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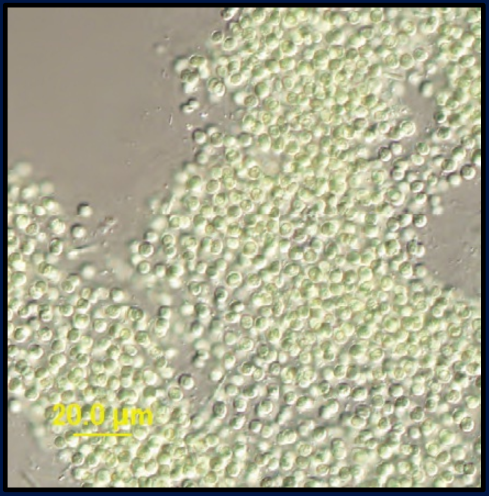
U.S. Geological Survey
Harmful Algal Bloom and Hypoxia Research



What Are Cyanobacteria?

- Cyanobacteria are true bacteria, but have chlorophyll-*a* like algae.
- Structurally the cyanobacteria are bacteria-like, but functionally they are algae-like.
- Because cyanobacteria function like algae in aquatic ecosystems, they typically are considered to be part of algal communities (this is why they often are called blue-green algae).

Gloeotrichia echinulata



Microcystis aeruginosa

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Images from Rosen and others, OFR 2010-1289
http://pubs.usgs.gov/of/2010/1289/

What is an Algal Bloom?

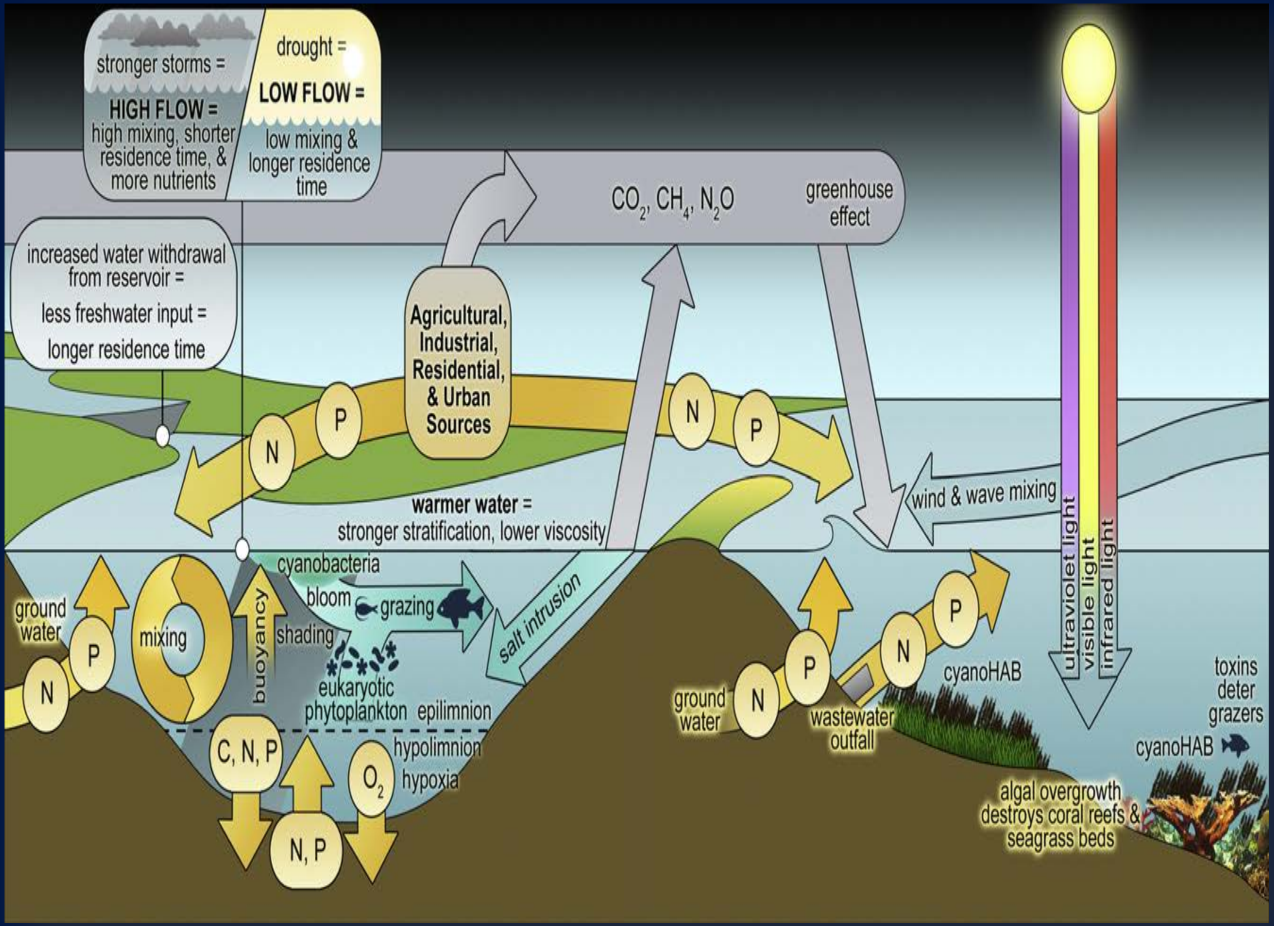
- The definition of a "bloom" is somewhat subjective.
- Common definitions include:
  - Algae have high cell densities (20,000 to 100,000 cells/mL).
  - Proliferation of algae is dominated by a single or a few species.
  - There is a visible accumulation of algae.

South Dakota - green algae bloom

Idaho - cyanobacteria bloom
photo courtesy of F. Wilhelm

What Causes Algal Blooms?

Many environmental factors influence the occurrence of algal blooms.
In general, an algal bloom indicates an ecosystem imbalance.



Courtesy of Hans Paerl

What Makes Some Algal Blooms Harmful?

Harmful algal blooms (HABs) can occur anytime water use is impaired due to excessive accumulations of algae.

- Ecologic Concerns
- Economic Concerns
- Public Health Concerns

Texas – golden algae bloom
Photo courtesy of TPWD and G. Turner

Kansas – cyanobacterial bloom

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What Cyanobacteria Produce Toxins and Taste-and-Odor Compounds?

	Hepatotoxins		Neurotoxins		Dermatoxins	Taste/Odor	
	CYL	MC	ANA	SAX		GEOS	MIB
Anabaena	X	X	X	X	X	X	?
Aphanizomenon	X	?	X	X	X	X	
Microcystis		X			X		
Oscillatoria/Planktothrix		X	X	X	X	X	X

Photos courtesy of A. St. Amand

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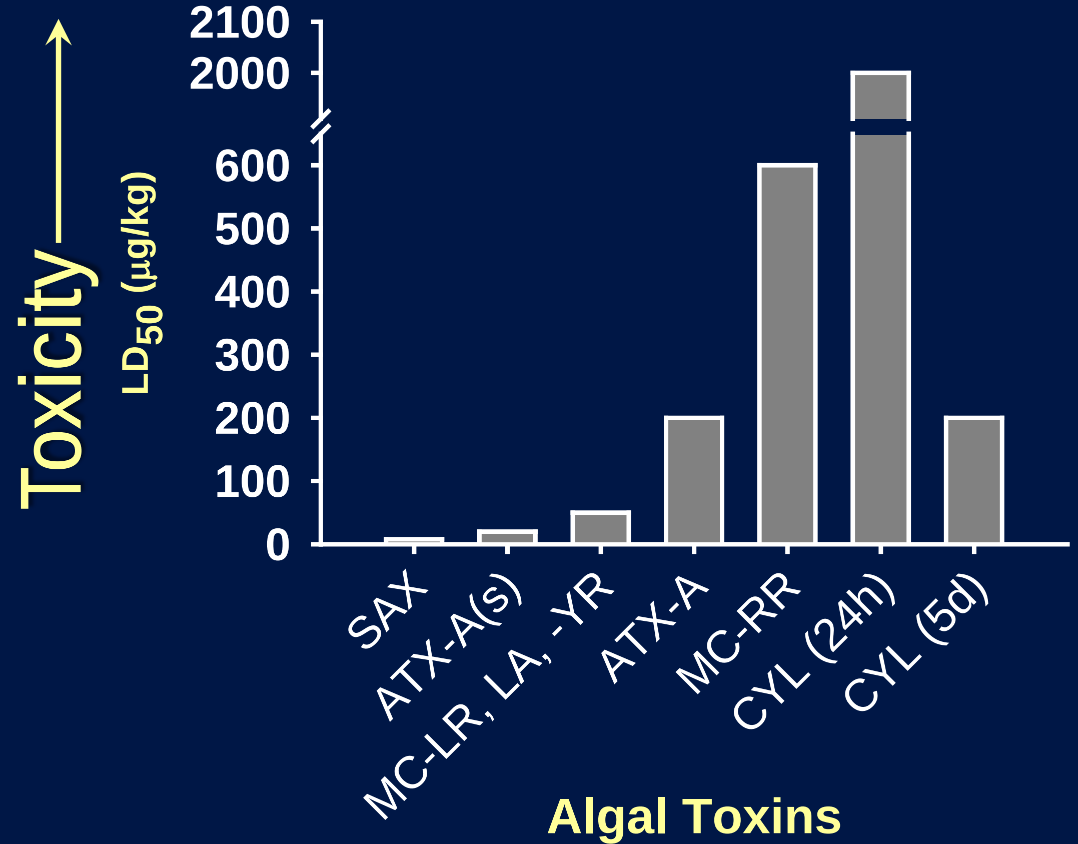
After Graham and others, 2008, TWRI Chapter 7.5
http://water.usgs.gov/owq/FieldManual/

How Toxic Are Cyanotoxins?



- Acute Toxicity
  - Neurotoxic
  - Hepatotoxic
  - Dermatoxic
- Chronic Toxicity
  - Carcinogen
  - Tumor Promotion
  - Mutagen
  - Teratogen
  - Embryolethality
  - Neurodegenerative Diseases

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After Chorus and Bartram, 1999

The August 2014 Toledo Incident Focused National Attention on the Potential for Cyantoxins in Drinking-Water

Toledo bans tap water after algae toxins found

Bi

Toledo Water Ban Persists After New Test Results Cause Concerns

by THE

August

Toledo-area water advisory expected to continue through Sunday as leaders await tests; water stations to remain open

Microcystin found in samples; boiling not recommended

Toledo, Ohio, Headed for Third Day With Drinking Water Ban

Nolan Feen

Toledo Water Ban Lifted But Test Results Kept Secret

BY KILEY KROH POSTED ON AUGUST 4, 2014 AT 3:21 PM UPDATED: AUGUST 4, 2014 AT 4:51 PM

Are There Regulations for Cyanotoxins?

USEPA Health Advisory Levels for Cyanotoxins in Finished Drinking Water:

- Microcystin: 0.3, 1.6 µg/L
- Cylindrospermopsin: 0.7, 3.0 µg/L

World Health Organization Provisional Recreational Guidance for Microcystin-LR

USEPA Health Advisory Levels for Cyanotoxins in Finished Drinking Water:

- Low Risk: <10 µg/L
- Moderate Risk: 10-20 µg/L
- High Risk: 20-2,000 µg/L
- Very High Risk: >2,000 µg/L

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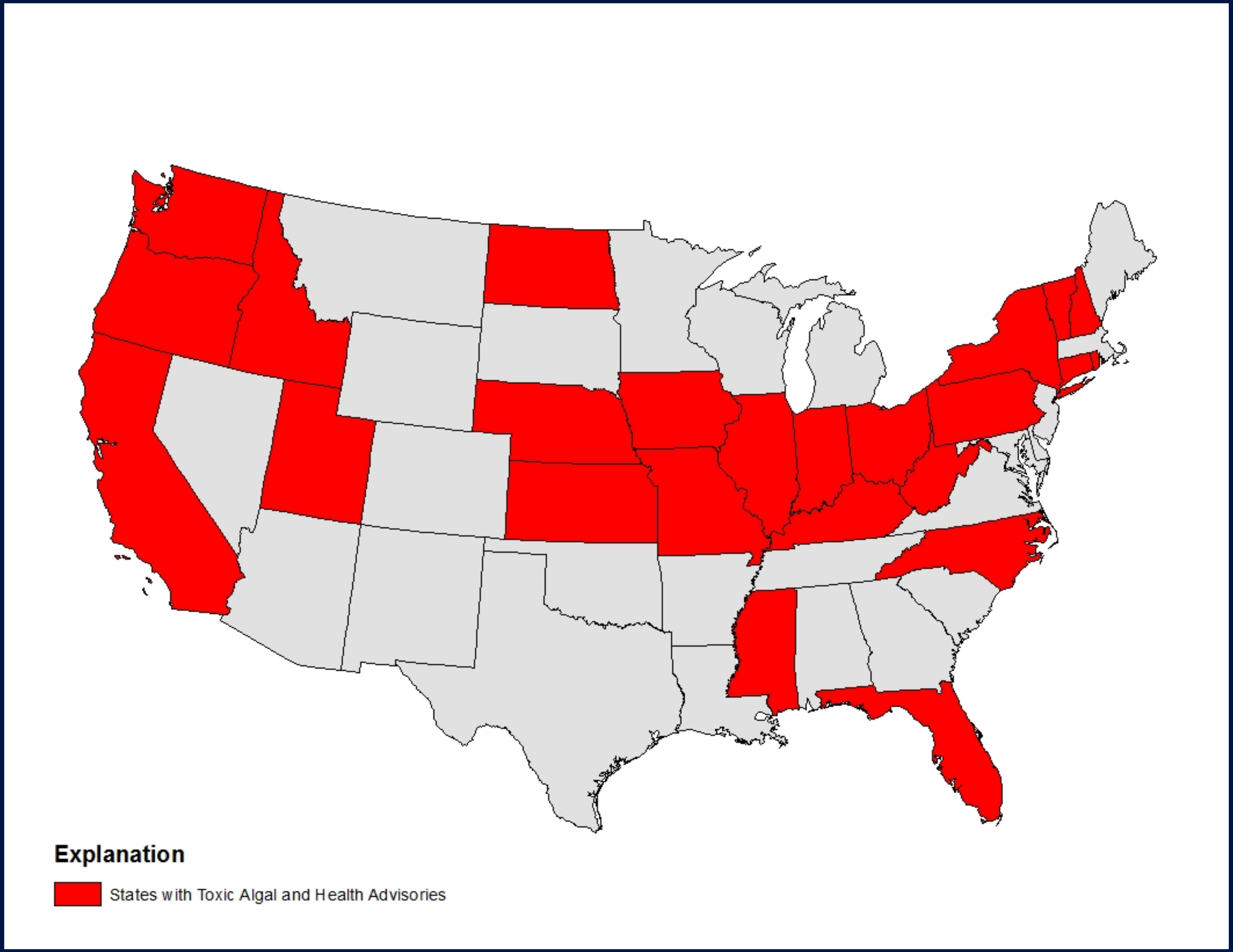
http://water.epa.gov/drink/standards/hascience.cfm
http://www.who.int/water_sanitation_health/dwq/chemicals/microcystinsum.pdf

In August 2015, 24 States Had Toxic Algal and Health Advisories for Cyanobacteria



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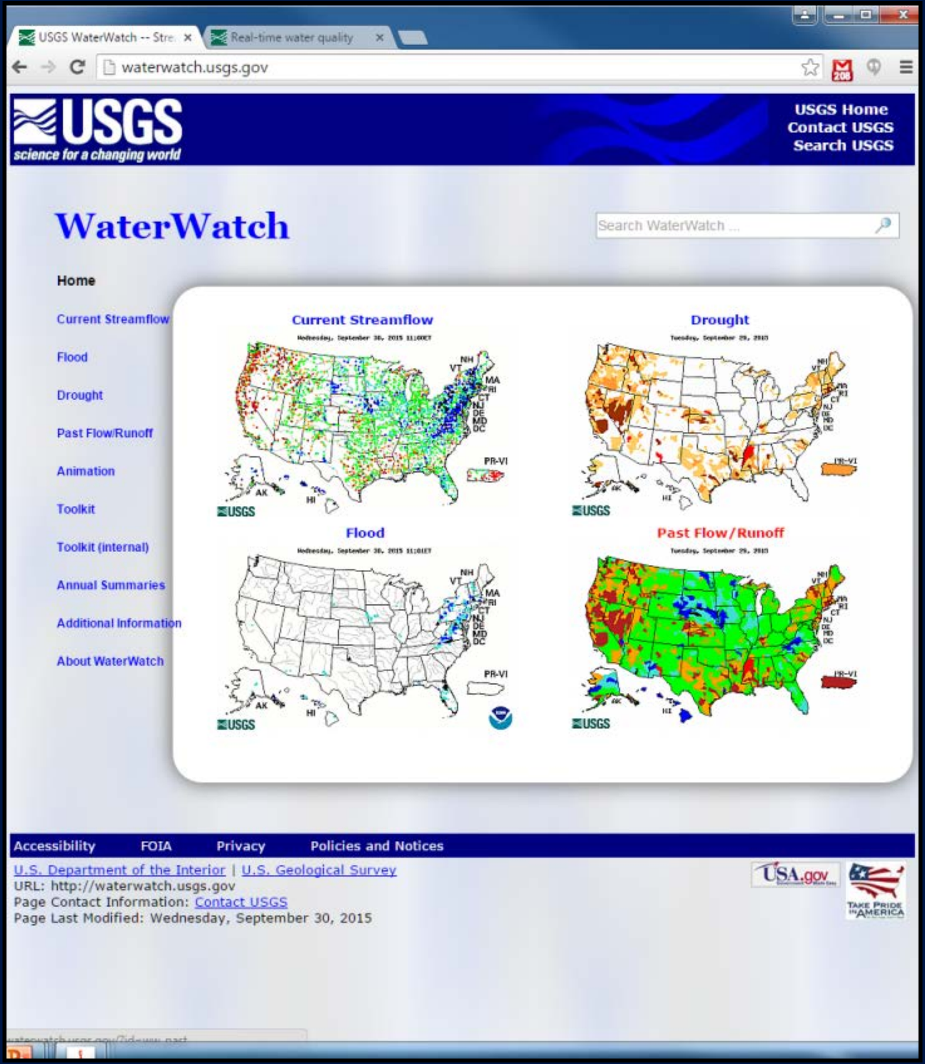
Data Compiled from EPA Freshwater HAB News

U.S. Geological Survey

Mission: The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.



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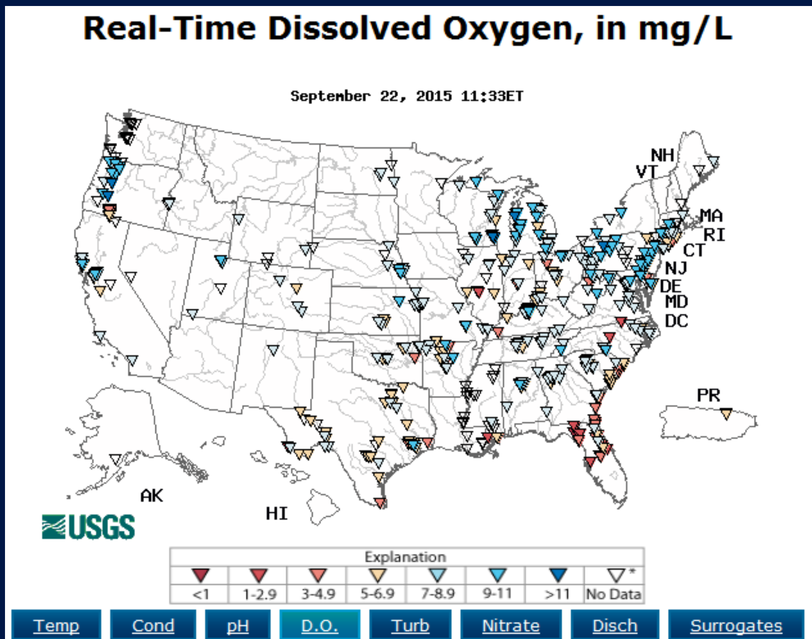
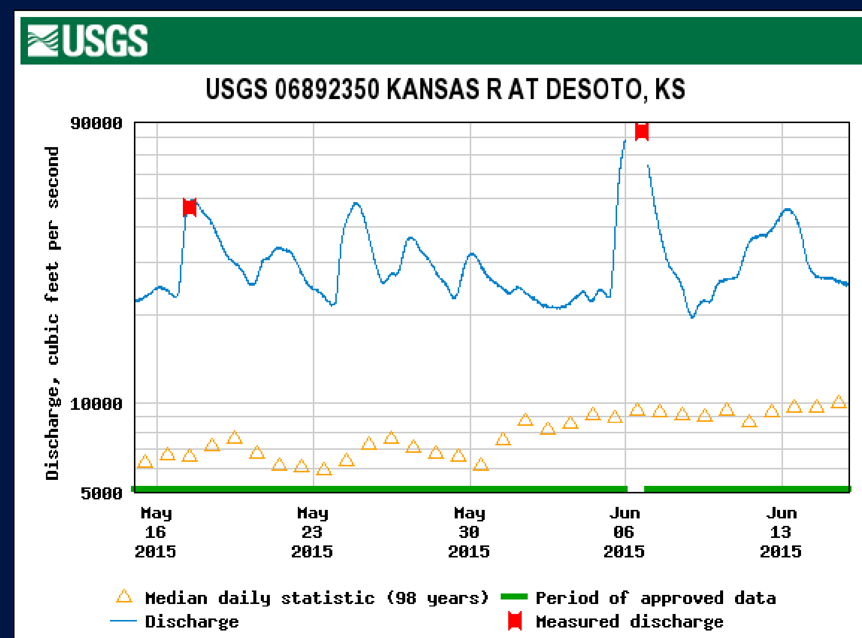
National Streamgage and Sensor Networks





http://waterwatch.usgs.gov/wqwatch
http://water.usgs.gov/wateralert/
http://waterdata.usgs.gov
http://nrtwq.usgs.gov

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U.S. Geological Survey Mission Areas

- Climate and Land Use Change
- Core Science Systems
- Ecosystems
- Energy and Minerals
- Environmental Health
- Natural Hazards
- Water

USGS Partnerships to Conduct HAB and Hypoxia Research, Monitoring, and Modeling

- Across Mission Areas
- Local, State, Tribal
- Federal
  - USACE, BOR, CDC, EPA, FDA, FWS, NASA, NIH, NOAA, USDA
- Universities

- Satellite Cyanobacteria Assessment Network (CyAN)
  - USGS, EPA, NOAA, NASA
  - Detect and quantify cyanobacterial blooms in freshwater systems using satellite data records
  - Mobile application development
  - 5-year project

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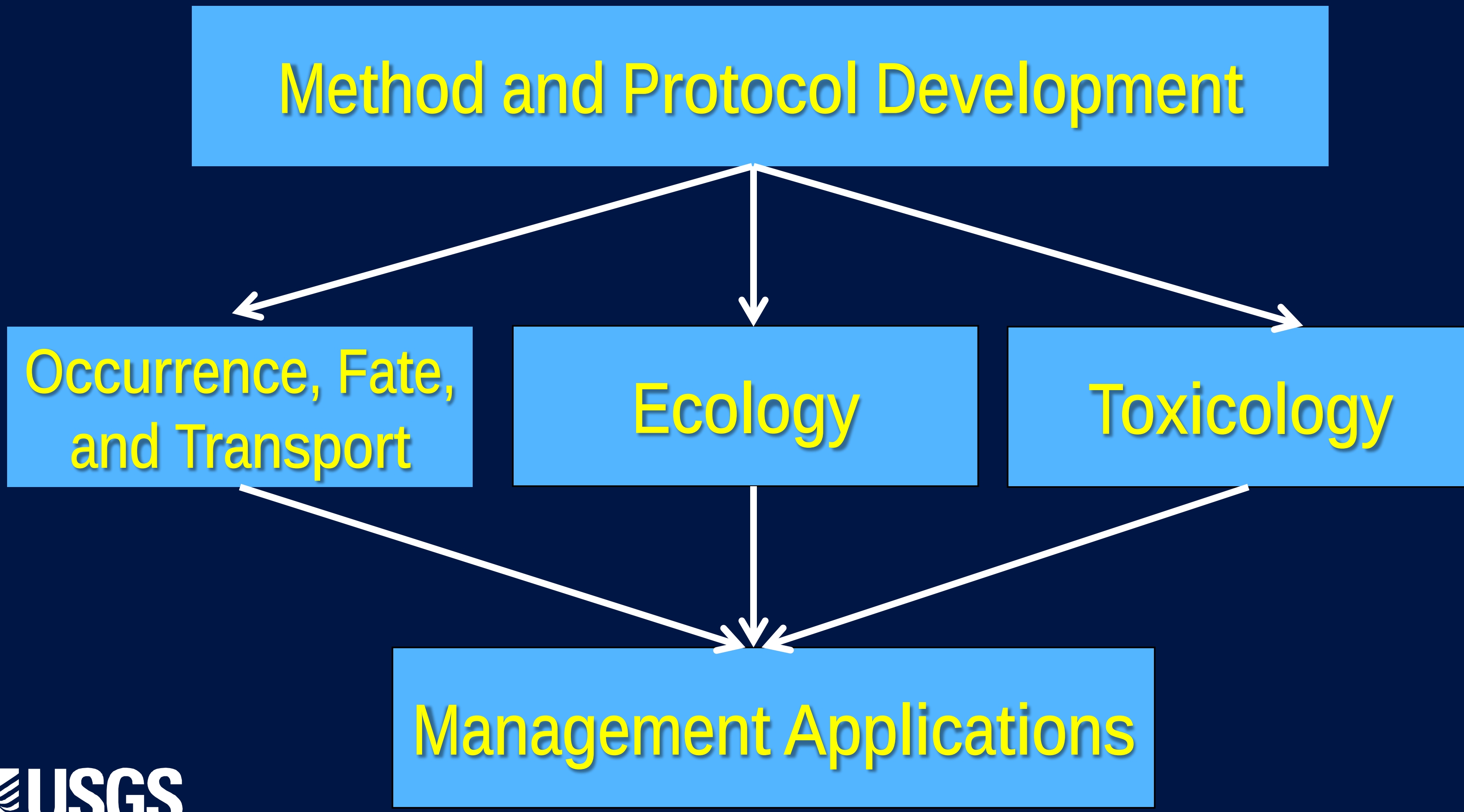
USGS HAB and Hypoxia Research, Monitoring, and Modeling



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Field and Laboratory Methods

- Guidelines for Nationally Consistent Science
  - http://water.usgs.gov/owq/FieldManual/Chapter7/7.5
- Robust and Quantitative Analytical Methods for Cyanotoxins in Water, Tissues, and Sediment
  - http://pubs.usgs.gov/of/2008/1341/
  - http://pubs.er.usgs.gov/publication/ofr20101289
- Morphological Taxonomy
  - http://pubs.er.usgs.gov/publication/ofr20151164
- Molecular Methods
  - http://dx.doi/org/10.311/sir20135189
- Other Developing Approaches

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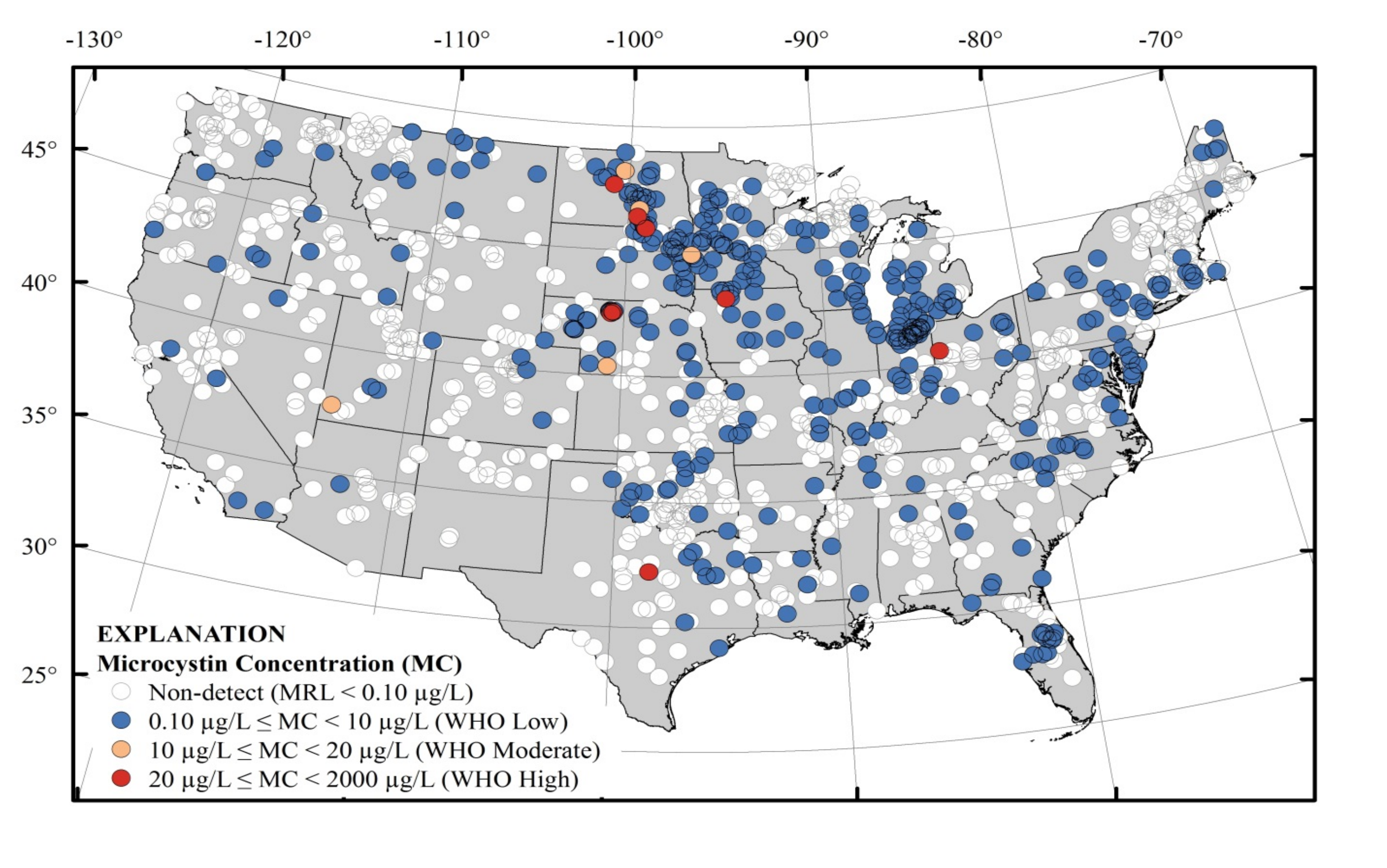
USGS Harmful Algal Bloom Research

Occurrence - National Assessment of Microcystin

Microcystins Occurred in 32 Percent of Lakes Across the Nation



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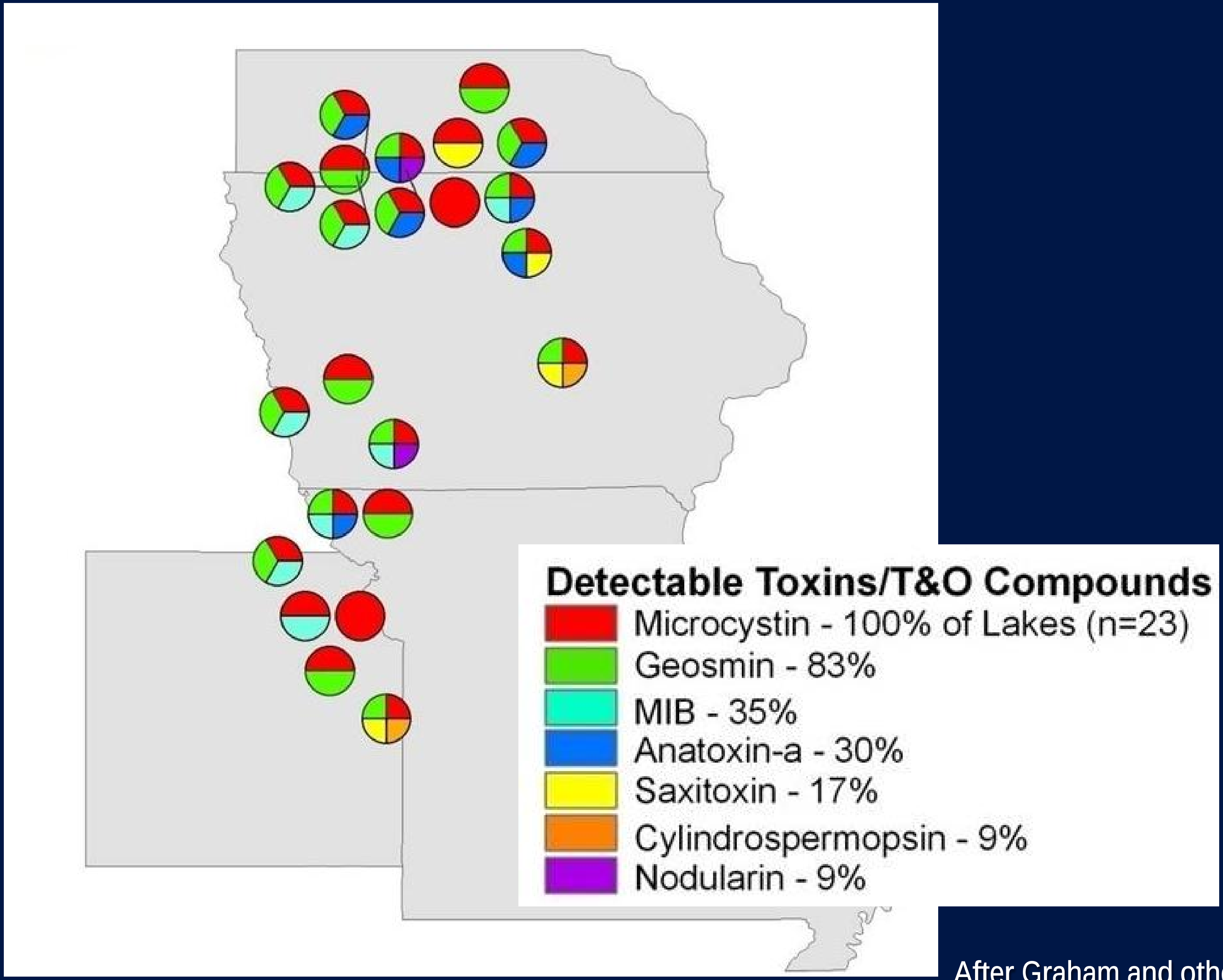
http://water.epa.gov/type/lakes/upload/nla_newlowres_fullrpt.pdf
Loftin and others, 2016

Occurrence – Regional Assessment of Mixtures

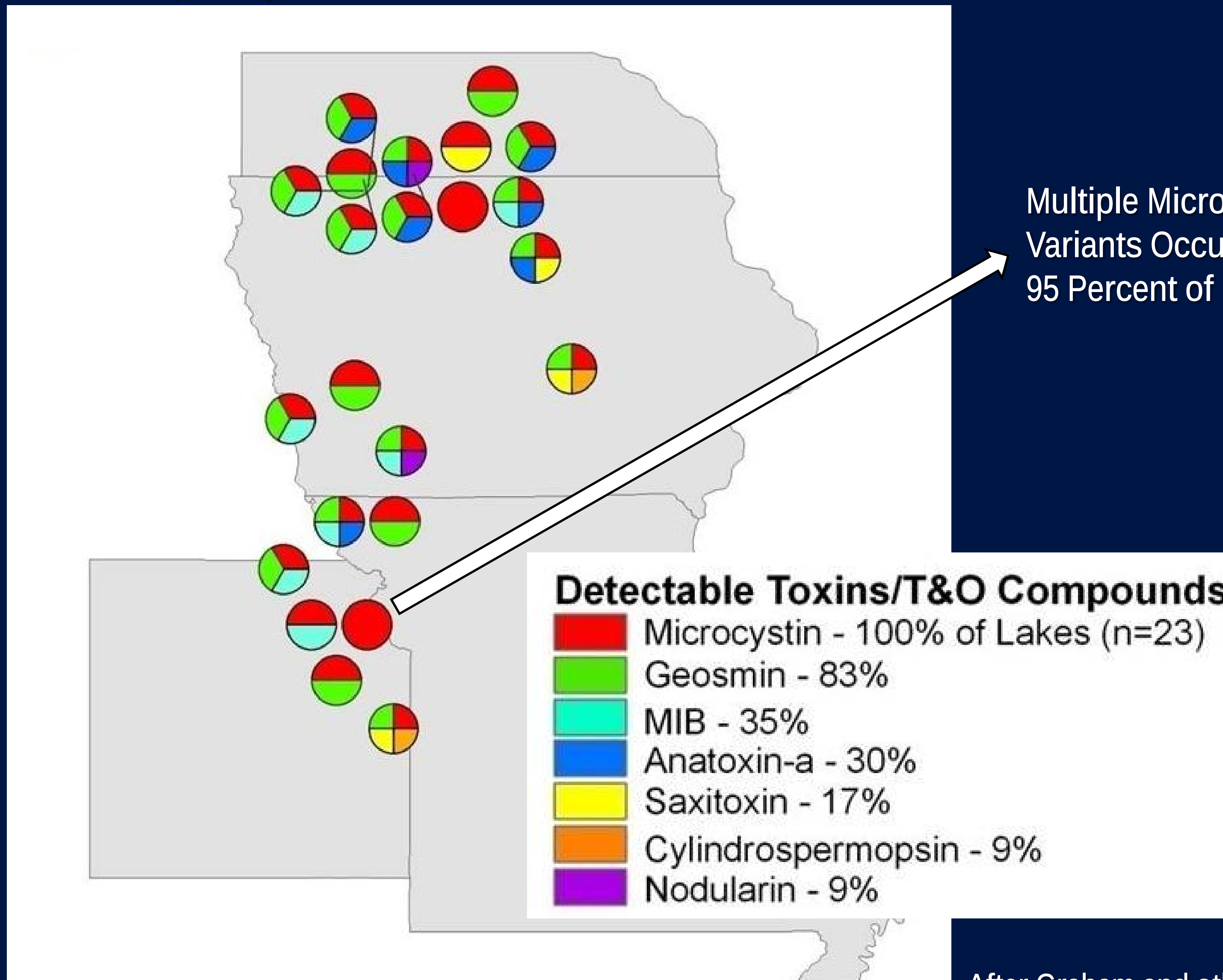
Multiple Cyanotoxins Occurred in 30 Percent of Blooms



After Graham and others, 2010

Occurrence – Regional Assessment of Mixtures

Multiple Cyanotoxins Occurred in 30 Percent of Blooms

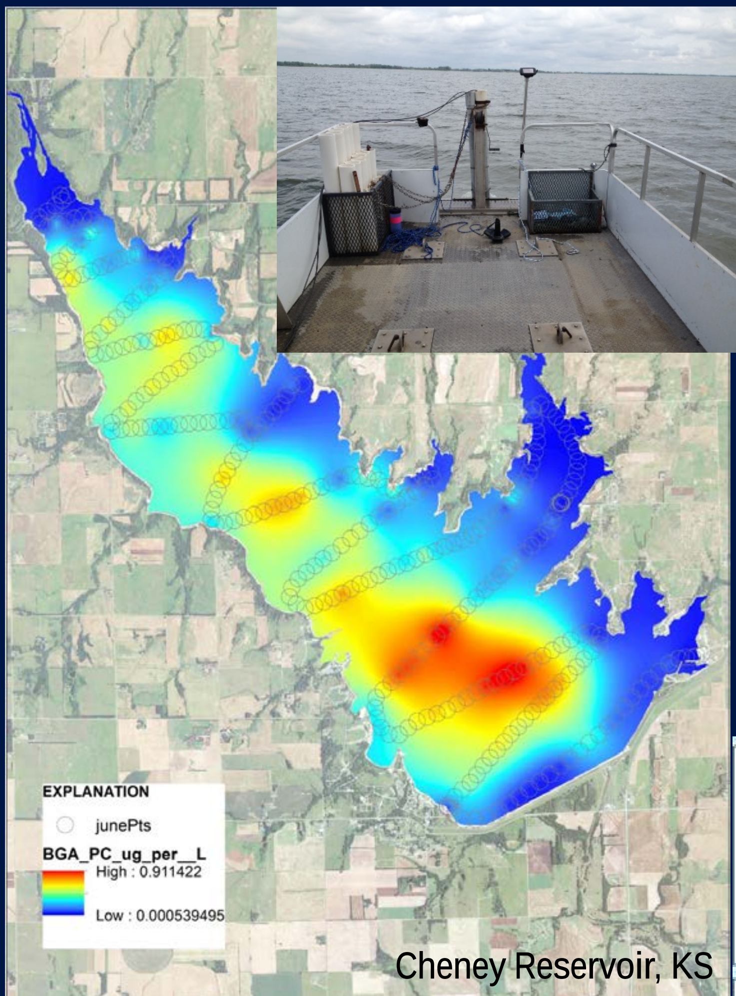


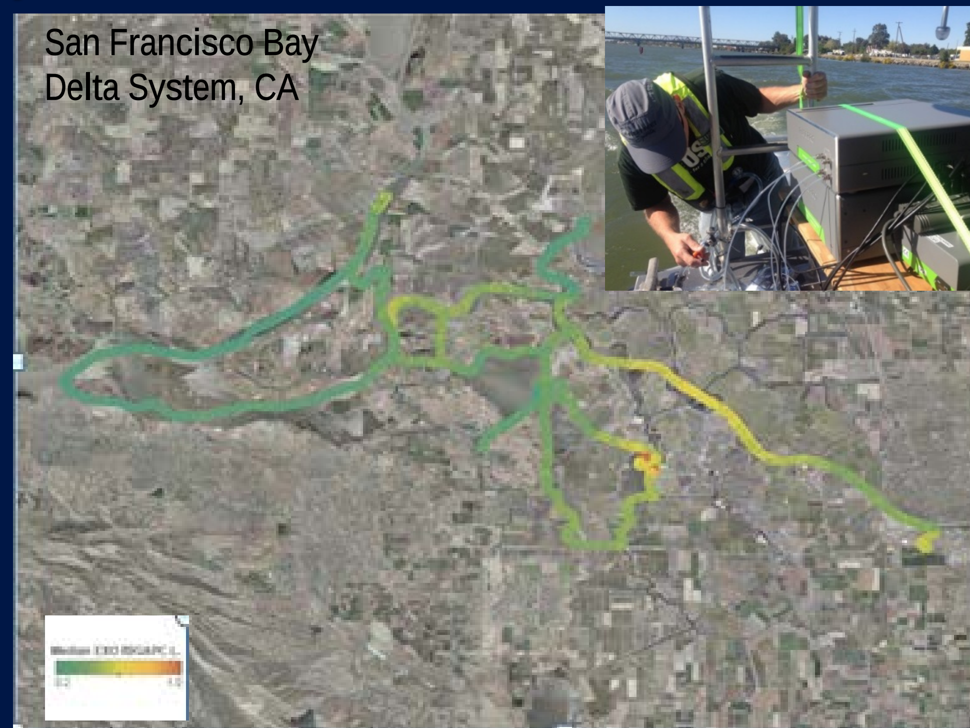
Multiple Microcystin Variants Occurred in 95 Percent of Blooms

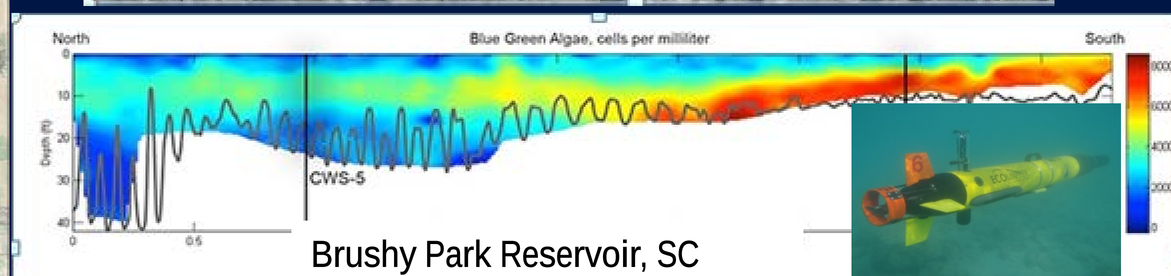
After Graham and others, 2010

Fate and Transport

Quantifying variability in cyanobacterial distribution is critical to understanding fate, transport, population dynamics, and environmental drivers.







Foster, KSWSC
Bergamaschi, CAWSC
Journey, SAWSC

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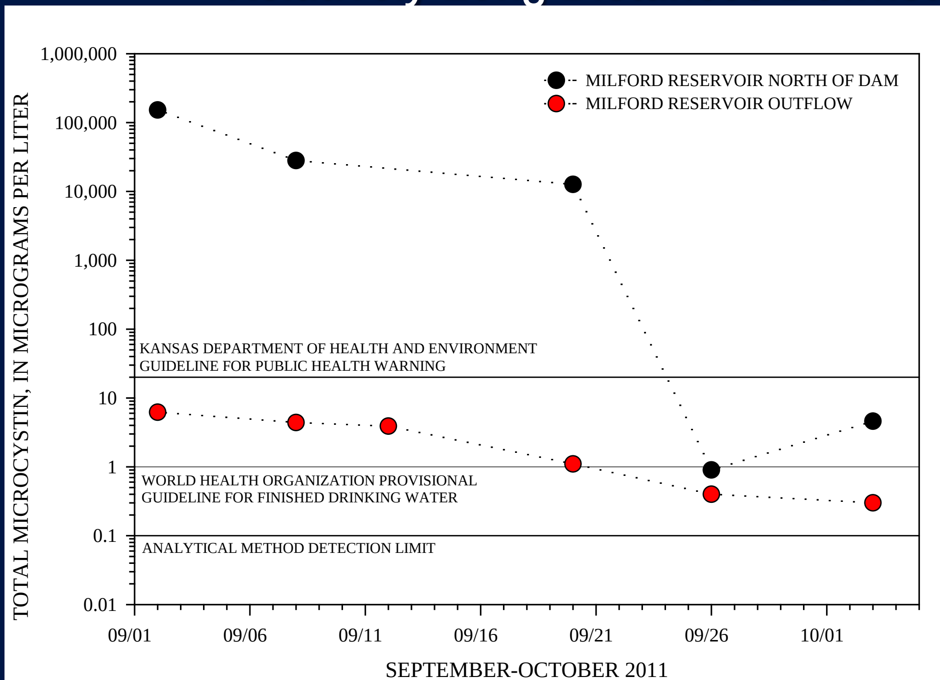
Fate and Transport

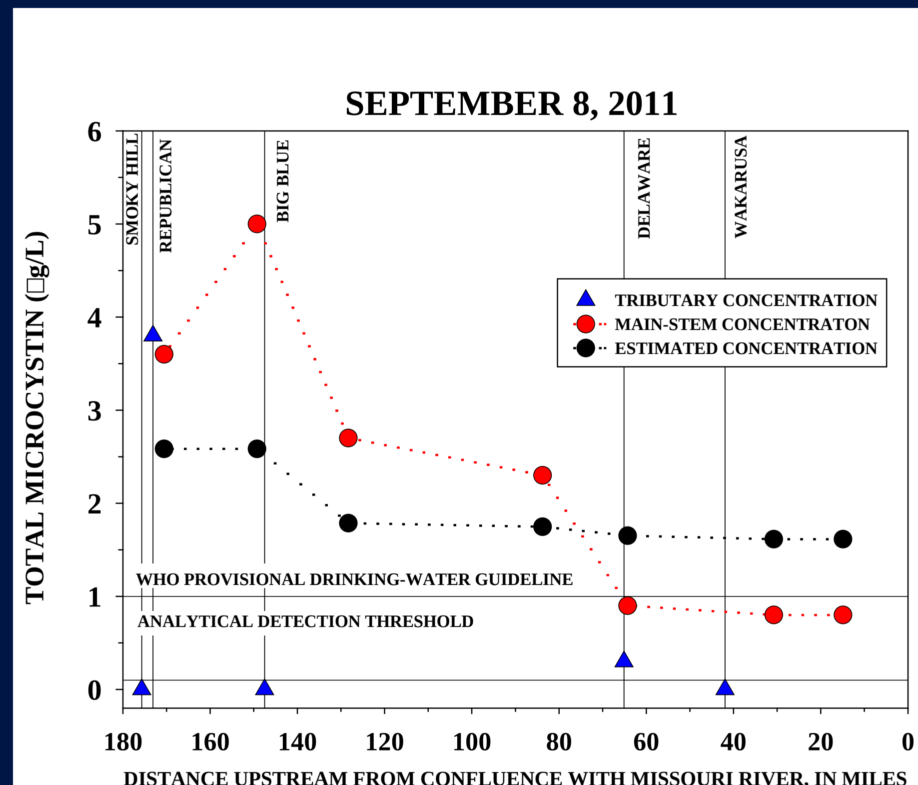
Cyanobacterial Toxins and Taste-and-Odor Compounds May Be Transported for Relatively Long Distances Downstream from Lakes and Reservoirs.




Milford Lake release sends algae to Kansas River

MARIA SUDEKUM FISHER, Associated Press

Published 09:10 p.m., Wednesday, September 21, 2011



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http://pubs.usgs.gov/sir/2012/5129/

Graham and others, 2012

Fate and Transport

Cyanotoxin Transport from Freshwater Environments May Affect Coastal Ecosystems.

OPEN ACCESS Freely available online
PLoS one

Evidence for a Novel Marine Harmful Algal Bloom: Cyanotoxin (Microcystin) Transfer from Land to Sea Otters

Melissa A. Miller[1,2]*, Raphael M. Kudela[2], Abdu Mekebri[3], Dave Crane[3], Stori C. Oates[1], M. Timothy Tinker[4], Michelle Staedler[5], Woutrina A. Miller[6], Sharon Toy-Choutka[1], Clare Dominik[7], Dane Hardin[7], Gregg Langlois[8], Michael Murray[5], Kim Ward[9], David A. Jessup[1]

1 Marine Wildlife Veterinary Care and Research Center, California Department of Fish and Game, Office of Spill Prevention and Response, Santa Cruz, California, United States of America, **2** Ocean Sciences Department, University of California Santa Cruz, Santa Cruz, California, United States of America, **3** Water Pollution Control Laboratory, California Department of Fish and Game, Office of Spill Prevention and Response, Rancho Cordova, California, United States of America, **4** Western Ecological Research Center, United States Geological Survey, Long Marine Laboratory, Santa Cruz, California, United States of America, **5** Monterey Bay Aquarium, Monterey, C
States of America, **6** Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine, University of California Davis, Davis, Californ
of America, **7** Applied Marine Sciences, Livermore, California, United States of America, **8** California Department of Public Health, Richmond, California,
America, **9** Division of Water Quality, State Water Resources Control Board, Sacramento, California, United States of America

Miller and others, 2010

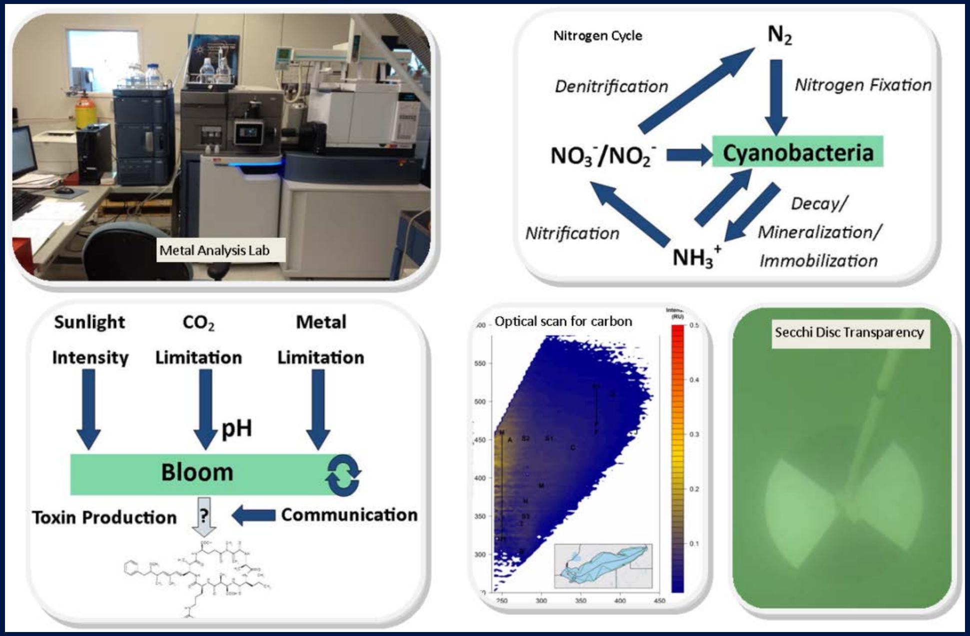
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0012576

Ecology

Integrated ecosystem studies combine multiple tools and technologies to better understand environmental drivers of HAB formation.

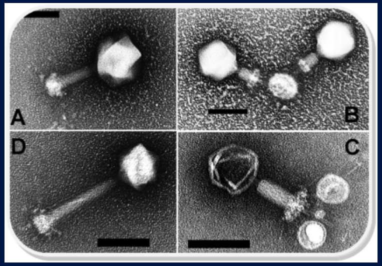
Does sediment seed next year's bloom?

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

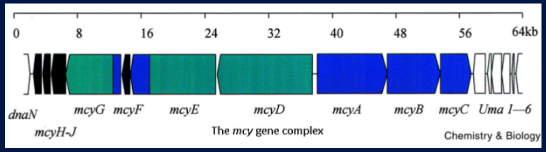


Do invasive species affect HABs?

Do viruses affect HABs?



How are cyanobacterial communities related to toxins?



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USGS GLRI CyanoHAB Research Team

Toxicology

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 Elliot, Carl Ostberg, Carla Conway, Amari Dolan-Caret, Kevin Feltz, Marshal Hoy, James Carter, and Kathy Echols

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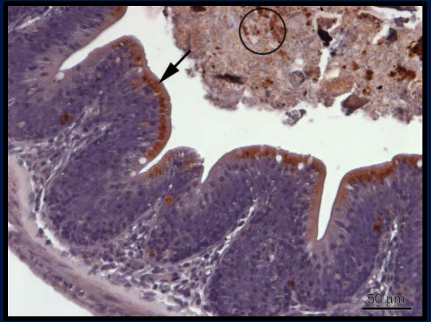
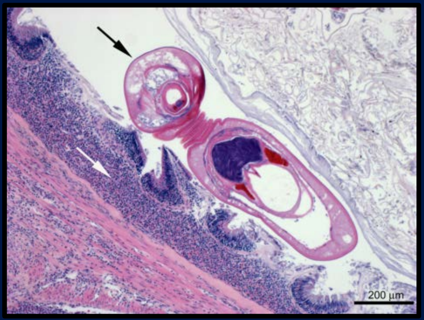
Effects of Microcystin on Juvenile Lost River Suckers

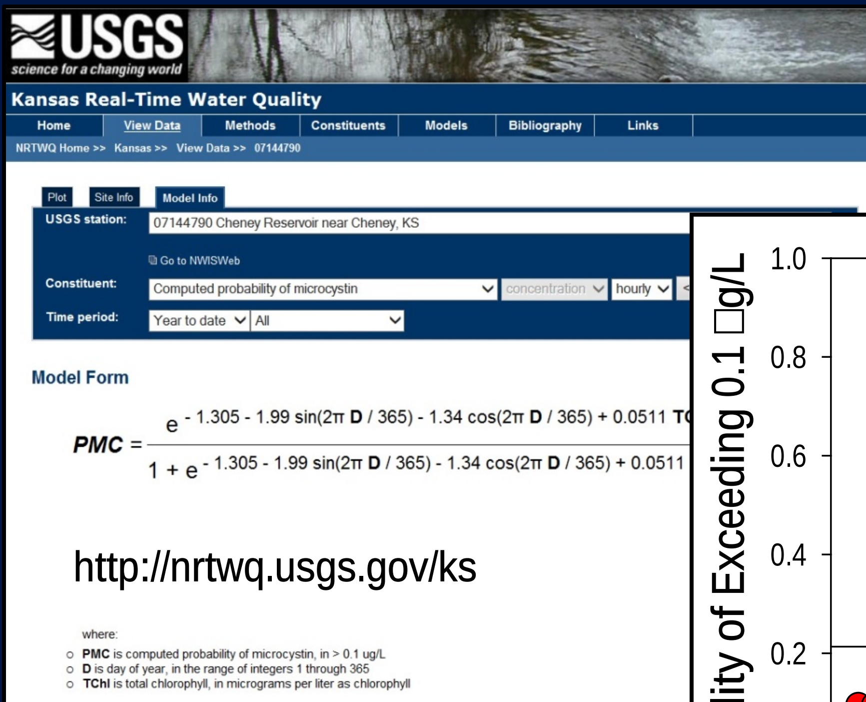
Barbara A. Martin[1], Kathy R. Echols[2], Kevin Feltz[2], Diane G. Elliott[3], and Carla M. Conway[3]
[1]USGS, Western Fisheries Research Center, Klamath Falls Field Station, 2795 Anderson Avenue Suite 106
[2]USGS Columbia Environmental Research Center, [3]USGS Western Fisheries Research Center

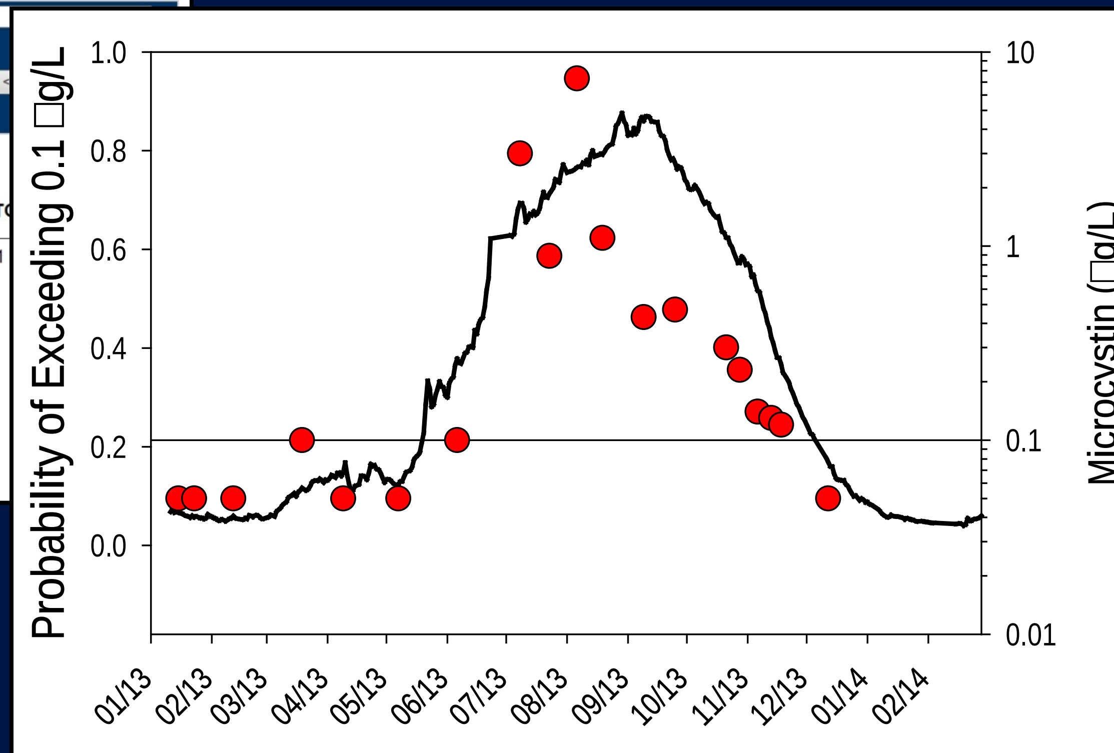




Predictive Modeling

The Logistic Regression Model for Probability of Microcystin Concentrations > 0.1 µg/L in Cheney Reservoir Includes a Seasonal Component and Chlorophyll as Explanatory Variables.





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

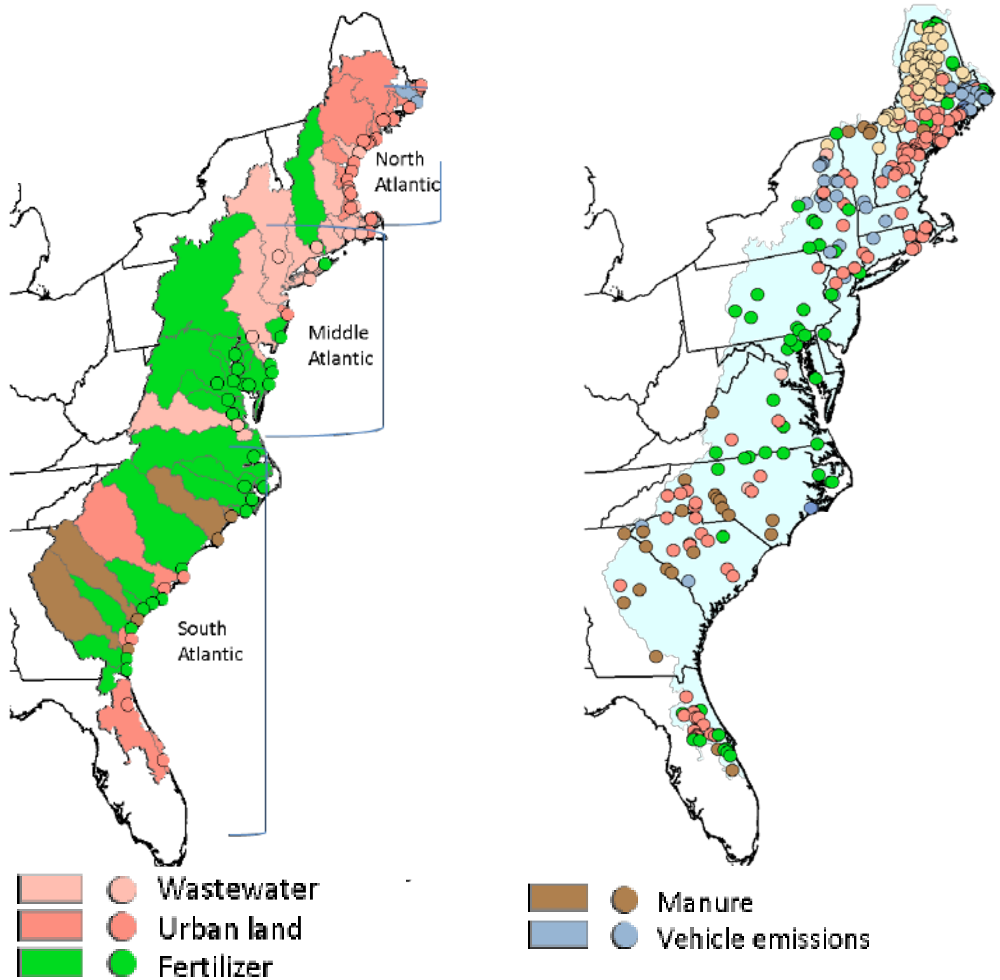
National Scale Modeling in Support of HAB and Hypoxia Research

"Nutrient input reductions are the most obvious targets which can be altered and as such should be a central part of any CyanoHAB mitigation strategies"

Paerl & Otten 2013

SPARROW models support management by identifying strength and source of nutrient loads

…to estuaries …to lakes



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U.S. Geological Survey
Harmful Algal Bloom and Hypoxia Research

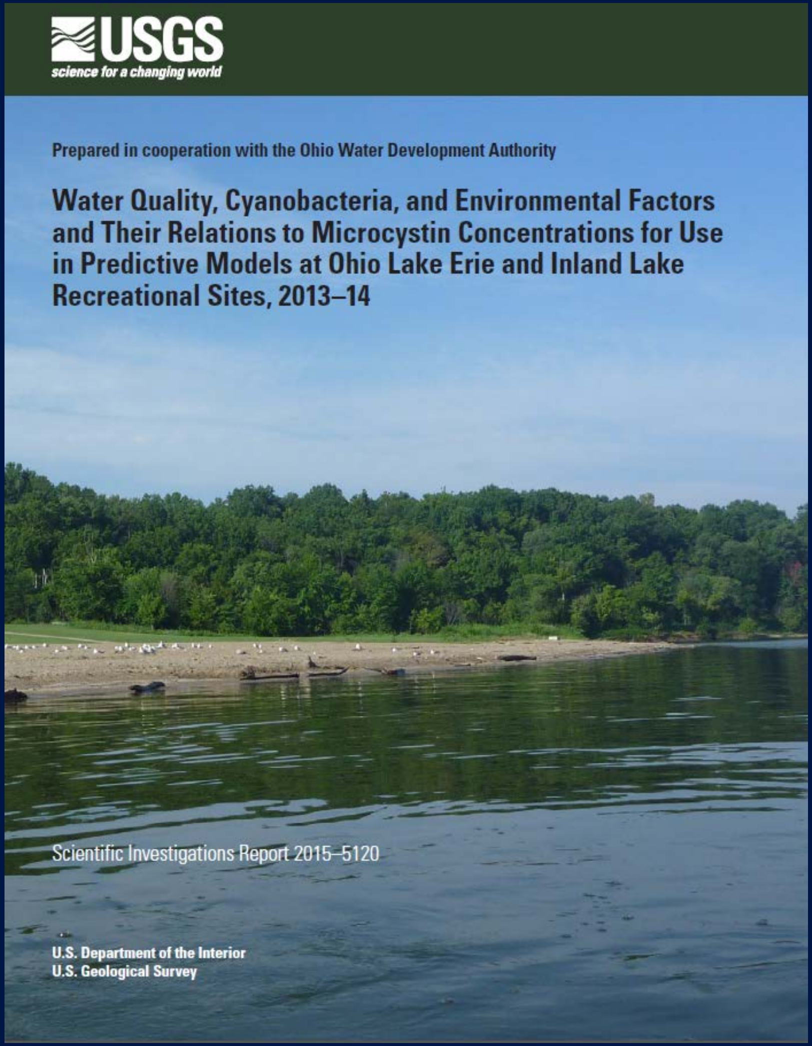
- The USGS conducts foundational science in support of basic and applied HAB and Hypoxia research across a range of spatiotemporal scales.

- USGS HAB and hypoxia research involves traditional approaches and emerging technologies.

- USGS HAB and hypoxia research is interdisciplinary and conducted collaboratively with a wide range of local, state, federal, tribal and university entities.

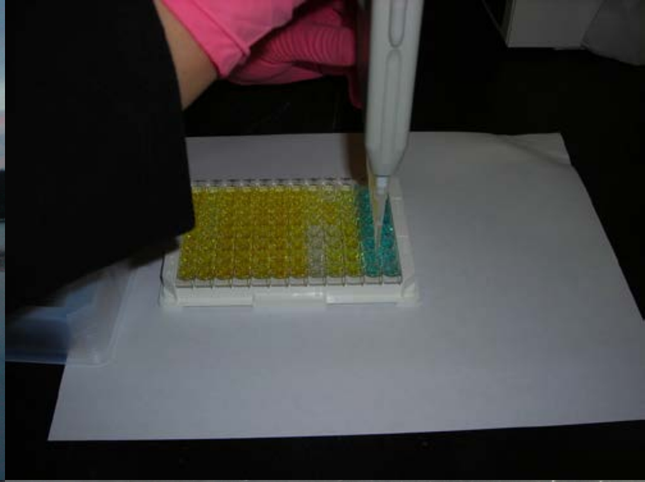
Unifying Themes in Harmful Algal Bloom Research

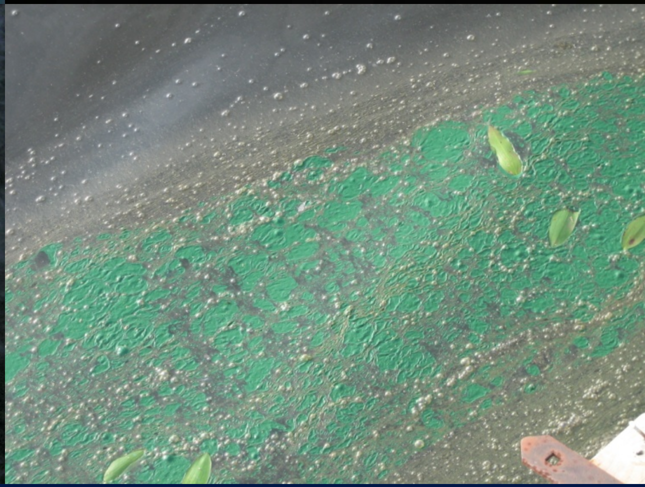
- Individual systems are unique.
- Spatial and temporal variability present challenges to data collection, analysis, and interpretation.
- Sensor technology and genetic approaches provide important information on spatiotemporal variability and environmental influences.
- A variety of tools for early warning and prediction are being developed and used.



http://pubs.er.usgs.gov/publication/sir20155120





Additional Information:

http://ks.water.usgs.gov/cyanobacteria/

jlgraham@usgs.gov
785-832-3511

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