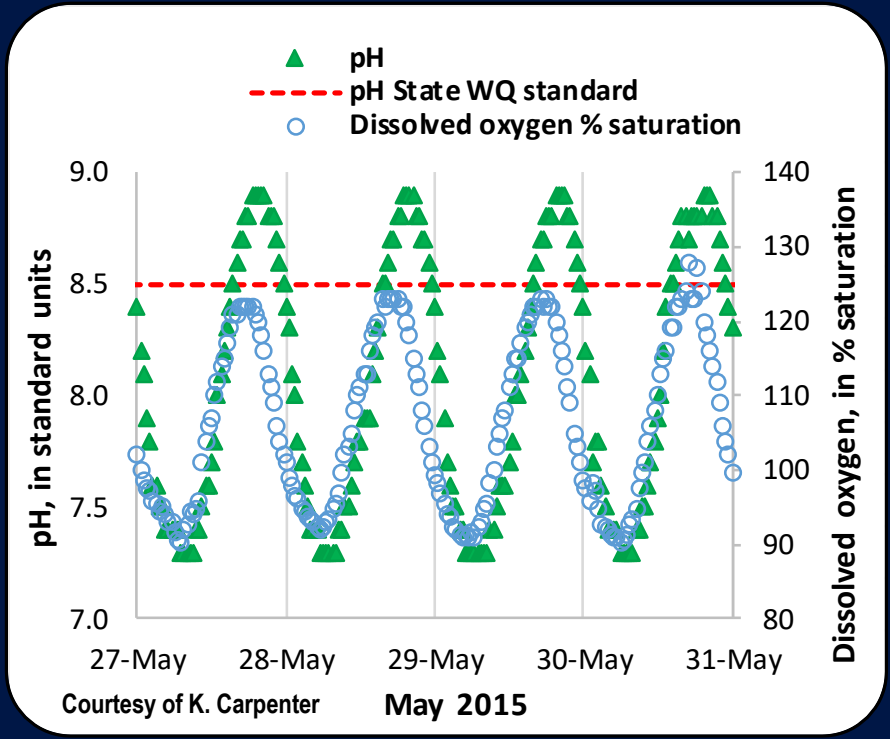
After collecting weekly to monthly data for two recreational seasons, the scientists identified factors that could be used to predict microcystin concentrations at a variety of freshwater sites.

WATERTECHNOLOGY STAFF | DECEMBER 14, 2015 | SHARE ON:

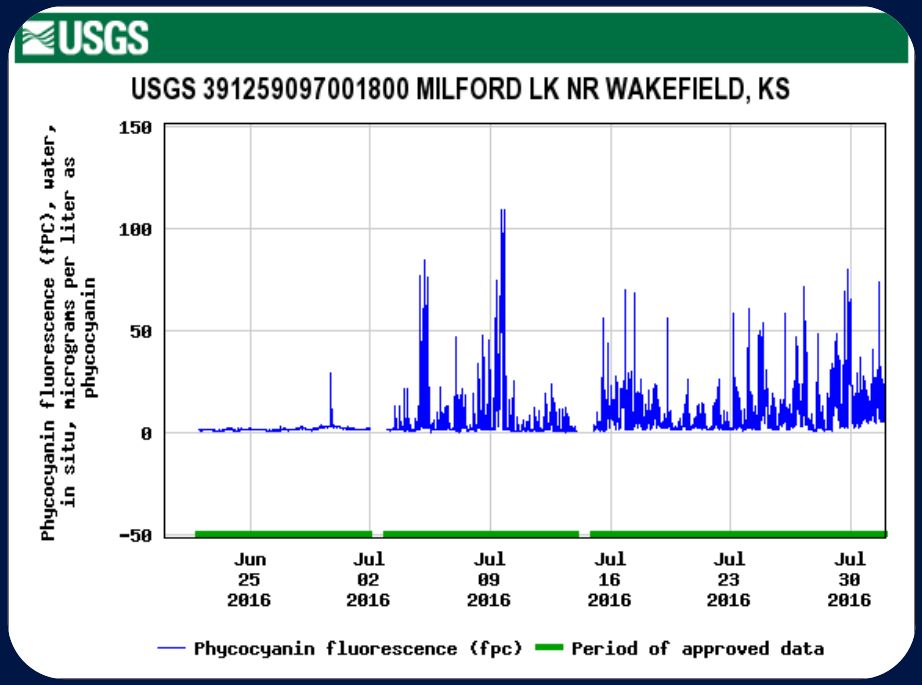


https://waterwatch.usgs.gov/wqwatch

Diurnal or noisy patterns in dissolved oxygen, pH and algal fluorescence may be indicative of cyanotoxin occurrence



Courtesy of K. Carpenter



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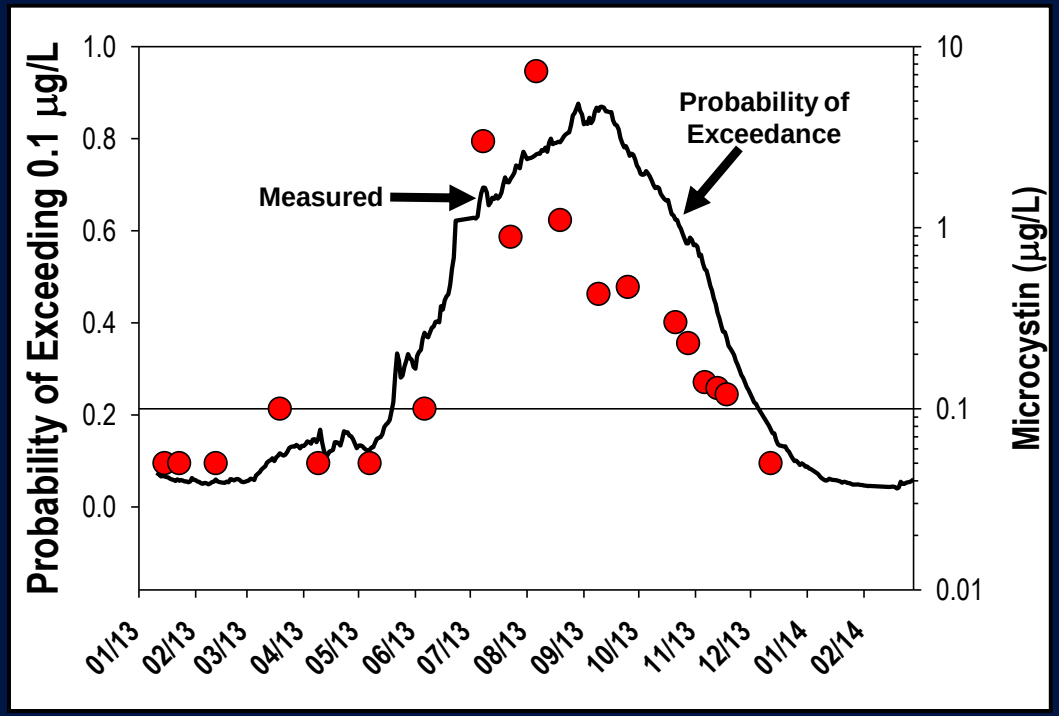
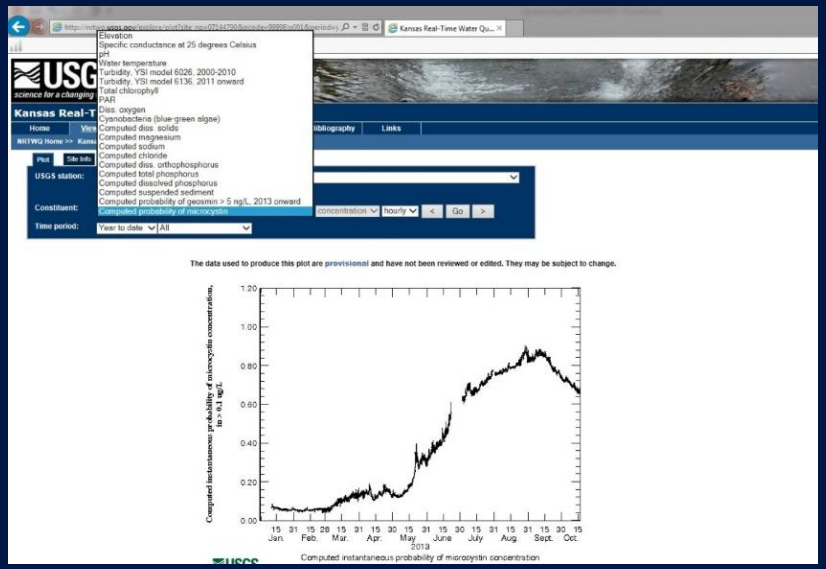
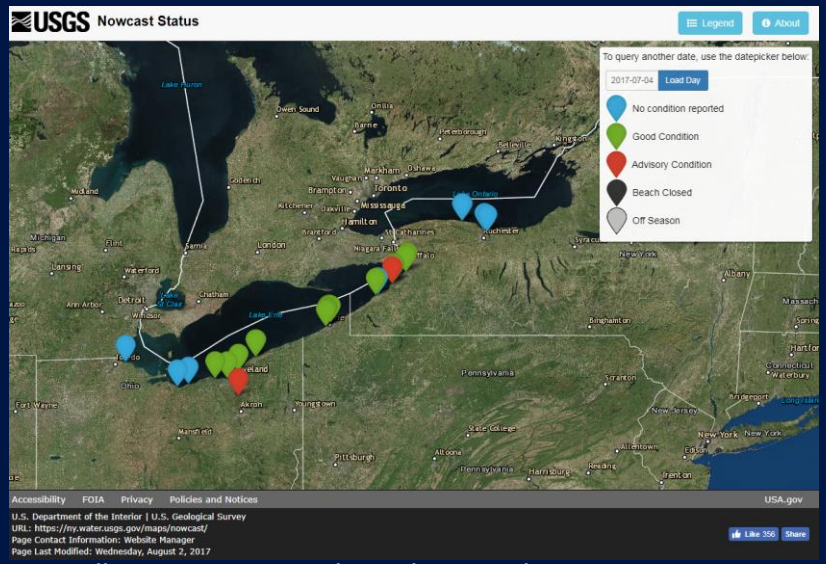
Water-quality monitors can be used to develop site-specific models to compute probability of cyanotoxin occurrence



After Graham and others, 2017
https://pubs.er.usgs.gov/publication/sir20175016



https://nrtwq.usgs.gov/ks



https://ny.water.usgs.gov/maps/nowcast/

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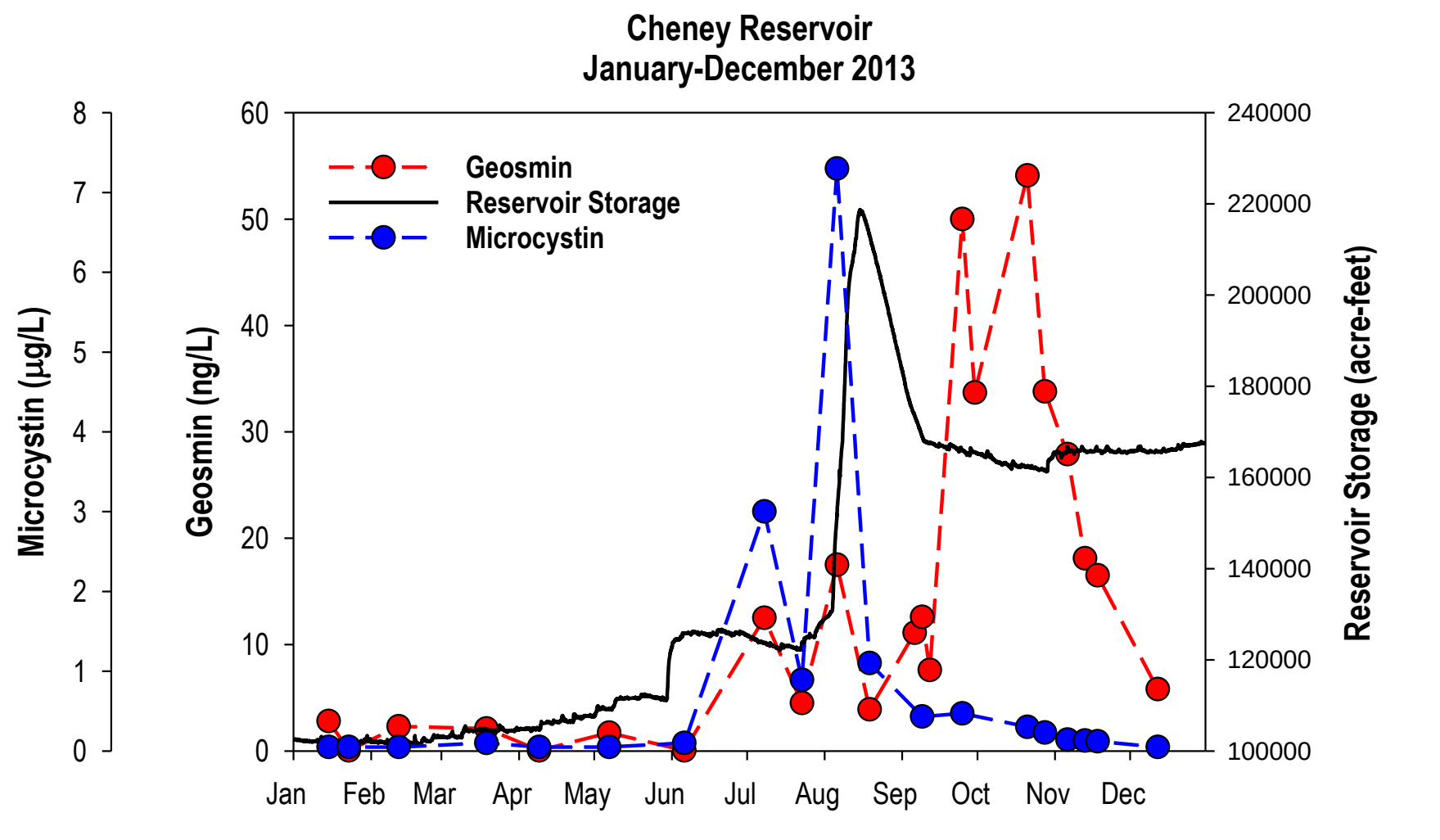
Anomalous events, such as large summer inflows, may alter ecosystem processes and require model recalibration



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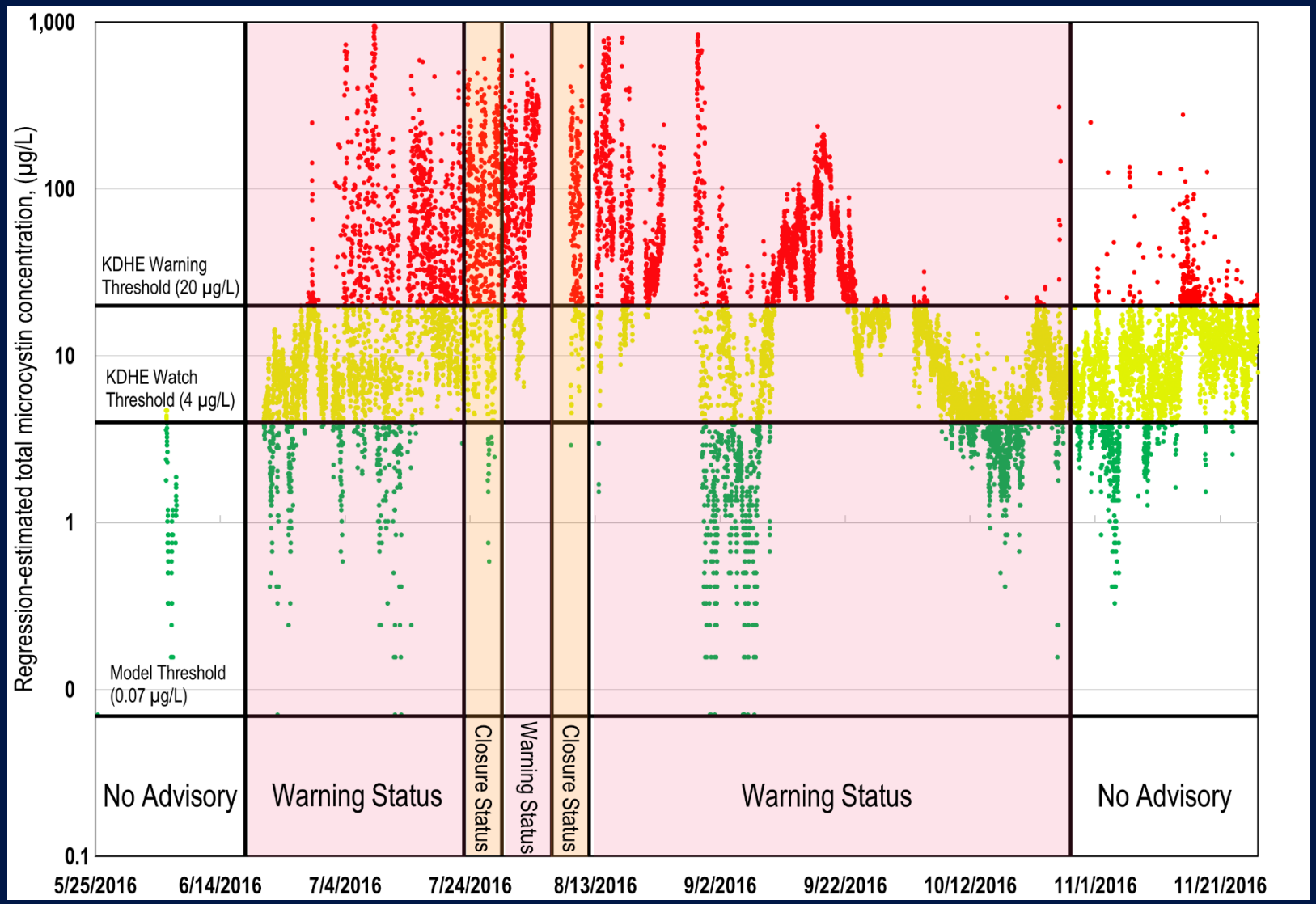
After Graham and others, 2017
https://pubs.er.usgs.gov/publication/sir20175016

Water-quality monitors can be used to develop site-specific models to compute cyanotoxin concentrations



Foster and others, in preparation

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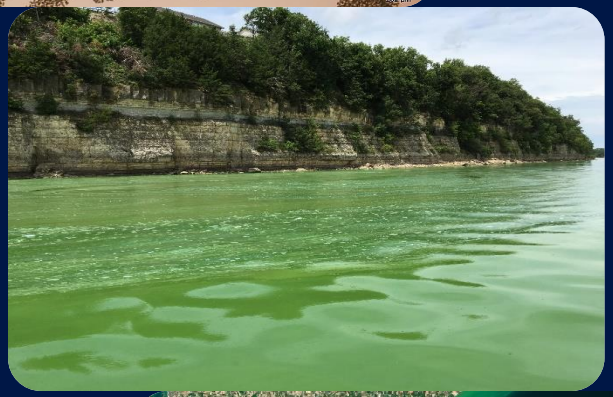
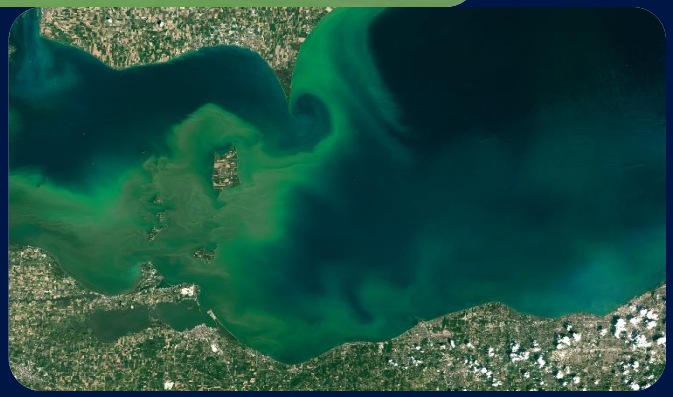
USGS has developed converging lines of evidence to identify when and where cyanotoxins may pose potential human health risks, but data gaps remain

- Status and trends
- Environmental fate and transport
- Environmental drivers
- Ecosystem effects
- Exposure and health
  - Real versus perceived risks
- Drinking water and food impacts
- Mitigation and management





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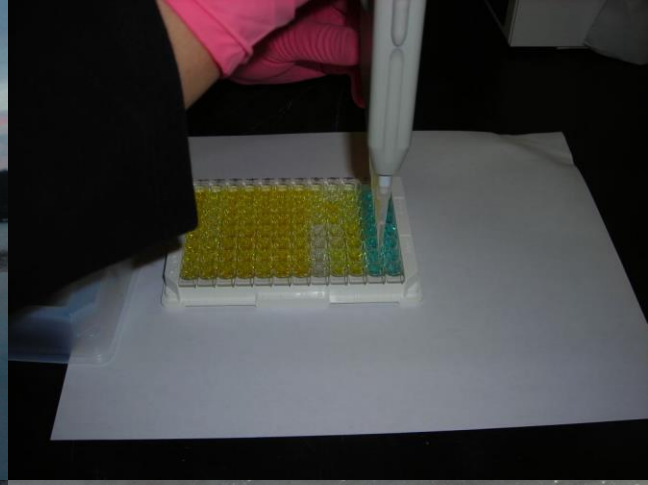
Cyanotoxins: Advancing Drinking Water Science to Protect Human Health

Ohio Case Study

Ruth Briland
Ohio EPA HAB Team

Ohio Environmental Protection Agency






Additional Information:

https://www.usgs.gov/news/science-harmful-algae-blooms

https://www2.usgs.gov/envirohealth

http://epa.ohio.gov/ddagw/HAB

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