National HAB Occurrence: Results and Approaches

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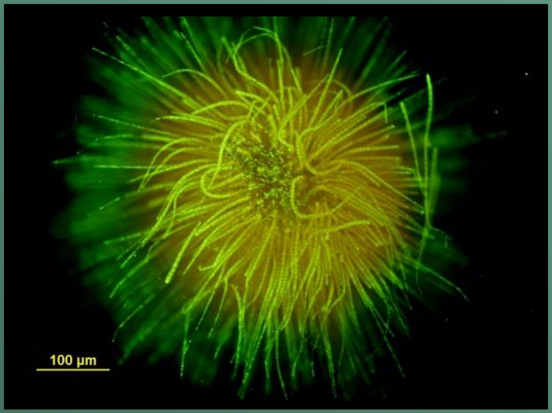
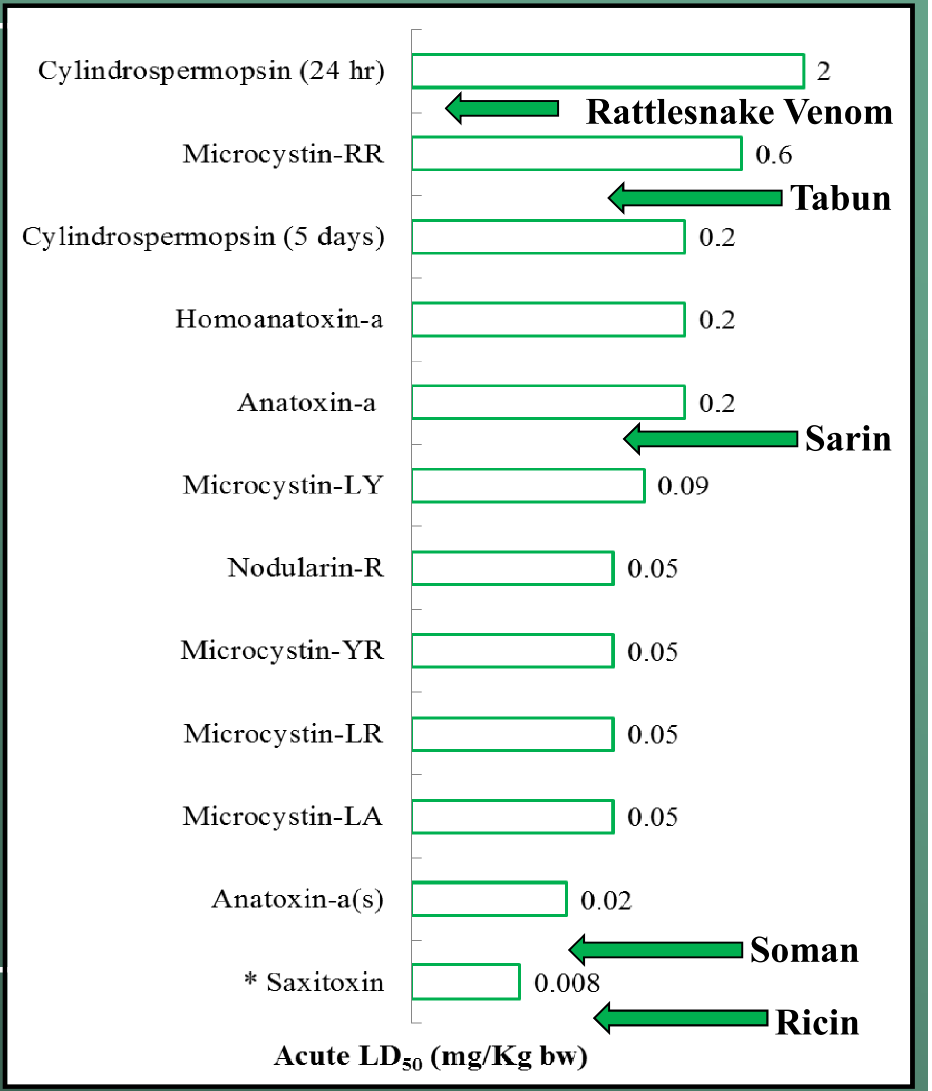


U.S. Department of the Interior
U.S. Geological Survey

http://pubs.usgs.gov/of/2010/1289

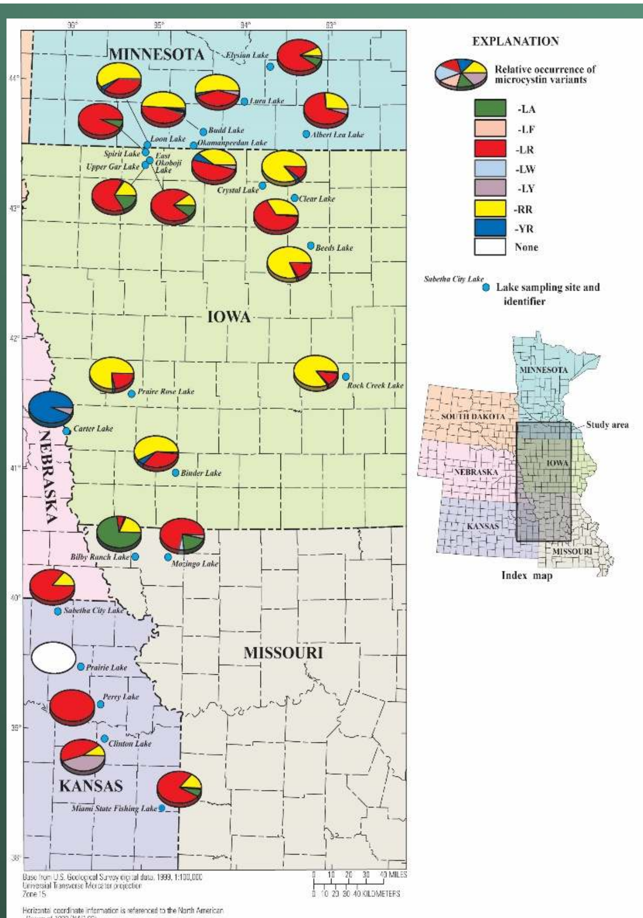
How Toxic are Cyanotoxins?

- **Acute Toxicity**
  - Cytotoxic
  - Dermatoxic
  - Hepatotoxic
  - Neurotoxic
- **Chronic Toxicity**
  - Carcinogen
  - Tumor promotor
  - Mutagen
  - Teratogen
  - Embryolethality
  - Neurodegenerative disease



After Chorus and Bartram, 1999; various references

USGS State Level Surveys in EPA Region 5



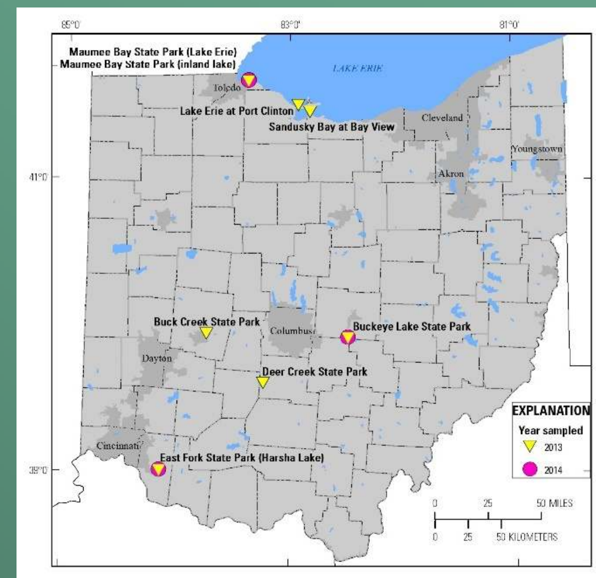


Figure 1. Locations of Ohio recreational lake sites and year(s) sampled.

- **Michigan survey completed in lakes**
- **2 separate NPS surveys in MI and MN**

http://pubs.acs.org/doi/abs/10.1021/es1008938
http://pubs.usgs.gov/sir/2015/5120/sir20155120.pdf
http://pubs.usgs.gov/of/2013/1019/pdf/ofr2013-1019.pdf

Regional and National CyanoHAB Occurrence Collaborations

- 2006 USGS Midwestern Lake Reconnaissance (n=23)
- 2007 EPA National Lakes Assessment (n=1331)
- 2011 EPA National Wetlands Assessment (n ~ 643)
- 2012-2014 USGS Albemarle Sound, NC (n ~ 39)
- 2014 USGS Southeastern Stream Quality Assessment (n=93)
- 2014-2016 USGS GLRI Lake Erie
- 2015 USGS Pacific Northwest Stream Quality Assessment (n=87)
- 2015 EPA National Coastal Assessment (n ~ 1300)
- 2016 EPA National Wetlands Assessment
- 2016 USGS Northeastern Stream Quality Assessment
- 2016 - 2019 NOAA MERHAB – Toxins at the Land/Sea Interface Coastal California
- 2017 USGS California Stream Quality Assessment

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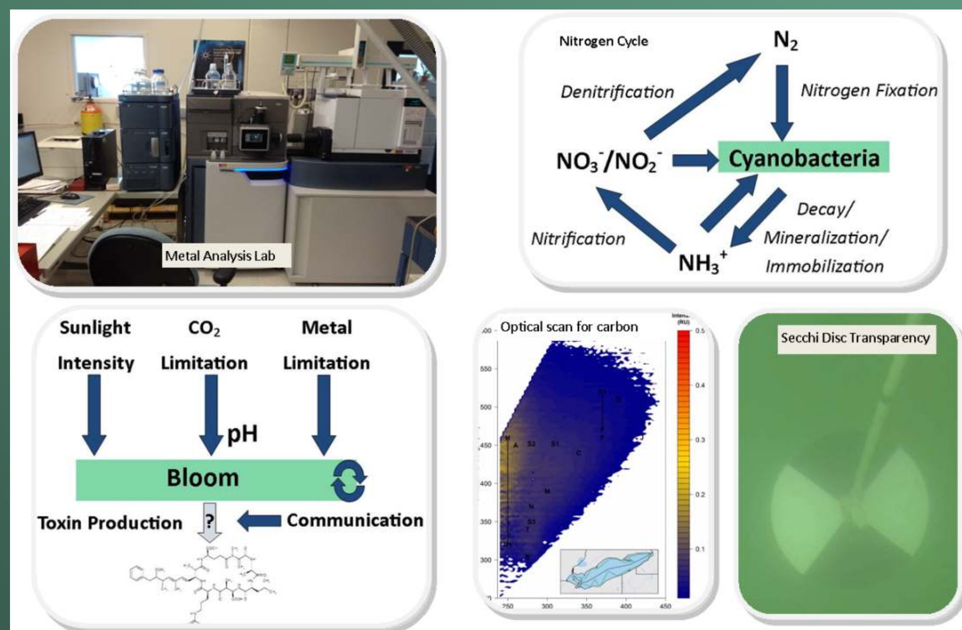
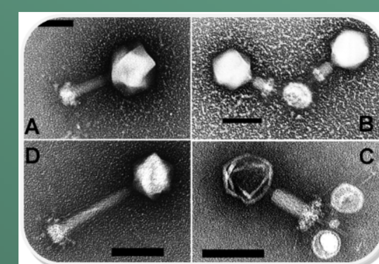
USGS Great Lakes Cyanobacterial HAB Research GLRI

What chemical, biological, and physical factors trigger HABs and toxins?





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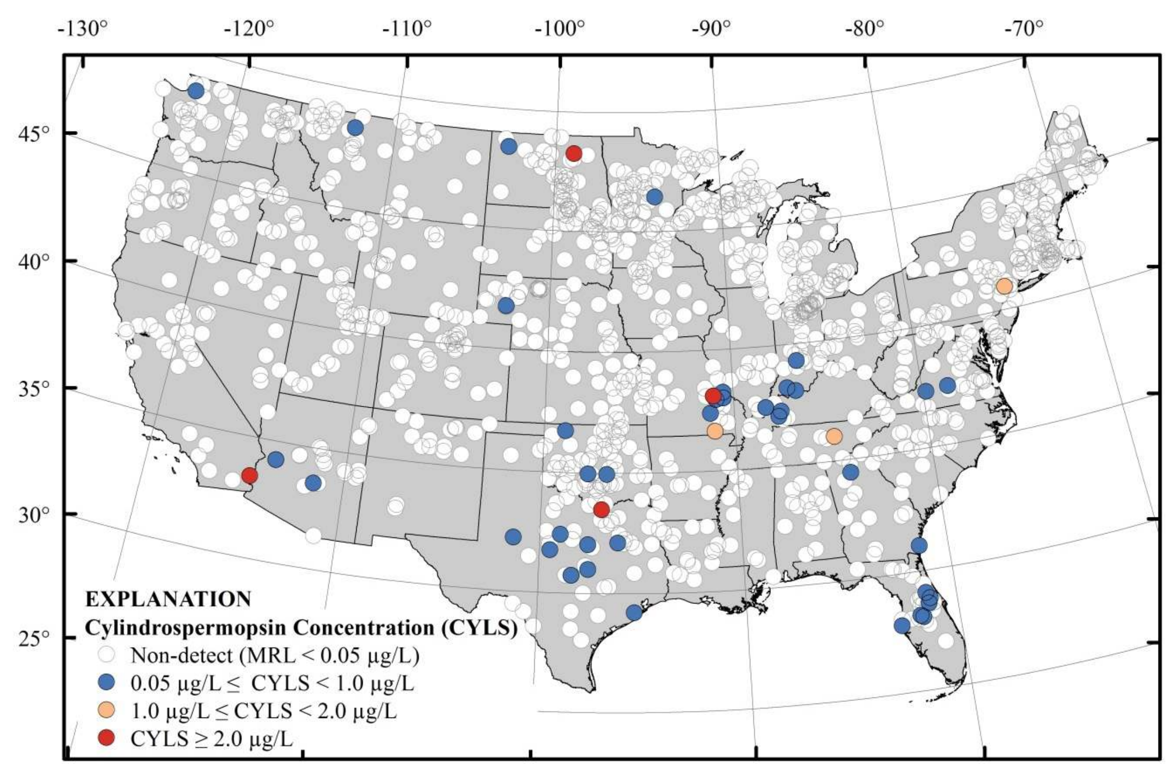
2007 NLA Results
Cylindrospermopsin (ELISA)



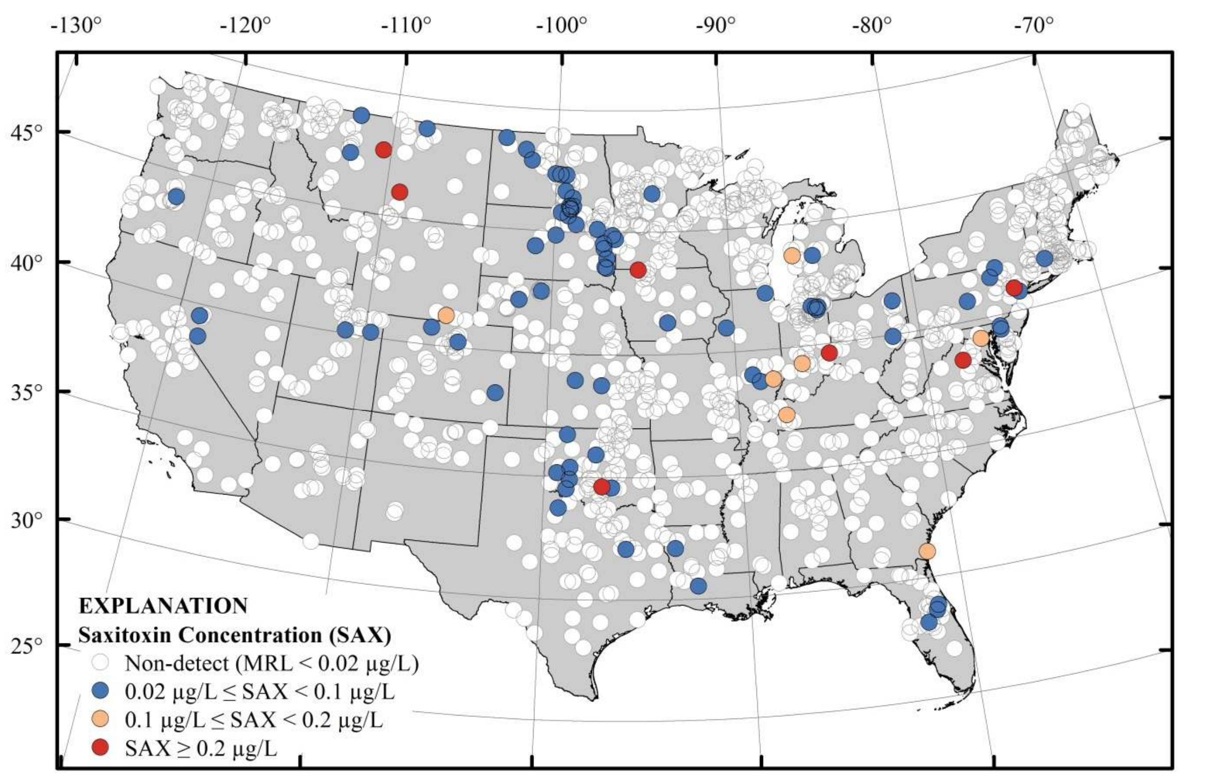
Integrated Photic Zone Samples

- **Occurrence: 4.0%**
- **Mean: 0.56 µg/L**
- **Median: 0.10 µg/L**
- **Max: 4.4 µg/L**

State recreational thresholds range from 4 to 6 µg/L.

Loftin et al. 2016, USGS Data Series, in press.
Loftin et al., 2016, Harmful Algae, in press.

2007 NLA Results
Saxitoxins (ELISA)



Integrated Photic Zone Samples

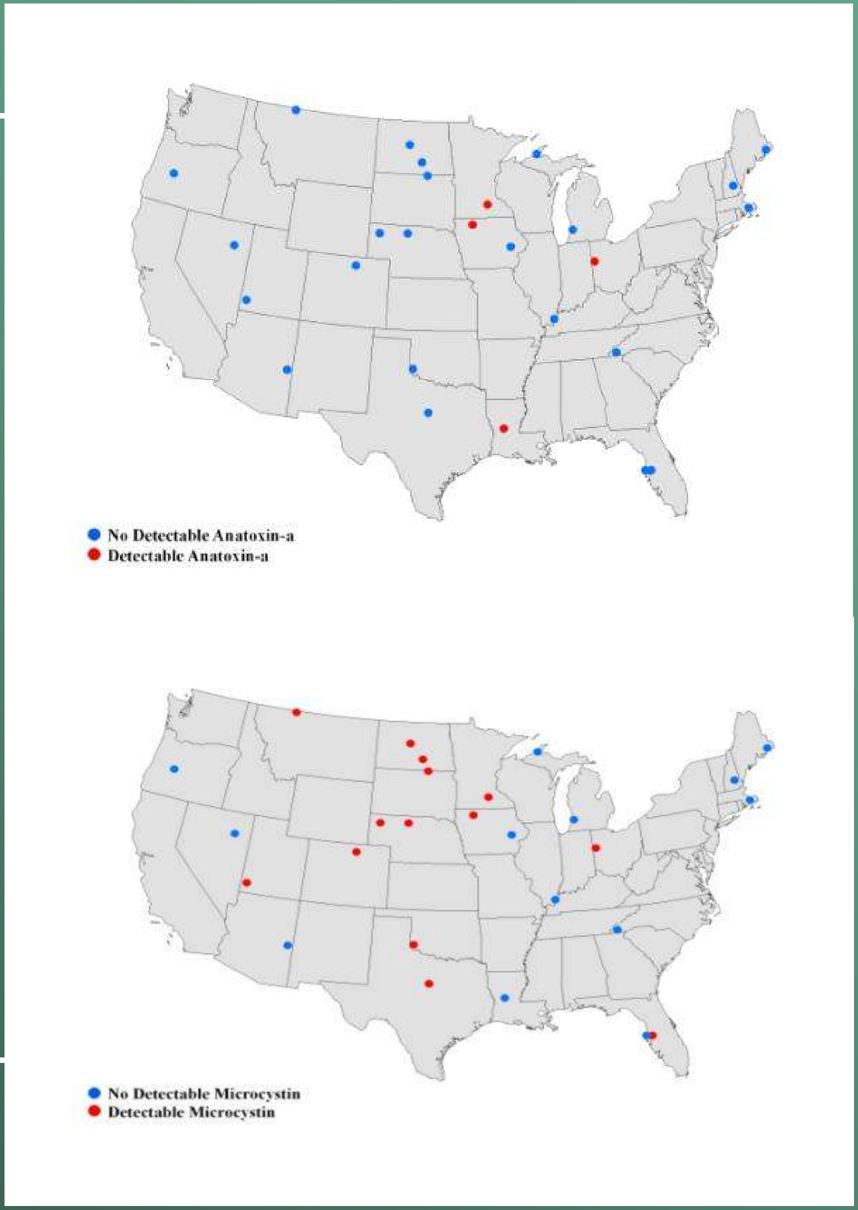
- **Occurrence: 7.7%**
- **Mean: 0.061 µg/L**
- **Median: 0.030 µg/L**
- **Max: 0.38 µg/L**

Few state inland recreational thresholds exist. 3 µg/L has been used in 1 case.

Loftin et al. 2016, USGS Data Series, in press.
Loftin et al., 2016, Harmful Algae, in press.

Cyanotoxins (LC/MS/MS) – 2% Subset

- **Sample selection included 13 of 27 (48%) detections by Microcystin ELISA.**
- **Anatoxin-a detected:**
  4 of 27 (15%) samples
- **Microcystins detected:**
  14 of 27 (59%) samples
- **Nodularin-R detected:**
  1 of 27 (3.7%) in Texas



Loftin et al., 2016, Harmful Algae, in press.

World Health Organization (WHO) Recreational Microcystin Guidance

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	< 10	< 10
Moderate	20,000 - 99,999	10 - 19.9	10 - 49.9
High	100,000-9,999,999	20 - 1999	50 - 4999
Very High	≥ 10,000,000	≥ 2000	≥ 5000

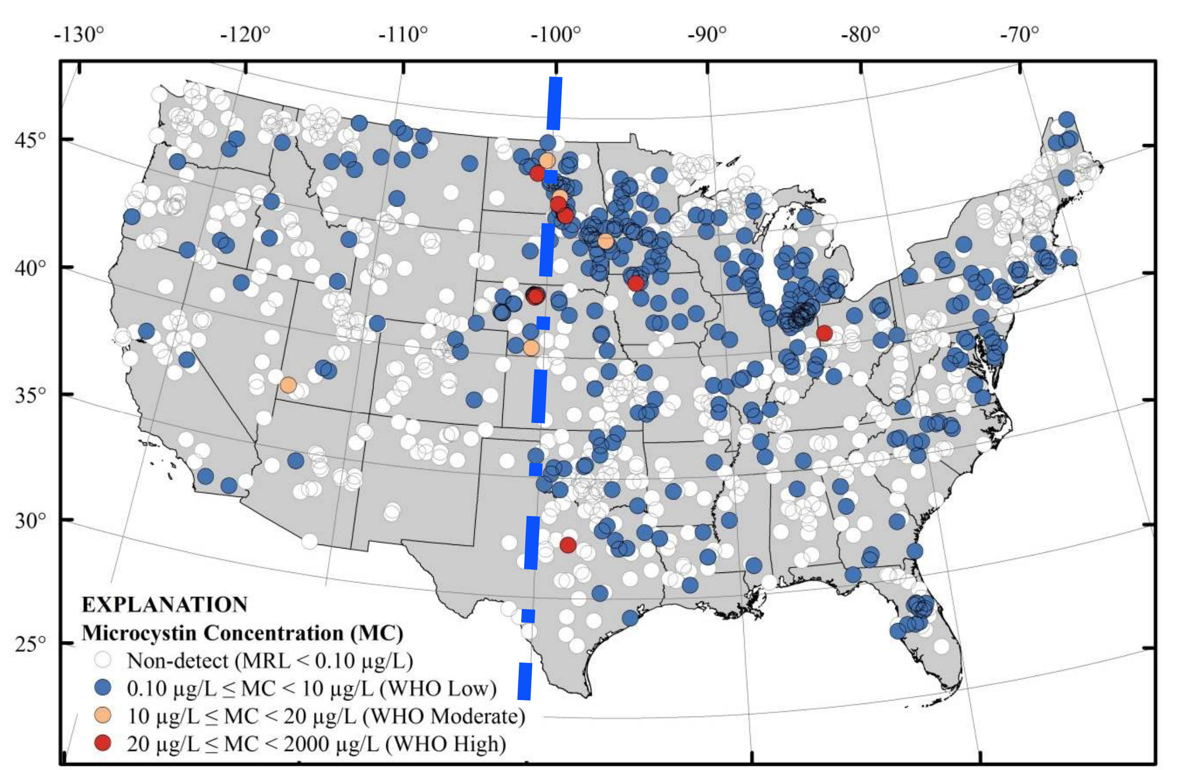
Cyanobacteria abundance and chlorophyll-a are used as surrogates for microcystin risk.

No US federal recreational guidance for any cyanotoxins. Some state guidance exists.

USGS

Chorus and Bartram, 1999
Graham, Loftin, Kamman, 2009, Lakeline, 18-24.

2007 NLA Results
Microcystins (ELISA)

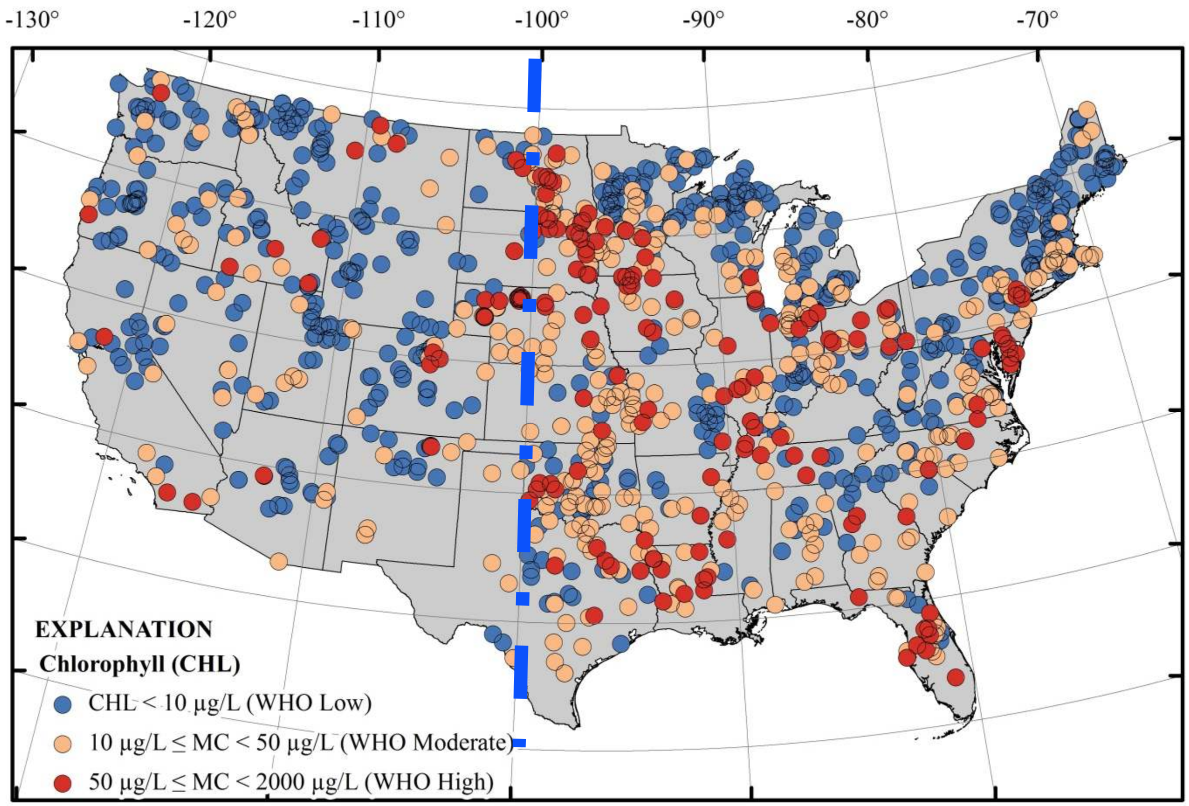


Integrated Photic Zone Samples

- **Occurrence: 32%**
- **Mean: 3.0 µg/L**
- **Median: 0.49 µg/L**
- **Max: 230 µg/L**

EPA 841-R-09-001 2007 National Lakes Assessment
Beaver et al., 2014, Harmful Algae, 36, 57-62.
Loftin et al. 2016, USGS Data Series, in press.
Loftin et al., 2016, Harmful Algae, in press.

2007 NLA Results
Chlorophyll



Integrated Photic Zone Samples

Occurrence: 99%

Mean: 29 µg/L

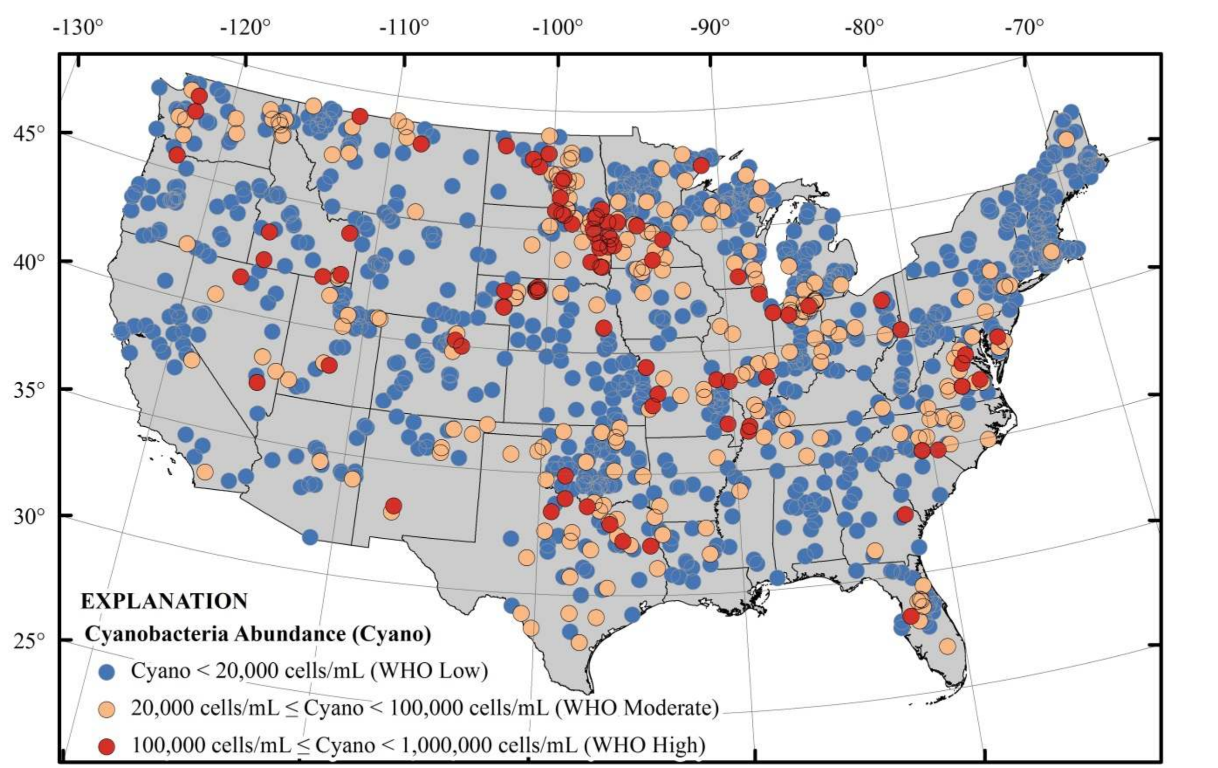
Median: 7.6 µg/L

Max: 940 µg/L

More eutrophic and hypereutrophic lakes east of -100° longitude.

Loftin et al., 2016, Harmful Algae, in press.

2007 NLA Results
Cyanobacterial Abundance



Integrated Photic Zone Samples

- **Occurrence: 98%**
- **Dominant: 76%**
- **Mean: 4.0 E4 cells/mL**
- **Max: 5.0 E6 cells/mL**

- **Potential Toxin Producer Frequency:**
- **Anatoxins: 81%**
- **Cylindrospermopsins: 67%**
- **Microcystins: 95%**
- **Nodularins: 0.24%**
- **Saxitoxins: 79%**

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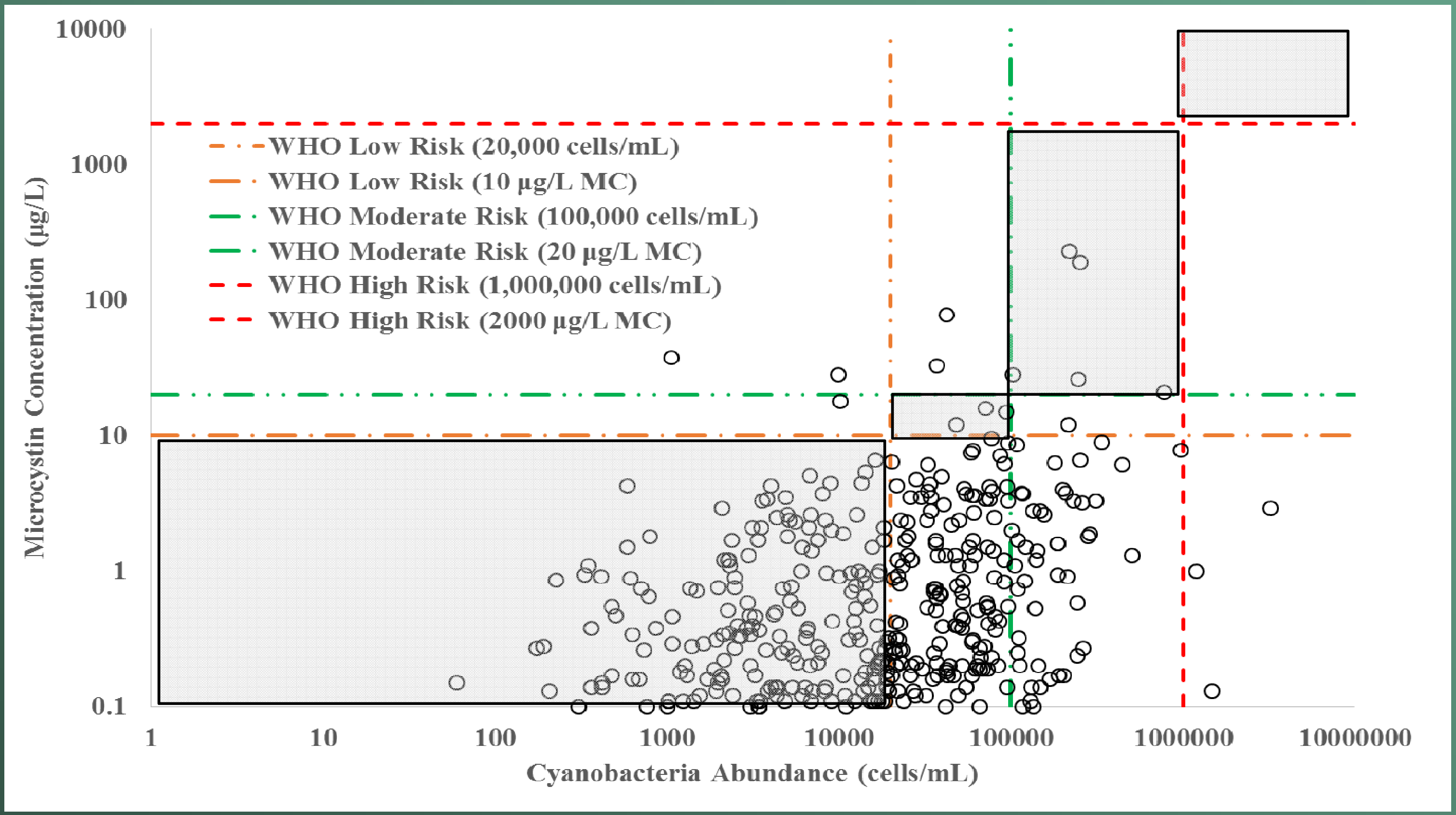
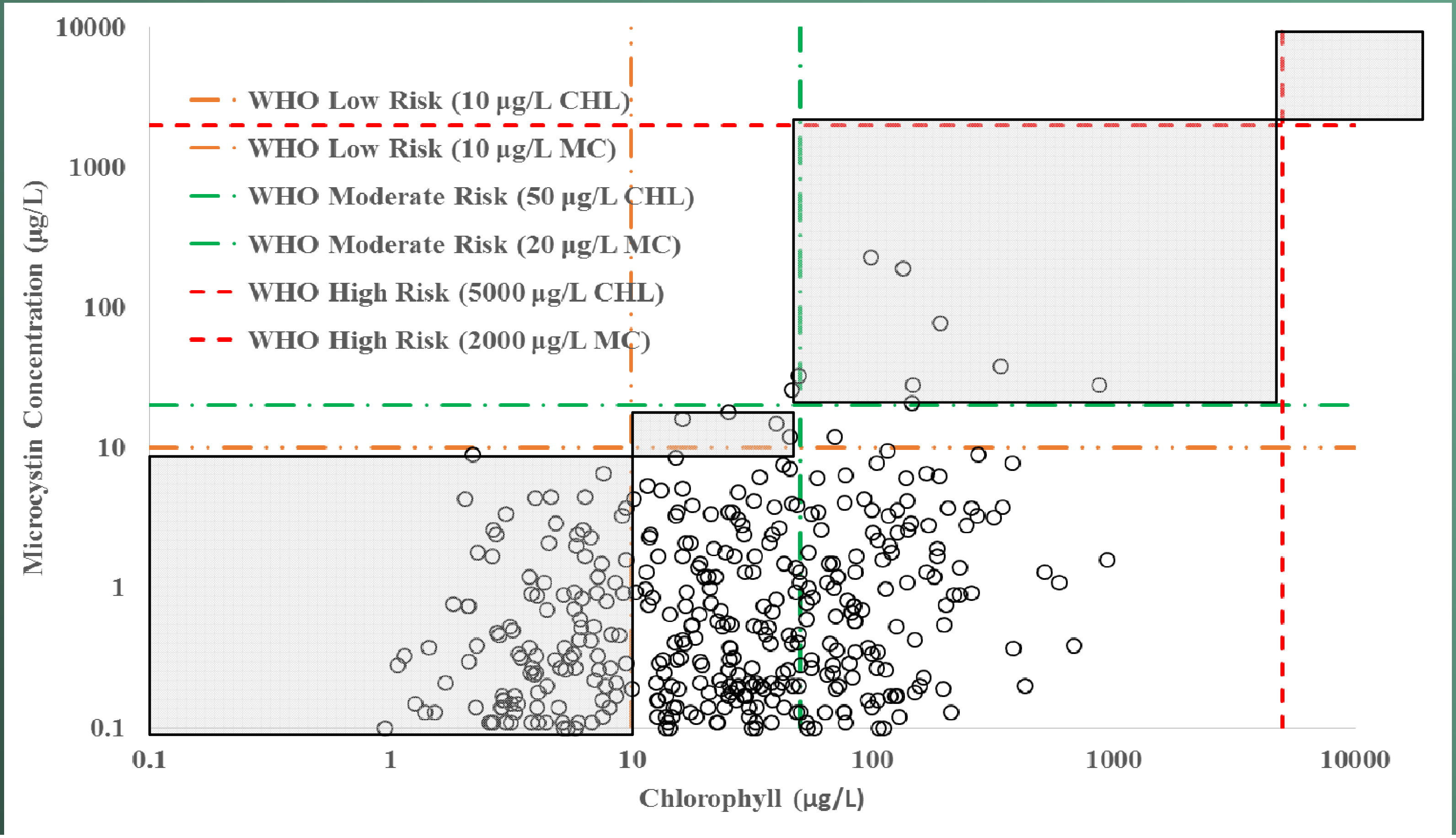
Loftin et al., 2016, Harmful Algae, in press.

WHO Cyanobacteria Abundance Over-predicts Microcystin Risk



Loftin et al., 2016, Harmful Algae, in press.

WHO Chlorophyll Over-predicts Microcystin Risk



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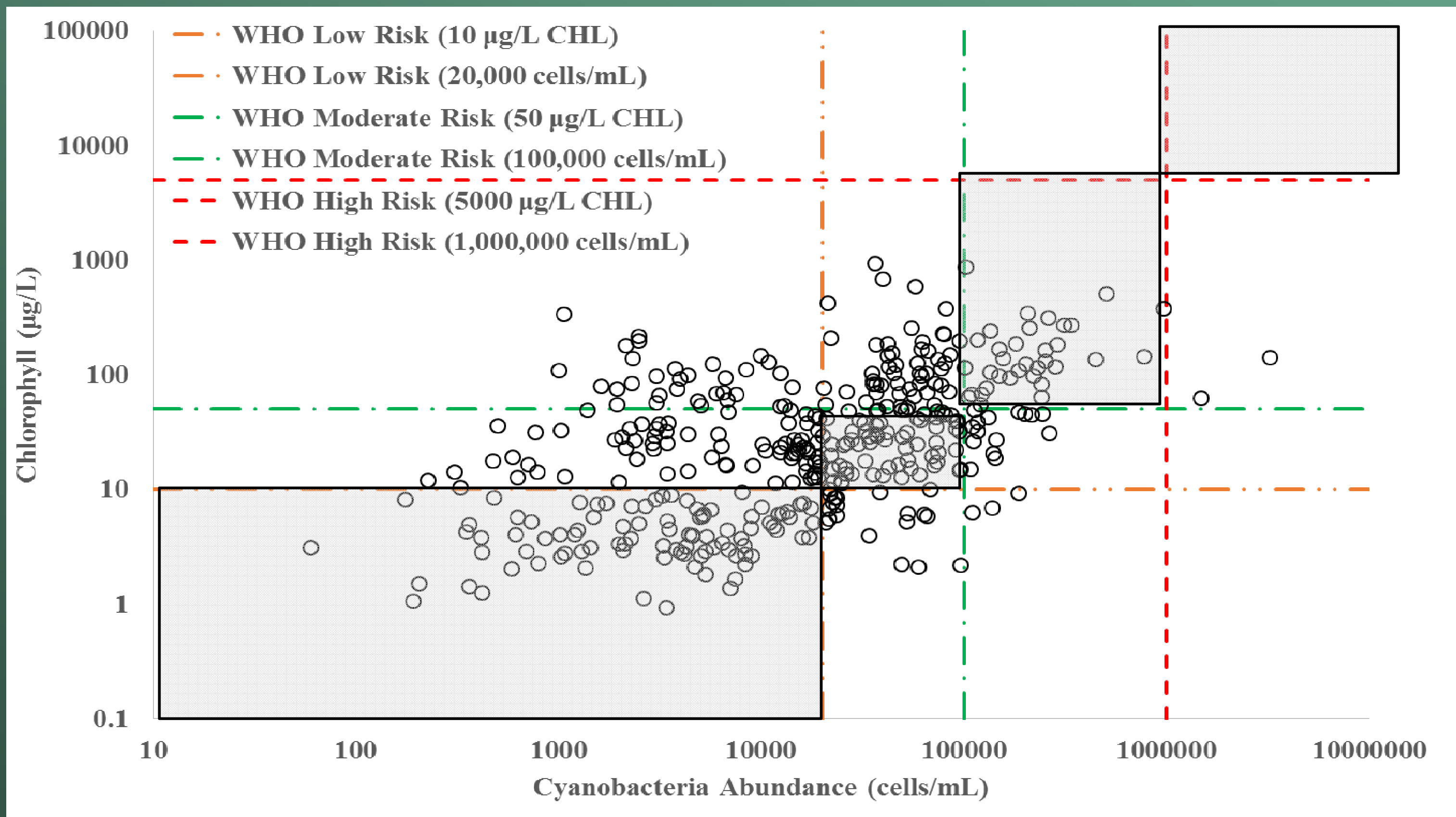
Loftin et al., 2016, Harmful Algae, in press.

WHO Chlorophyll and Cyanobacteria Abundance Have Better Agreement, but Can Still Be Problematic.

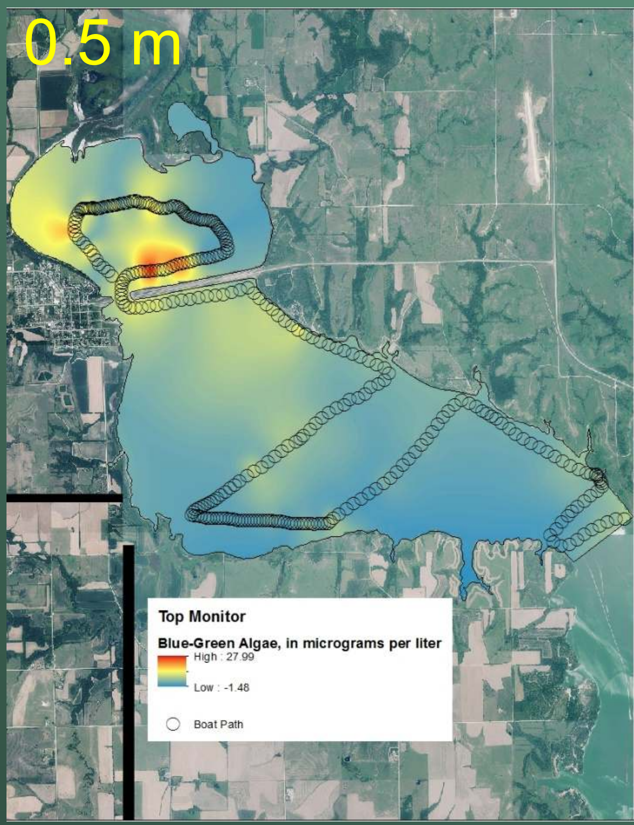


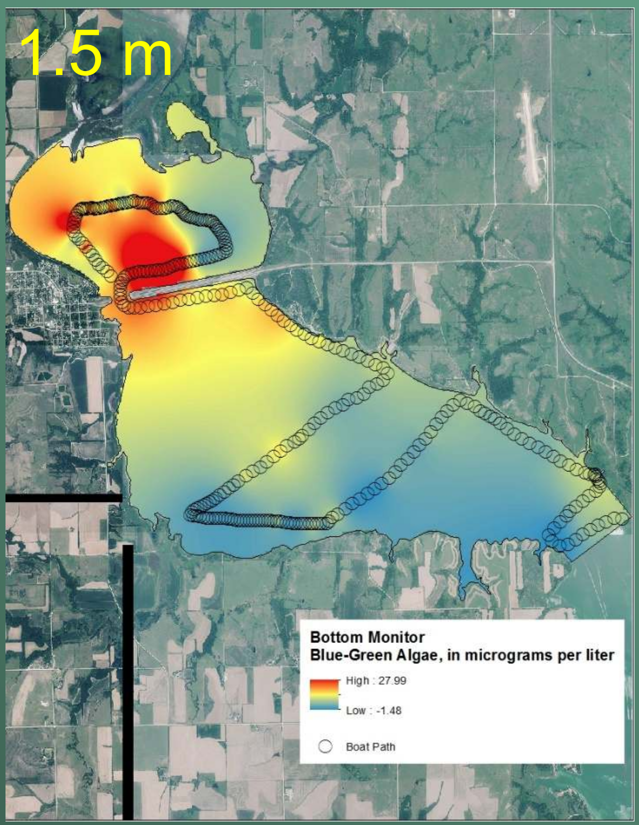
Has relevance for detection of cyanoHABs by satellite.

Loftin et al., 2016, Harmful Algae, in press.

Spatial HAB Research-

Blooms aren't always at the surface…





New sensor technologies allow new applications, such as high resolution spatial data collection.

Horizontal and Vertical Profiles

Milford Reservoir, KS, July 2015

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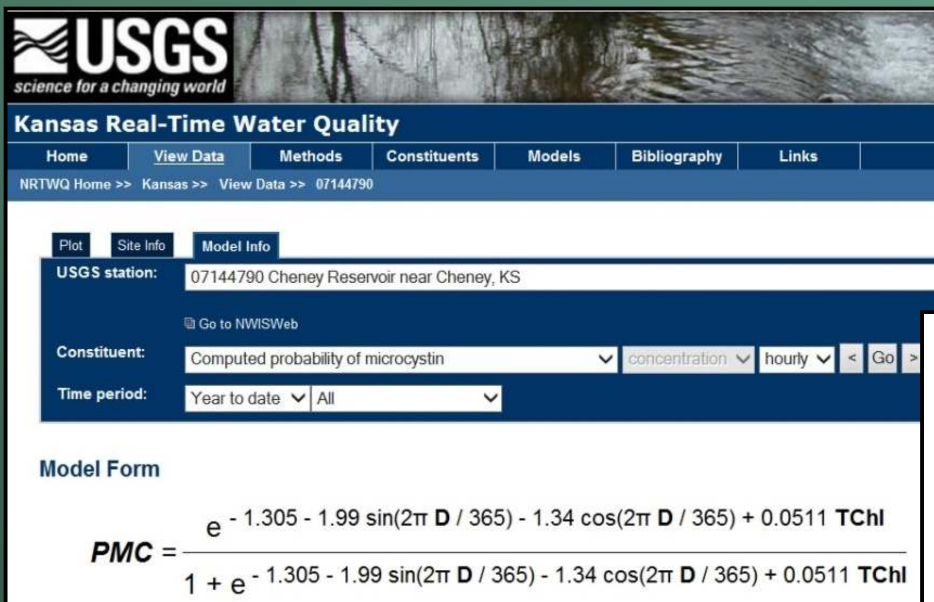
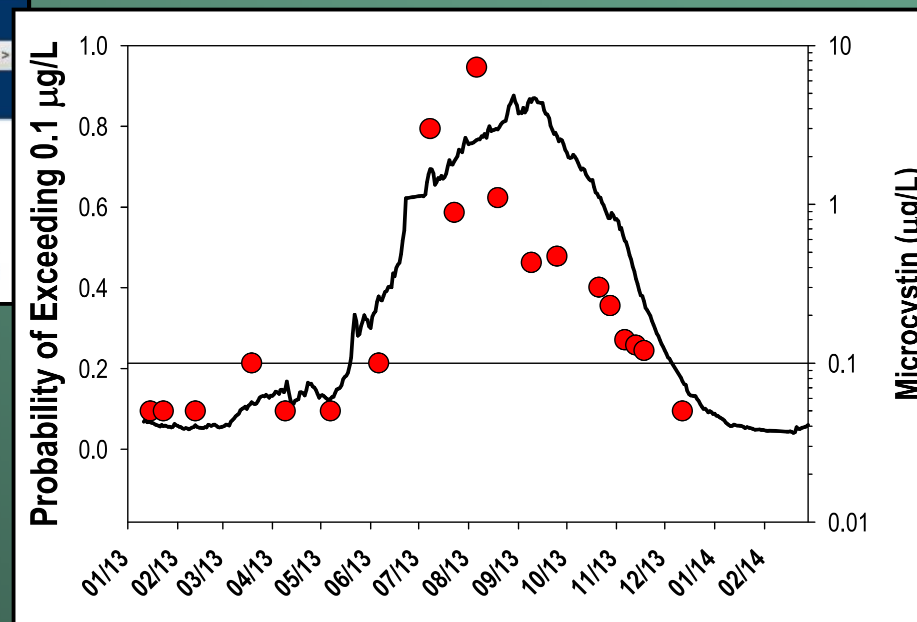
Continuous Water-Quality Monitoring

Developing Models to Compute Probability of Cyanotoxin Occurrence in Real Time



Cheney Reservoir, KS



Stone and Graham, http://pubs.usgs.gov/of/2013/1123/
http:/nrtwq.usgs.gov/ks

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Conclusions

- Cyanotoxins were detected in 92% of states and 38% of lakes sampled. Issue is National.
- Microcystins occurred the most frequently, but other toxins were detected.
- Co-occurrence of cylindrospermopsins, microcystins, and saxitoxins was rare (0.32%) in integrated photic zone samples.
- WHO surrogate guidance (chlorophyll, cyanobacteria) usually over predicts microcystin recreational risk.
- Chlorophyll agrees better with cyanobacteria abundance which gives credibility to remote sensing approaches focused on chlorophyll reflectance.
- So let's discuss the interagency CyAN project

How Do We Monitor HABs as a Nation?

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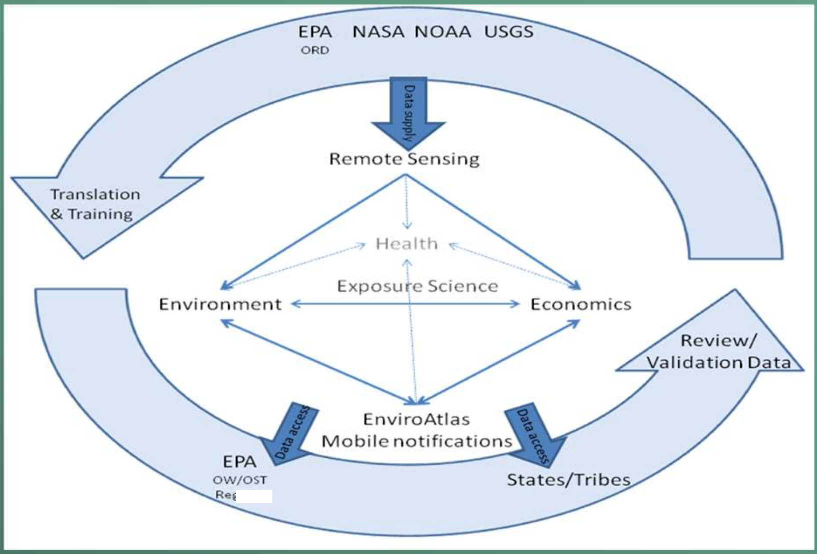
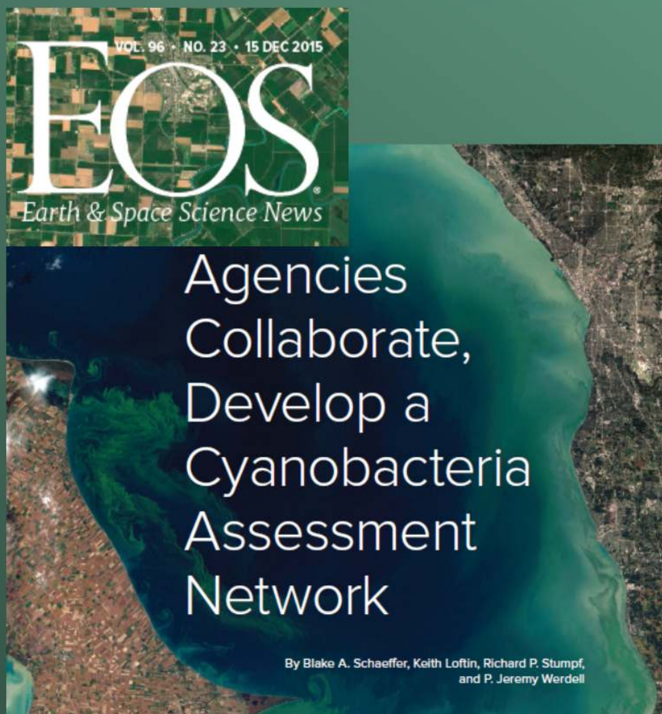
CyAN (Cyanobacteria Assessment Network) Project

- **Using multiple satellite platforms to see U.S. HABs in attempt to provide early warning.**
- **Brings the strengths of multiple agencies together.**



CyAN Technical Approach



https://eos.org/project-updates/agencies-collaborate-develop-a-cyanobacteria-assessment-network

Remote Sensing

Uniform and systematic approach for identifying cyanobacteria blooms.

Strategy for evaluation and refinement of algorithms across platforms.

Environment

Identify landscape linkages causes of chlorophyll-a and cyanobacteria.

Health

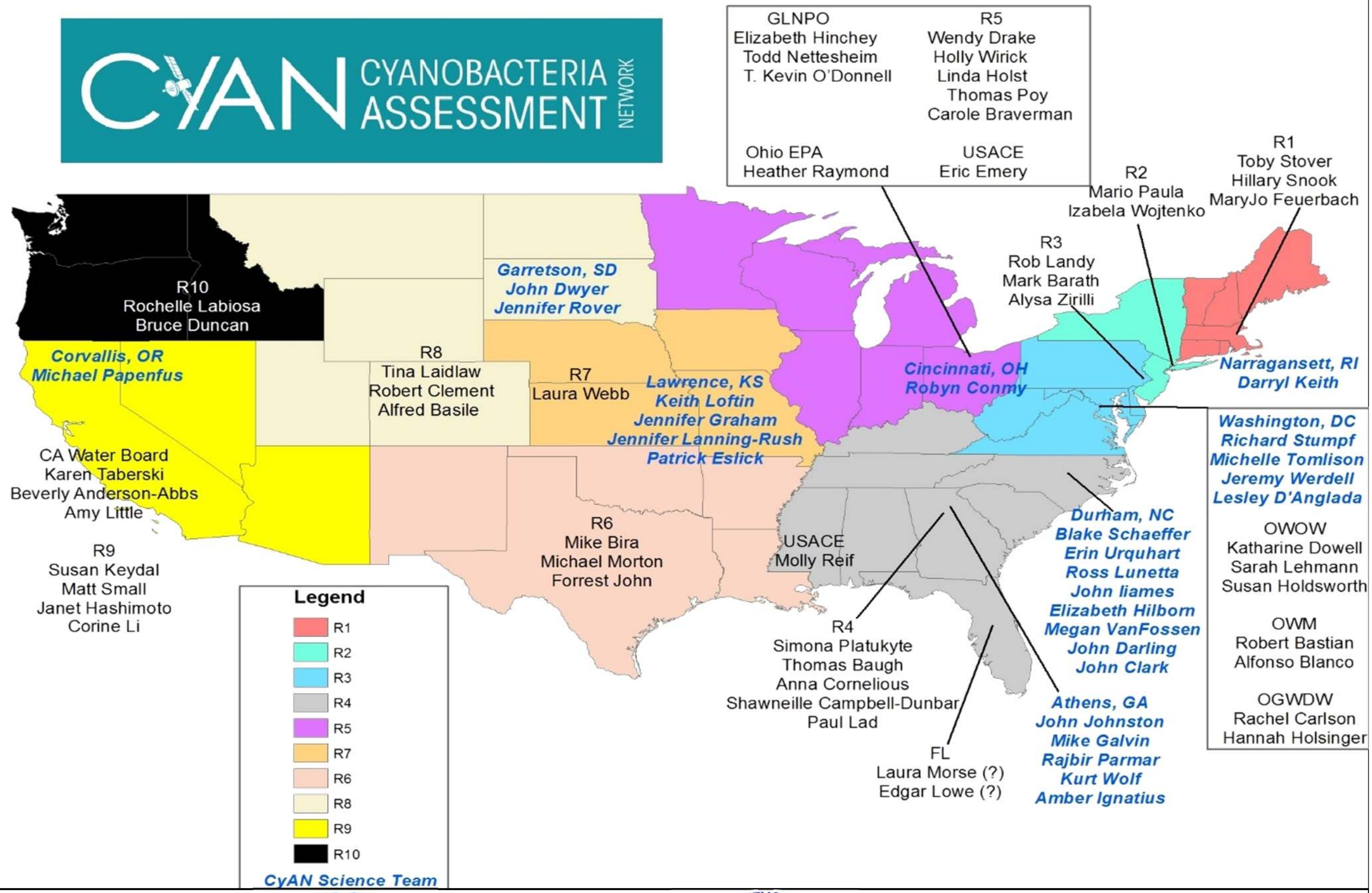
Exposure and human health effects in drinking and recreational waters.

Economics

Behavioral responses and economic value of the early warning system.

Notifications

Bring the technology to EPA, states and tribal partners.


CYAN CYANOBACTERIA ASSESSMENT NETWORK
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Wendy Drake
Holly Wirick
Linda Holst
Thomas Poy
Carole Braverman
Ohio EPA
Heather Raymond
USACE
Eric Emery
R2
Mario Paula
Izabela Wojtenko
R1
Toby Stover
Hillary Snook
MaryJo Feuerbach
R3
Rob Landy
Mark Barath
Alysa Zirilli
R10
Rochelle Labiosa
Bruce Duncan
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Amy Little
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Susan Keydal
Matt Small
Janet Hashimoto
Corine Li
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Hannah Holsinger
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John Johnston
Mike Galvin
Rajbir Parmar
Kurt Wolf
Amber Ignatius
Legend
R1
R2
R3
R4
R5
R7
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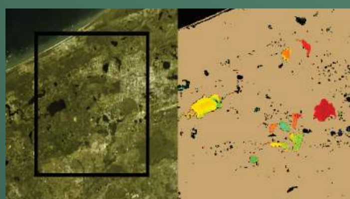
R8
R9
R10
CyAN Science Team

National HAB Database: Highly Desired Lake/Reservoir Data Sets

- Phytoplankton (cyanobacteria)
  - Abundance
  - Relative Abundance
  - Biovolume
- Pigments
  - Chlorophyll including pheophytin data
  - Phycocyanin
- Cyanotoxins
- Organic Matter – TOC, DOC, SUVA, CDOM, FDOM, Water Color
- Particulates - Secchi Depth, Suspended Solids, turbidity

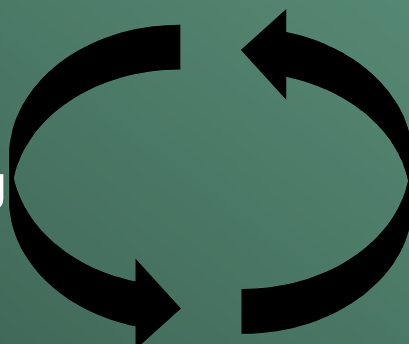
USGS science for a changing world

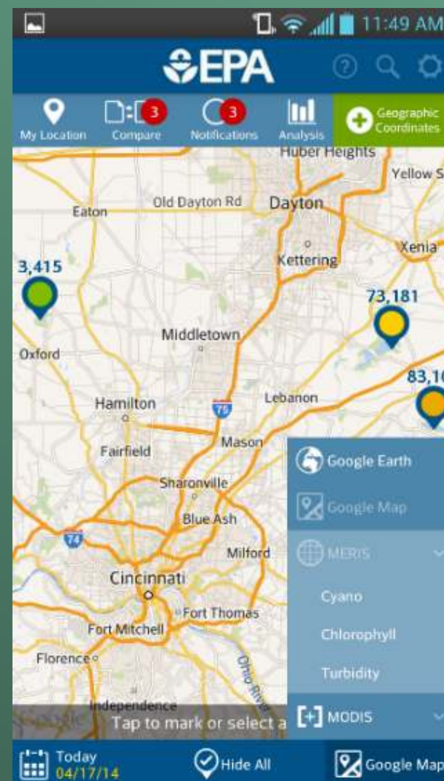
CyAN Early Warning System

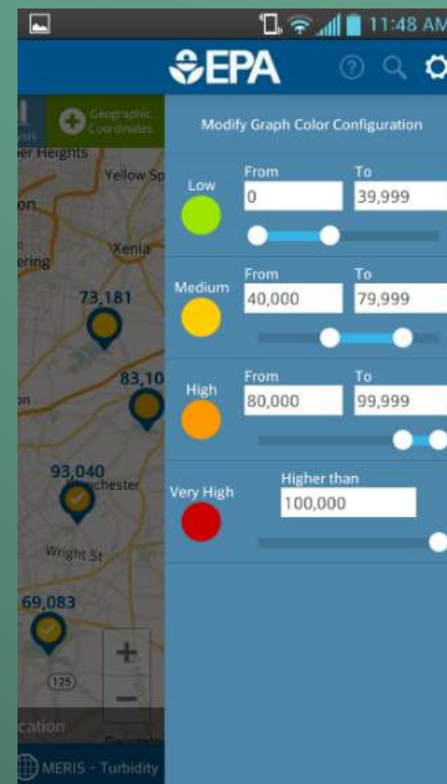


Remote Sensing

Field Data







Future of HAB Research and Monitoring

- Integrated monitoring approaches from field to space
- Directed event-response
- Proactive public health protection
- Needs still include short and long-term solutions
- Predictive models need to be supported by mechanistic understanding of processes.

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