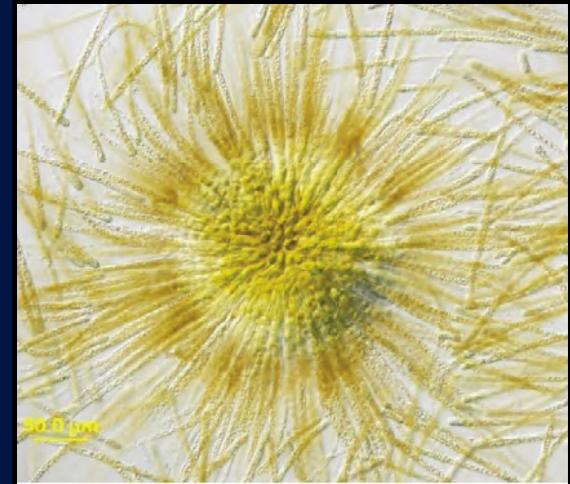


U.S. Geological Survey Harmful Algal Bloom and Hypoxia Research

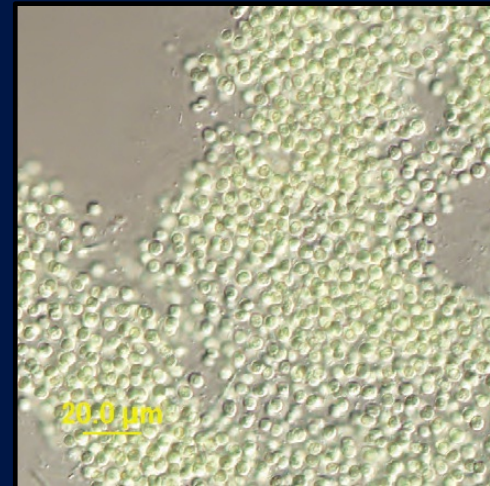


What Are Cyanobacteria?

- 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

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.



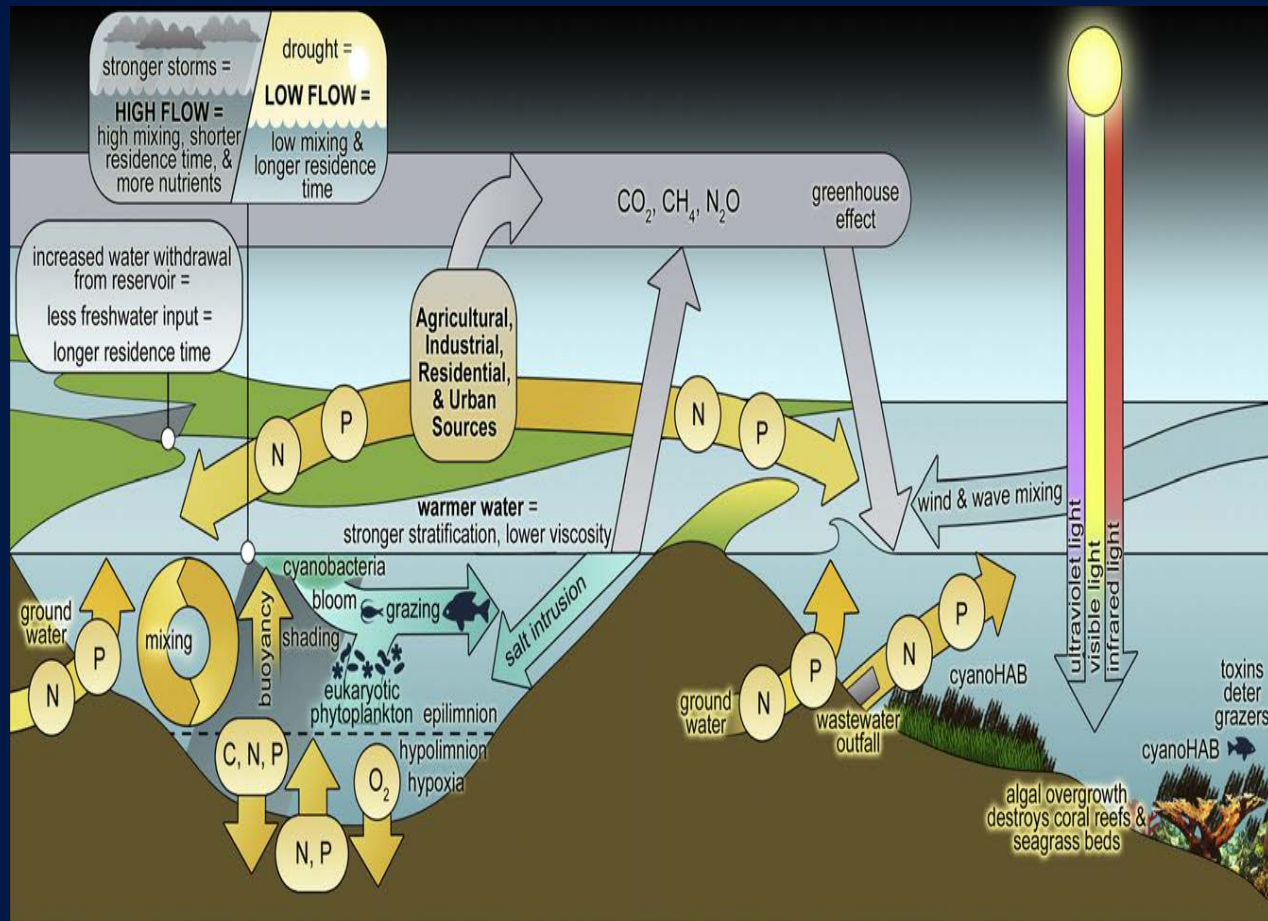
South Dakota - green algae bloom



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.



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



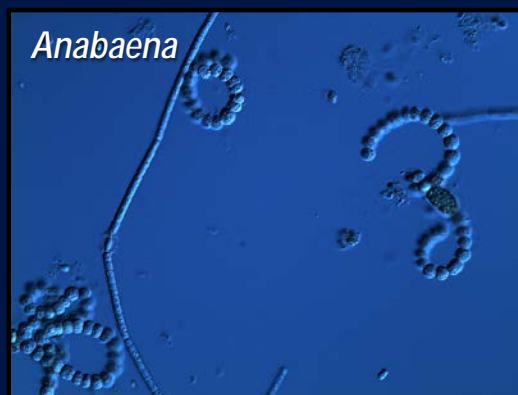
Texas – golden algae bloom
Photo courtesy of TPWD and G. Turner



Kansas – cyanobacterial bloom

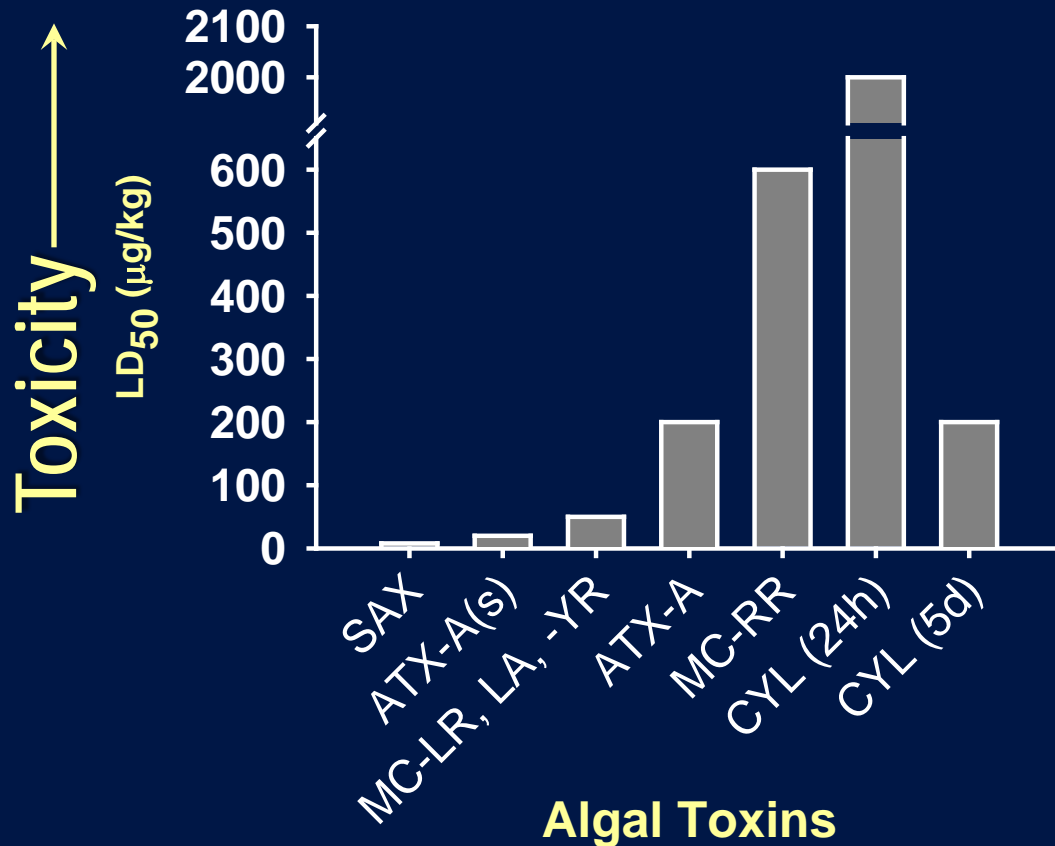
What Cyanobacteria Produce Toxins and Taste-and-Odor Compounds?

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



Photos courtesy of A. St. Amand

How Toxic Are Cyanotoxins?



- Acute Toxicity
 - Neurotoxic
 - Hepatotoxic
 - Dermatotoxic
- Chronic Toxicity
 - Carcinogen
 - Tumor Promotion
 - Mutagen
 - Teratogen
 - Embryoletality
 - Neurodegenerative Diseases

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 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 $\mu\text{g/L}$
- Cylindrospermopsin: 0.7, 3.0 $\mu\text{g/L}$

World Health Organization Provisional Recreational Guidance for Microcystin-LR

USEPA Health Advisory Levels for Cyanotoxins in Finished Drinking Water:

- Low Risk: $<10 \mu\text{g/L}$
- Moderate Risk: $10\text{-}20 \mu\text{g/L}$
- High Risk: $20\text{-}2,000 \mu\text{g/L}$
- Very High Risk: $>2,000 \mu\text{g/L}$

DANGER

LAKE CLOSED
Harmful Algae Present

People & Animals May Get Sick

STOP

KEEP OUT OF LAKE

In case of harmful algae contact, call doctor/veterinarian if people/animals have nausea, vomiting, diarrhea, rash, irritated eyes, seizures, breathing problems or other unexplained illness

Report new algae-blooms to Kansas Department of Health and Environment:
www.kdhe.ks.gov/algae-bloom
or call 785-296-1864

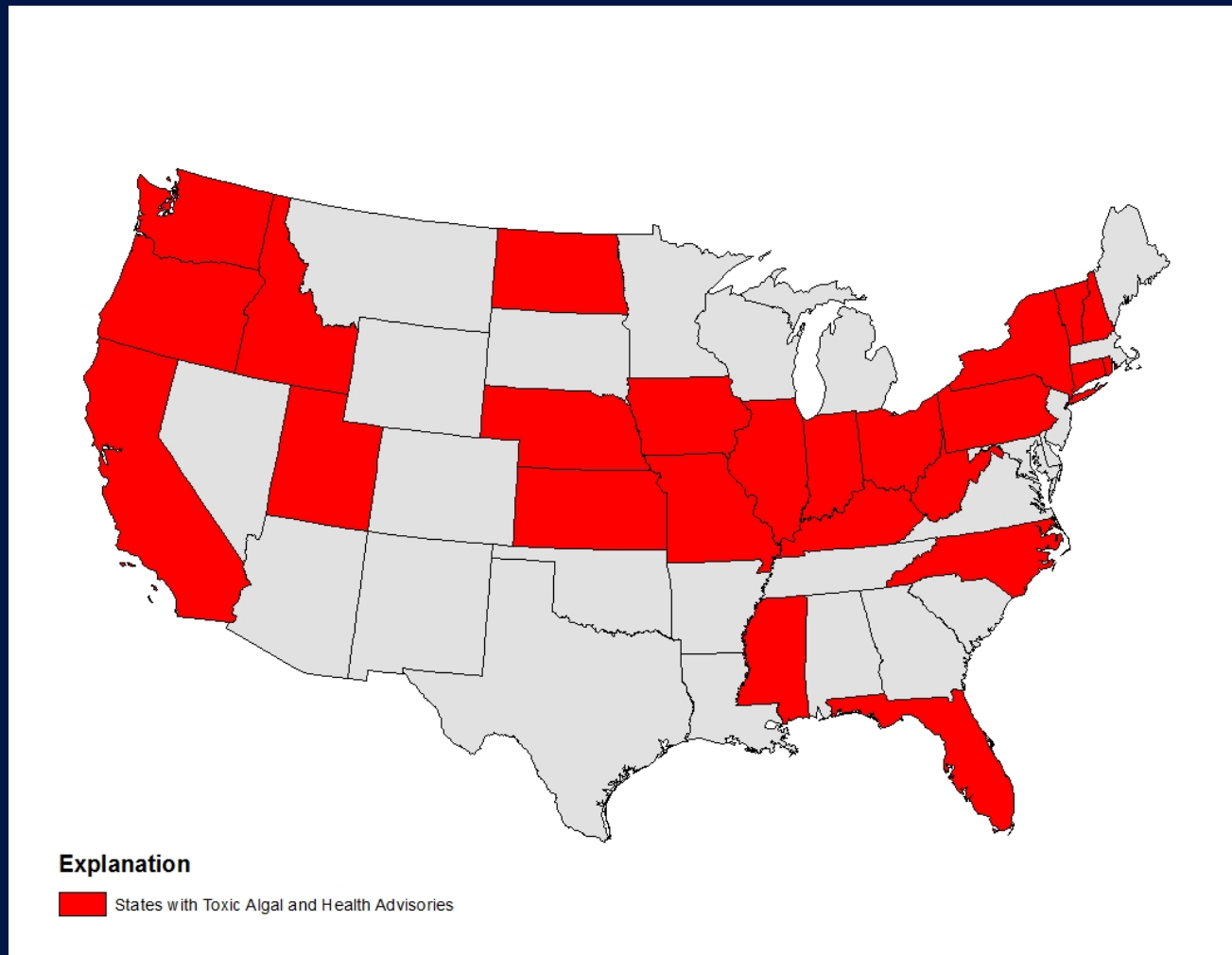
Report possible algae-bloom illness to Kansas Department of Health and Environment:
www.kdhe.ks.gov/algae-bloom
or call 877-427-7317

For more information:
Scan this code or visit kdhe.ks.gov/algae-bloom

Posted on:

Kansas Dept. of Health and Environment 2000 SW Jackson, Topeka, Kansas 66612, 785-296-1500 www.kdhe.ks.gov

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



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.

The screenshot displays the USGS WaterWatch website interface. At the top, there is a navigation bar with the USGS logo and the tagline "science for a changing world". To the right of the logo are links for "USGS Home", "Contact USGS", and "Search USGS". Below the navigation bar is a search bar labeled "Search WaterWatch ...".

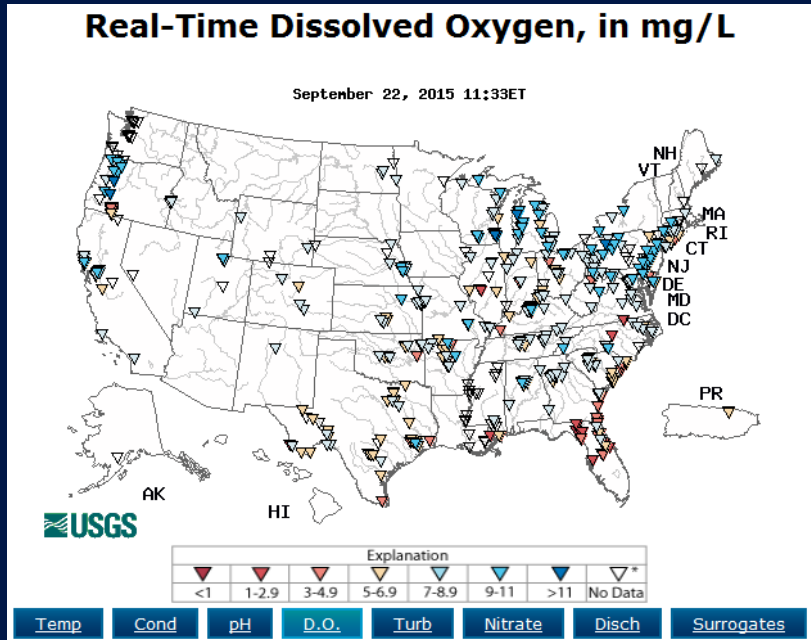
The main content area features a sidebar on the left with a "Home" link and a list of navigation options: "Current Streamflow", "Flood", "Drought", "Past Flow/Runoff", "Animation", "Toolkit", "Toolkit (internal)", "Annual Summaries", "Additional Information", and "About WaterWatch".

The central part of the page contains four maps of the United States, each with a title and a date:

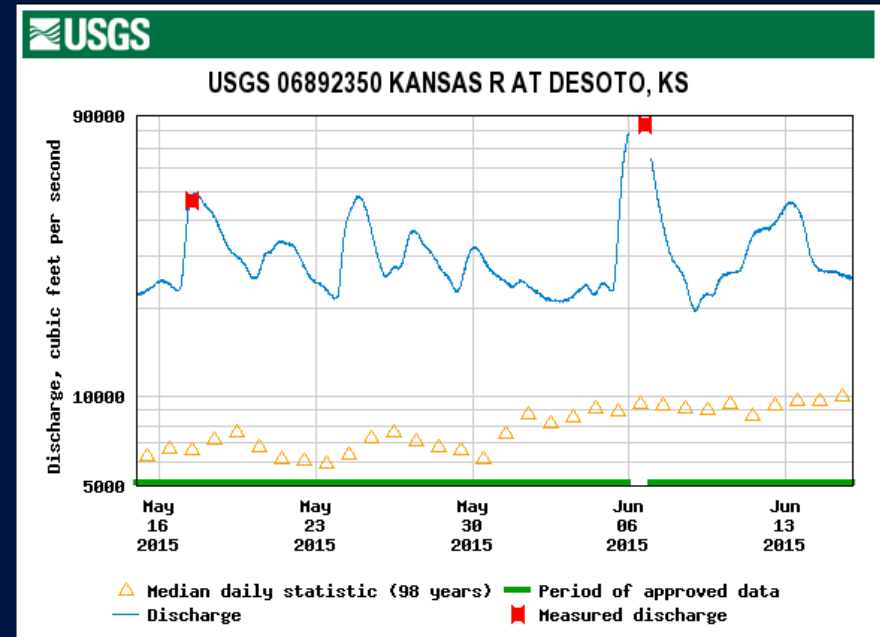
- Current Streamflow**: Wednesday, September 30, 2015 11:00ET. The map shows a color-coded distribution of streamflow across the country.
- Drought**: Tuesday, September 29, 2015. The map shows areas of drought in shades of orange and red.
- Flood**: Wednesday, September 30, 2015 11:00ET. The map shows areas of flooding in shades of blue and green.
- Past Flow / Runoff**: Tuesday, September 29, 2015. The map shows past flow and runoff patterns.

At the bottom of the page, there is a footer with links for "Accessibility", "FOIA", "Privacy", and "Policies and Notices". Below these links is the text: "U.S. Department of the Interior | U.S. Geological Survey", "URL: http://waterwatch.usgs.gov", "Page Contact Information: [Contact USGS](#)", and "Page Last Modified: Wednesday, September 30, 2015". On the right side of the footer, there are logos for "USA.gov" and "TAKE PRIDE IN AMERICA".

National Streamgauge and Sensor Networks



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



U.S. Geological Survey Mission Areas

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

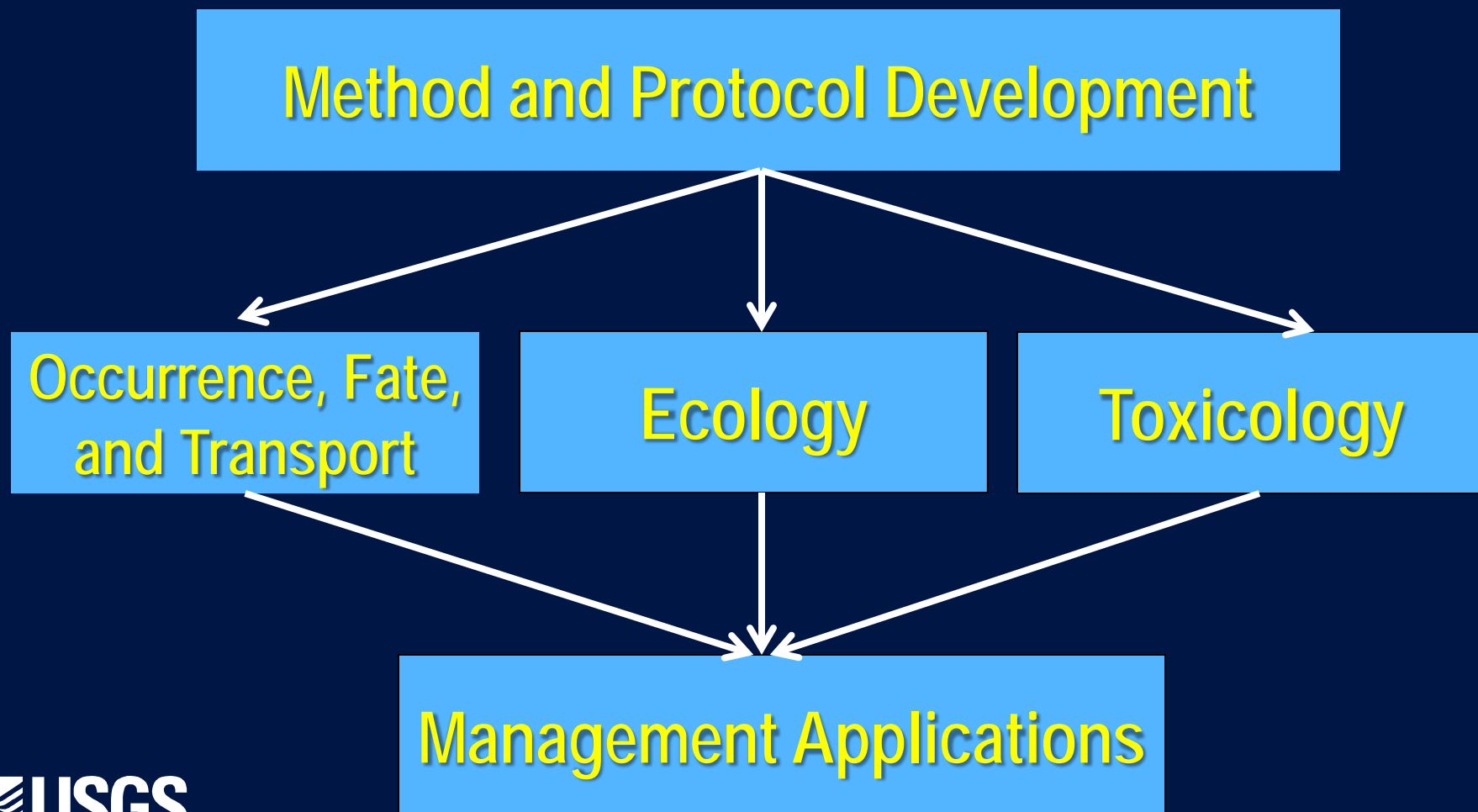


USGS Partnerships to Conduct HAB and Hypoxia Research, Monitoring, and Modeling

- 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



USGS HAB and Hypoxia Research, Monitoring, and Modeling



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

USGS
science for a changing world

Prepared in collaboration with Abraxis, LLC, Delaware Department of Natural Resources and Environmental Control, Division of Water Resources Environmental Laboratory, and the University of Delaware

Comparison of Two Cell Lysis Procedures for Recovery of Microcystins in Water Samples from Silver Lake in Dover, Delaware, with Microcystin Producing Cyanobacterial Accumulations

USGS
science for a changing world

Prepared in cooperation with the Ohio Lake Erie Commission

Relations Between DNA- and RNA-Based Molecular Methods for Cyanobacteria and Microcystin Concentration at Maumee Bay State Park Lakeside Beach, Oregon, Ohio, 2012

USGS

Prepared in cooperation with the U.S. Environmental Protection Agency

Microphotographs of Cyanobacteria Documenting the Effects of Various Cell-lysis Techniques

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science for a changing world

CYANOBACTERIA IN LAKES AND RESERVOIRS: TOXIN AND TASTE-AND-ODOR SAMPLING GUIDELINES

By Jonathan L. Grubb, Keith A. Loftis, Andrew C. Ziegler, and Michael S. Hesse

7.5 Cyanobacteria in lakes and reservoirs: Toxin and taste-and-odor sampling guidelines

7.5.1 Light intensity and thermal stratification

7.5.2 Cyanobacteria, toxins, and taste-and-odor

7.5.2.A Cyanobacterial abundance, seasonality, and biomass

7.5.2.B Toxins

7.5.2.C Taste-and-odor compounds

7.5.3 Temporal and spatial variability of cyanobacteria

7.5.3.A Temporal variability

7.5.3.B Spatial variability

7.5.4 Study objectives and design

7.5.5 Sample collection

7.5.5.A Single-grab and composite samples

7.5.5.B Surface samples

7.5.5.C Discrete-depth samples

7.5.5.D Depth-integrated samples

7.5.5.E Continuous depth-integrated or disintegrator depth-integrated samples

7.5.5.F Quality control

7.5.5.G Analytical data

7.5.6 Sample holding, storage, processing, and distribution

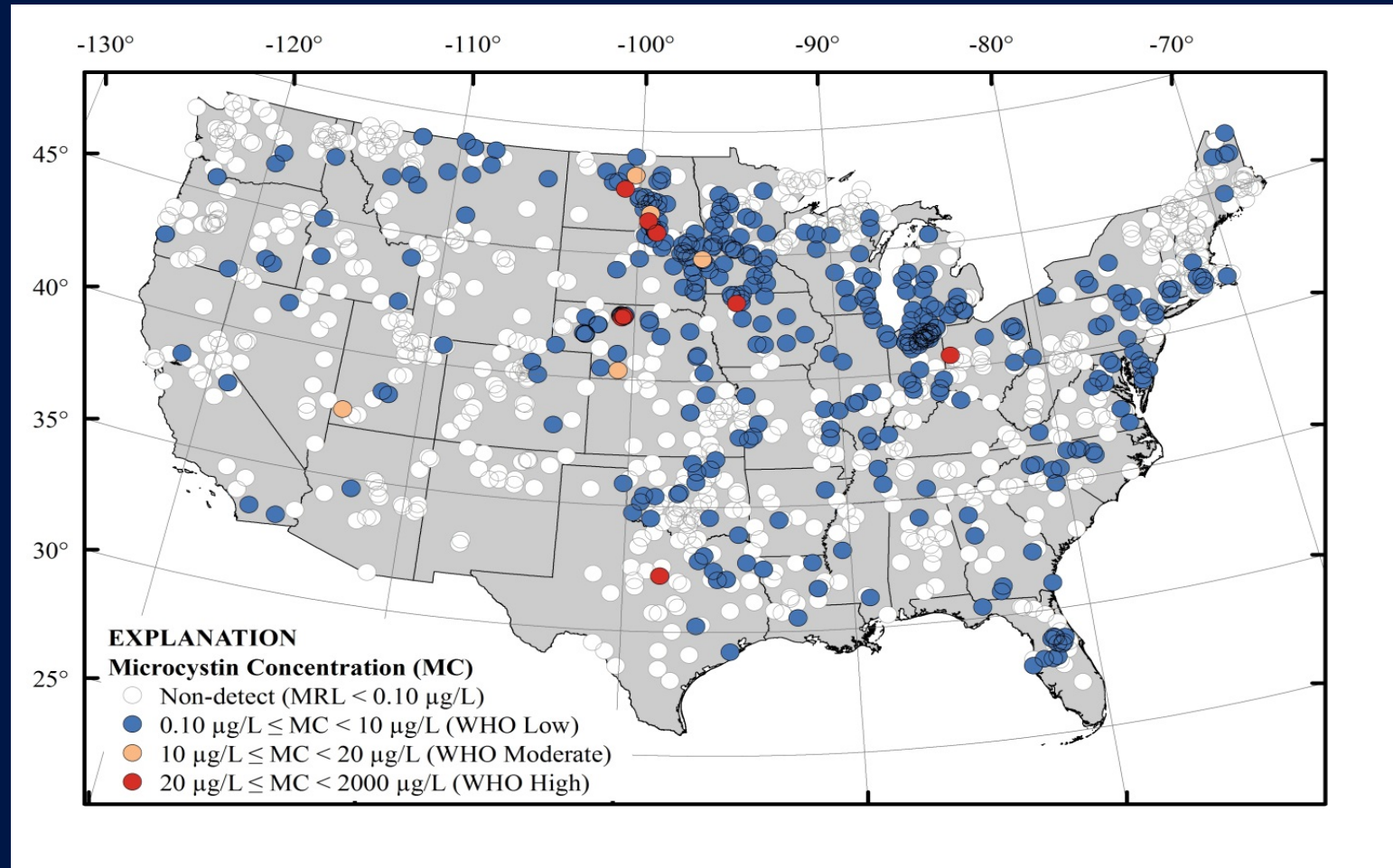
7.5.6.A Sample holding, storage, and processing

Field and Laboratory Guide to Freshwater Cyanobacteria Harmful Algal Blooms for Native American and Alaska Native Communities

Open-File Report 2015-1164
U.S. Department of the Interior
U.S. Geological Survey

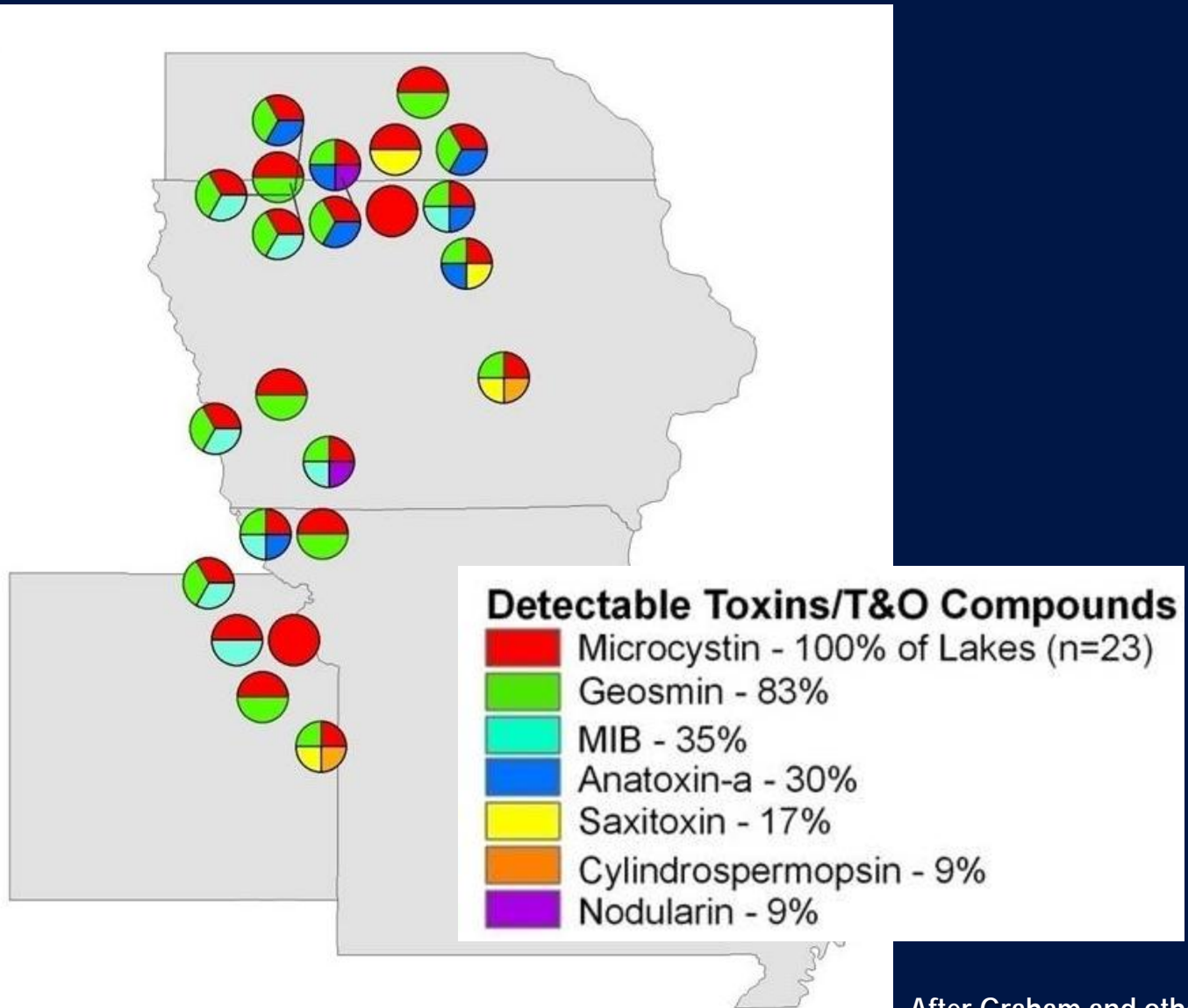
Occurrence - National Assessment of Microcystin

Microcystins Occurred in 32 Percent of Lakes Across the Nation



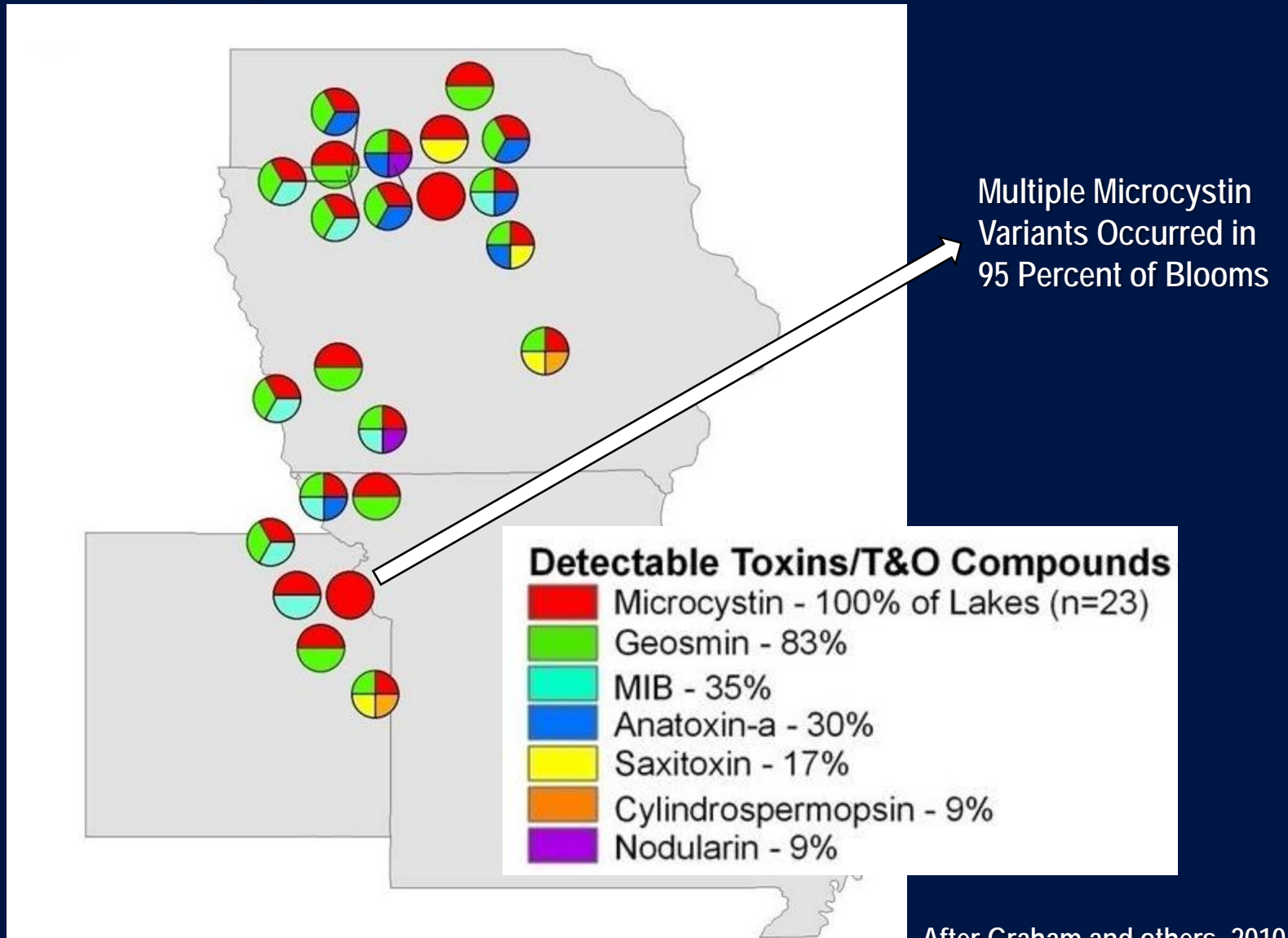
Occurrence – Regional Assessment of Mixtures

Multiple Cyanotoxins Occurred in 30 Percent of Blooms



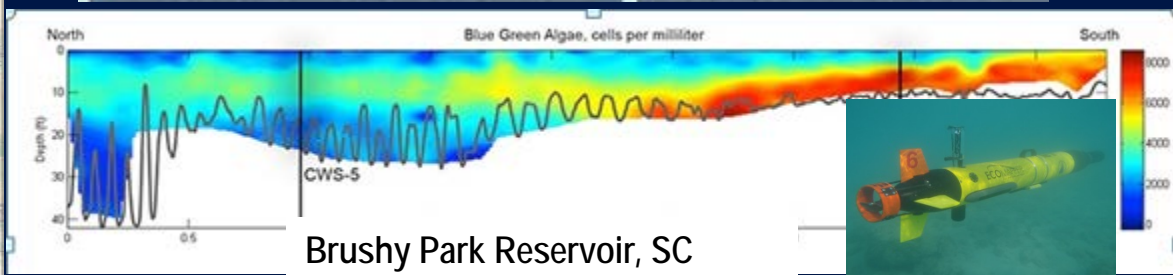
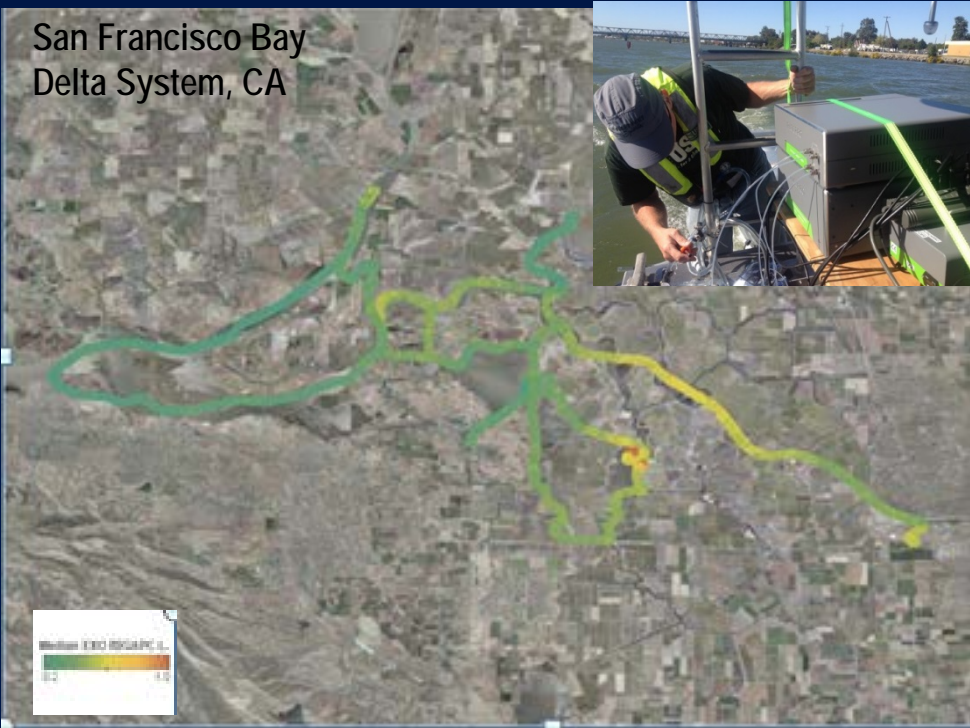
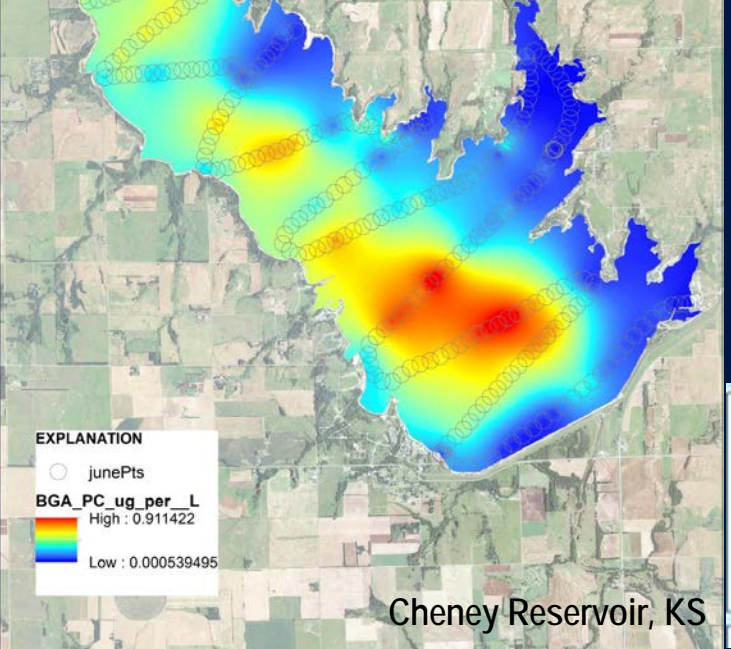
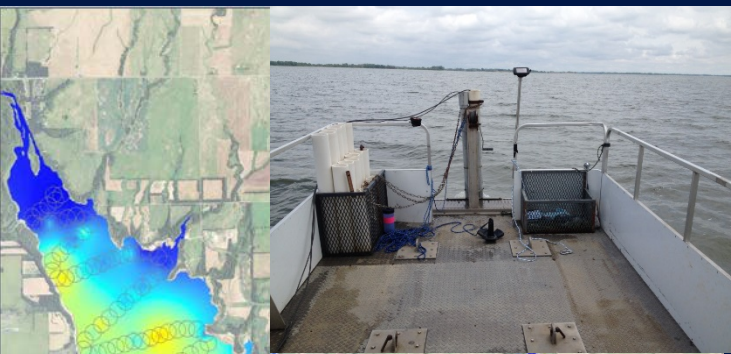
Occurrence – Regional Assessment of Mixtures

Multiple Cyanotoxins Occurred in 30 Percent of Blooms



Fate and Transport

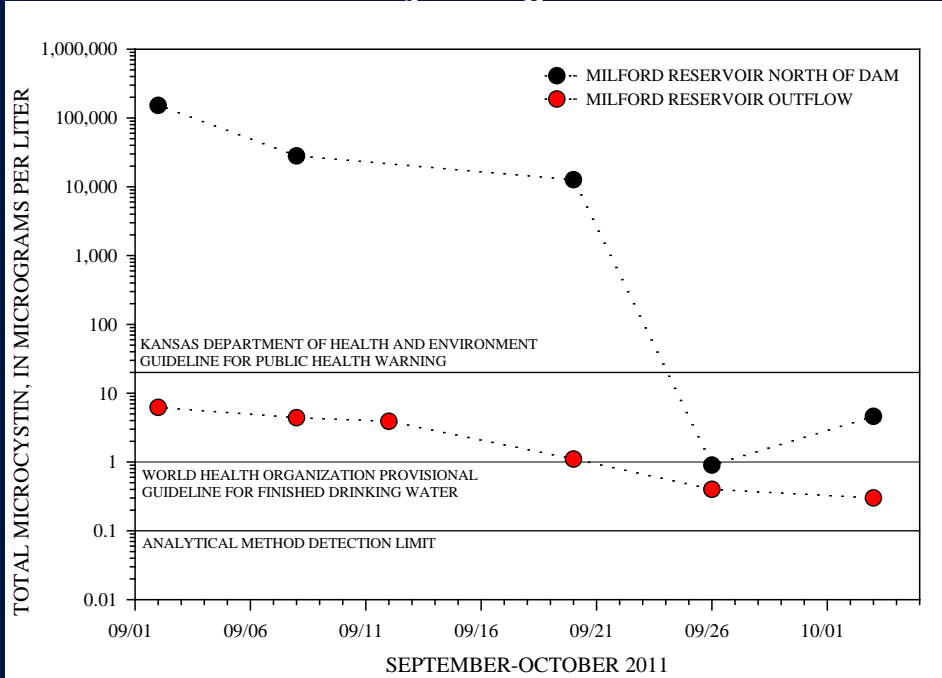
Quantifying variability in cyanobacterial distribution is critical to understanding fate, transport, population dynamics, and environmental drivers.



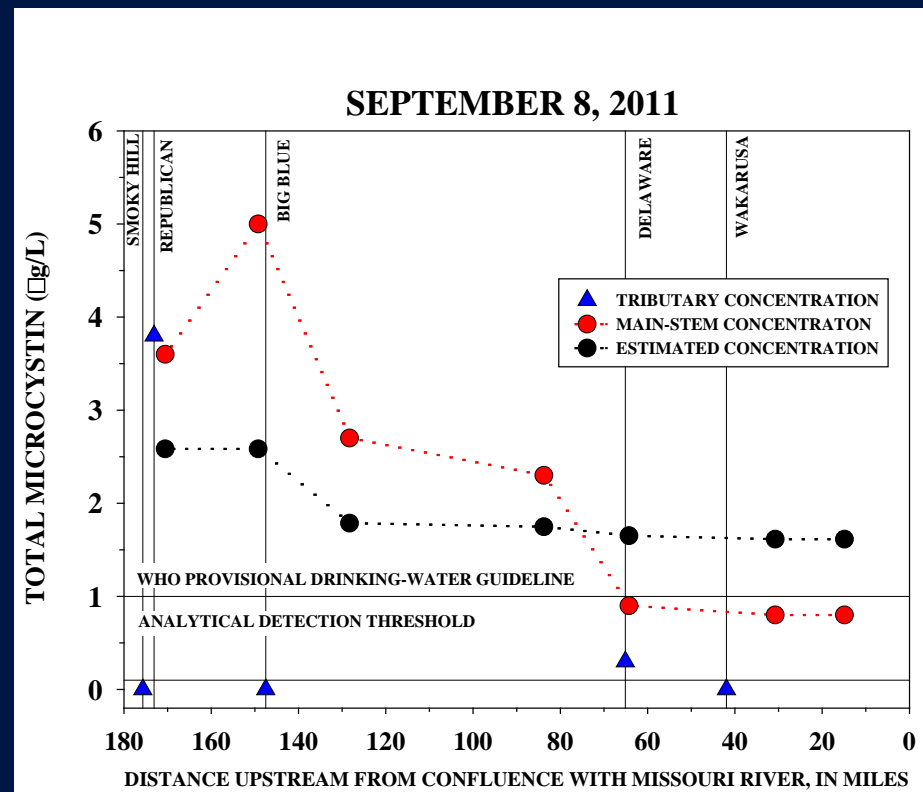
Foster, KSWSC
Bergamaschi, CAWSC
Journey, SAWSC

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



Fate and Transport

Cyanotoxin Transport from Freshwater Environments May Affect Coastal Ecosystems.

OPEN ACCESS Freely available online



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

Melissa A. Miller^{1,2*}, Raphael M. Kudela², Abdu Mekebri³, Dave Crane³, Stori C. Oates¹, M. Timothy Tinker⁴, Michelle Staedler⁵, Woutrina A. Miller⁶, Sharon Toy-Choutka¹, Clare Dominik⁷, Dane Hardin⁷, Gregg Langlois⁸, Michael Murray⁵, Kim Ward⁹, David A. Jessup¹

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, California, United States of America, **6** Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine, University of California Davis, Davis, California, United States of America, **7** Applied Marine Sciences, Livmore, California, United States of America, **8** California Department of Public Health, Richmond, California, United States of America, **9** Division of Water Quality, State Water Resources Control Board, Sacramento, California, United States of America

Miller and others, 2010



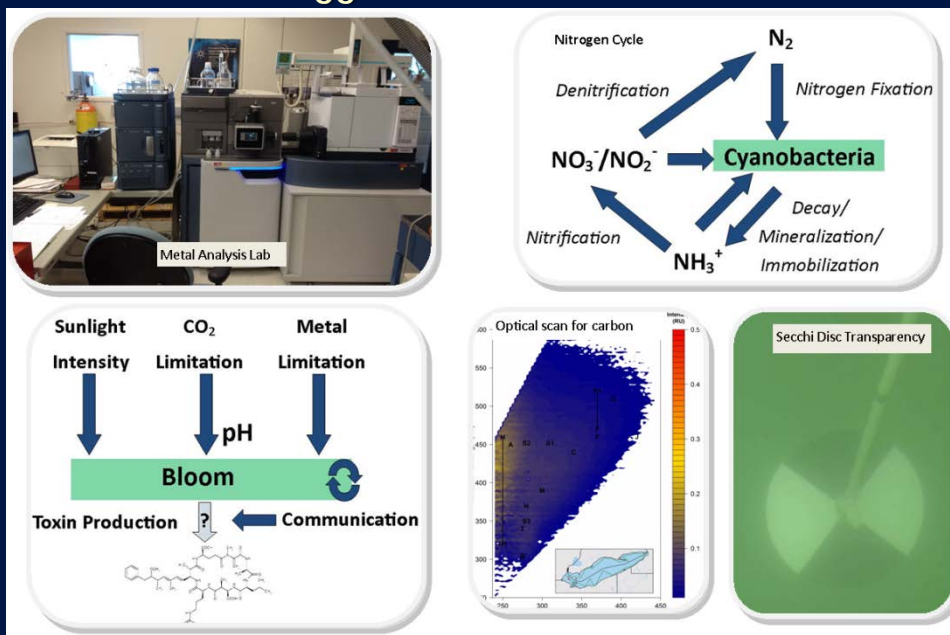
Ecology

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

Does sediment seed next year's bloom?



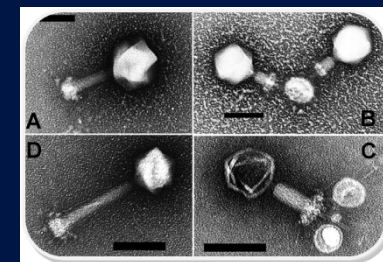
What chemical, biological, and physical factors trigger HABs and toxins?



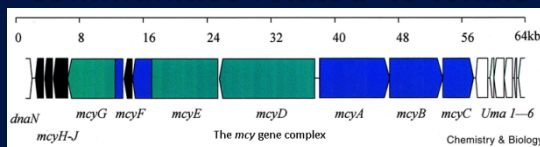
Do invasive species affect HABs?



Do viruses affect HABs?



How are cyanobacterial communities related to toxins?



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



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

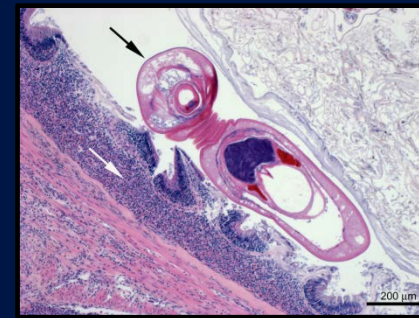
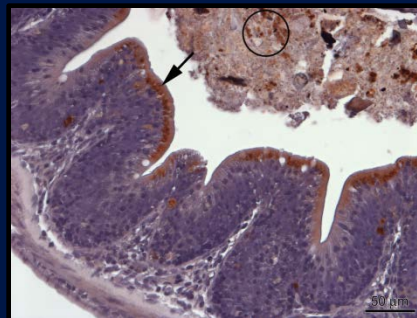


Effects of Microcystin on Juvenile Lost River Suckers

Barbara A. Martin¹, Kathy R. Echols², Kevin Feltz², Diane G. Elliott³, and Carla M. Conway³

¹USGS, Western Fisheries Research Center, Klamath Falls Field Station, 2795 Anderson Avenue Suite 106

²USGS Columbia Environmental Research Center, ³USGS 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.

USGS
science for a changing world

Kansas Real-Time Water Quality

Home View Data Methods Constituents Models Bibliography Links

NRTWQ Home >> Kansas >> View Data >> 07144790

Plot Site Info Model Info

USGS station: 07144790 Cheney Reservoir near Cheney, KS

Constituent: Computed probability of microcystin concentration hourly

Time period: Year to date All

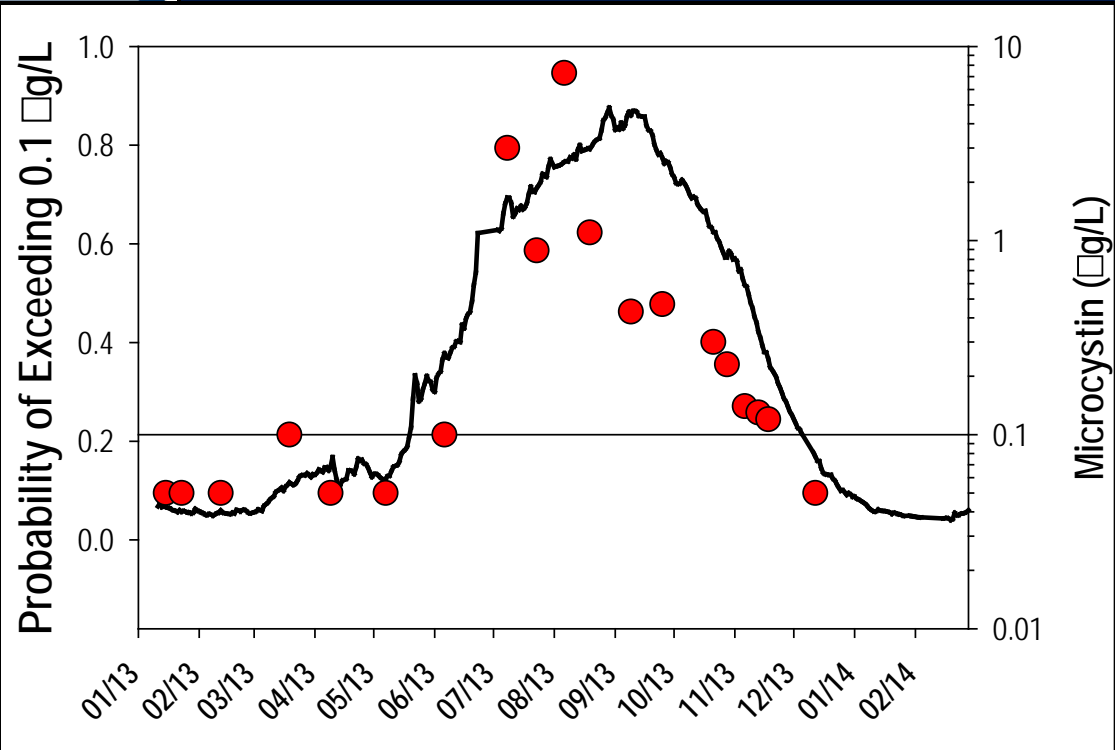
Model Form

$$PMC = \frac{e^{-1.305 - 1.99 \sin(2\pi D / 365) - 1.34 \cos(2\pi D / 365) + 0.0511 TChl}}{1 + e^{-1.305 - 1.99 \sin(2\pi D / 365) - 1.34 \cos(2\pi D / 365) + 0.0511 TChl}}$$

<http://nrtwq.usgs.gov/ks>

where:

- PMC is computed probability of microcystin, in > 0.1 ug/L
- D is day of year, in the range of integers 1 through 365
- TChl is total chlorophyll, in micrograms per liter as chlorophyll



National Scale Modeling in Support of HAB and Hypoxia Research

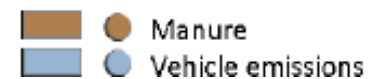
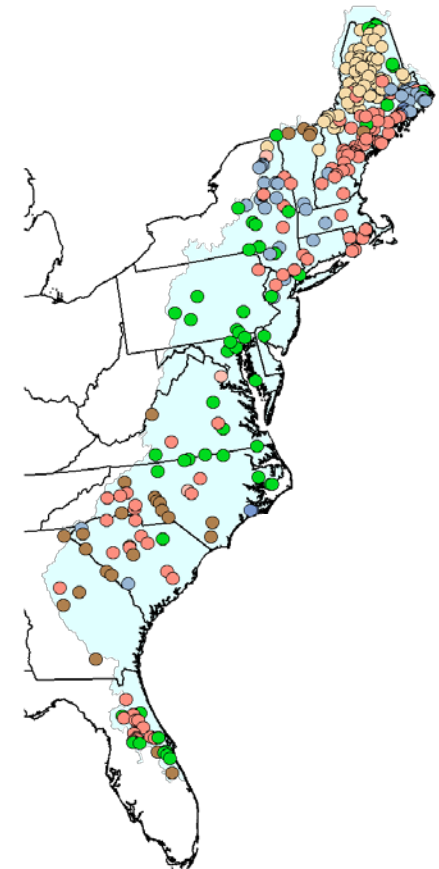
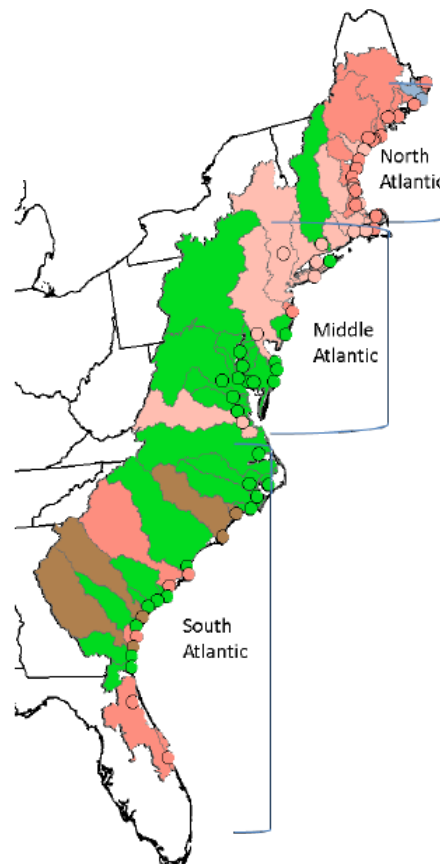
“Nutrient input reductions are the most obvious targets which can be altered and as such should be a central part of any CyanoHAB mitigation strategies”

Paerl & Otten 2013

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

...to estuaries

...to lakes



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.



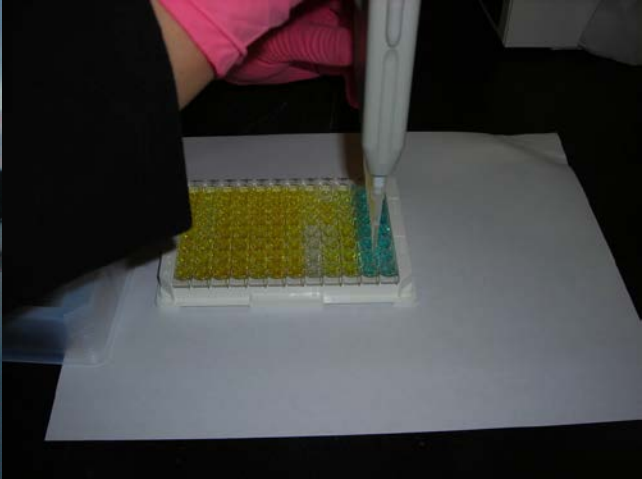
Prepared in cooperation with the Ohio Water Development Authority

**Water Quality, Cyanobacteria, and Environmental Factors
and Their Relations to Microcystin Concentrations for Use
in Predictive Models at Ohio Lake Erie and Inland Lake
Recreational Sites, 2013–14**



Scientific Investigations Report 2015–5120

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



Additional Information:

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

jlgraham@usgs.gov

785-832-3511