

Cyanotoxin Occurrence in the United States

A 20 Year Retrospective



Jennifer L. Graham
U.S. Geological Survey

Great Plains and Midwest Harmful Algal Blooms Workshop

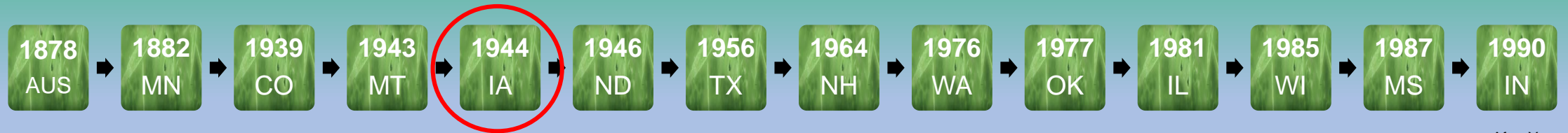
February 4, 2020

First Reports of Cyanotoxins



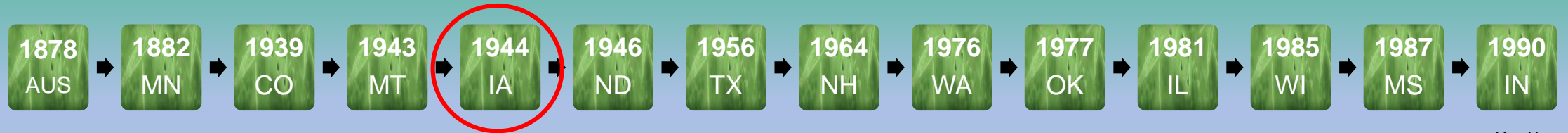
After Yoo et al., 1995

First Reports of Cyanotoxins



After Yoo et al., 1995

First Reports of Cyanotoxins



After Yoo et al., 1995

Toxic Algae in Iowa Lakes

By EARL T. ROSE

1953

Reprinted from PROCEEDINGS OF THE IOWA
ACADEMY OF SCIENCE, Volume 61.

Blue-Green Algae Control at Storm Lake

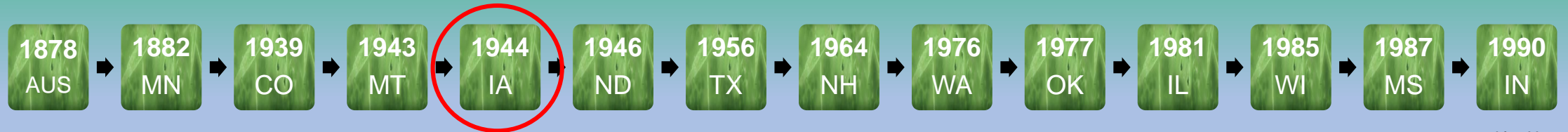
By EARL T. ROSE

1954



Photo Credit: S. Panken, University of Missouri

First Reports of Cyanotoxins



After Yoo et al., 1995

Toxic Algae in Iowa Lakes

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Blue-Green Algae Control at Storm Lake

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- Blooms are a nuisance issue that can sometimes be toxic
- Usually, but not always, a summer phenomenon
- High nutrients and “other ideal ecological conditions” result in blooms
- Potential producers include: *Aphanizomenon*, *Anabaena*, *Coelosphaerium*, *Gloeotrichia*, *Microcystis*, and *Nodularia*
- Toxins are complex organic substances that are “almost impossible to determine”

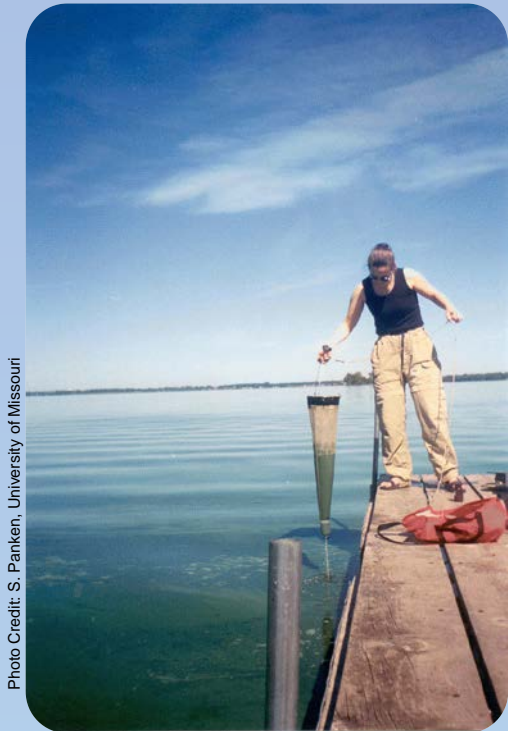


Photo Credit: S. Panken, University of Missouri

First Reports of Cyanotoxins

1878
AUS

1882
MN

1939
CO

In This Issue:

ET&C FOCUS

Focus articles are part of a regular series intended to sharpen understanding of current and emerging topics of interest to the scientific community.

1985
WI

1987
MS

1990
IN

After Yoo et al., 1995

Toxic Algae

By EARL

Reprinted from PROCEEDINGS OF THE
ACADEMY OF SCIENCE

Blue-Green Algae (Cyanobacteria)

By EARL

Are Harmful Algal Blooms Becoming the Greatest Inland Water Quality Threat to Public Health and Aquatic Ecosystems?

Bryan W. Brooks,*† James M. Lazorchak,‡ Meredith D.A. Howard,§ Mari-Vaughn V. Johnson,|| Steve L. Morton,# Dawn A.K. Perkins,†† Euan D. Reavie,††† Goffredo G. Goffredo,§§§ and Jeffery A. Steevens##

†Department of Environmental Science, Center for Reservoir and Aquatic Systems Research, Baylor University, Waco, Texas, USA

‡Office of Research and Development, US Environmental Protection Agency, Cincinnati, Ohio, USA

§Southern California Coastal Water Research Project, Costa Mesa, California, USA

||Natural Resources Conservation Service, US Department of Agriculture, Temple, Texas, USA

#National Centers for Coastal Ocean Science, Center for Coastal Environmental and Watershed Resource Management, National Oceanic and Atmospheric Administration, Charleston, South Carolina, USA

††Wisconsin State Laboratory of Hygiene, University of Wisconsin-Madison, Madison, Wisconsin, USA

†††Natural Resources Research Institute, Center for Water and the Environment, University of Minnesota, Duluth, Minnesota, USA

§§Department of Environmental Health Science, Arnold School of Public Health, University of South Carolina, South Carolina, USA

|||Beagle Bioproducts, Columbus, Ohio, USA

##US Army Engineer Research and Development Center, Vicksburg, Mississippi, USA

- Blooms are a nuisance issue that can sometimes be toxic
- Usually, but not always, a summer phenomenon
- High nutrients and “other ideal ecological conditions” result in blooms
- Potential producers include: *Aphanizomenon*, *Anabaena*, *Coelosphaerium*, *Gleotrichia*, *Microcystis*, and *Nodularia*
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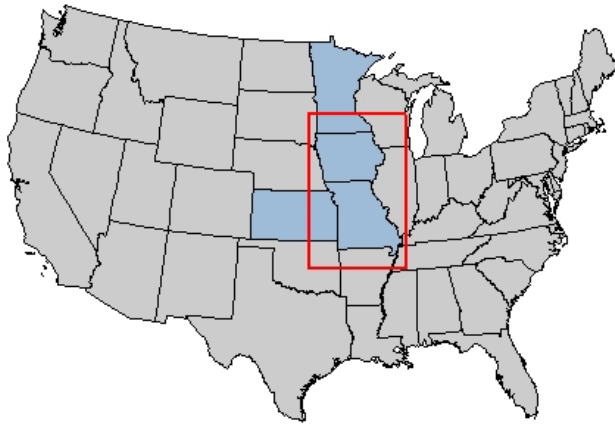
Cyanotoxins are Diverse

	<u>Hepatotoxins</u>		<u>Neurotoxins</u>		<u>Dermatotoxins</u>
	CYL	MC	ANA	SAX	
<i>Anabaena/Dolichospermum</i>	X	X	X	X	X
<i>Aphanizomenon</i>	X	?	X	X	X
<i>Microcystis</i>		X			X
<i>Oscillatoria/Planktothrix</i>		X	X	X	X



Photo Credit: A. St. Amand, PhycoTech

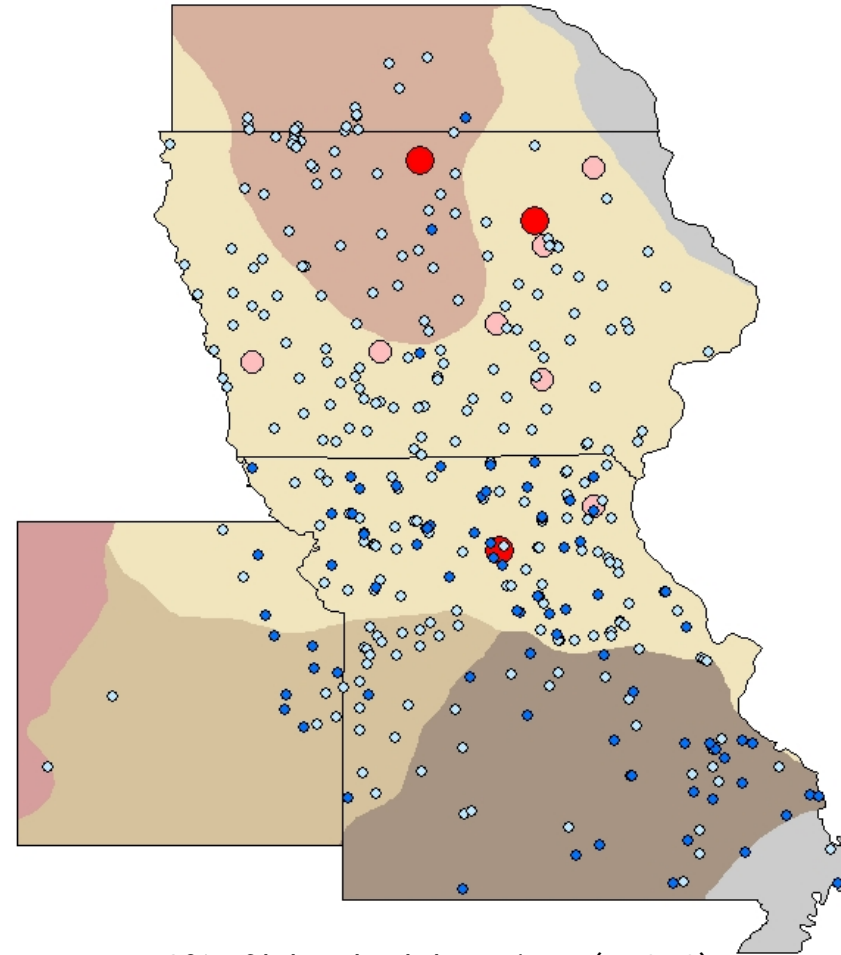
Microcystins are Widespread and Common



- OZARK HIGHLANDS (OH)**
- OSAGE PLAINS (OP)**
- DISSECTED TILL PLAINS (DT)**
- WESTERN LAKE (WL)**
- PLAINS BORDER (PB)**

CONCENTRATION/RISK

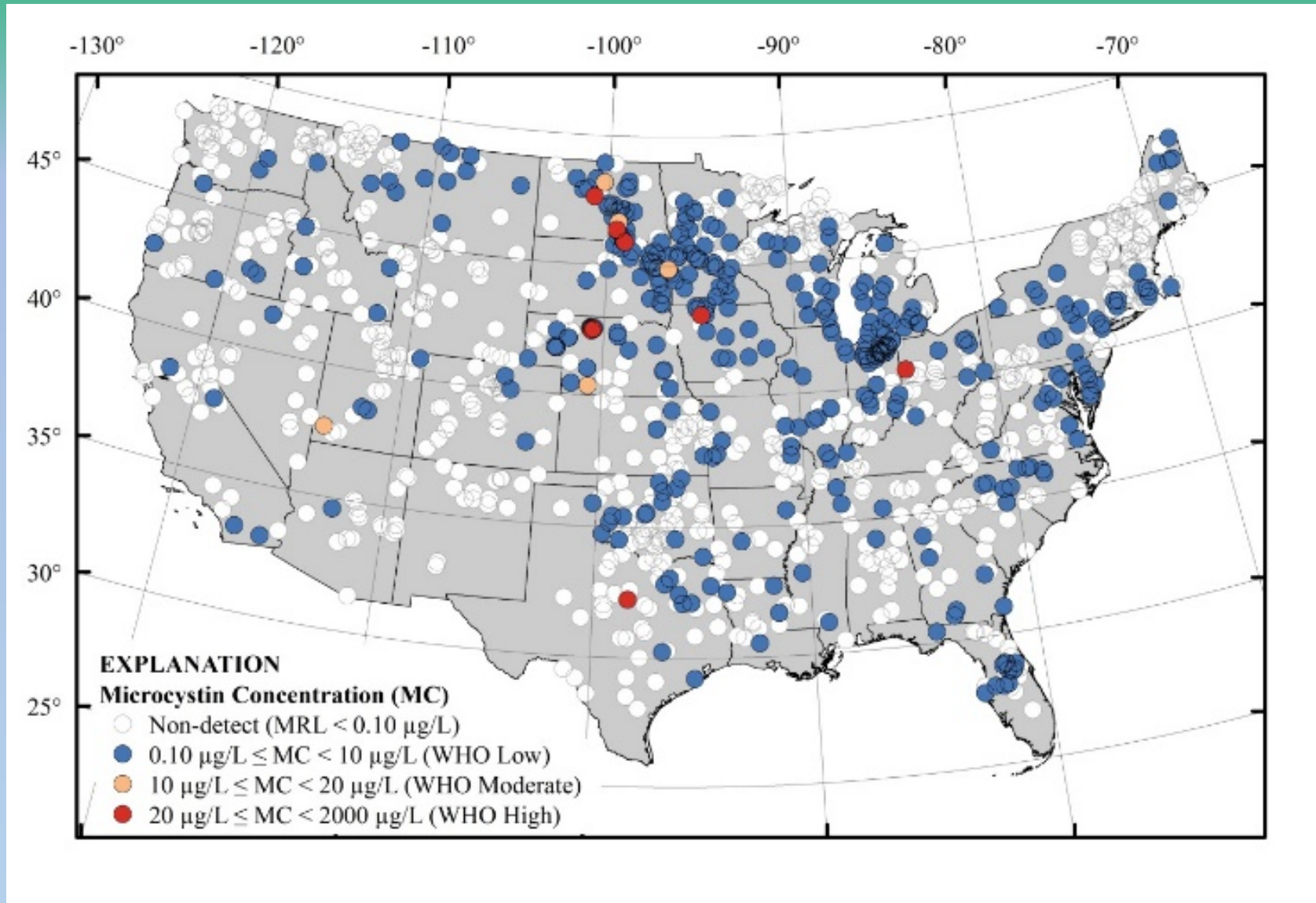
- NOT DETECTED**
- LOW (<10 µg/L)**
- MODERATE (10-20 µg/L)**
- HIGH (> 20 µg/L)**



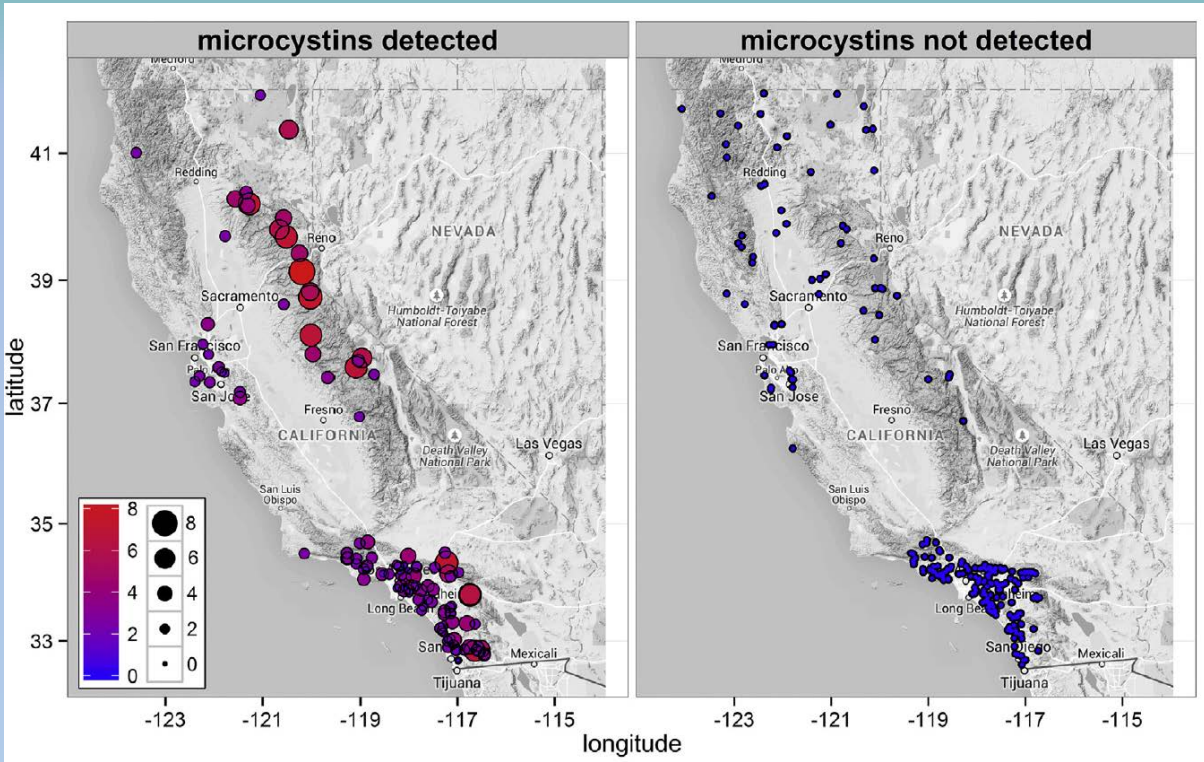
78% of lakes had detections (n=359)

Maximum concentration: 52 µg/L

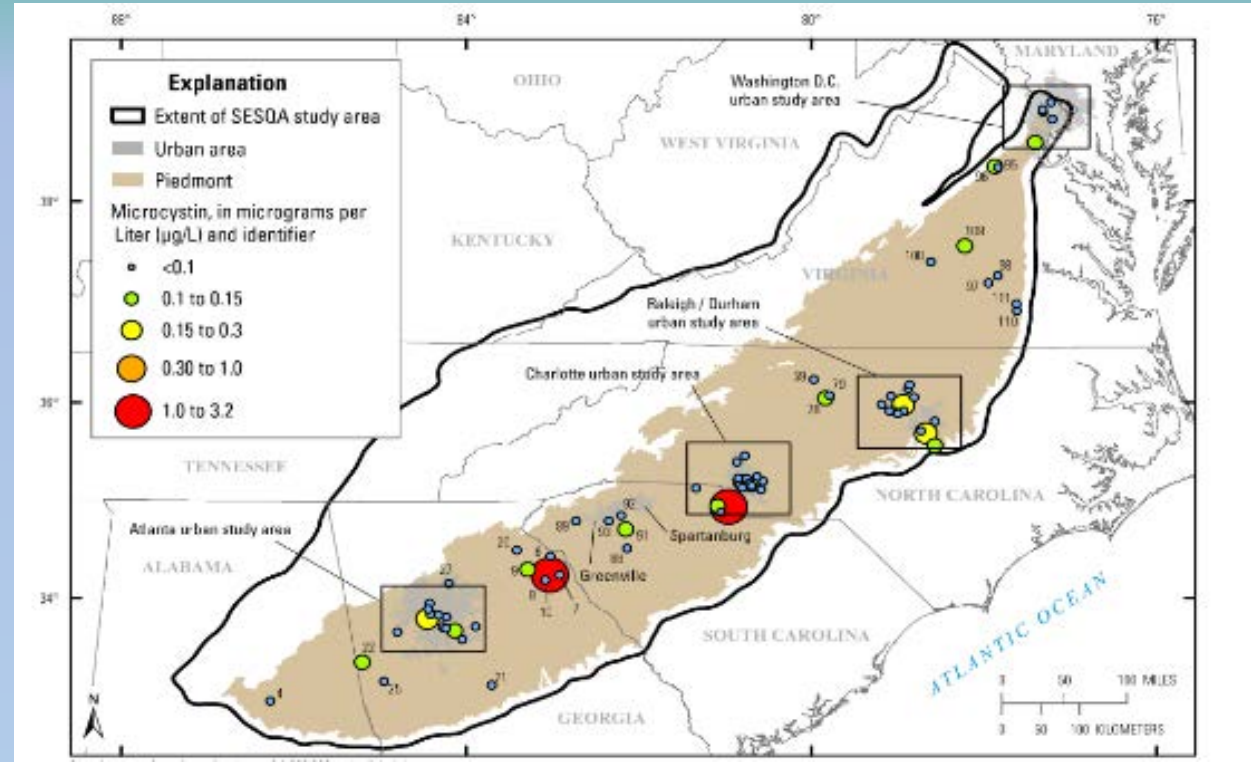
Microcystins are Widespread and Common



Microcystins are Widespread and Common

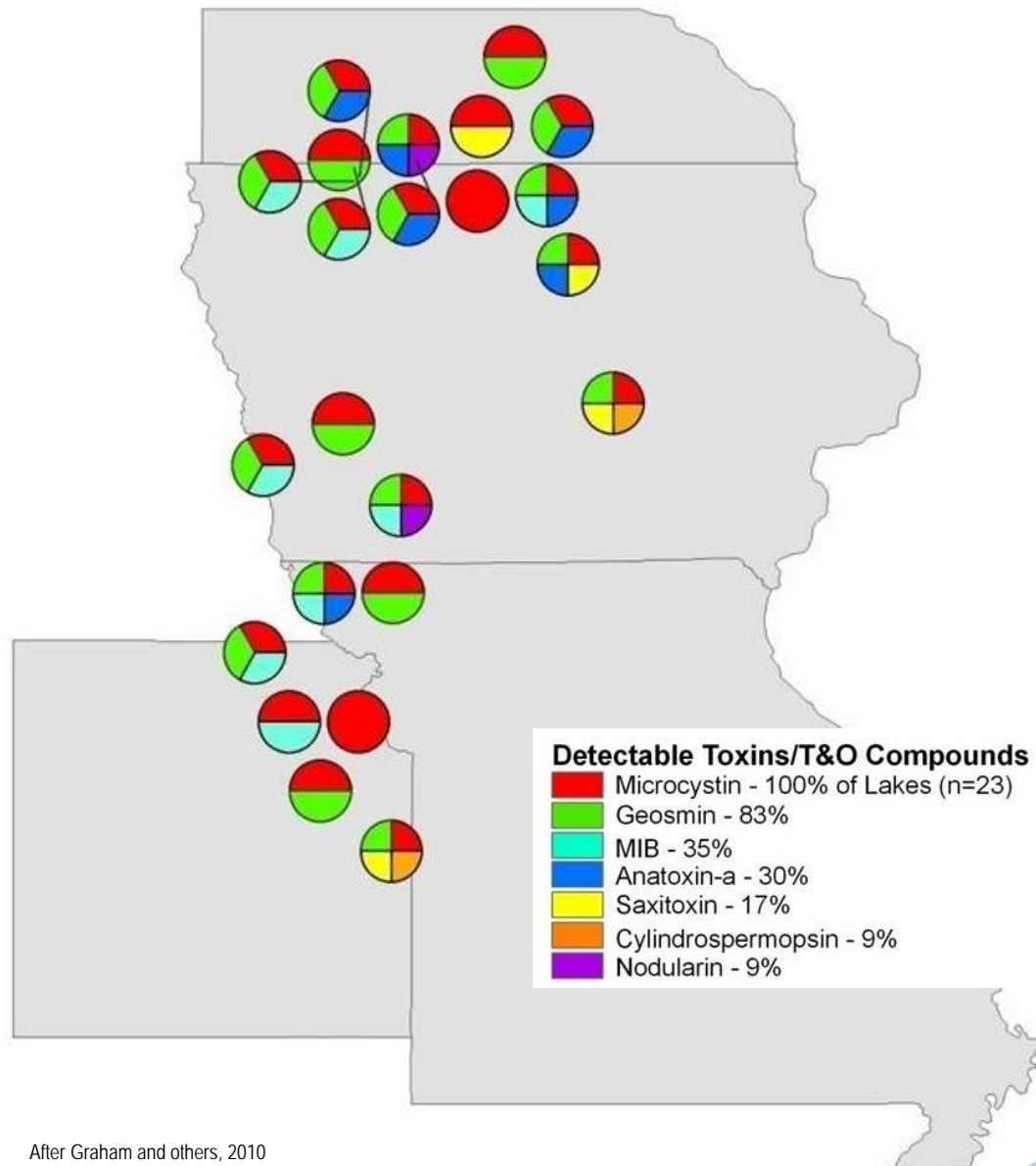


Fetscher et al., 2015



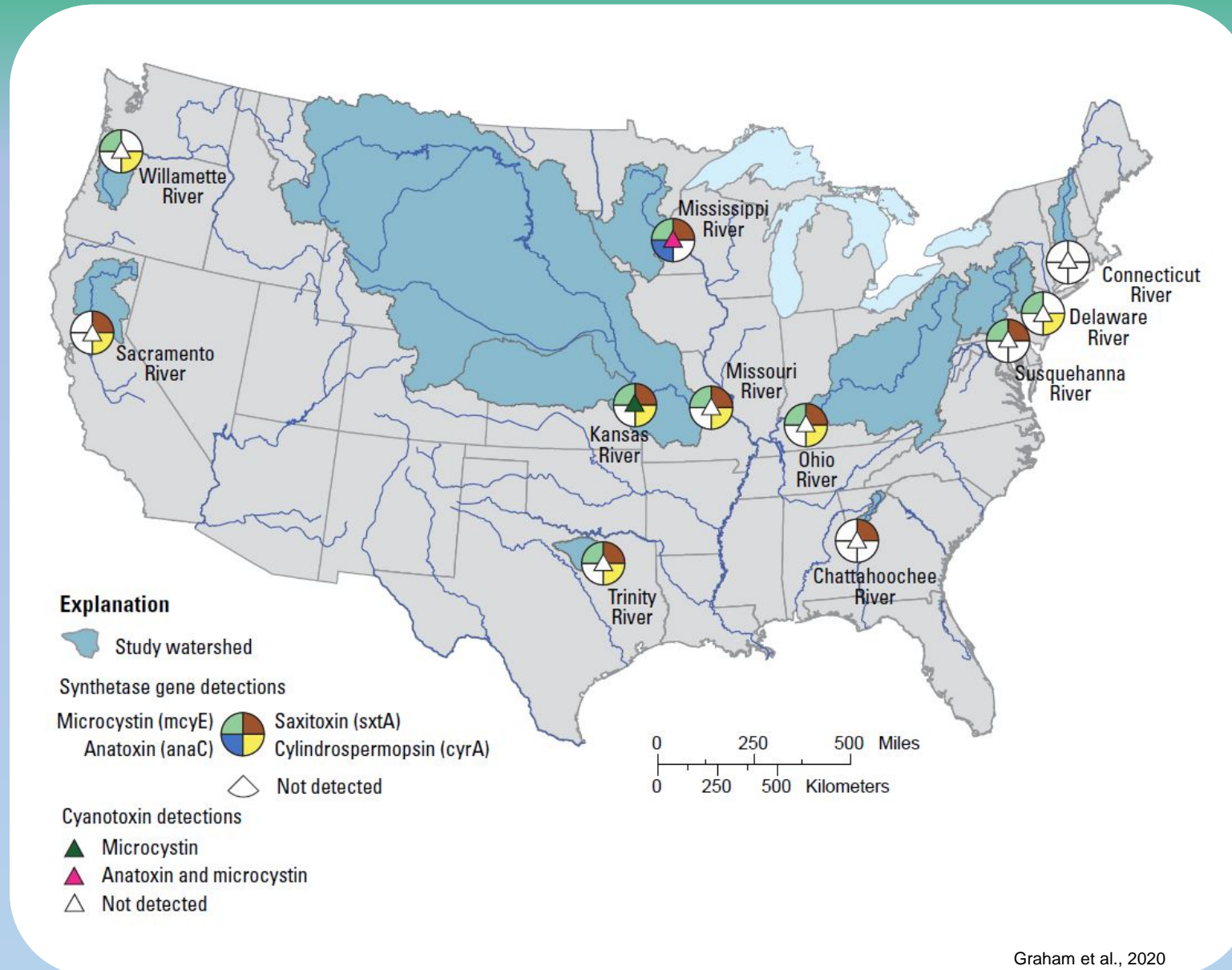
Loftin et al., 2016

Other Cyanotoxins Occur Less Frequently

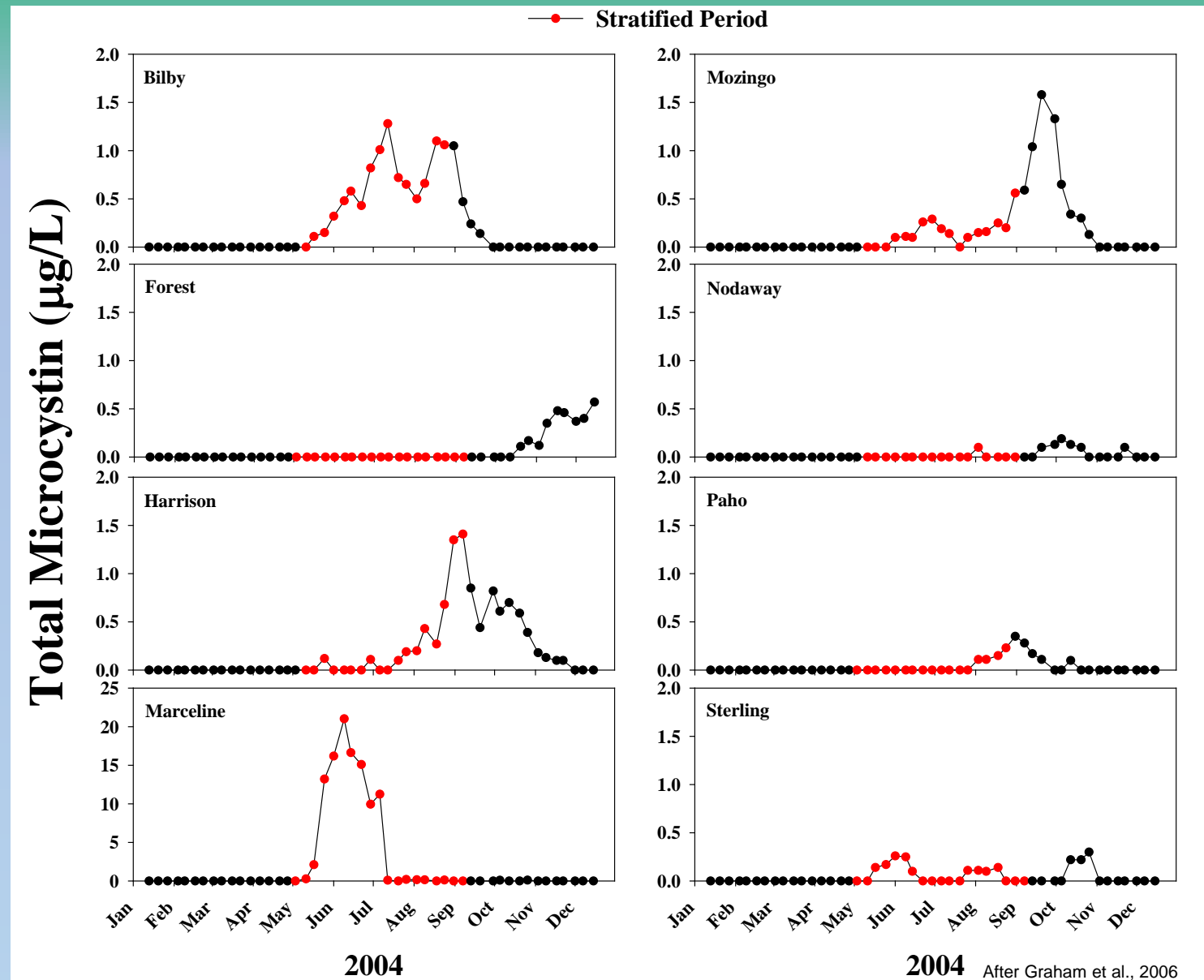


After Graham and others, 2010

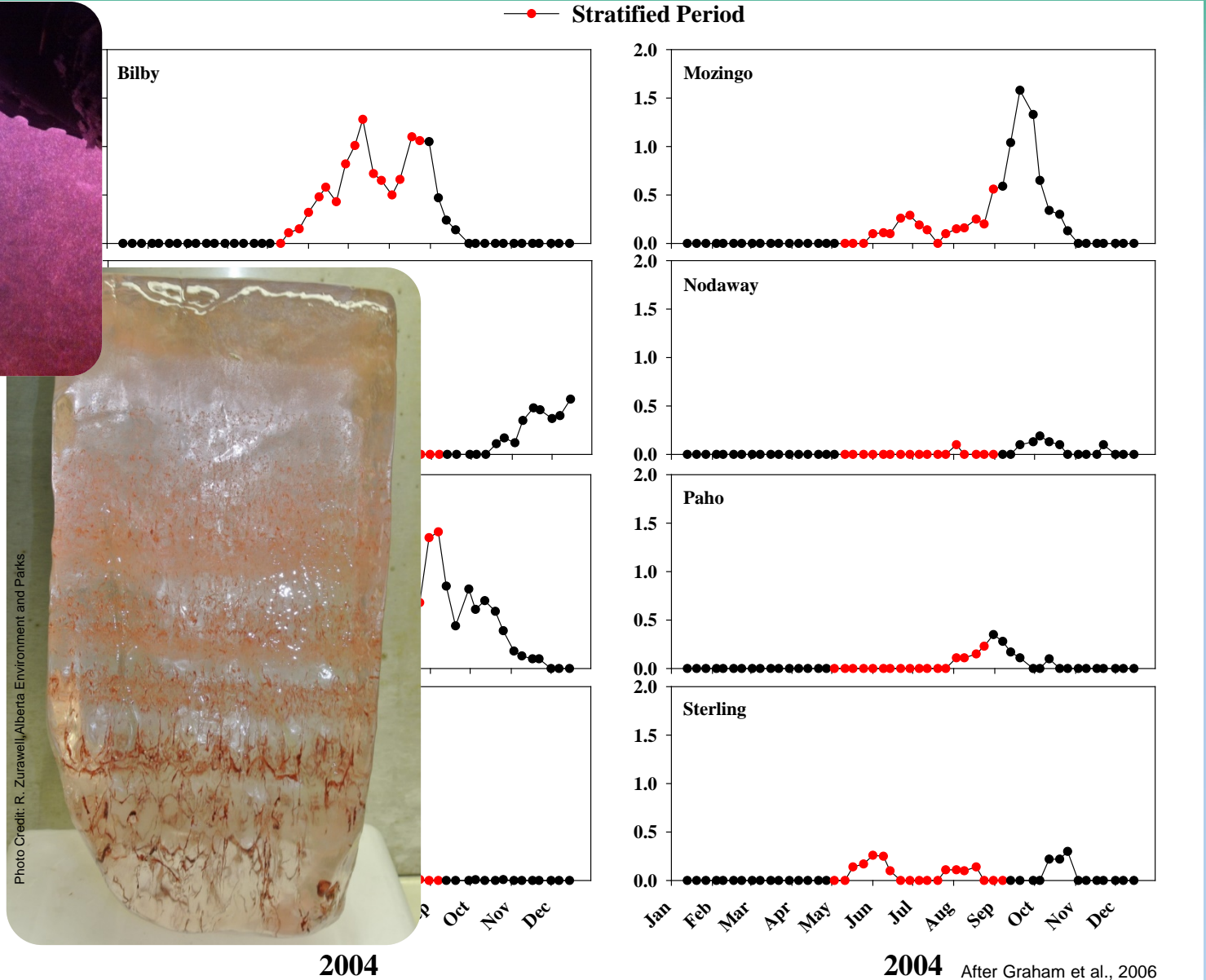
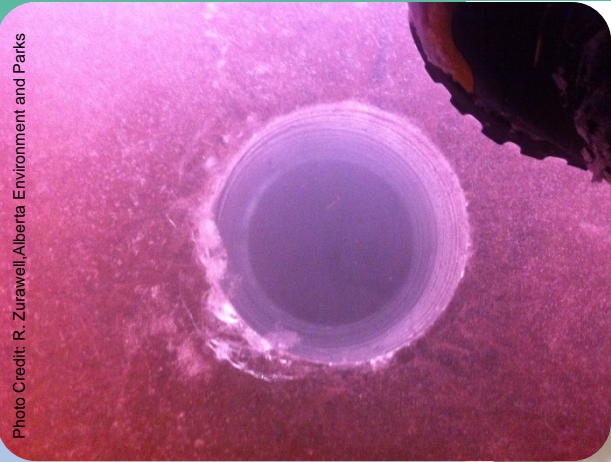
Advances in Analytical Approaches Allow Assessment of Occurrence in Novel Ways



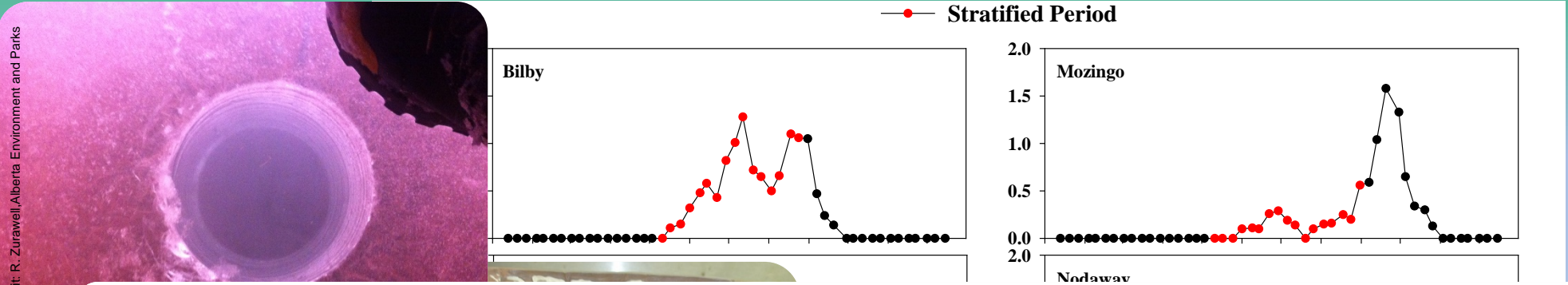
Cyanotoxins are Usually, But Not Always, a Summer Phenomenon



Cyanotoxins are Usually, But Not Always, a Summer Phenomenon

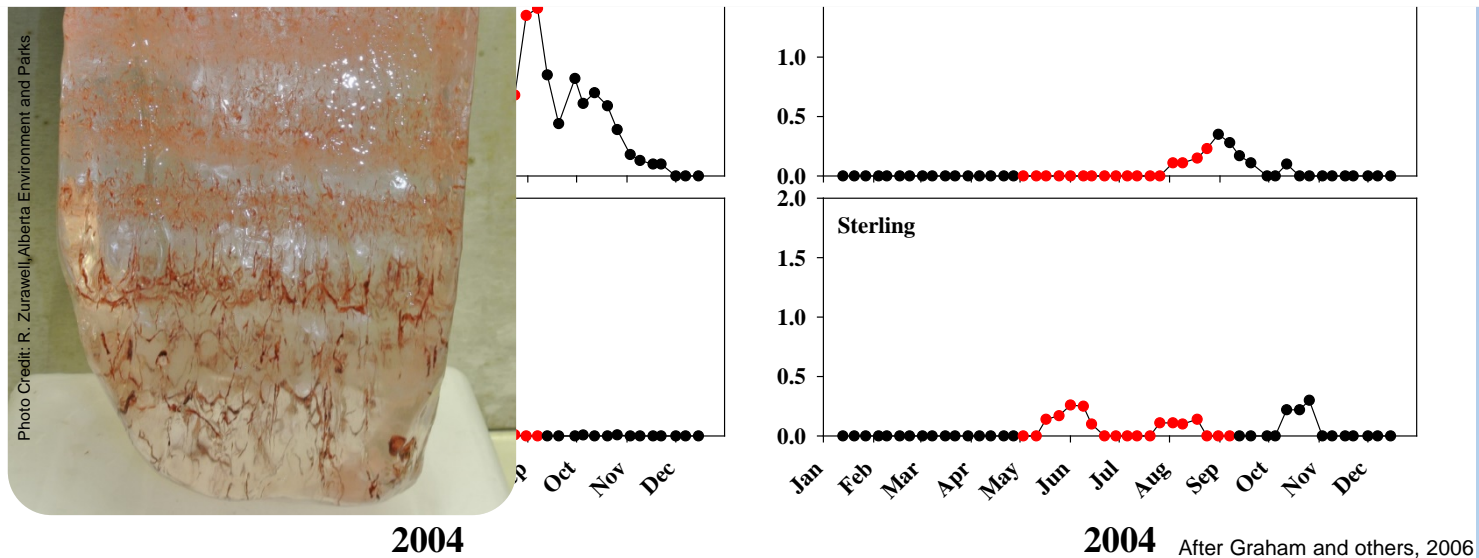


Cyanotoxins are Usually, But Not Always, a Summer Phenomenon

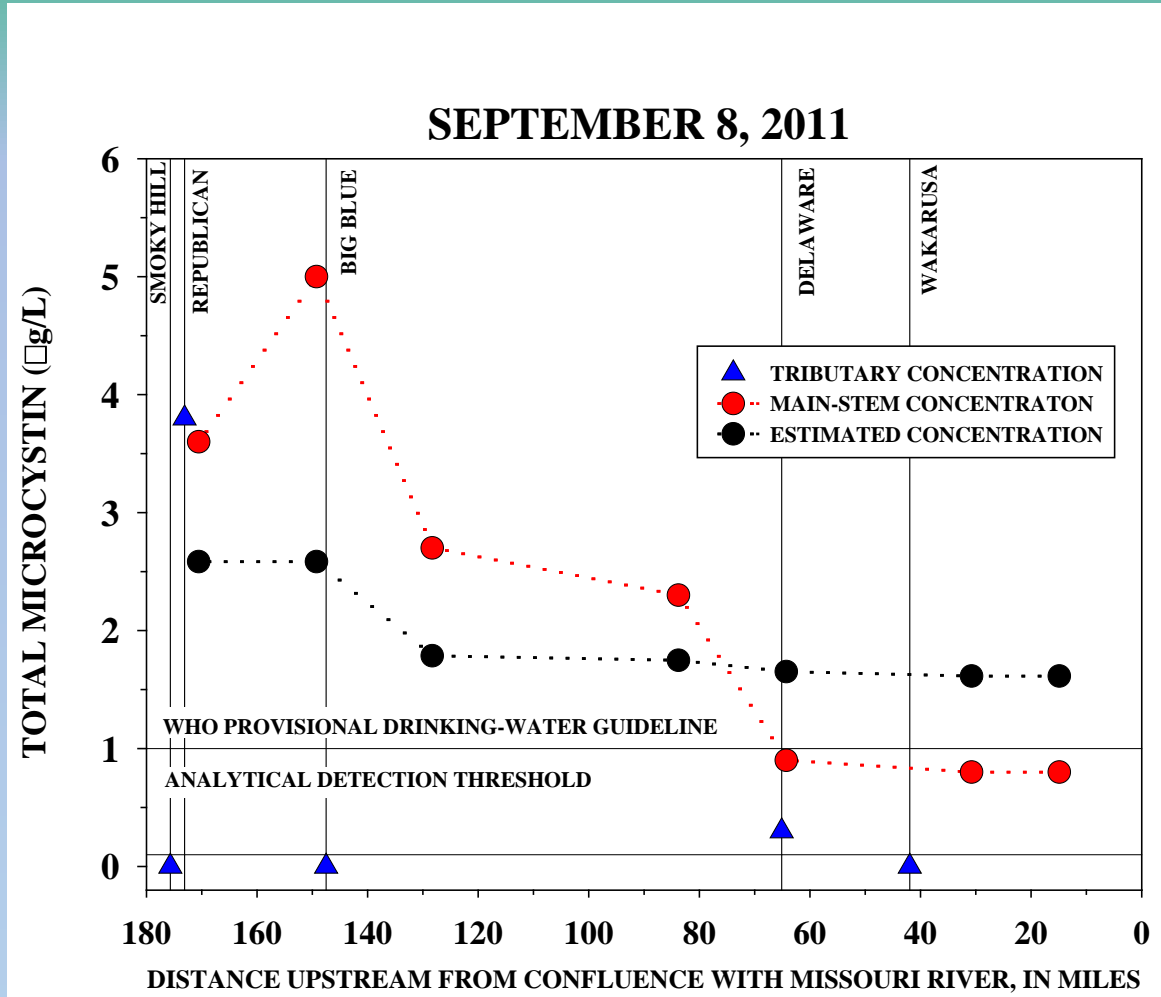


Maryville continues to curb water issues as Mozingo Lake raises concern for cyanotoxins

Kendrick Calfee | Community News Editor | @KoalaCalfee Jan 23, 2020 0

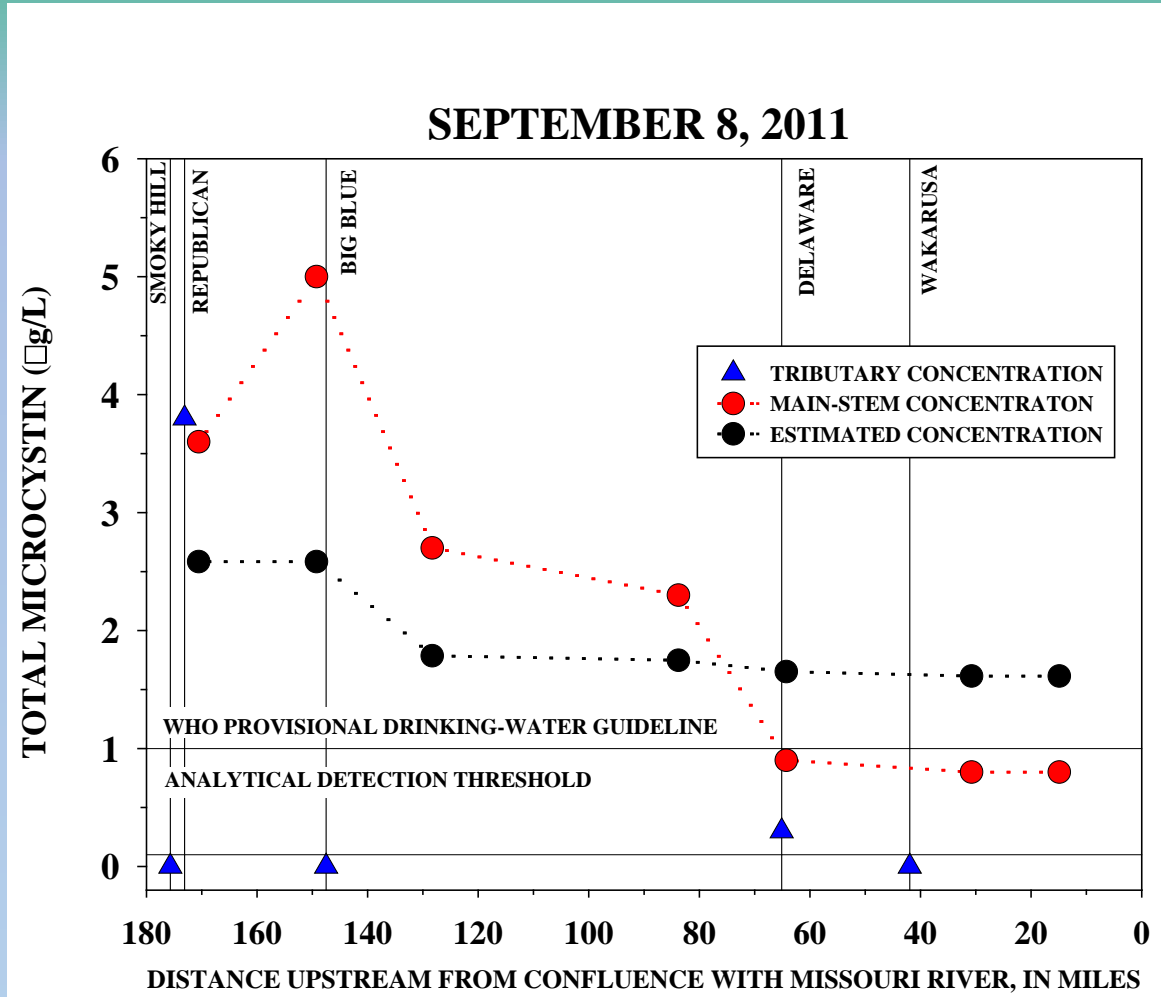


Cyanotoxins May Be Transported for Long Distances Downstream of Source Areas



Graham et al., 2012

Cyanotoxins May Be Transported for Long Distances Downstream of Source Areas



Graham et al., 2012

OPEN ACCESS Freely available online

PLoS one

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

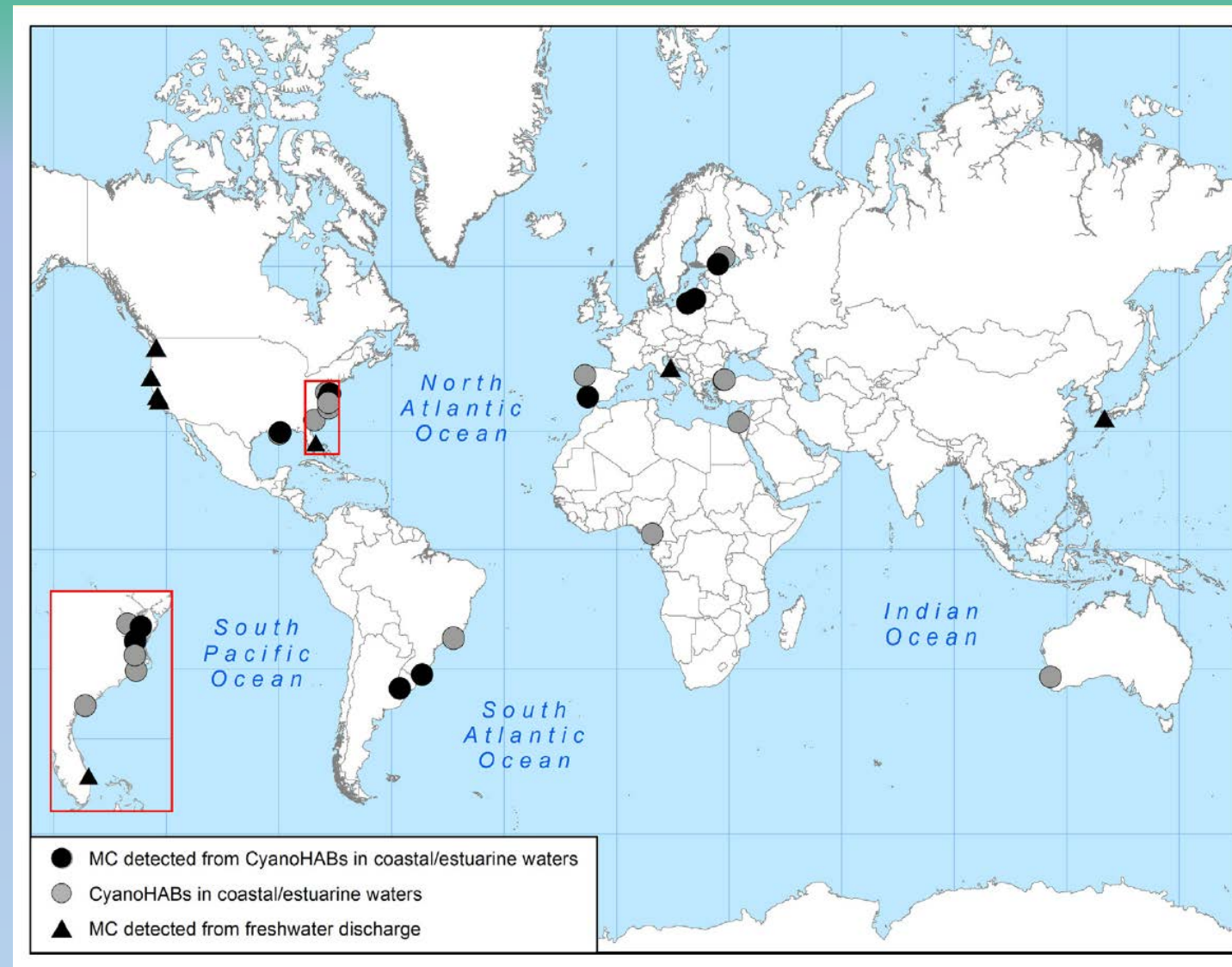
Melissa A. Miller^{1,2*}, Raphael M. Kudela², Abdu Mekebri³, Dave Crane³, Stori C. Oates¹, M. Timothy Tinker⁴, Michelle Staedler⁵, Woutrina A. Miller⁶, Sharon Toy-Choutka¹, Clare Dominik⁷, Dane Hardin⁷, Gregg Langlois⁸, Michael Murray⁵, Kim Ward⁹, David A. Jessup¹

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, California Department of Fish and Game, Ocean Sciences Center, United States Geological Survey, Long Beach, California, United States of America, ³ Department of Pathology, University of California, Davis, California, United States of America, ⁴ Applied Marine Sciences, Live Oak, California, United States of America, ⁵ Division of Water Quality, State



Photo Credit: Getty Images

Cyanotoxins May Occur in Coastal and Estuarine Environments



Is Cyanotoxin Occurrence Increasing?

SECTIONS HOME SEARCH The New York Times

Trump's Unreleased Taxes Threaten Yet Another Campaign Promise

COURT DEPARTMENT OF CORRECTION Court Decisions Force Arkansas to Halt Execution

U.S.

Reeking, Oozing Algae Closes South Florida Bays

By LES NEUBAUER JULY 1, 2016



f t e

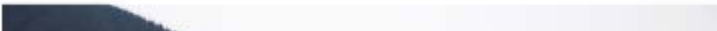
Toledo's tap water undrinkable for a second day; test results delayed



As Climate Warms, Algae Blooms In Drinking Water Supplies

September 3, 2018 4:29 PM ET
Updated on 9/3/18 Things Considered

DIRK VANDERHART FROM



POLLUTION AUGUST 15/17

Blue-green toxic algae invades Florida river

By James Rogers | Fox News



STUART, FL — JULY 13: Green algae is seen in the St. Lucie River near Pelican Park on July 12, 2018 in Stuart, Florida. Water releases which carry the green algae from Lake Okechobee released Friday morning into the Calochee/Calahoo River and into the St. Lucie River at West Mayaca. (Photo by Joe Riedel/Getty Images) (2018 Getty Images)


LIVING

Toxic algae blooms becoming more common across US

By Associated Press June 22, 2018 | 4:02pm



Toxic algae bloom found in Ohio River



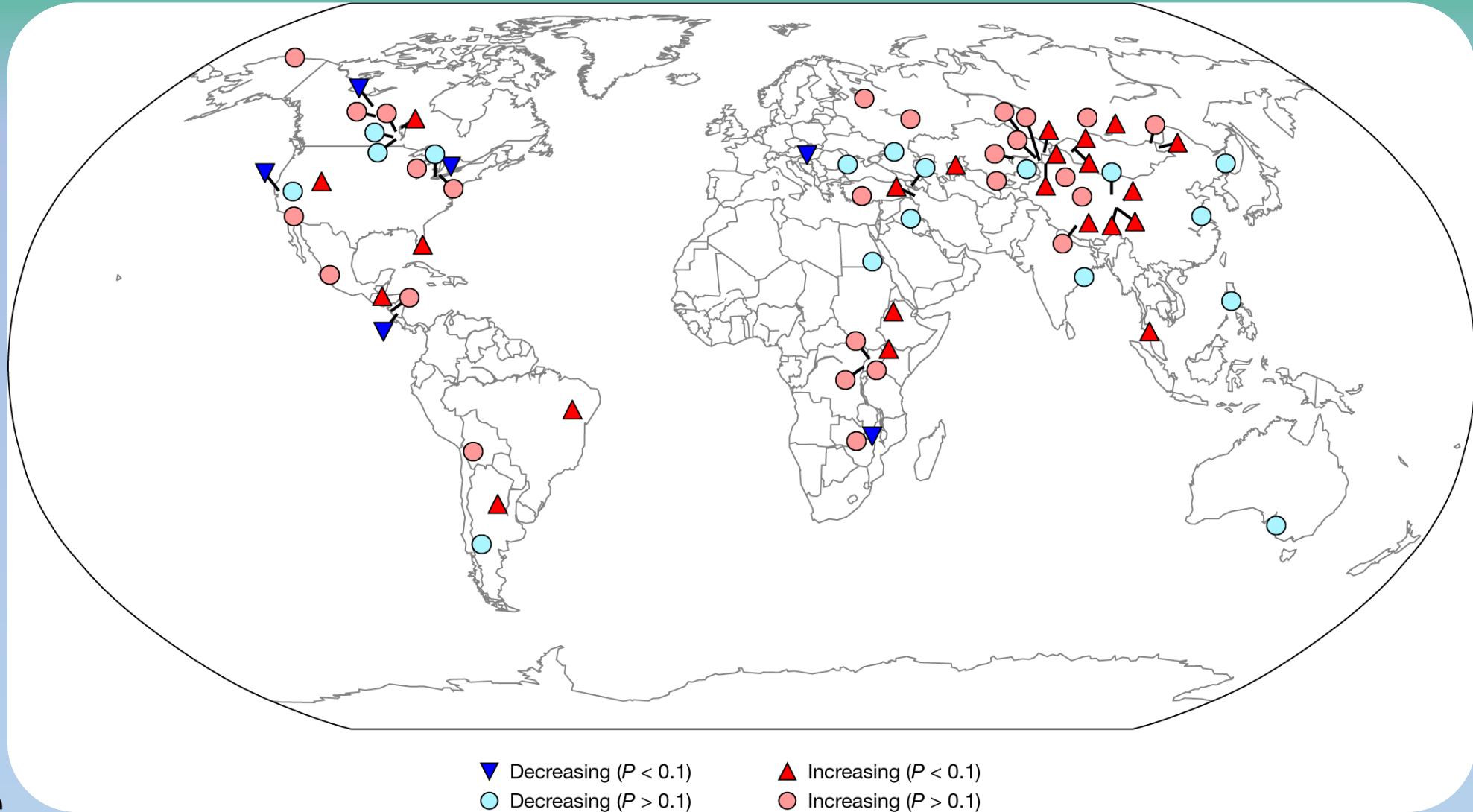
HIDE CAPTION

Photo shows algae near the City of Toledo water intake cuts, in Lake Erie, about 2.5 miles off the shore of Curtice, Ohio. - Hiram M.

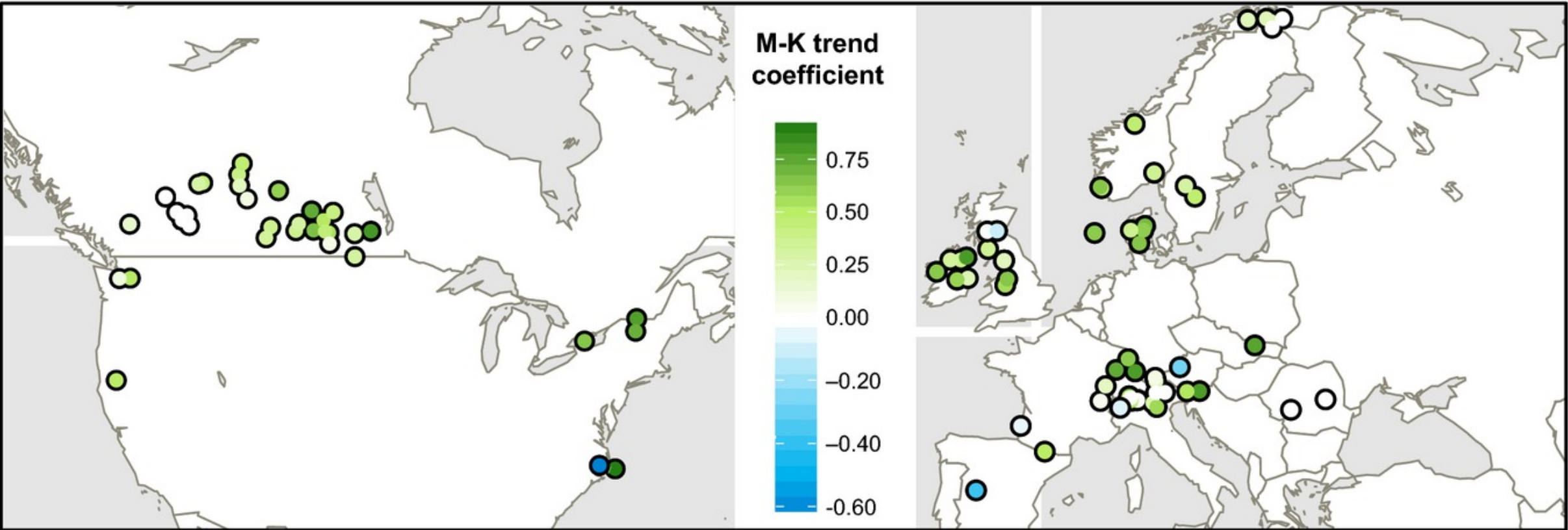
AM AM

Toxic algae have reached the Ohio River. A bloom of microcystis, a blue-green algae capable of producing liver and nerve toxins that can sicken people and kill pets, has formed in the Ohio River near Belmont County

Since the 1980's, Peak Summertime Bloom Intensity Has Increased in Some Lakes



Cyanobacterial Abundance Has Also Increased



Taranu et al., 2015

Cyanobacterial Abundance Has Also Increased

Toxins **2015**, 7, 353-366; doi:10.3390/toxins7020353

OPEN ACCESS

toxins

ISSN 2072-6651

www.mdpi.com/journal/toxins

Article

Human Illnesses and Animal Deaths Associated with Freshwater Harmful Algal Blooms—Kansas

Ingrid Trevino-Garrison ^{1,†,*}, Jamie DeMent ^{2,†}, Farah S. Ahmed ¹, Patricia Haines-Lieber ¹, Thomas Langer ¹, Henri Ménager ¹, Janet Neff ¹, Deon van der Merwe ^{3,†} and Edward Carney ^{1,†}

Time Period	Median Number of Health Alerts*
1989-1995	13
1996-2002	18
2003-2009	25

After Trevino-Garrison et al., 2015

*Based on 2010 Kansas Department of Health Public Health Alert Criteria (advisory $\geq 20,000$ cells/mL; warning $\geq 100,000$ cells/mL)

Has Cyanotoxin Occurrence and Concentration Increased?

Lake and Reservoir Management, 25:253–263, 2009
 © Copyright by the North American Lake Management Society 2009
 ISSN: 0743-8141 print / 1040-2381 online
 DOI: 10.1080/07438140903143239

Microcystin in Missouri reservoirs

Jennifer L. Graham* and John R. Jones

Department of Fisheries and Wildlife Sciences, University of Missouri, 302 Anheuser-Busch
 Natural Resources Building, Columbia, MO, 65211-7420, USA

Table 4.-Annual means, medians, and maxima of total microcystin values. Summary statistics are based on samples collected during each year.

Year	Reservoir n	% Detection	Total microcystin ($\mu\text{g/L}$)				
			n	% Detection	Mean	Median	Maximum
2004	76	42	514	23	0.34	<0.1	21
2005	95	52	380	26	0.25	<0.1	11
2006	127	46	508	20	0.16	<0.1	4.9

Note: Reservoir n indicates the number of reservoirs sampled each year. n indicates the number of samples collected during each year.

Percentage of Monitoring Sites with Measurable toxins

Toxin	2017 n=99	2018 n=99
Cylindrospermopsin	16%	41%
Microcystin	83%	61%

Results from reservoir sites
 sampled both seasons

Courtesy of T. Thorpe, University of Missouri

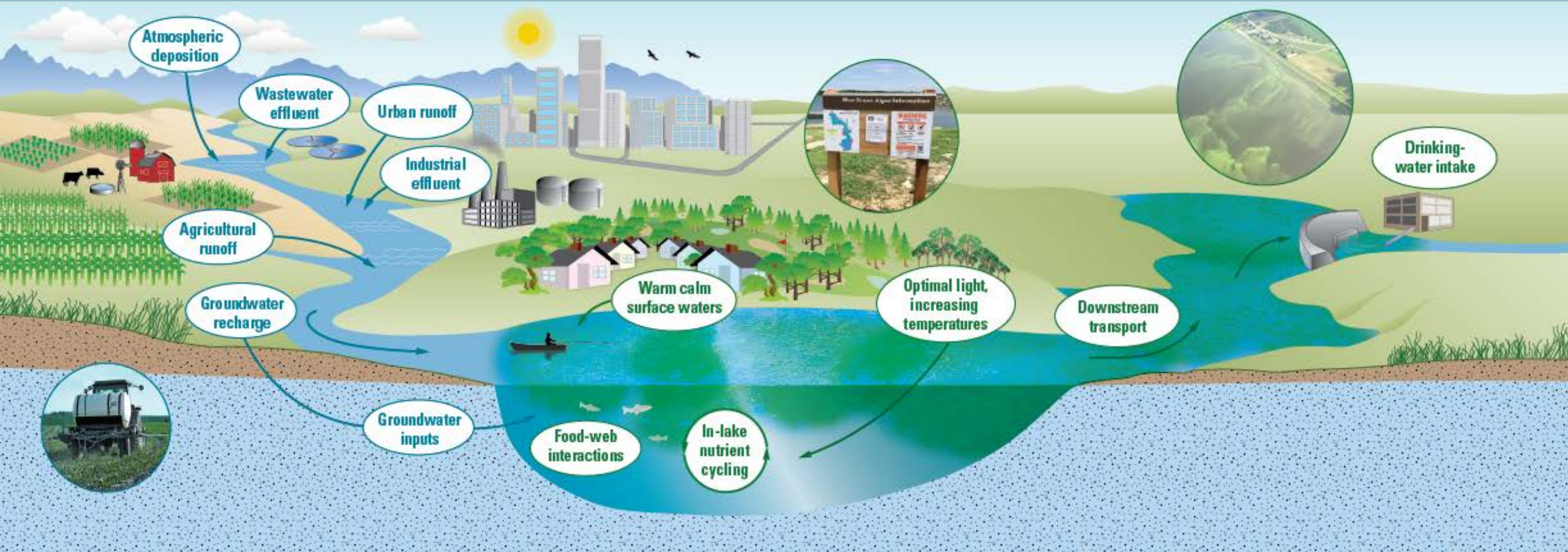
Cylindrospermopsin

36 reservoirs, 1 sample each

% Detection: 14

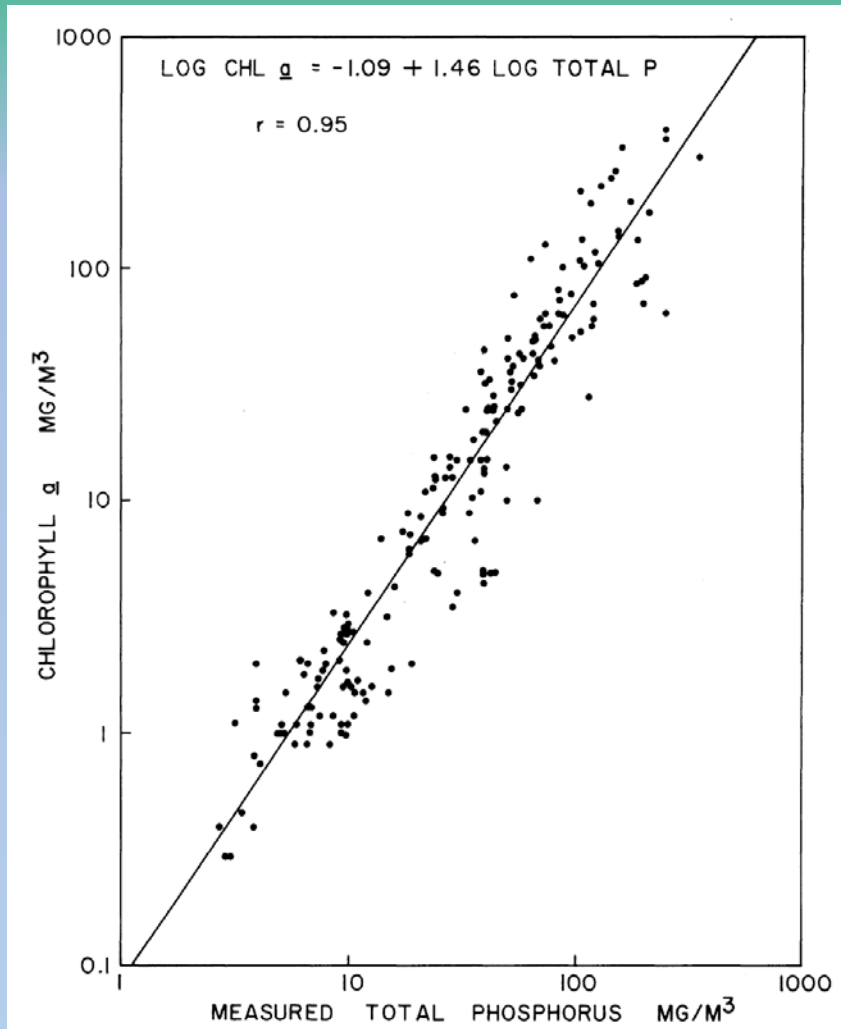
Maximum: <1 $\mu\text{g/L}$

What Causes Cyanobacterial Blooms?

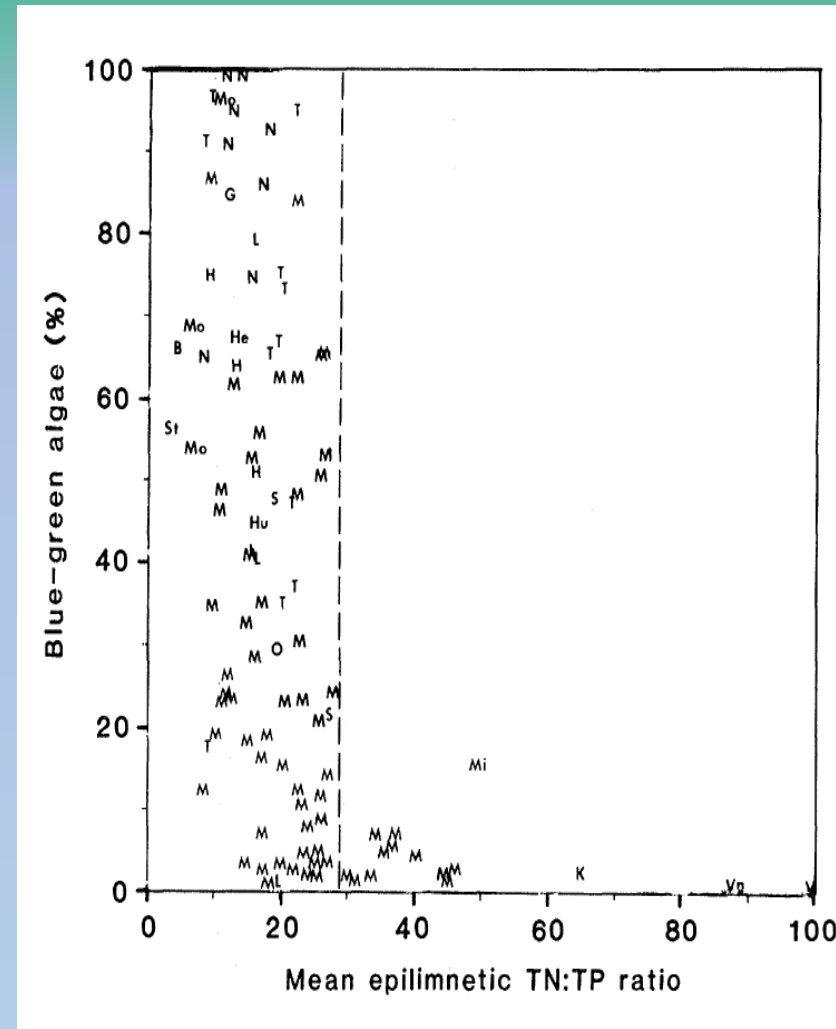


Graham et al., 2016

Nutrients Play a Key Role

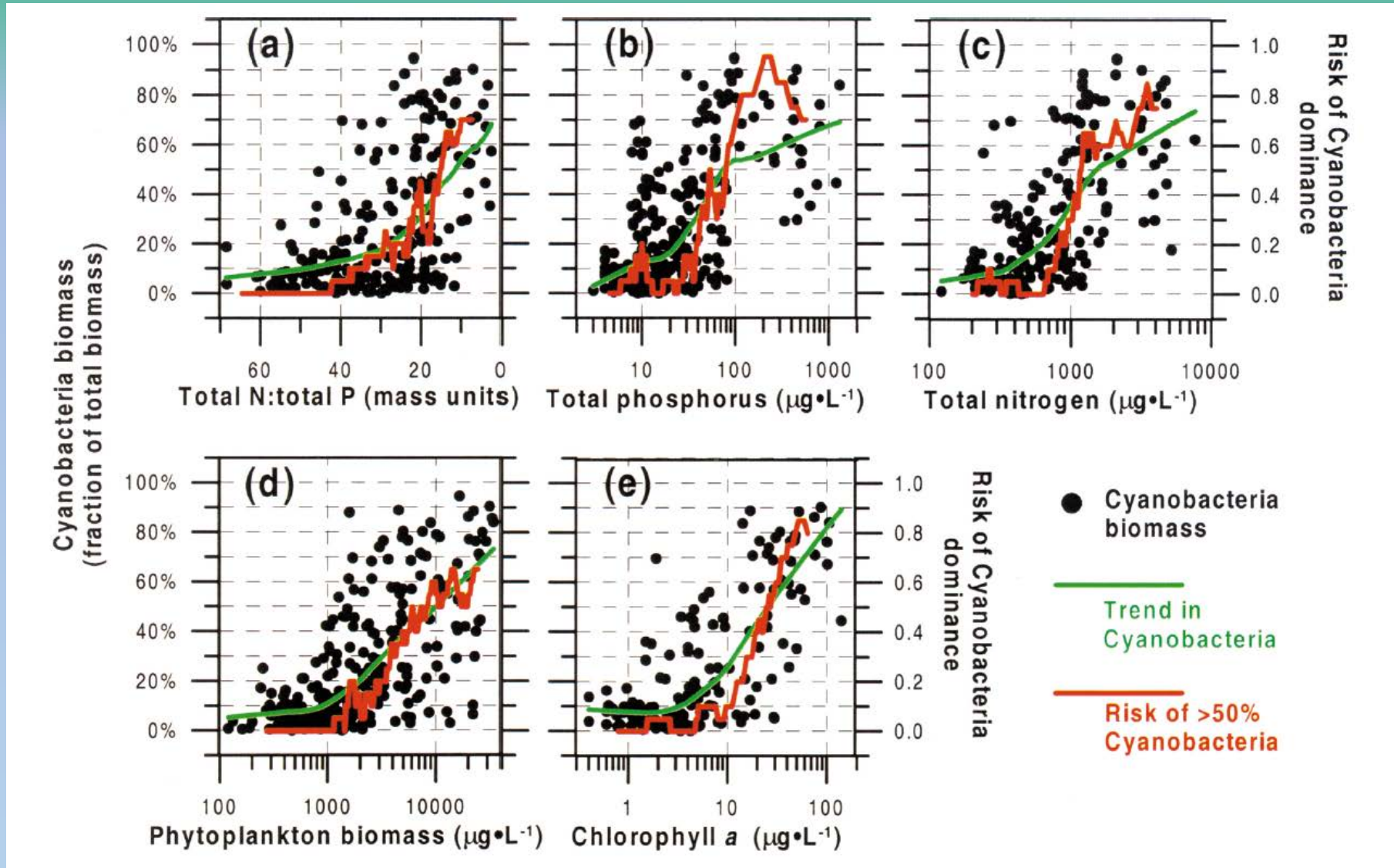


Jones and Bachmann, 1976

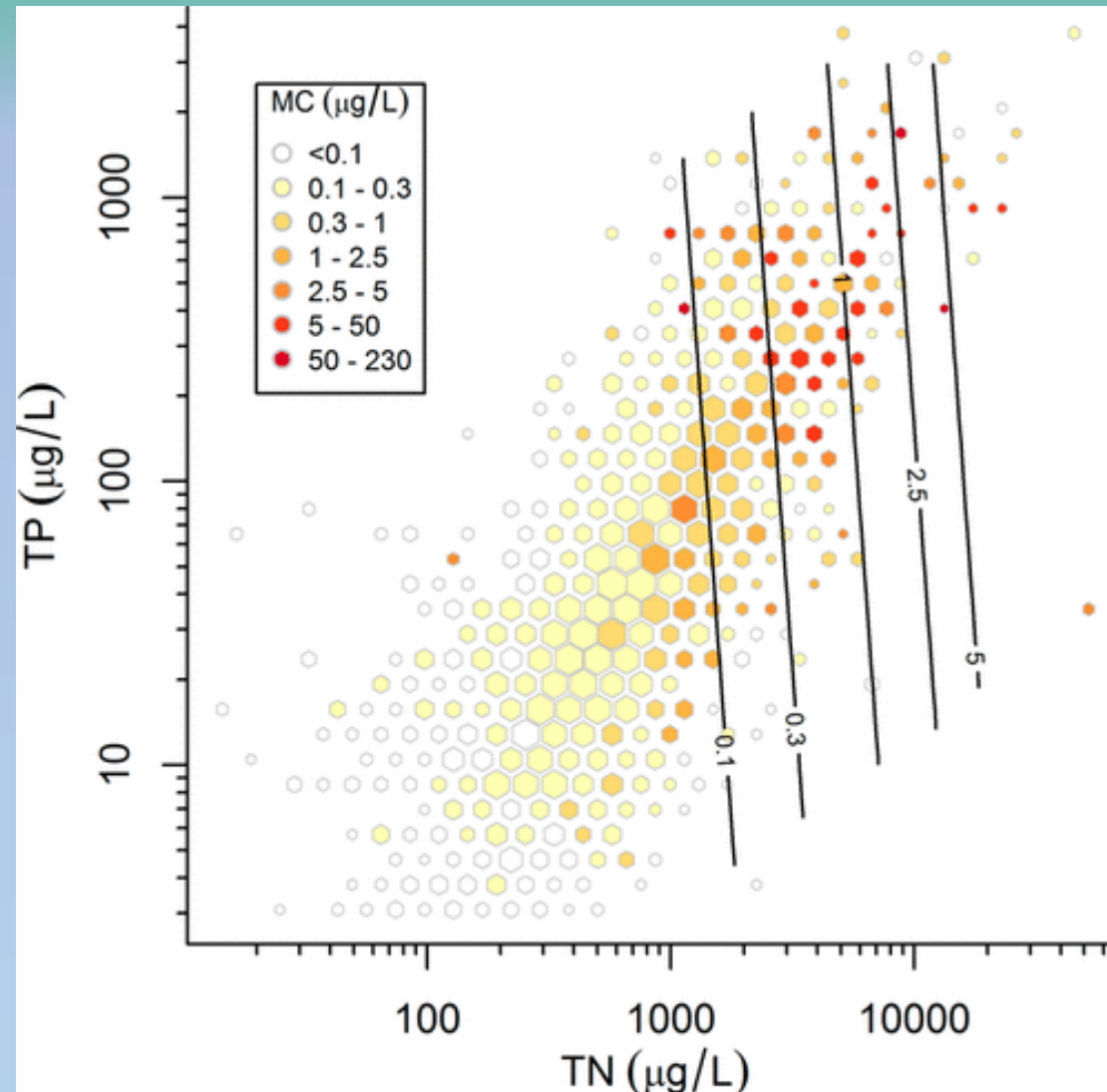


Smith, 1983

Nutrients Play a Key Role

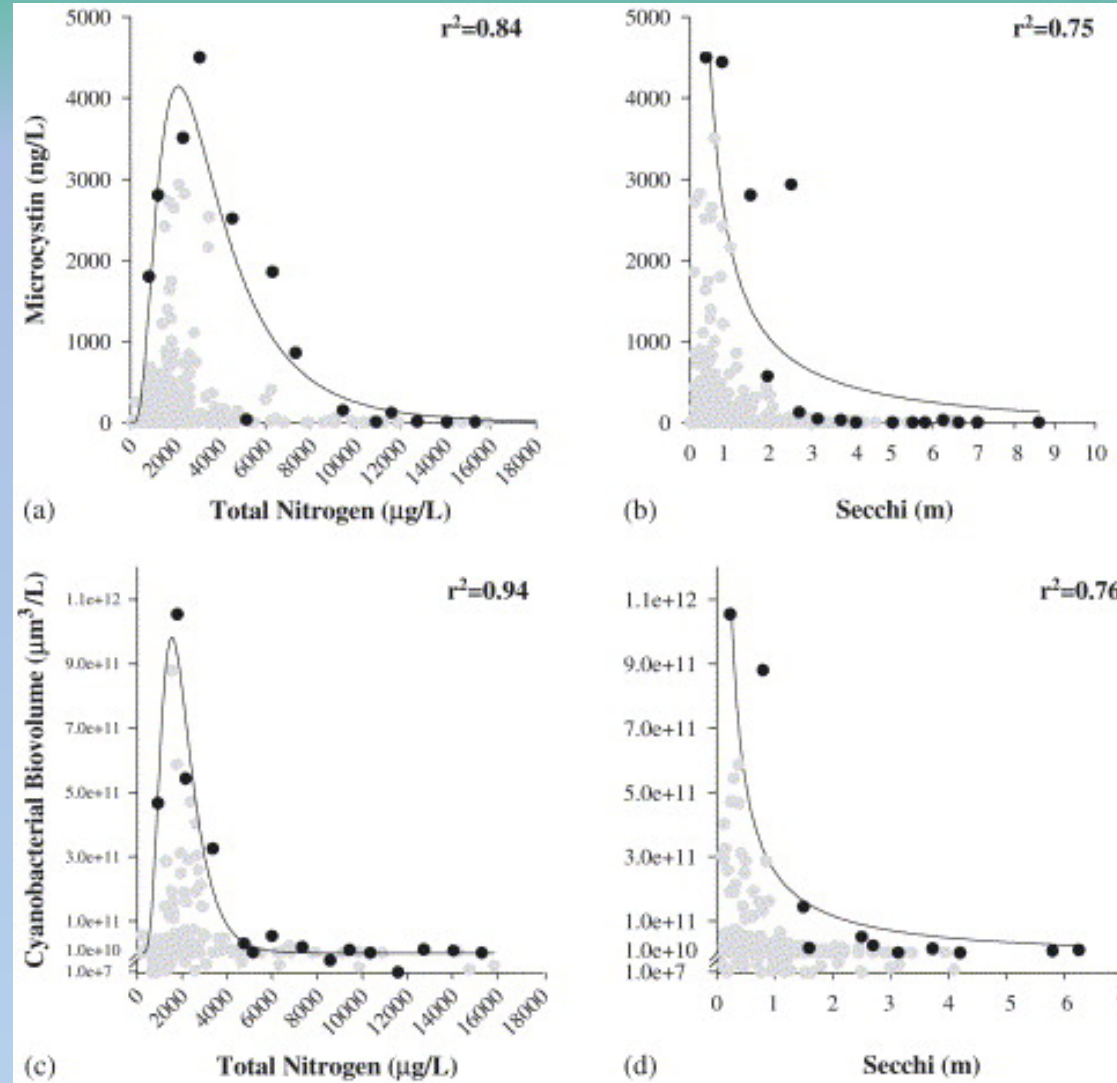


Relations Between Cyanotoxins and Environmental Variables are Similar to Those Observed for Cyanobacteria

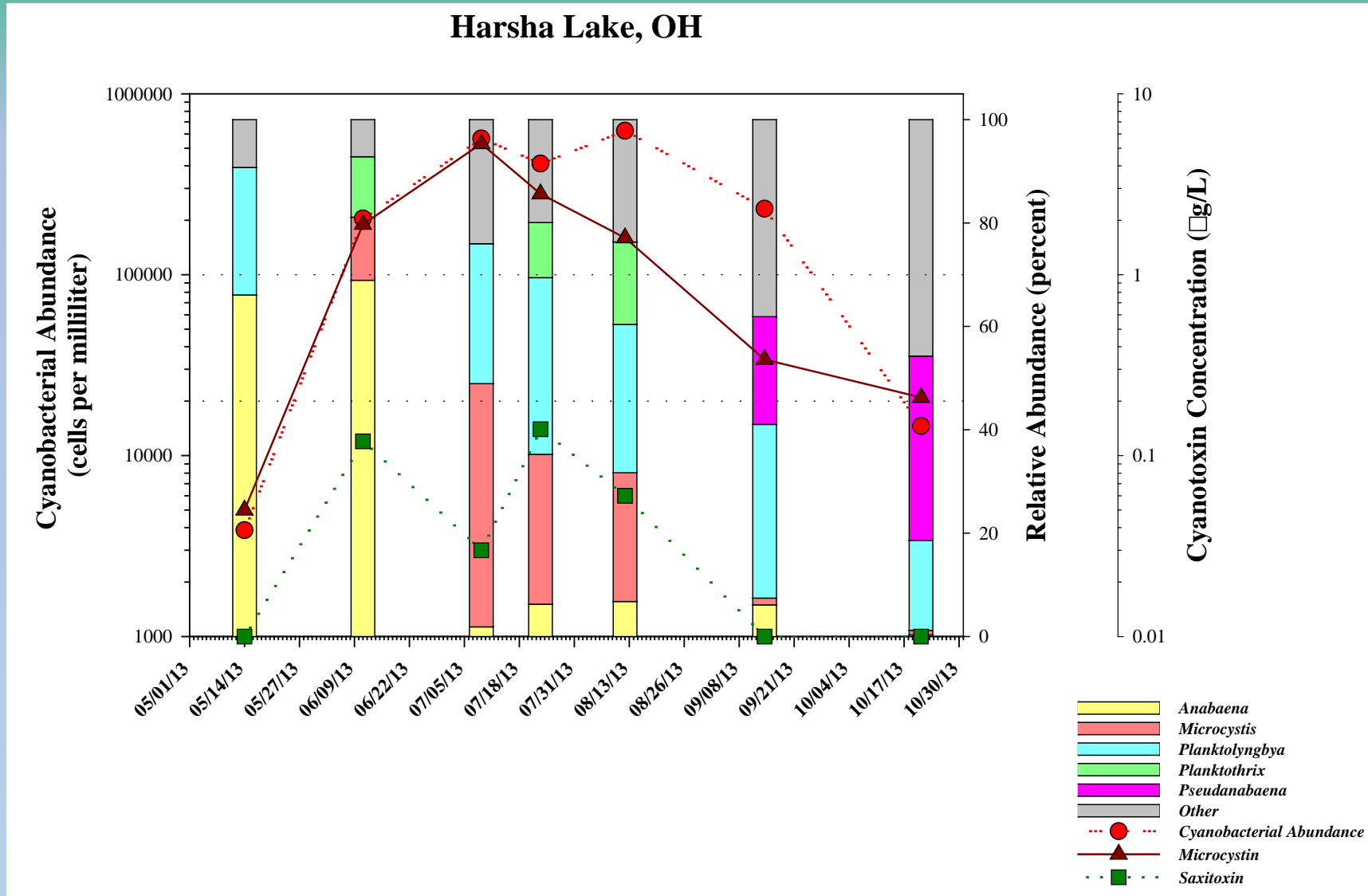


Yuan and Pollard, 2017

Relations Between Cyanotoxins and Environmental Variables are Similar to Those Observed for Cyanobacteria



Cyanotoxin Occurrence is Not Necessarily Tightly Coupled to Cyanobacterial Abundance or Community Composition



Individual Lakes Are Unique

Reservoir	Strongest Correlate	r_s	p-value	n
Bilby	Conductance	-0.86	<0.01	48
Forest	Chlorophyll > 35 μm	0.67	<0.01	49
Harrison	Total Nitrogen	0.78	<0.01	49
Marceline	Dissolved Organic Carbon	0.66	<0.01	49
Mozingo	Magnesium	-0.84	<0.01	13
Nodaway	Nitrate	-0.46	<0.01	49
Paho	<i>Ceriodaphnia</i> abundance	0.81	<0.01	28
Sterling	Sodium	0.60	0.03	13

Paradigms Are Changing

Marine Pollution Bulletin 124 (2017) 591–606



Contents lists available at ScienceDirect

Marine Pollution Bulletin

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



Eutrophication, harmful algae and biodiversity — Challenging paradigms in a world of complex nutrient changes



Patricia M. Glibert

University of Maryland Center for Environmental Science, Horn Point Laboratory, PO Box 6775, Cambridge, MD 21613, USA

Blurred lines: Multiple freshwater and marine algal toxins at the land-sea interface of San Francisco Bay, California

Melissa B. Peacock^{a,b,c,*}, Corinne M. Gible^{b,d}, David B. Senn^d, James E. Cloern^e, Raphael M. Kudela^b

^a Northwest Indian College, 2522 Kwina Rd, Bellingham, WA, 98226, USA

^b Ocean Sciences Department, 1156 High Street, University of California, Santa Cruz, CA 95064, USA

^c San Francisco Estuary Institute, 4911 Central Avenue, Richmond, CA 94804, USA

^d California Department of Fish and Wildlife, Office of Spill Prevention and Response, Marine Wildlife Veterinary Care and Research Center, 151 McAllister Way, Santa Cruz, CA 95060, USA

^e United States Geological Survey MS496, 345 Middlefield Rd, Menlo Park, CA 94025, USA



Review

Harmful algal blooms: A climate change co-stressor in marine and freshwater ecosystems

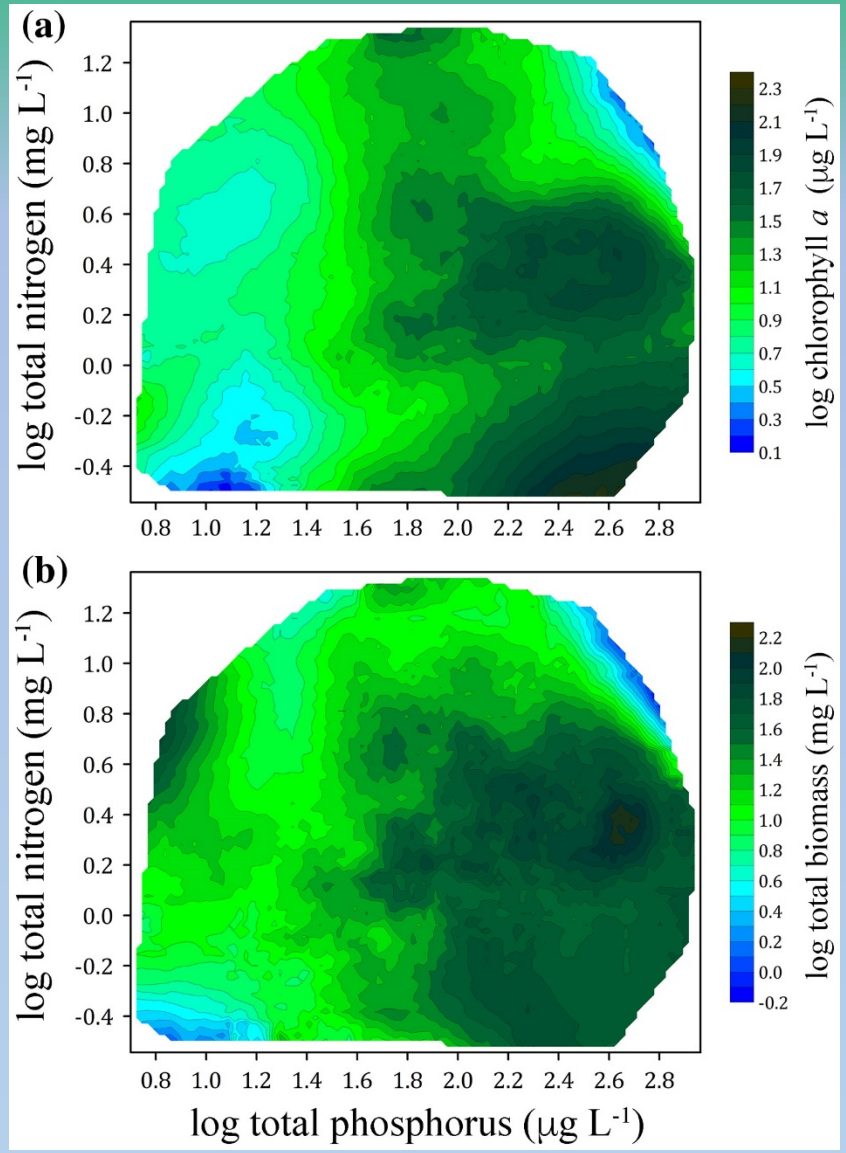
Andrew W. Griffith^{a,b}, Christopher J. Gobler^{a,*}

^a School of Marine and Atmospheric Sciences, Stony Brook University, Southampton, NY, 11968, United States

^b Department of Biological Sciences, University of Southern California, Los Angeles, CA 90089, United States



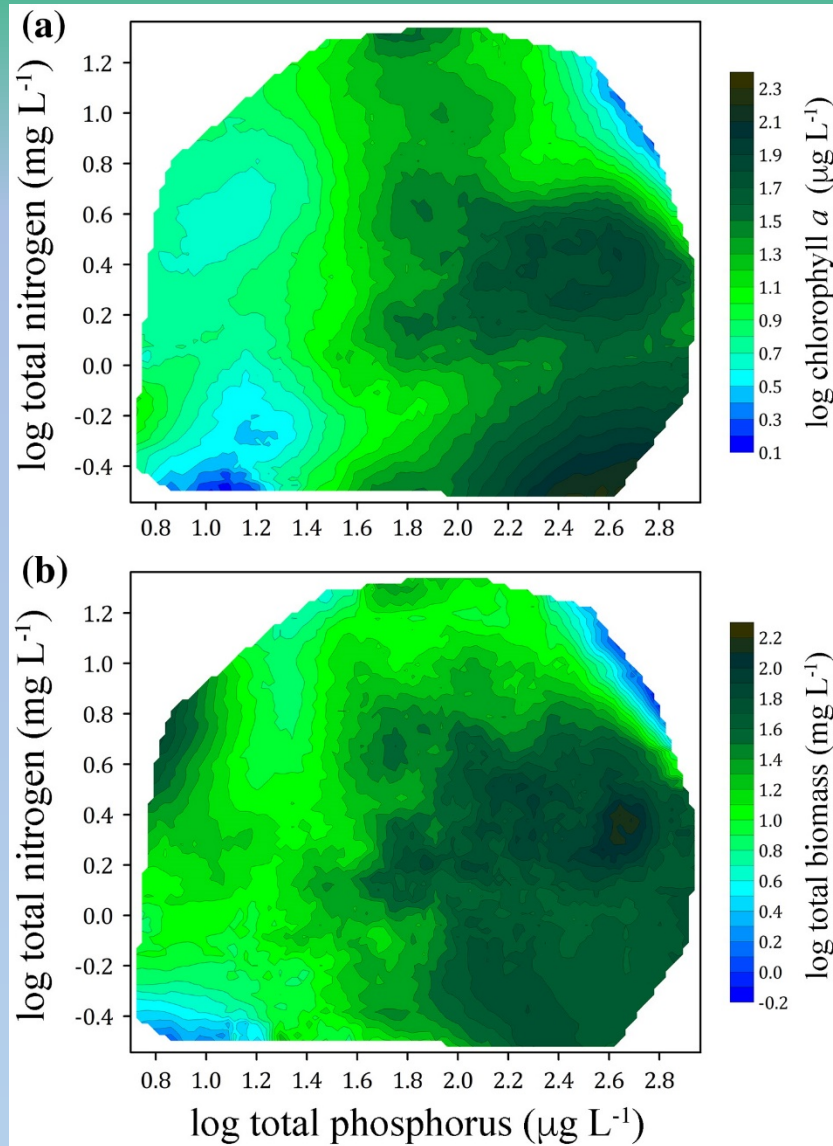
Paradigms Are Changing



Relationship of chlorophyll to phosphorus and nitrogen in nutrient-rich lakes
Christopher T. Filstrup & John A. Downing
Pages 385-400 | Published online: 09 Oct 2017
[Download citation](#) <https://doi.org/10.1080/20442041.2017.1375176> [Check for updates](#)

Filstrup and Downing, 2017

Paradigms Are Changing



Relationship of chlorophyll to phosphorus and nitrogen in nutrient-rich lakes

Christopher T. Filstrup & John A. Downing

Pages 385-400 | Published online: 09 Oct 2017

Download citation

<https://doi.org/10.1080/20442041.2017.1375176>

Check for updates

- High nutrients and low biomass did not coincide with shifts in nutrient limitation, light availability, cellular Chl- a content, phytoplankton composition, or zooplankton grazing pressure.
- Nitrate comprised most of TN and occurred with reduced dissolved organic matter.
- Hypothesis: Photolysis of nitrate may produce reactive oxygen species that damage DOM and phytoplankton.

Filstrup and Downing, 2017

Cyanotoxin Blooms Are Occurring in Oligotrophic Systems

Skaneateles Lake algae outbreak could be toxic, state DEC says

Updated Aug 6; Posted Aug 6 2018



The state has confirmed that algae floating in Skaneateles Lake near the village of Skaneateles is toxic. (Gregory Simmons | Special to Syracuse.com)

Skaneateles Lake beaches closed after harmful algae blooms pop up

Updated Aug 7; Posted Aug 7

SKANEATELES LAKE

DEC confirms harmful algal bloom on Skaneateles Lake, now dissipated

The Citizen staff Aug 7, 2018

Swimmers, Pets Told to Avoid Algal Bloom on Skaneateles Lake; City Monitoring Water Quality

By SCOTT WILLIS & CAMERON TIRADO - AUG 8, 2018

Toxin-producing algae found again in Skaneateles Lake

Updated Sep 6, 1:51 PM; Posted Sep 6, 1:36 PM

Cyanotoxin Blooms Are Occurring in Oligotrophic Systems

Skaneateles Lake algae outbreak could be toxic, state DEC says

Updated Aug 6; Posted Aug 6 2018

2018 Summer Maximum
Total Phosphorus: 7 $\mu\text{g/L}$
Chlorophyll: 1.6 $\mu\text{g/L}$
Shoreline Microcystin: 940 $\mu\text{g/L}$



The state has confirmed that algae floating in Skaneateles Lake near the village of Skaneateles is toxic. (Gregory Simmons | Special to Syracuse.com)



The Spatiotemporal Variability of Cyanobacteria Poses Unique Challenges to Monitoring and Assessment

July 20, 2016 at 3:54 pm



Photo Credit: G. Foster, USGS

July 20, 2016 4:09 pm

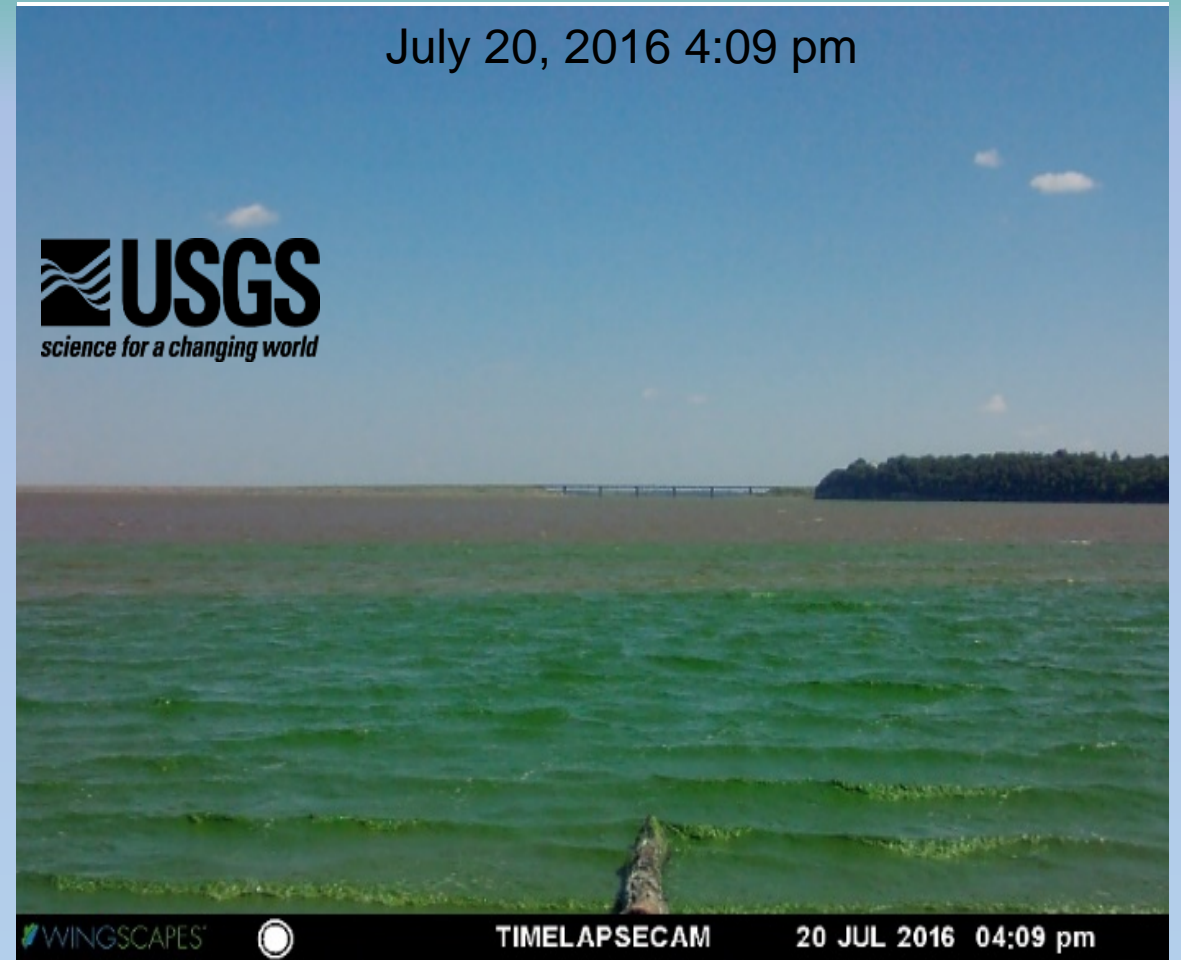


Photo Credit: G. Foster, USGS

Milford Lake, KS

Knowledge Gaps

A considerable amount of research is being conducted...toward the determination of causes and control of algal blooms. An expansion and integration of these studies is indicated as a very real need.

~E. T. Rose, 1953

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





Jennifer Graham
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518-285-5706