EPA Region 4 Harmful Algal Bloom
Southeastern Regional Workshop Agenda

Pre-Workshop Webinar – Tuesday, May 8th, 2018

** Recording Region 4 HABs Webinar - May 8th, 2018

HABs Overview		
Time	**Presentation Title**	**Presenter**
12:45 – 1:00 pm	Log in	
1:00 – 1:10 pm	Welcome and opening remarks	Lesley D'Anglada, EPA
1:10 – 1:40 pm	Controlling Global Proliferation of HABs in the Face of Increasing Human and Climatic Pressures	Hans W. Paerl, University of North Carolina at Chapel Hill
1:40 – 2:10 pm	Impact of Harmful Algal Blooms on Human and Animal Health	Elizabeth Hilborn, EPA
2:10 – 2:40 pm	Cyanotoxins in Freshwaters of the United States: Occurrence and Emerging Technologies	Jennifer Graham, USGS
2:40 – 2:50 pm	Break	
Research and Collaborations		
2:50 – 3:10 pm	Recent Intensification of Harmful Cyanobacteria Blooms in Midwestern Reservoirs	Nathan Smucker, EPA
3:10 – 3:30 pm	NOAA Harmful Algal Bloom Program: National Perspectives	Marc Suddleson, NOAA
3:30 – 3:50 pm	Harmful Algal Blooms and Public Health Surveillance: The One Health Harmful Algal Bloom System (OHHABS)	Virginia Roberts, CDC
3:50 – 4:10 pm	Cyanobacteria Monitoring and Applications using Satellite Sensing	Blake Schaeffer, EPA
4:10 – 4:30pm	Q&A and Open Discussion	EPA
4:30 pm	Adjourn	

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Biographies of Presenters

Dr. Hans W. Paerl is Kenan Professor of Marine and Environmental Sciences at the University of North Carolina's Institute of Marine Sciences. His research addresses microbially-mediated nutrient cycling and primary production dynamics, environmental controls and management of harmful algal blooms, and assessing effects of human and climatic alterations of water quality and sustainability of inland, estuarine and coastal marine waters. Dr. Paerl has published over 250 peer reviewed articles and book chapters on these subjects. He received the 2003 G. Evelyn Hutchinson Award from the Association of the Sciences of Limnology and Oceanography, and the 2011 Odum Award from the Coastal and Estuarine Research Federation for addressing the causes, consequences and controls of eutrophication in aquatic ecosystems. In 2015, Dr. Paerl was named a Fellow of the American Geophysical Union.
E-mail: hans_paerl@unc.edu; Phone: 252-726 6841, Ext. 133

Dr. Elizabeth (Betsy) Hilborn is a graduate of the University of North Carolina at Chapel Hill where she earned a BS in Biology, she earned her Doctorate in Veterinary Medicine at North Carolina State University. She completed her Master of Public Health at the University of North Carolina at Chapel Hill, and served as a Fellow in the Centers for Disease Control and Prevention's Epidemic Intelligence Service. She is Board Certified in the American College of Veterinary Preventive Medicine. For over 20 years, Dr. Hilborn has worked as an environmental health scientist and epidemiologist at the US Environmental Protection Agency's Office of Research and Development where her research focuses on emerging infections and the health effects of environmental and waterborne contaminants such as toxic cyanobacteria.
Email: Hilborn.E@epa.gov; Phone: 919-966-0658

Dr. Jennifer Graham has been a Research Hydrologist with the U.S. Geological Survey in Lawrence, Kansas since 2005. Since 1997, Jennifer's research has focused on the effects of anthropogenic influence on aquatic ecosystems. She also is a nationally recognized expert in cyanobacteria and associated nuisance compounds. For the past nineteen years she has conducted research on environmental factors influencing the occurrence of cyanotoxins in the United States. She has conducted both regional and single system studies at a variety of spatiotemporal scales.
E-mail: jlgraham@usgs.gov; Phone: 541-737-1795

Dr. Nathan Smucker is an Ecologist with EPA's Systems Ecology Division in the National Exposure Research Lab. Nate's work focuses on understanding how humans affect aquatic ecosystems, with the goal being to better inform how we can improve and protect their water quality, ecology, and beneficial uses in the future. Specifically, Nate has worked on developing ecological indicators and nutrient management targets based on

stressor-response relationships of biota and on characterizing how watershed conditions, restoration, and management practices affect downstream water bodies and HABs.
Email: Smucker.Nathan@epa.gov; Phone:

Mr. Marc Suddleson has worked at NOAA for over 20 years as a contractor and federal employee. Since 2002, in his current position as an oceanographer and manager of national research programs, he has promoted the development of research leading to better management of coastal resources and related industries facing increasing threats from ocean-related phenomena. He manages a portfolio of science projects that are developing new ocean sensor technologies and successfully demonstrating how they can help safeguard our seafood supply, document changes in ocean conditions and biological communities, and improve access to data supporting science-based resource management and public policy. Mr. Suddleson has lead the creation of strong partnerships between NOAA and other federal laboratories, academic institutions, management agencies, and industry that have led to significant science, technology and management breakthroughs. Mr. Suddleson has authored or contributed to many regional and national strategic research planning efforts that continue to guide NOAA and other federal science investment decisions. Marc is currently serving on the Federal Laboratory Consortium for Technology Transfer Executive Board.
Email: marc.suddleson@noaa.gov Phone: 240- 533-0305

Ms. Virginia Roberts is an Epidemiologist in the Waterborne Disease Prevention Branch, within the National Center for Emerging and Zoonotic Infectious Diseases at the CDC. She collaborates with state, territorial, and federal partners on waterborne disease outbreak surveillance, reporting, and prevention; manages surveillance activities for the One Health Harmful Algal Bloom System and the waterborne disease outbreak reporting module of the National Outbreak Reporting System; and coordinates a Great Lakes Restoration Initiative project designed to improve waterborne disease prevention capacity in Great Lake States. She received a joint MSPH in environmental and occupational health and epidemiology from Emory University in 2007.
Email: evl1@cdc.gov; Phone: 404.718.4871

Dr. Blake Schaeffer earned his PhD from North Carolina State University studying harmful algal bloom ecology. Blake is currently with the U.S. Environmental Protection Agency, located in Research Triangle Park, North Carolina. His research focus is applying satellite remote sensing technology to monitor water quality in coasts, estuaries, lakes, and reservoirs. He currently leads the collaborative CyAN effort between the EPA, NASA, NOAA, and USGS to detect cyanobacteria blooms from satellite.
E-mail: schaeffer.blake@epa.gov; Phone: 919-541-5571

Mitigating global proliferation of harmful cyanobacterial blooms (CyanoHABs) in the face of increasing human and climatic pressures

Hans Paerl and colleagues,
UNC-Chapel Hill Institute of Marine Sciences and many other places!








CyanoHABs: a global indicator of nutrient over-enrichment

- Freshwater Ecosystems (lakes, reservoirs, rivers)



- Estuaries



- Coastal waters & seas

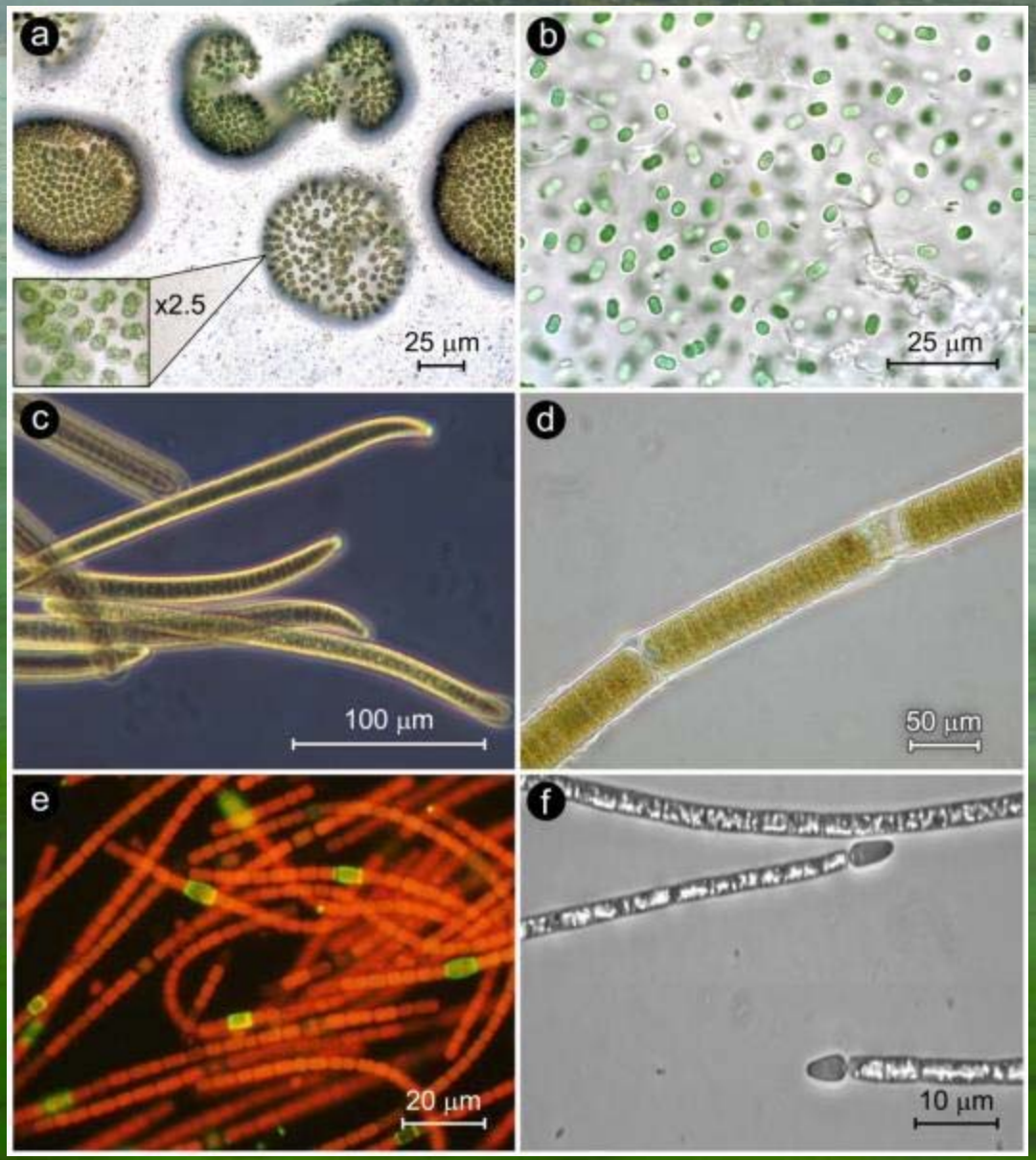


The Planktonic CyanoHAB "Players"

Coccoid, solitary/colonial (e.g. *Microcystis* & picocyanos). Most do not fix N_2

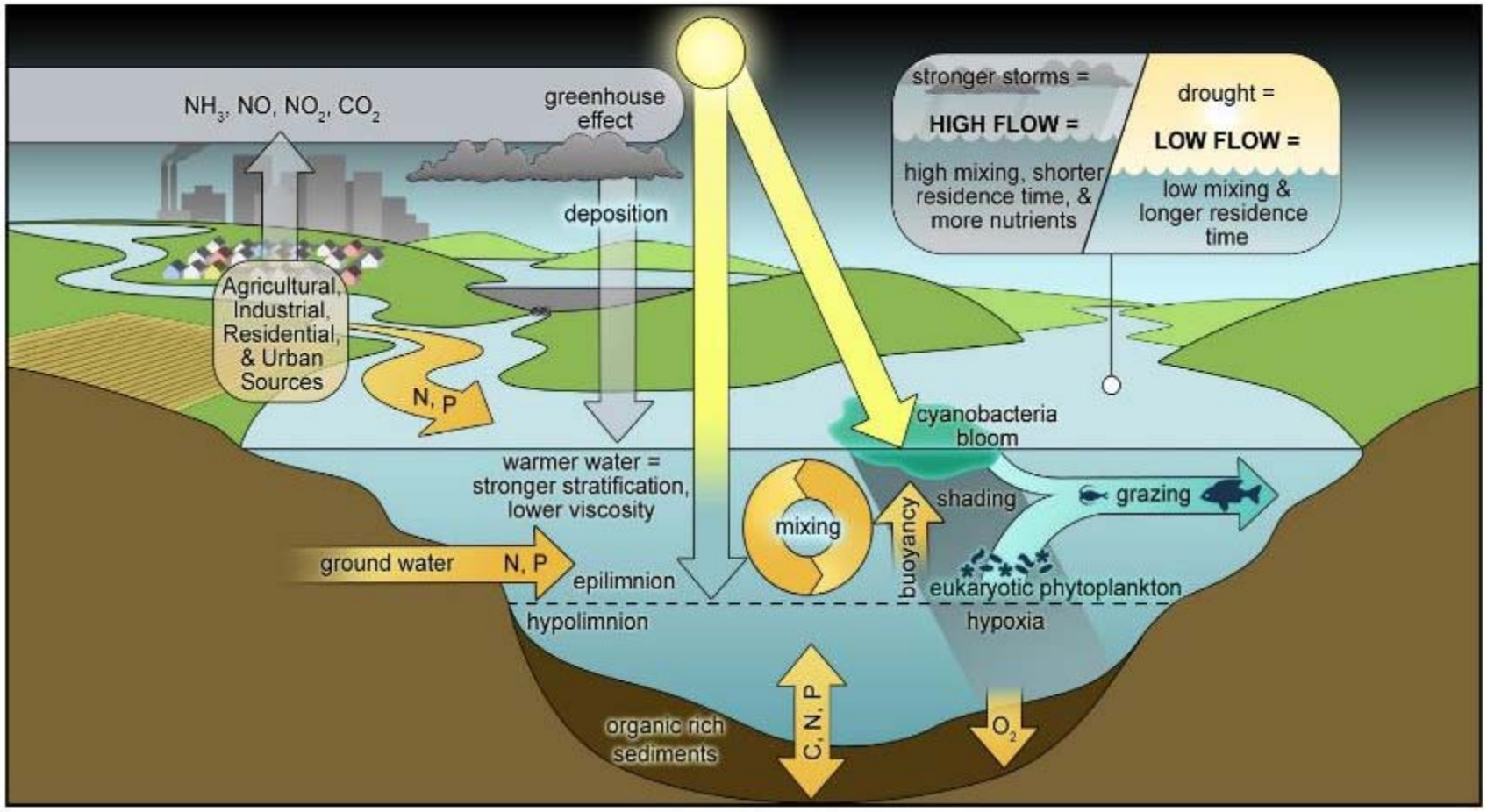
Filamentous, non-heterocystous (e.g. *Lyngbya, Oscillatoria*). Some species fix N_2

Filamentous, heterocystous (e.g. *Anabaena, Nodularia, Cylindrospermopsis*). All fix N_2



What drives CyanoHABs? Interactive physical, chemical and biotic factors

The "nutrient knob" is the one we can tweek most effectively



Paerl et al., 2016

Which nutrients to control? N, P or both?
Recent controversy regarding nutrient limitation/impacts

"Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment"

Schindler et al. Proceedings of the National Academy of Science USA 105:11254-11258 (2008).

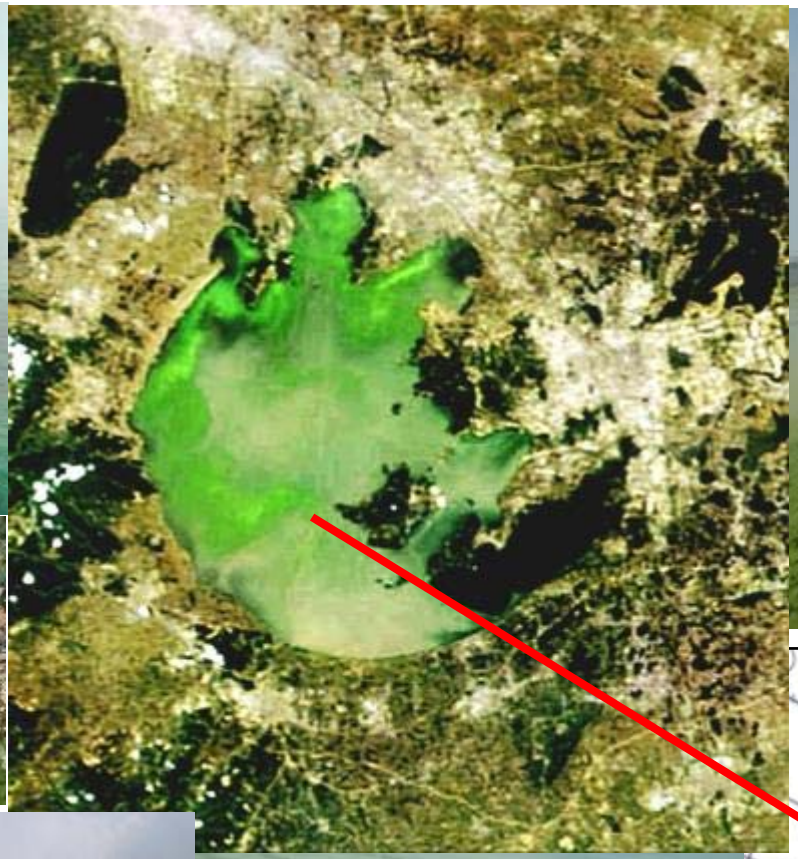
Conclusion by Schindler et al. (2008) (based on Lake 227) extended to coastal waters assumes that N_2 fixation will supply ecosystem N needs
Therefore, why worry about N?

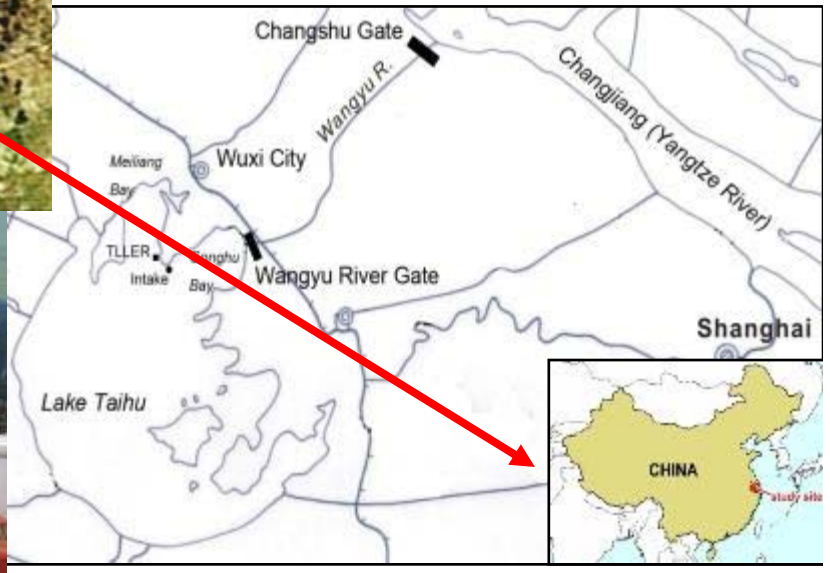
$$N_2 + 6H^+ \rightarrow 2NH_3$$

This assumption has been challenged
(Lewis and Wurtsbaugh 2008; Howarth and Paerl 2008; Conley et al., 2009; Scott & McCarthy 2010: Lewis et al. 2011; Paerl et al., 2016)

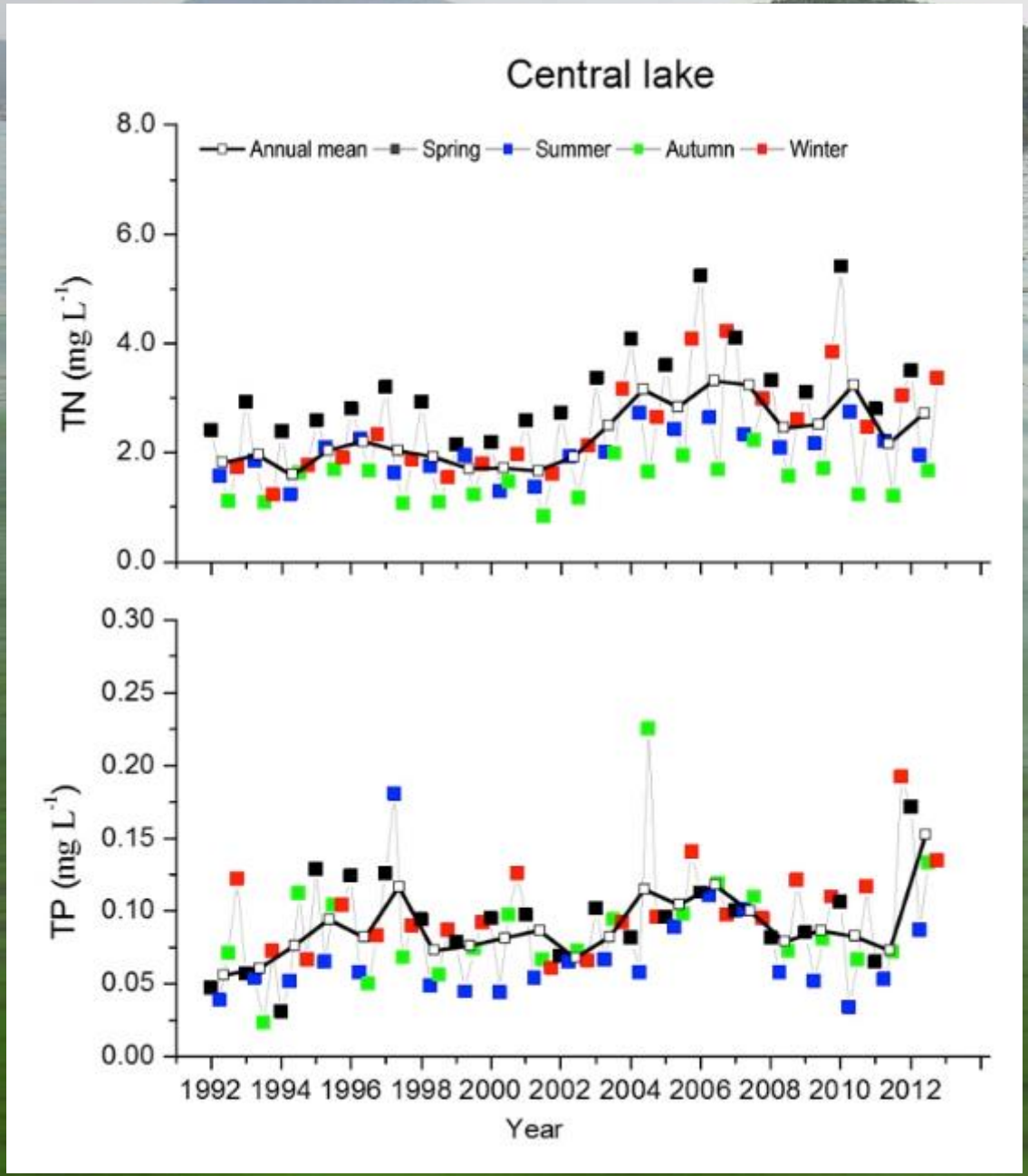
The CyanoHAB "poster child", Lake Taihu, 3rd largest lake in China

Nutrient over-enrichment associated with unprecedented human development in the Taihu Basin over past 3 decades. Taihu has experienced a "state change"





Recent history of nutrient (TN, TP) increases in Lake Taihu 1992-2012

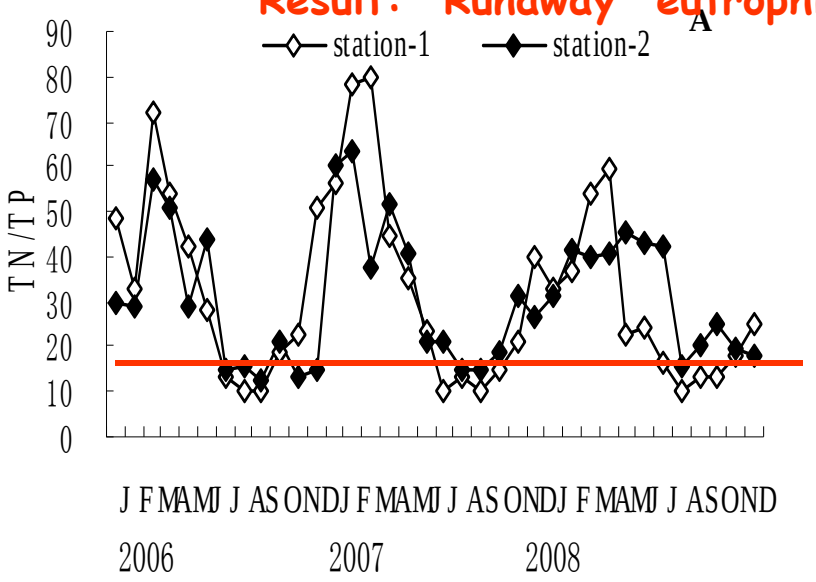


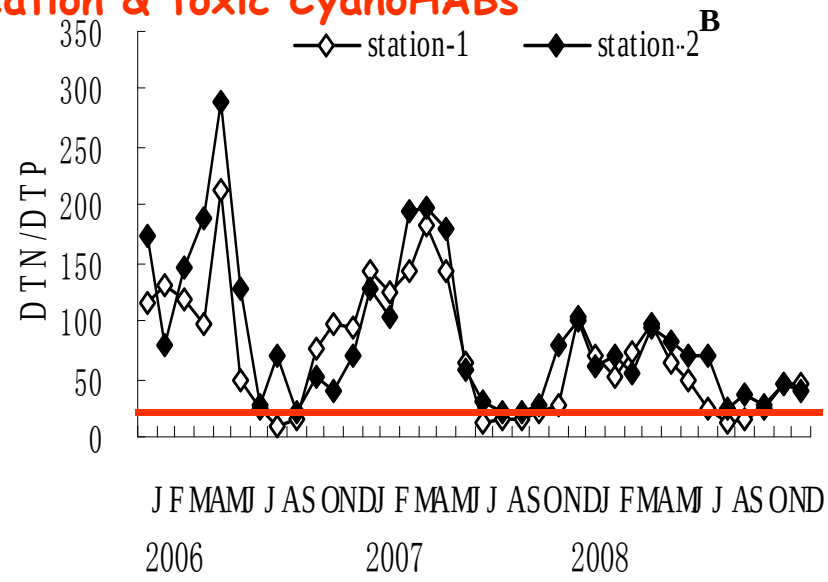
Qin et al., 2010
Xu et al., 2015

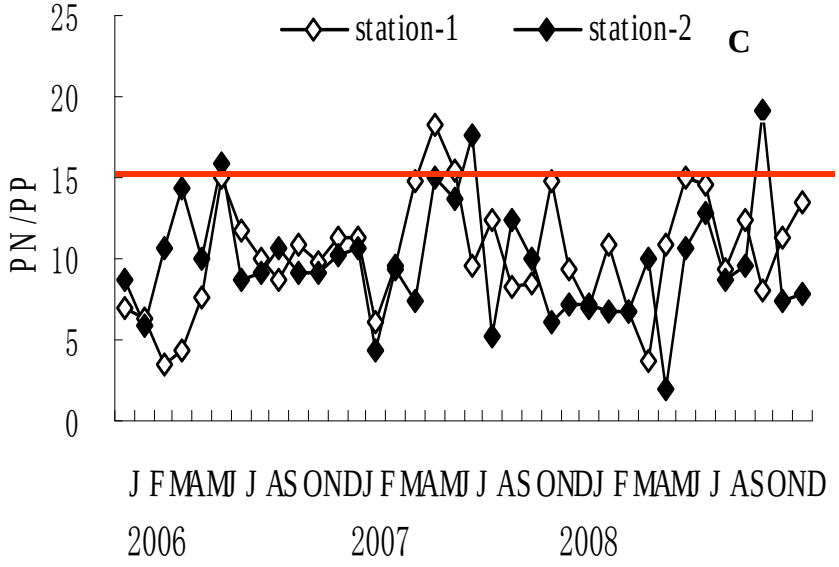
The "nutrient problem" in Taihu

N & P inputs exceed what's needed for balanced algal growth.

Result: "Runaway" eutrophication & toxic CyanoHABs







Nutrient (N&P) ratios in Taihu

Redfield (balanced growth)
~15:1 (N:P)

HYPOTHESIS

Dual (N & P) reductions will be needed to stem eutrophication and CyanoHABs

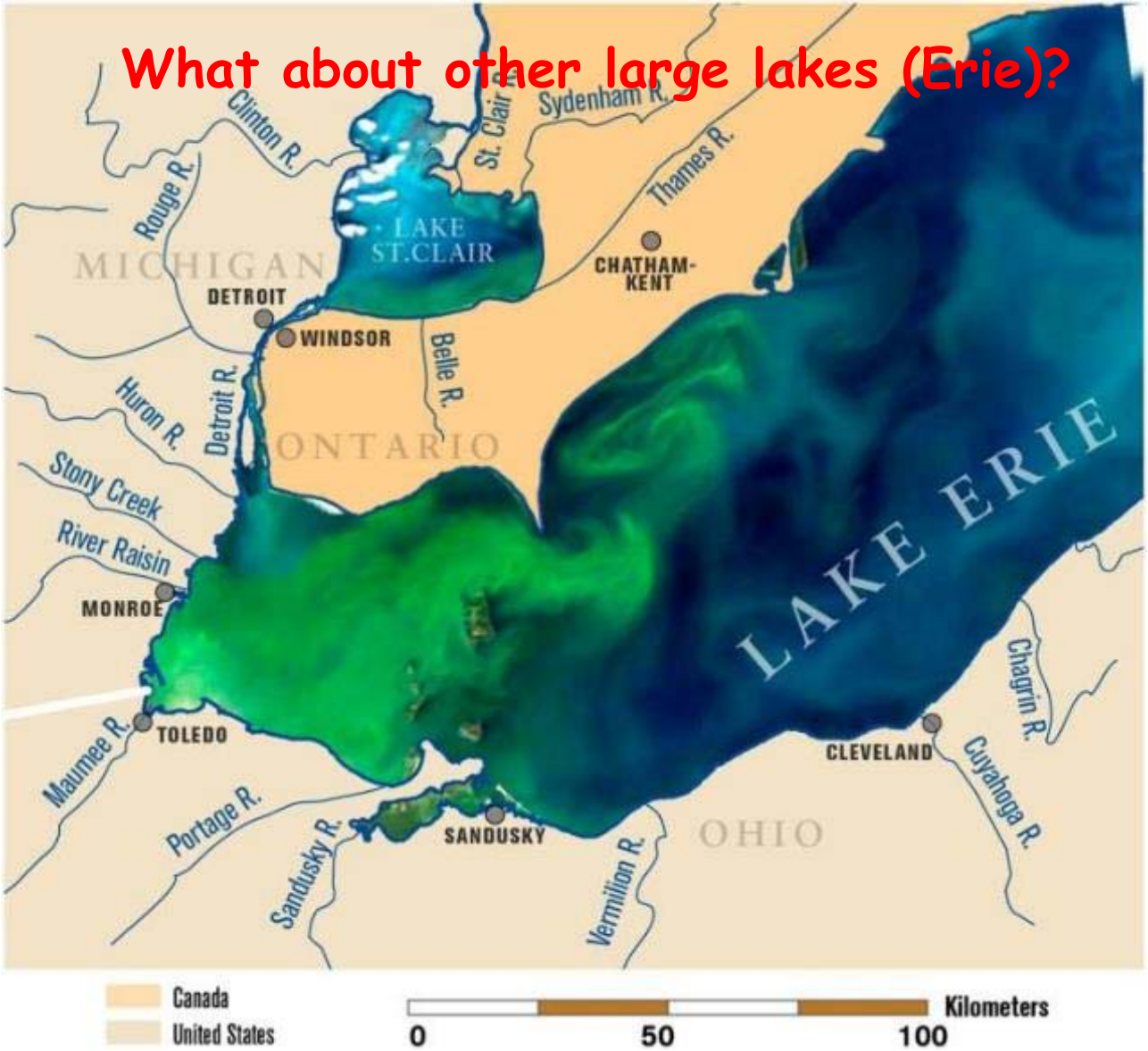
Xu et al. 2010; Paerl et al. 2011, 2014

Effects of nutrient (N & P) additions on phytoplankton production (Chl *a*) in Lake Taihu, China: **Both N & P inputs matter!!**

Xu et al. 2010; Paerl et al. 2011

Taihu: a "looking glass" for eutrophying aquatic ecosystems worldwide?

What about other large lakes (Erie)?



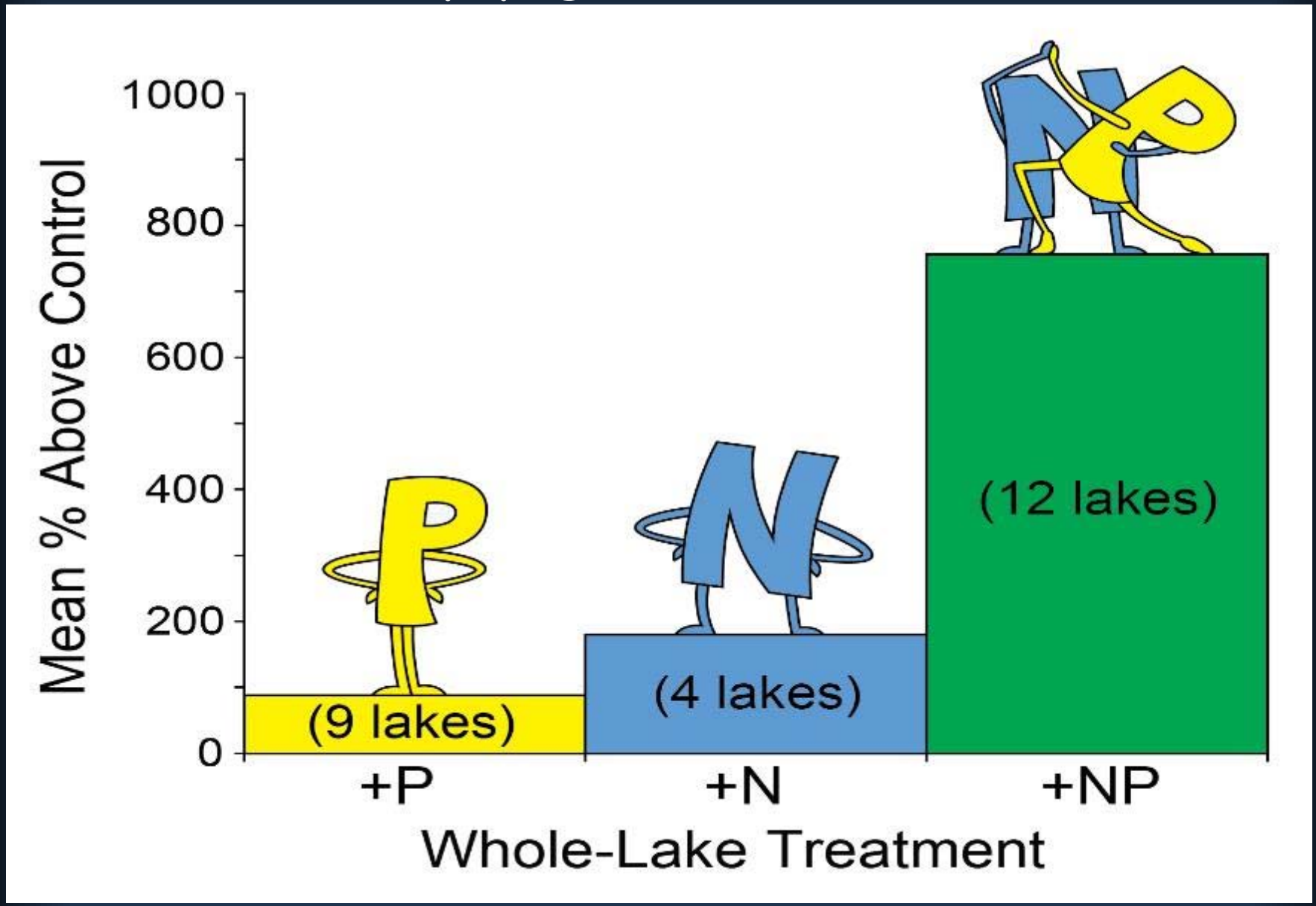
Looking beyond "P only"

Davis et al. (2009). The effects of temperature and nutrients on the growth and dynamics of toxic and non-toxic strains of *Microcystis* during cyanobacteria blooms. *Harmful Algae* 2009, *8*, 715-725.

Chaffin et al., (2013) Nitrogen Constrains the Growth of Late Summer Cyanobacterial Blooms in Lake Erie. *Advances in Microbiology* 3, 16-26.

Gobler et al., (2016) The dual role of nitrogen supply in controlling the growth and toxicity of cyanobacterial blooms. *Harmful Algae 54:87-97*

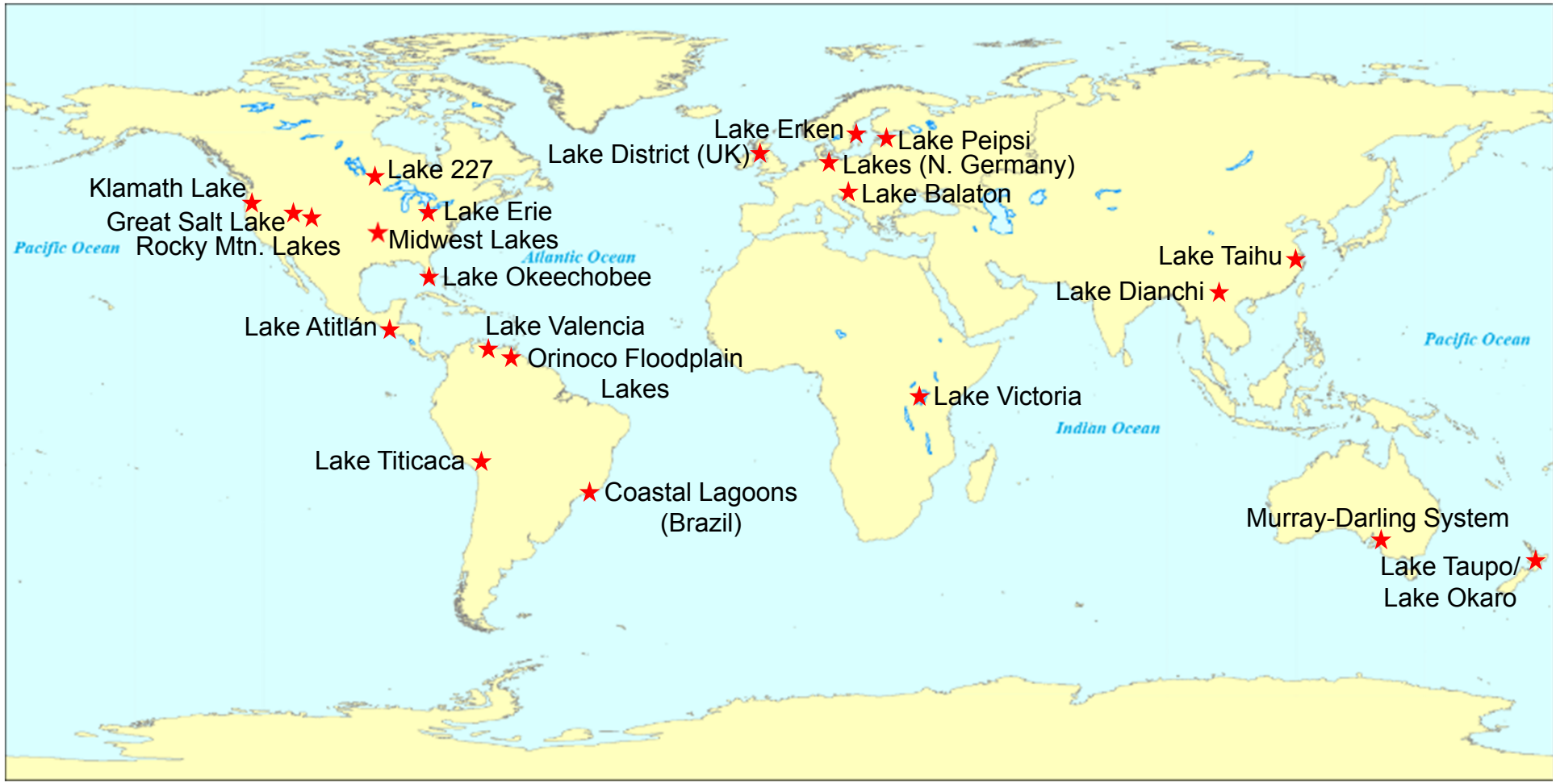
Lets ask other eutrophying lakes? Whole-Lake Fertilization



Co-Limitation Dominant

Lewis et al., 2011; Wurtsbaugh et al., 2012; Paerl et al., 2016

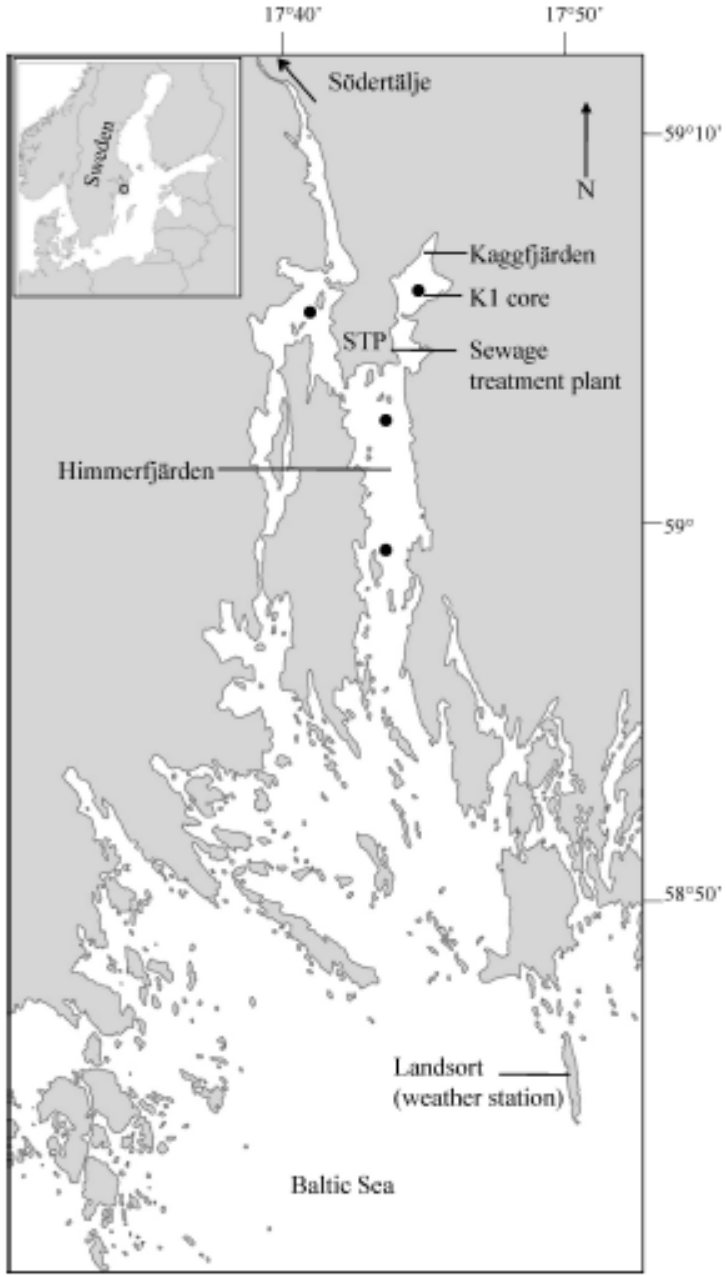
Large lakes and reservoirs in which algal blooms (mostly cyanobacteria) have been shown to be N & P stimulated



Sources: Havens et al., 2003; Elser et al. 2007; North et al., 2007; Lewis & Wurtsbaugh 2008; Conley et al., 2009; Moisander et al., 2009; Lewis et al. 2011; Abell et al., 2011; Özkundakci et al., 2011; Paerl et al., 2014; and many others.

Reducing nutrient loads to control CyanoHABs. It works if there's a will: The Himmerfjärden, Sweden, case.

Courtesy: Ulf Larsson & Ragnar Elmgren
Stockholm University



The Himmerfjärden case: Baltic coastal area with large Sewage treatment plant,

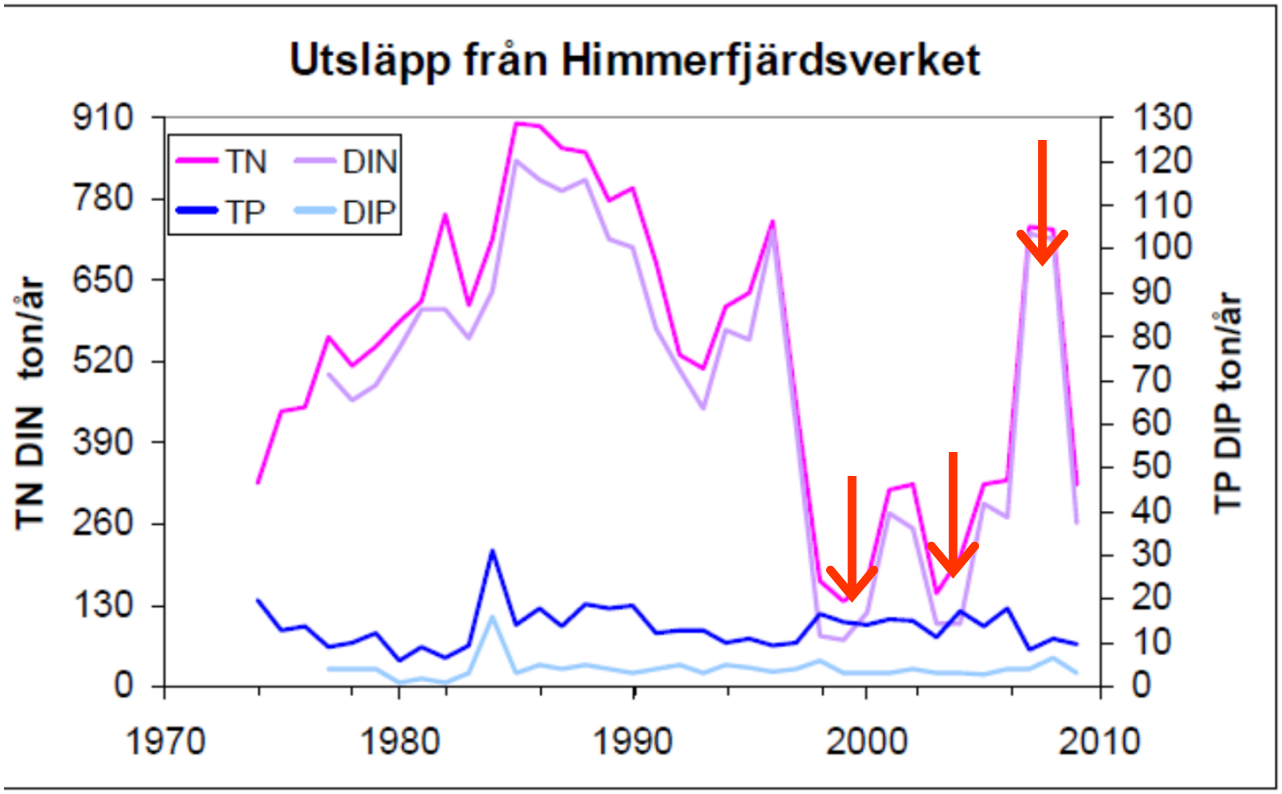
P removal since 1976

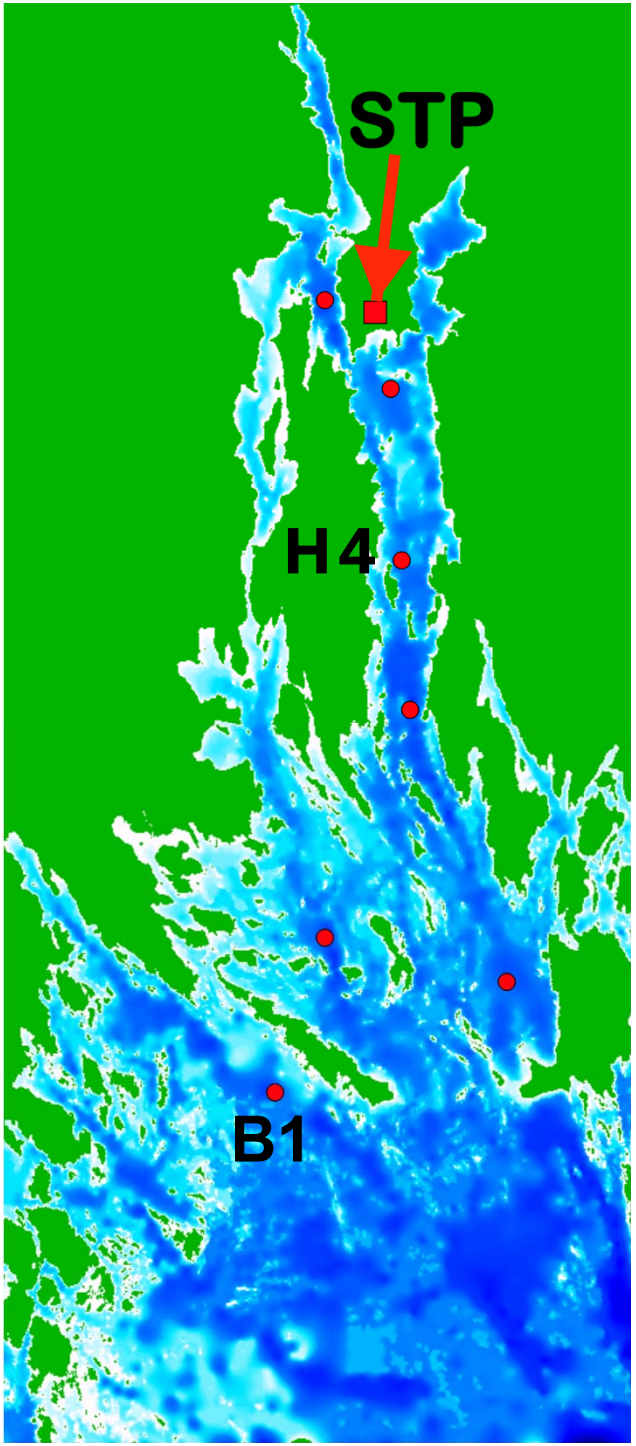
N removal started in 1993 (50%) & 2000 (80%).

No N removal 2004-2008

EFFECTS ON PHYTOPLANKTON (Chl a)?

Plant loads , tonnes/ year

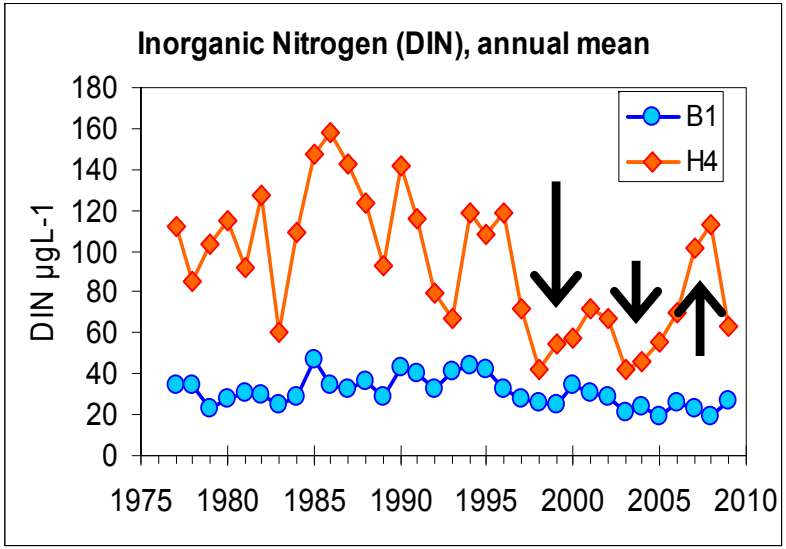


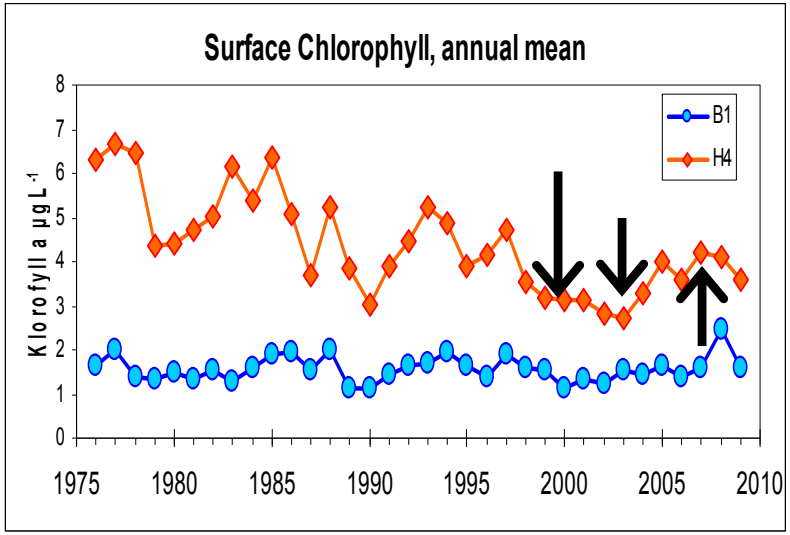


H4 =Eutrophicated station

B1= Reference station

The results: Reducing DIN inputs reduced Chl a and controlled CyanoHABs

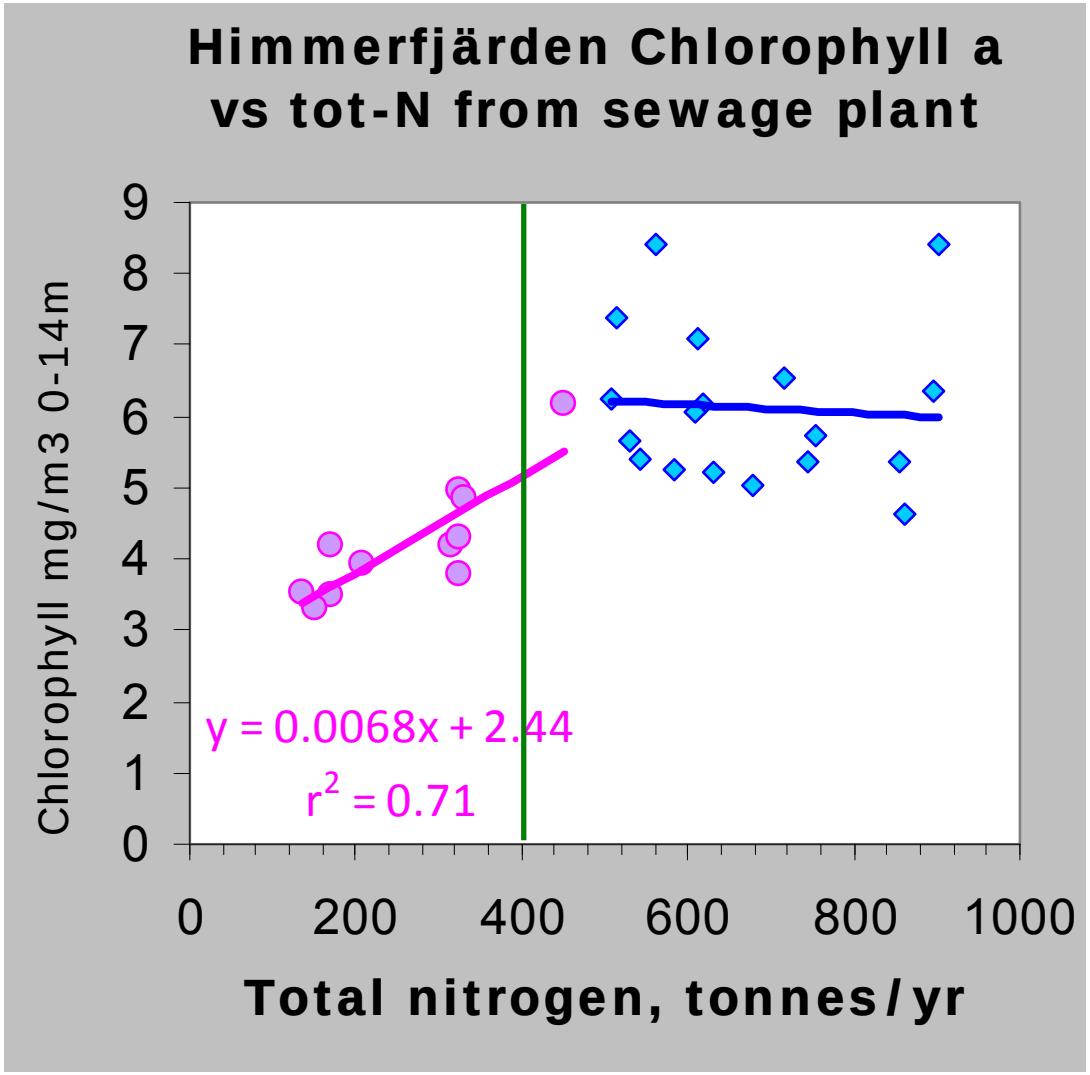




Larsson and Elmgren, 2016

Developing a N loading-bloom threshold

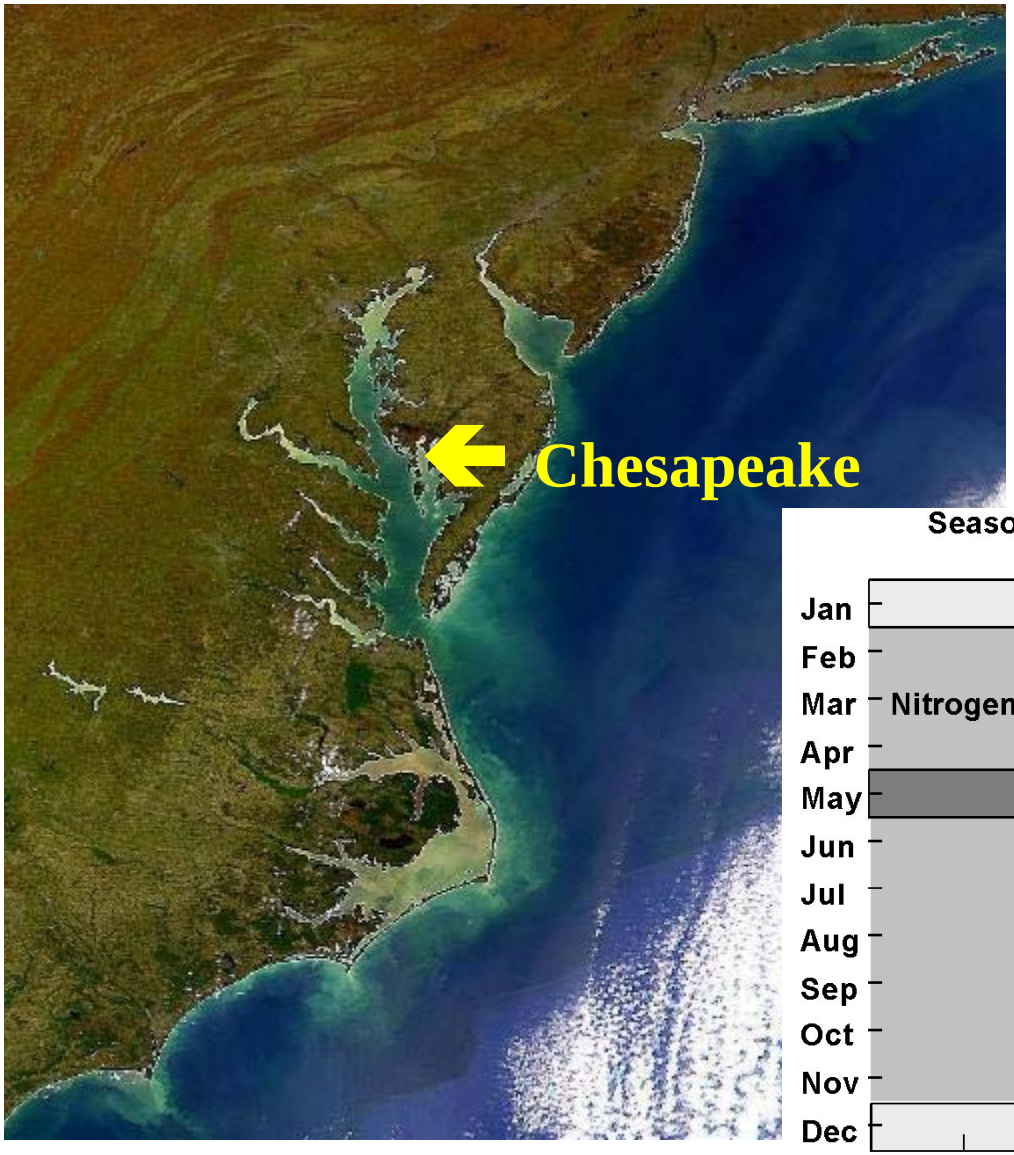
Stockholm University



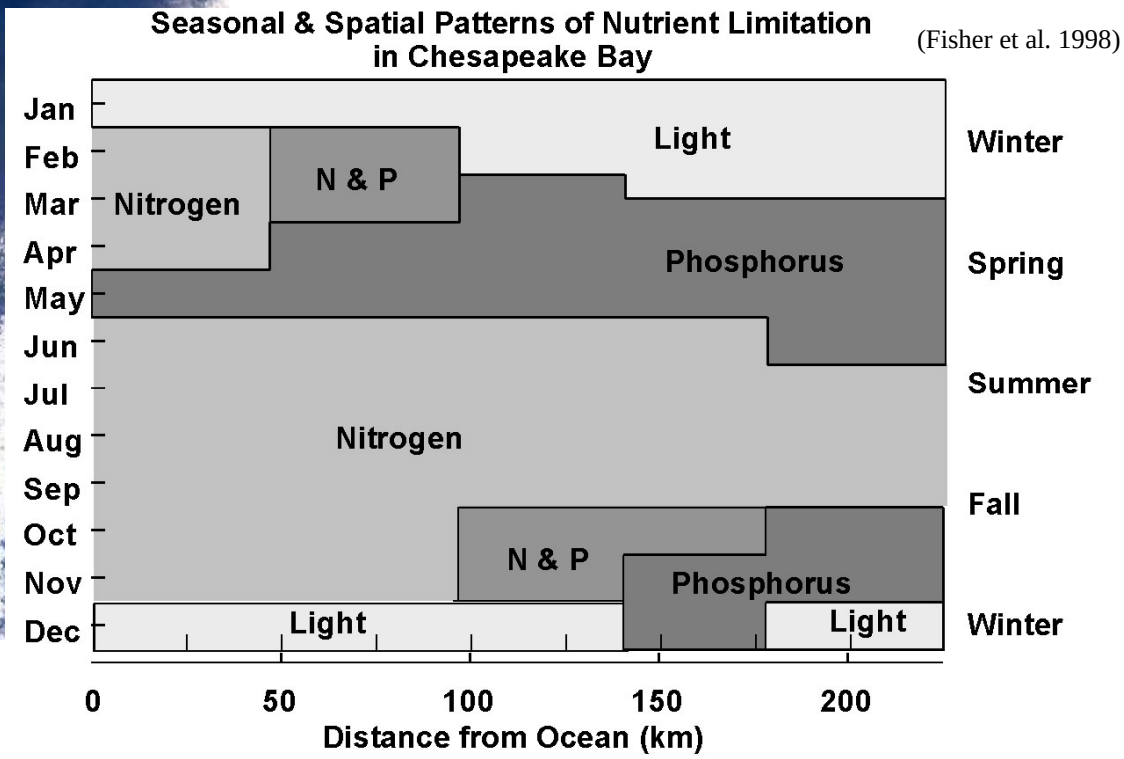
Lowering nitrogen discharge below 400 tonnes/yr clearly reduced local phytoplankton biomass.

Source:
Ulf Larsson, pers.comm.

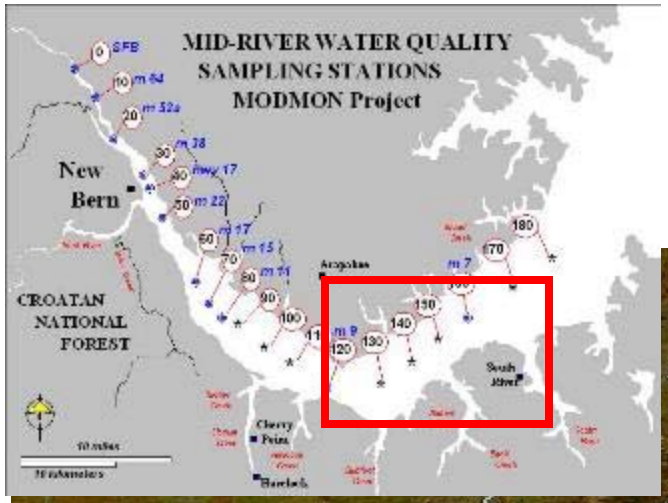
Nutrient limitation dynamics in the Chesapeake Bay

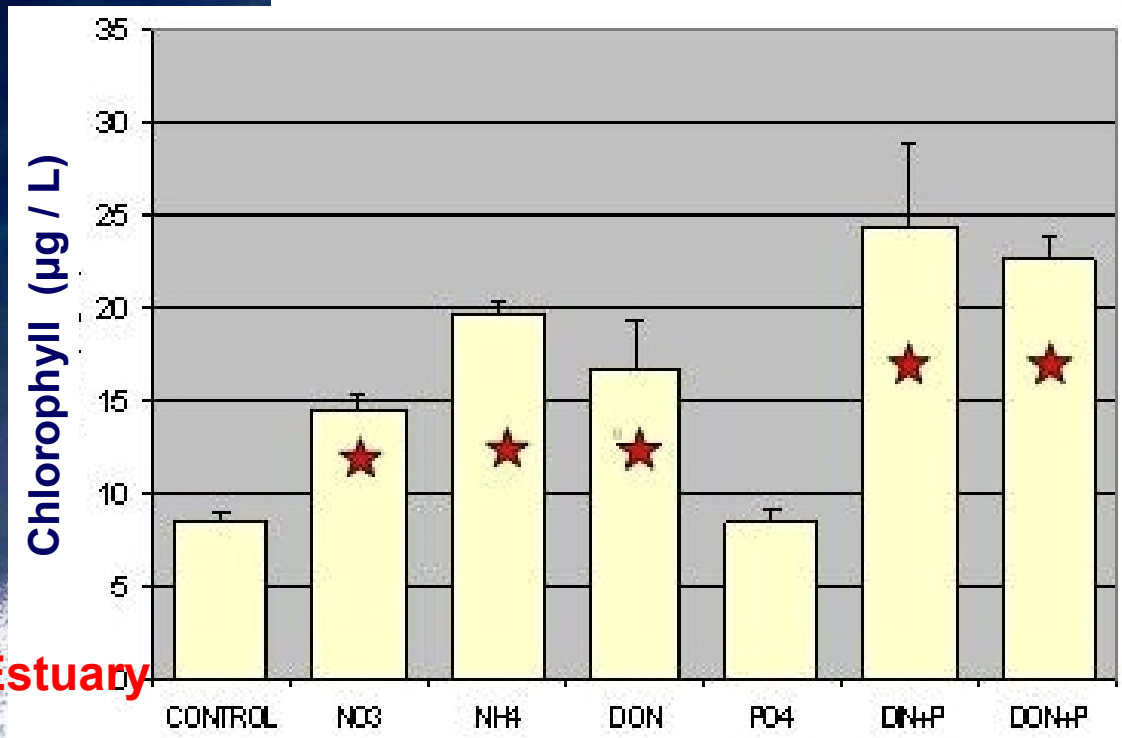


Fisher et al. 1998



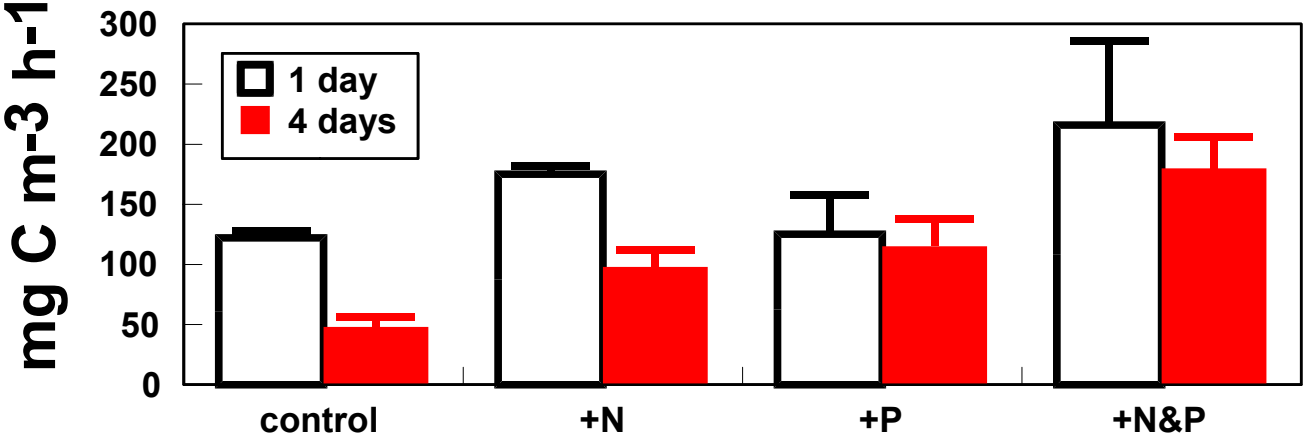
Nutrient limitation in the Neuse R.Estuary,NC

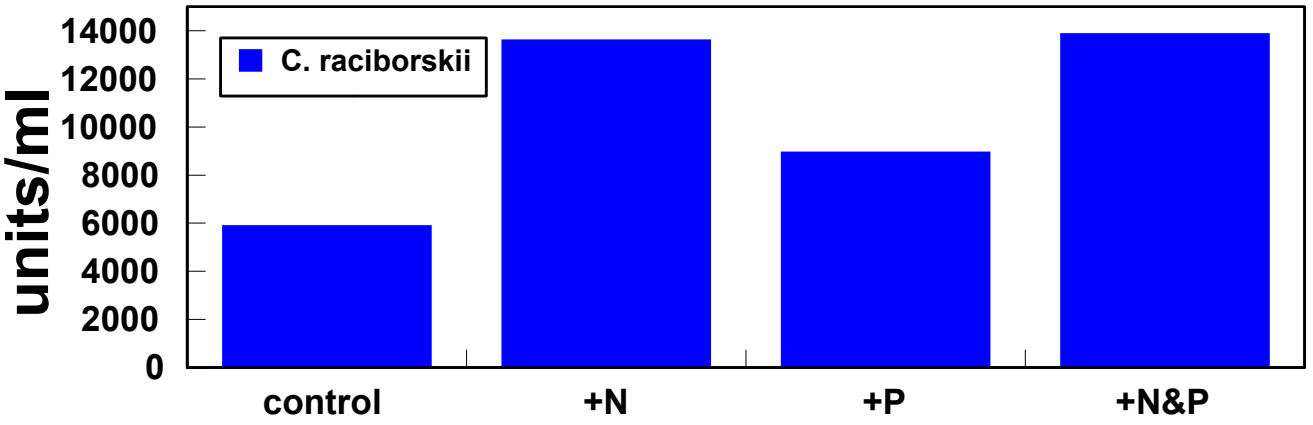




Paerl et al., 1995; Gallo 2006

St. Johns R. System, FLorida: Nitrogen and Phosphorus Effects on CyanoHAB Growth and Bloom Potential (*Cylindrospermopsis raciborskii*)





Take home message: *Cylindrospermopsis raciborskii* is opportunistic
Dual N & P input constraints will likely be needed to control it

Piehler et al, 2009

Lets go back to the "P only paradigm" from whole-lake experiments, suggesting that P alone controls algal biomass (Schindler et al., 2008)

Argument:

If nitrogen is in short supply, nitrogen fixation by cyanobacteria will make up the nitrogen deficit:

Limnol. Oceanogr., 55(3), 2010, 1265–1270

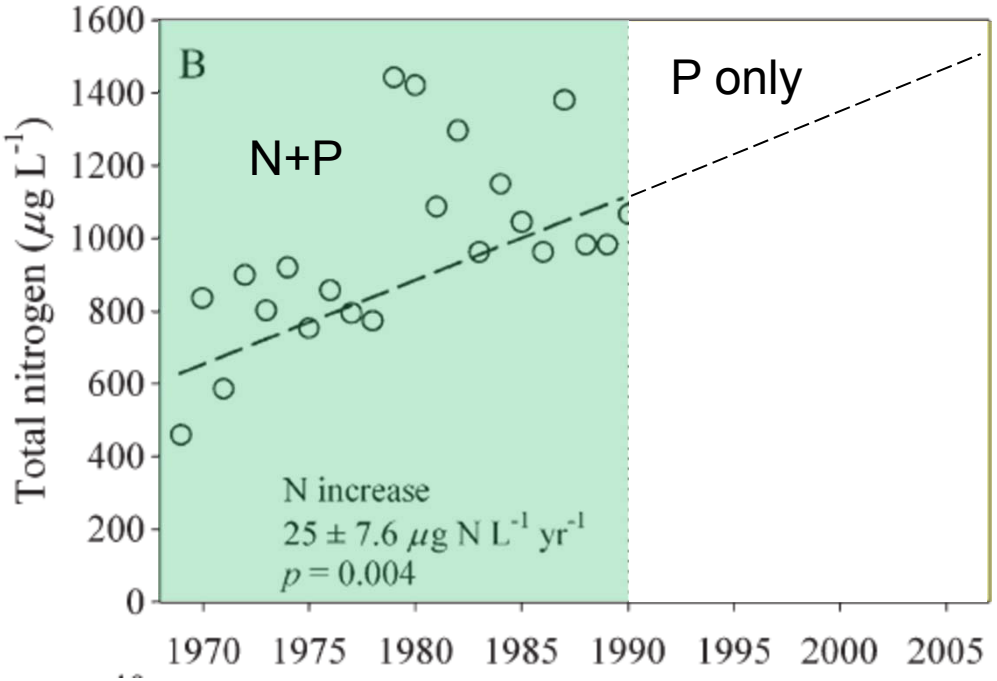
doi:10.4319/lo.2010.55.3.1265

Nitrogen fixation may not balance the nitrogen pool in lakes over timescales relevant to eutrophication management

J. Thad Scott[a,*] and Mark J. McCarthy[b,c]

[a] Department of Crop, Soil, and Environmental Science, University of Arkansas, Fayetteville, Arkansas
[b] Département des sciences biologiques, Université du Québec à Montréal, Montréal, Québec, Canada
[c] Marine Science Institute, The University of Texas at Austin, Austin, Texas

Lake 227 in ELA:
20 years N+P fertilization
20 years P only fertilization

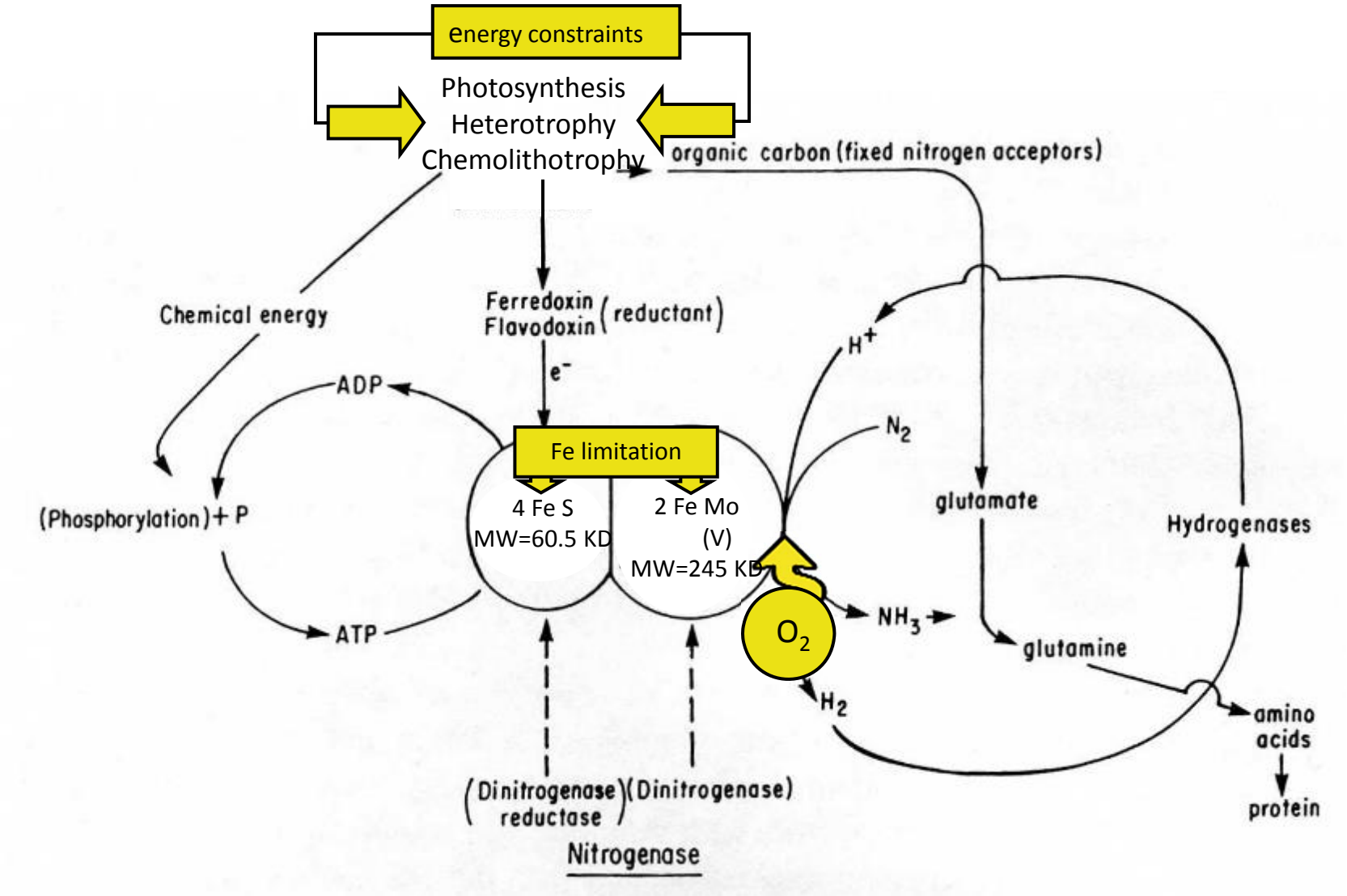


N loss rate (1 g N m^{-2} y^{-1})
≈ lake denitrification rate

Chan and Campbell 1980

$$4NO_3 + 5(CH_2O) + 4H^+ \xrightarrow[\text{denitrifiers}]{\text{Microbial}} 2N_2 + 5CO_2 + 7H_2O$$

Why doesn't N_2 fixation provide N needed to ecosystem demands?
Controls on N_2 fixation: Its not just P



Overall, N_2 losses from eutrophic systems by denitrification exceed "new" N inputs via N_2 fixation

Annual estimates of ecosystem N_2 fixation, denitrification, and net ecosystem N_2 flux in eutrophic lakes with CyanoHABs.

Location	N_2 Fixation (g N m^{-2} yr^{-1})	Denitrification (g N m^{-2} yr^{-1})	Net N_2 Flux (g N m^{-2} yr^{-1})[1]
Lake 227 (ELA)[2]	0.5	5-7	-6.5 – -4.5
Lake Mendota[2]	1.0	1.2	-0.2
Lake Okeechobee[2]	0.8 – 3.5	0.3 – 3.0	-2.2 – 0.5
Lake Erken[2]	0.5	1.2	-0.7
Lake Elmdale	10.4[3]	18[4]	-7.6
Lake Fayetteville	10.6[3]	23[4]	-12.4
Lake Wedington	7.0[3]	12[4]	-5.0

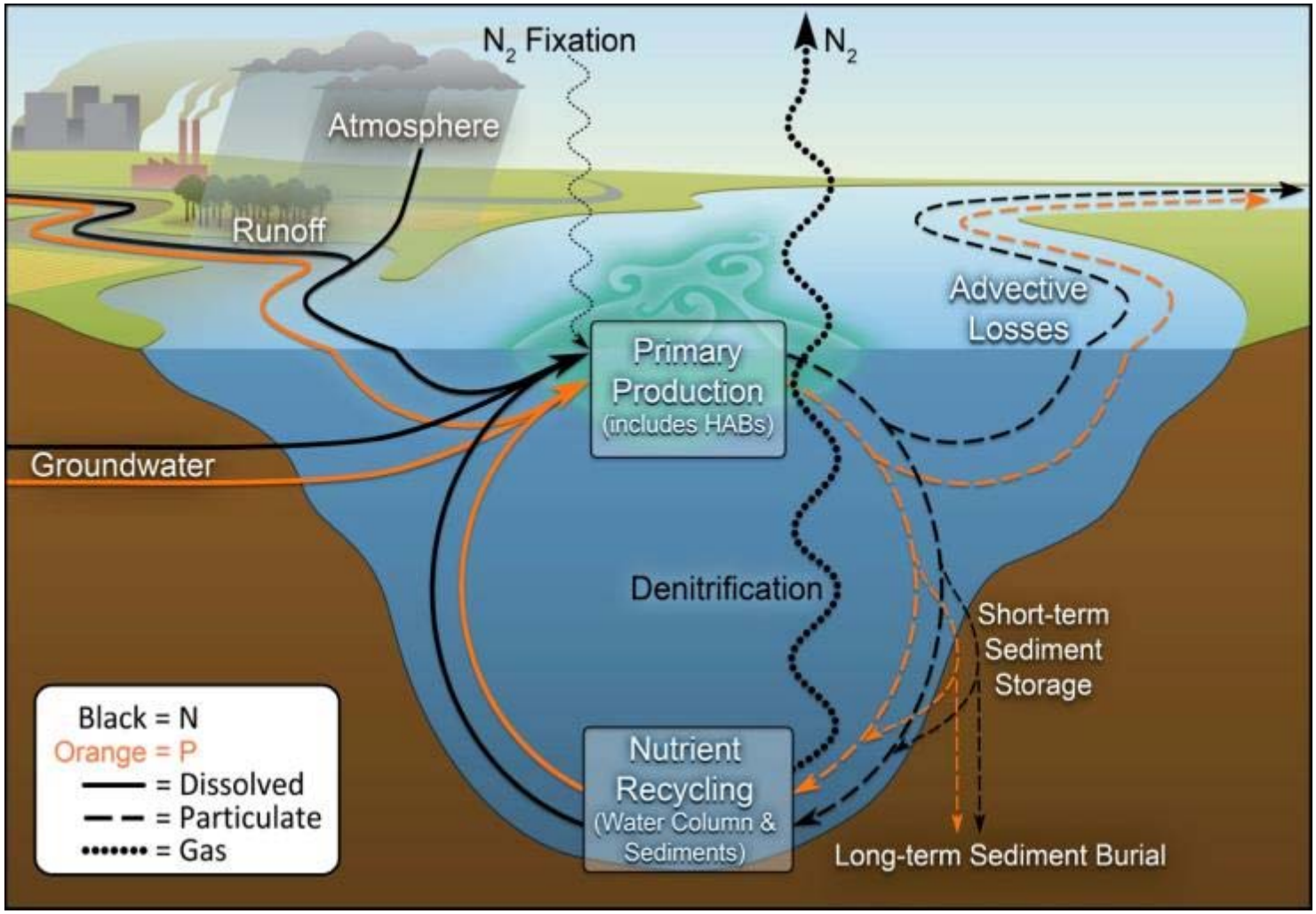
[1]Net negative N_2 flux represents reactive N loss, positive represents gain; [2]Paerl and Scott (2010); [3]J.T. Scott (unpublished data); [4]Grantz et al. (2012); Paerl et al., in review

Conclusions: 1. N_2 fixation does NOT meet ecosystem N demands

2. More N inputs will accelerate eutrophication

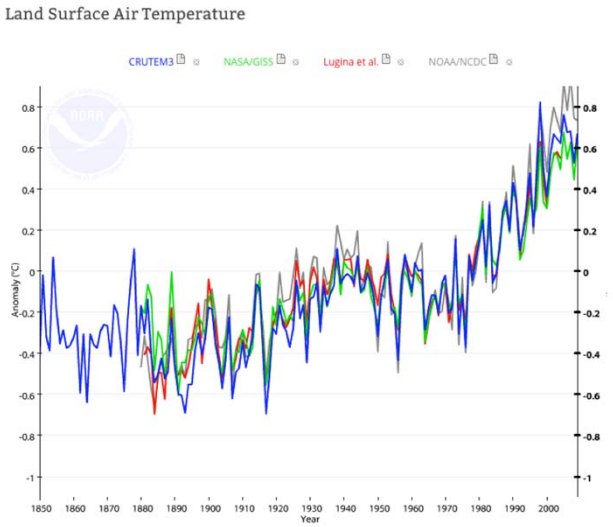
3. We Gotta get serious about controlling N (as well as P) !!

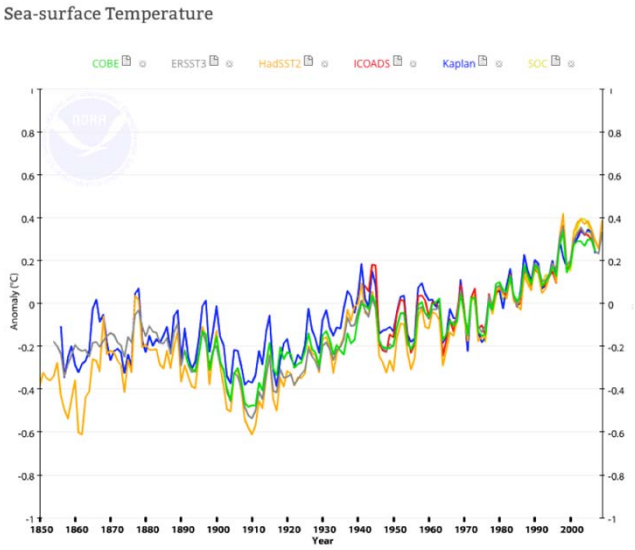
Conclusion: N limitation is pervasive in aquatic ecosystems, even ones receiving anthropogenic N enrichment



Bottom line: Need to reduce N along with P to control PP and bloom formation

Additional "twist" due to Climate Change: Its Getting Warmer



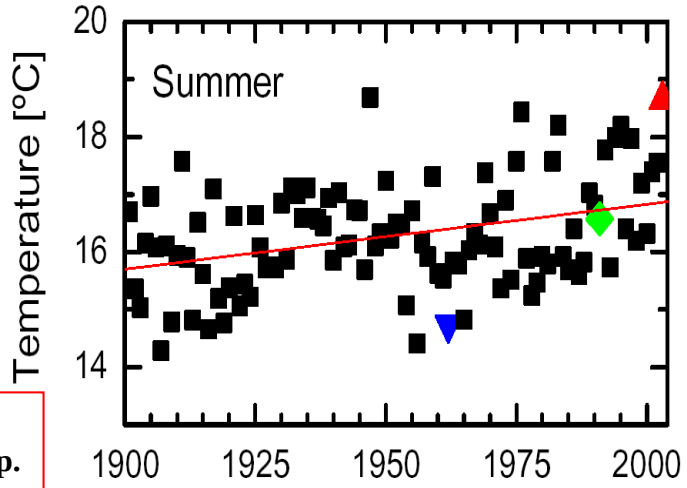


Additional Evidence

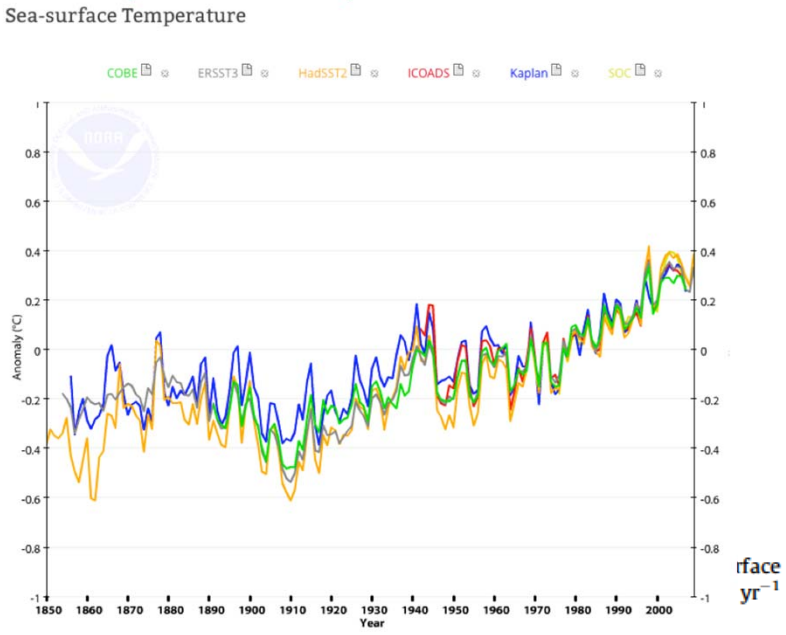
2003 was the hottest summer in 500 years in Europe!

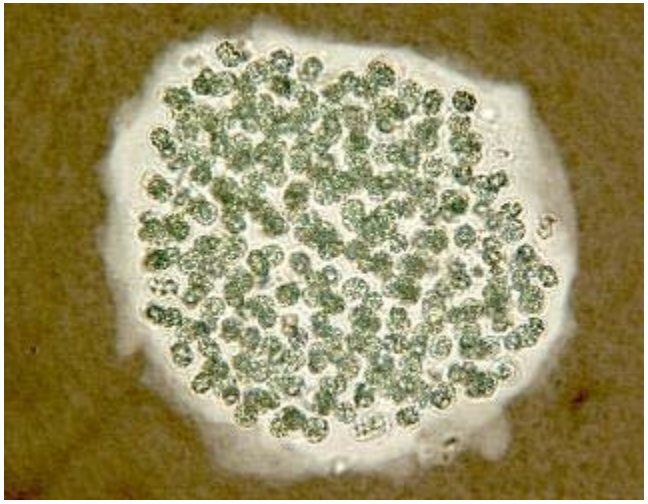
2005, 2009, 2014, 2016 were the h

2010 hottest year

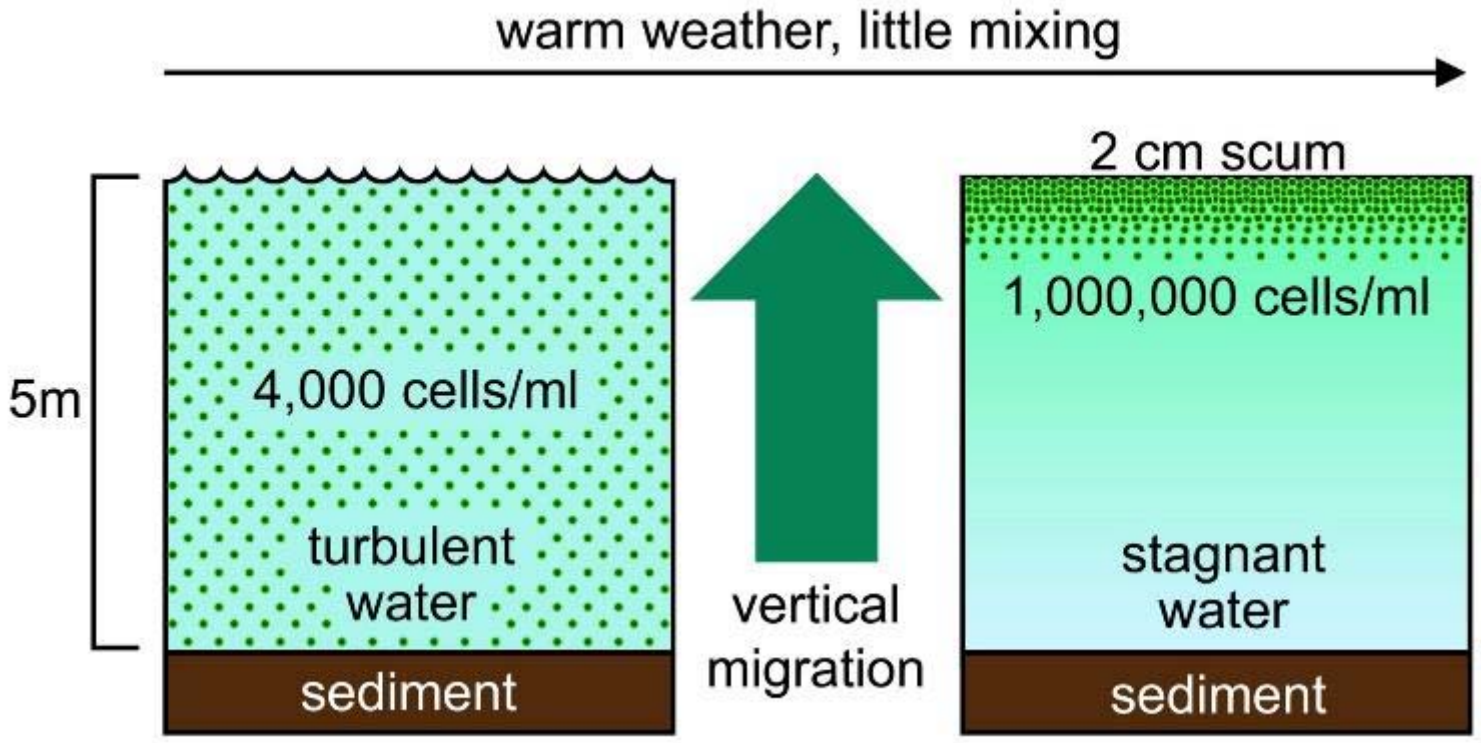


Huisman et al. 2006
Mean epilimnetic Temp.
In Dutch lakes





Warming leads to stronger vertical stratification…….
Buoyant cyanobacteria favored by stronger stratification

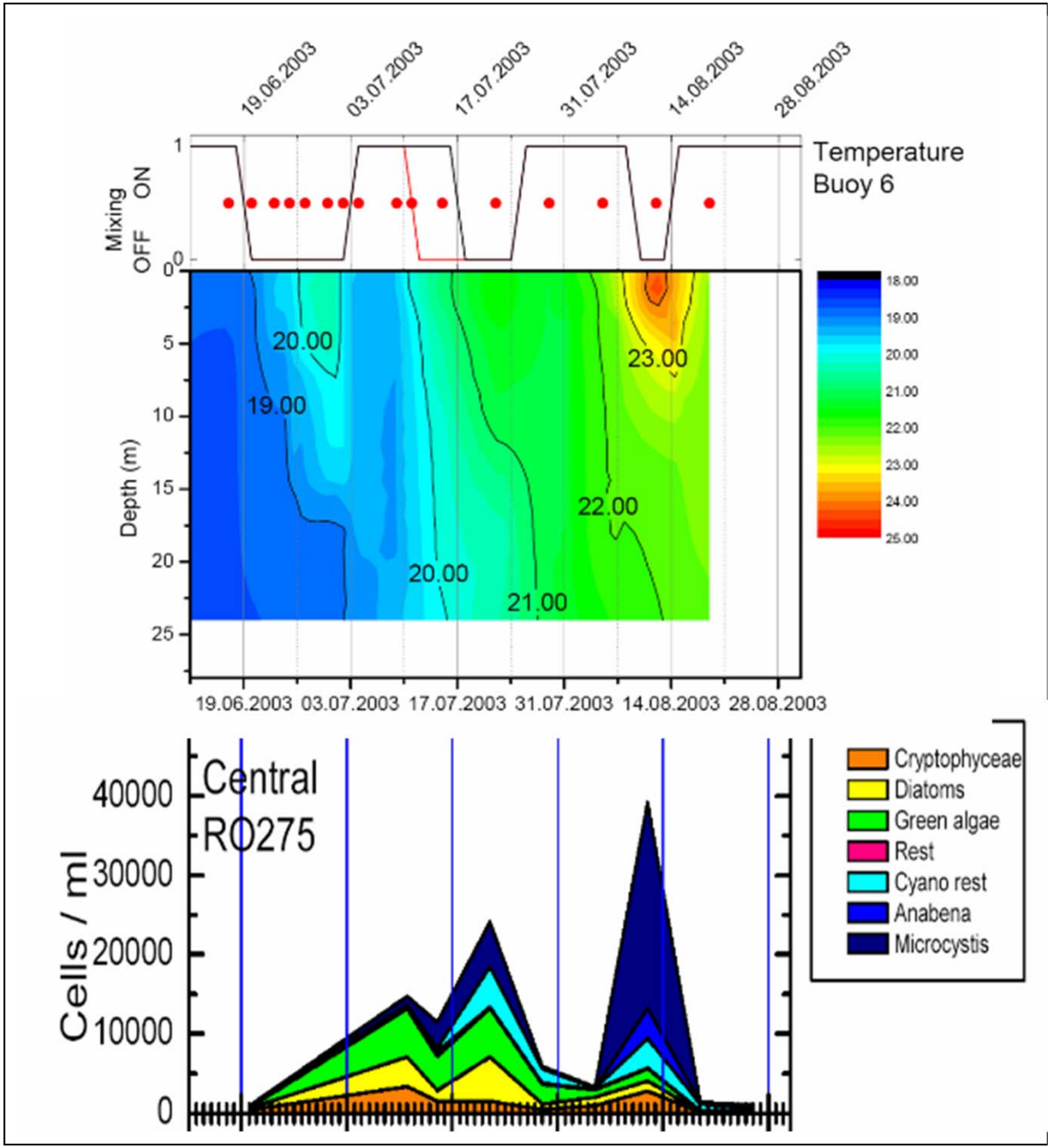


Paerl and Huisman 2009

Example
Mid August 2003:
Lake Nieuwe Meer, Netherlands

Heatwave & little mixing

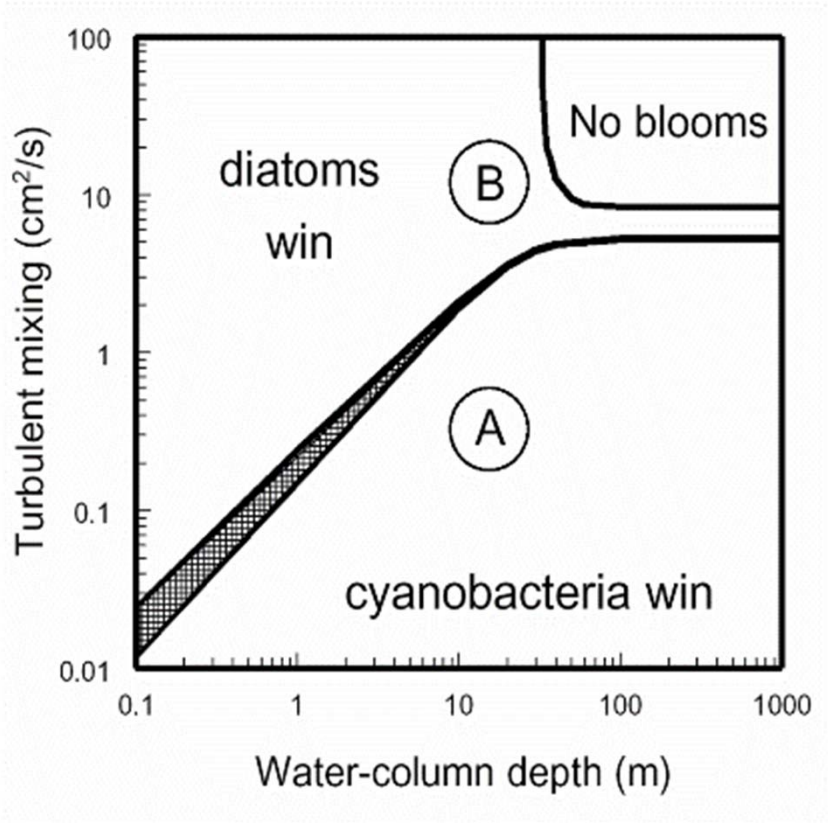
Microcystis benefits!



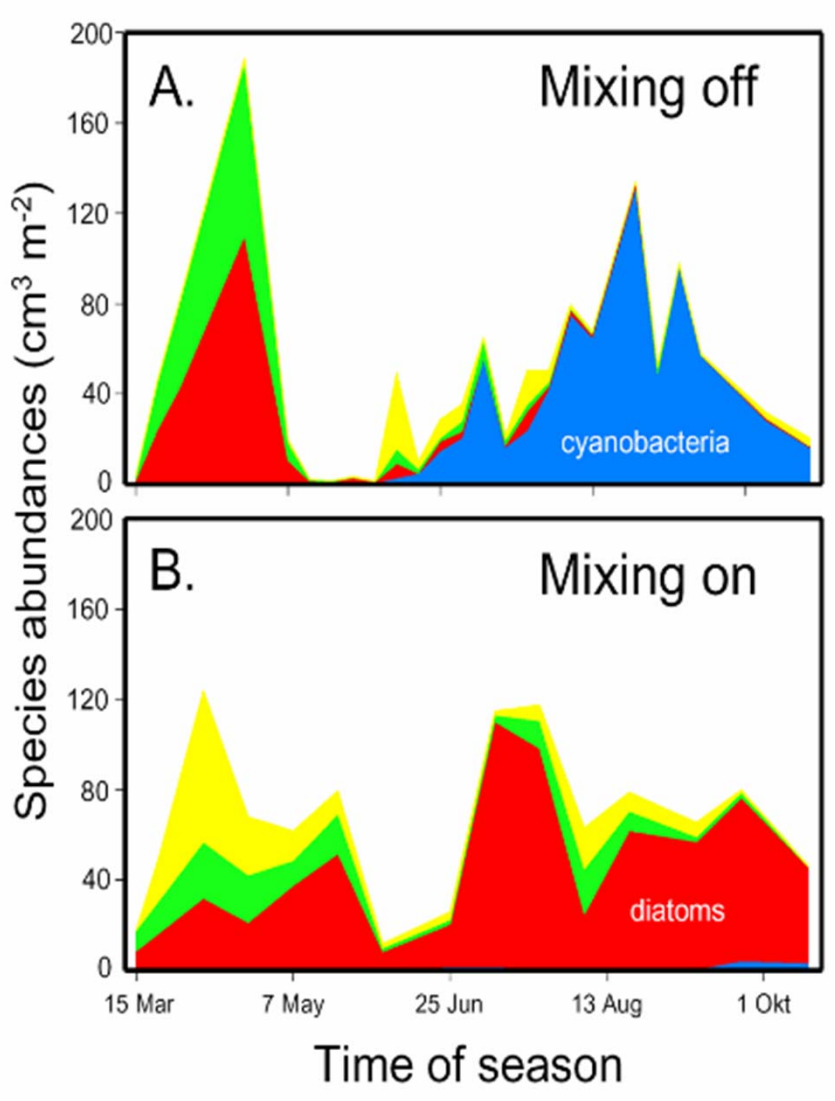
Jöhnk et al., 2008

Testing the Model

Theory

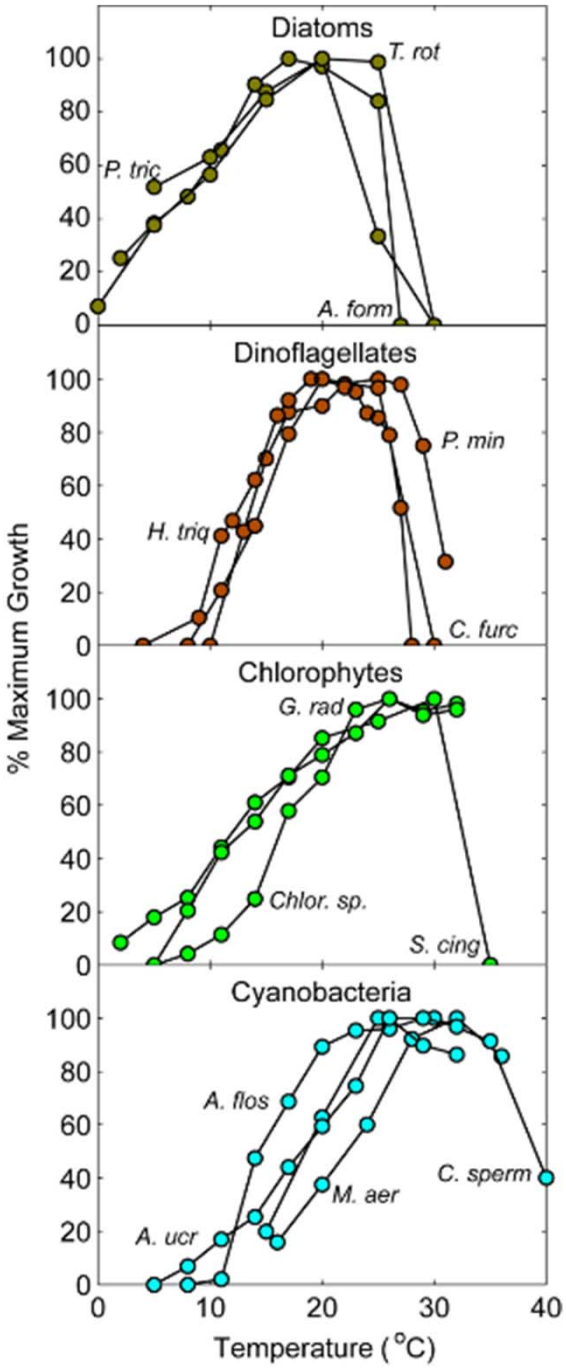


Lake data



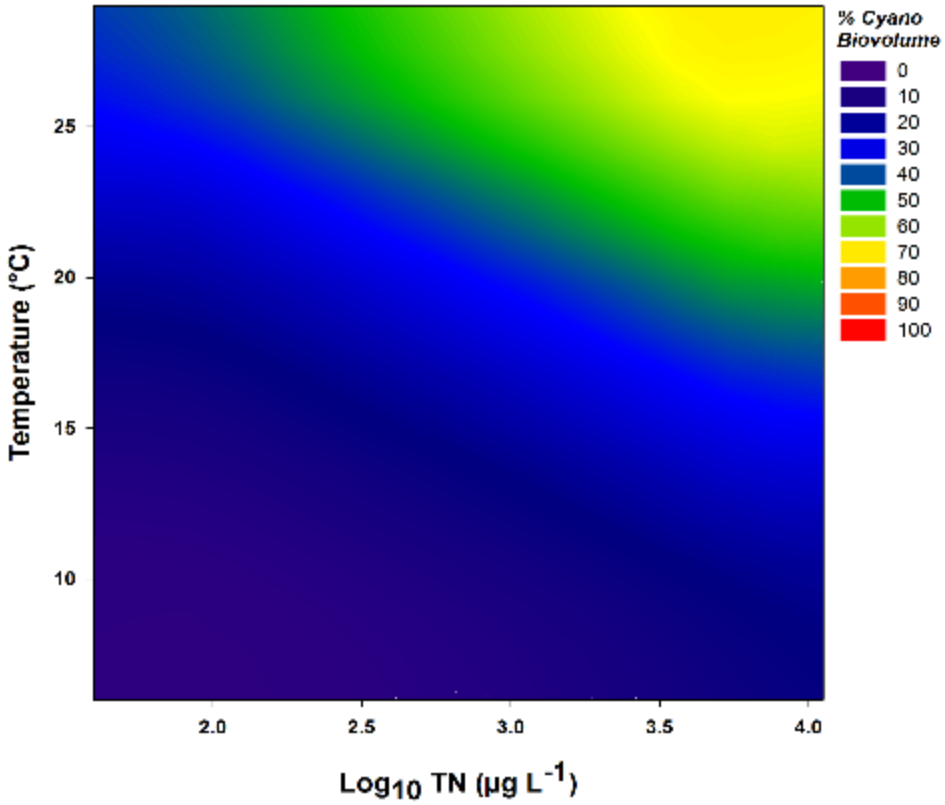
Huisman et al., 2004

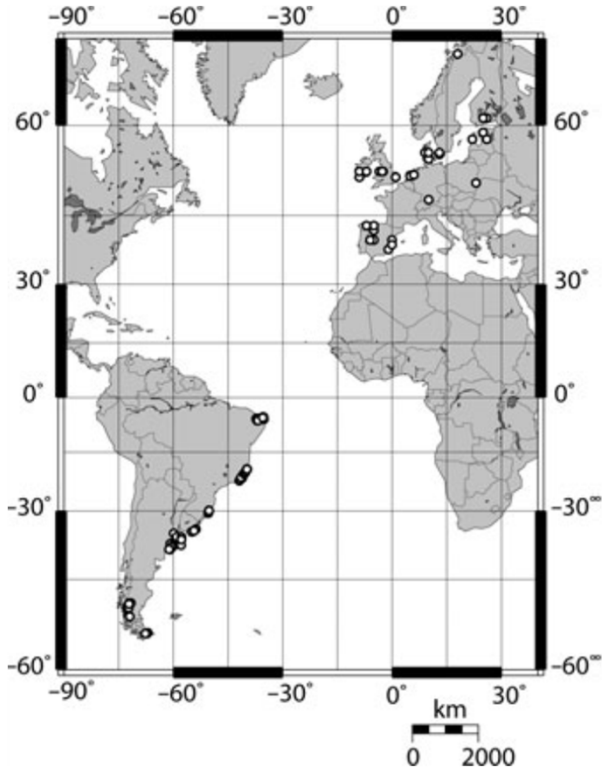
Temperature affects growth rates



Refs.: Kraweik 1982, Grzebyk & Berland 1996; Kudo et al., 2000, Litaker et al., 2002, Briand et al., 2004, Butterwick et al., 2005, Yamamoto & Nakahara 2005, Reynolds 2006

Cyanobacterial dominance along temperature & nutrient (TN) gradients in 143 lakes

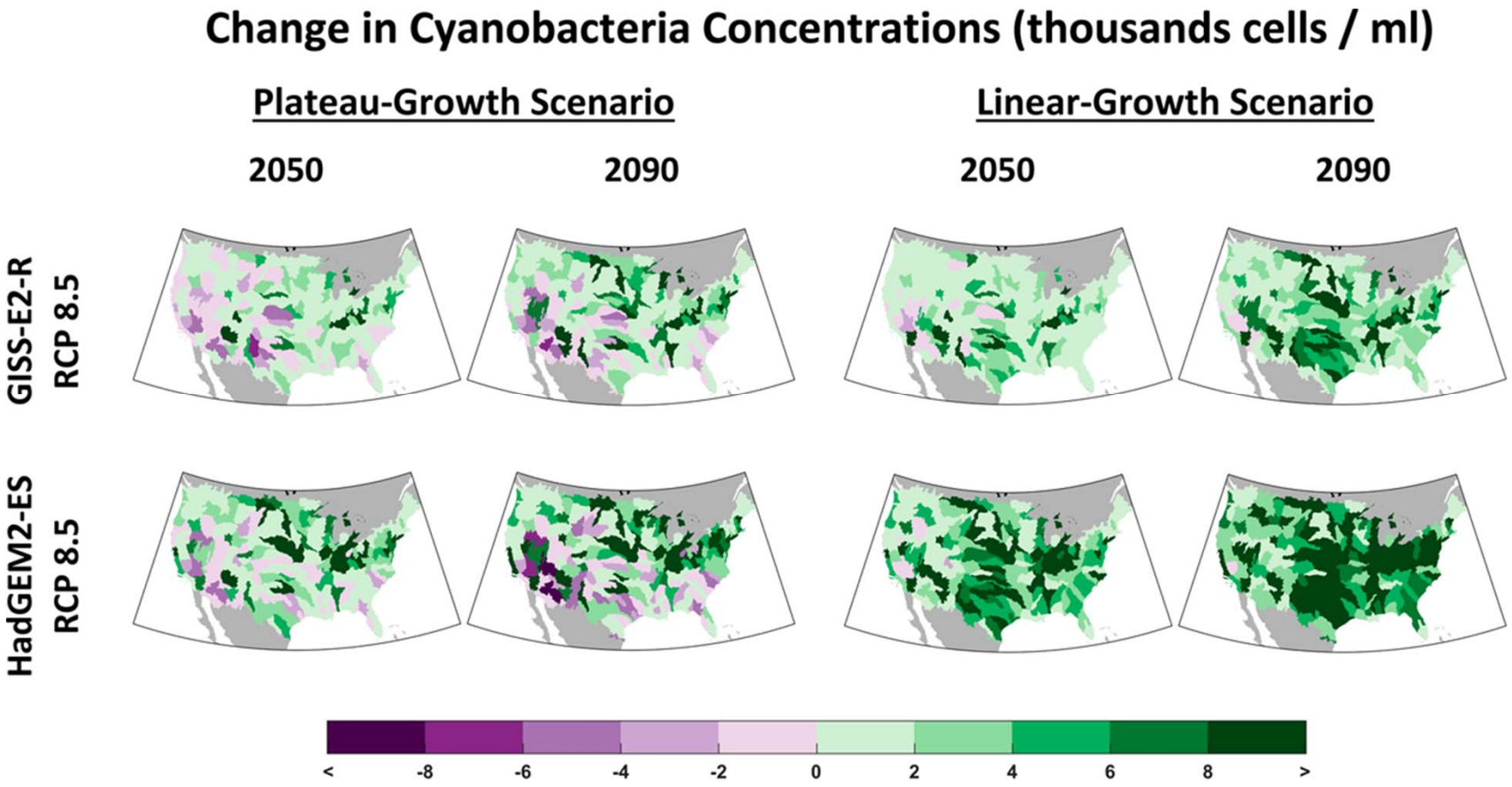




Percentage of cyanobacterial biovolume in phytoplankton communities as a function of water temperature and nutrients in 143 lakes along a climatic gradient in Europe and South America.
(a) Combined effects of temperature and nutrients as captured by a logistic regression model
(b) Response surface obtained from interpolation of the raw data using inverse distance weighting.

Data replotted from Kosten et al. (2011). Global Change Biology DOI: 10.1111/j.1365-2486.2011.02488.x

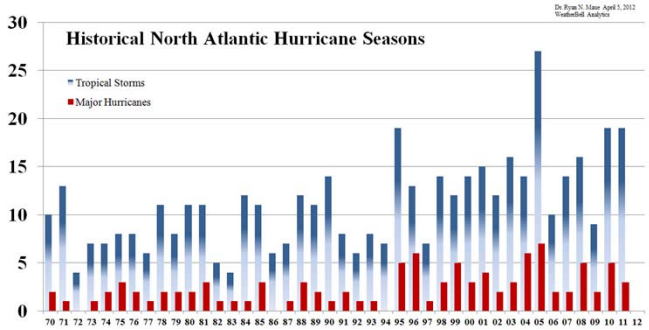
Modeling impacts of warming on cyanobacterial bloom potential

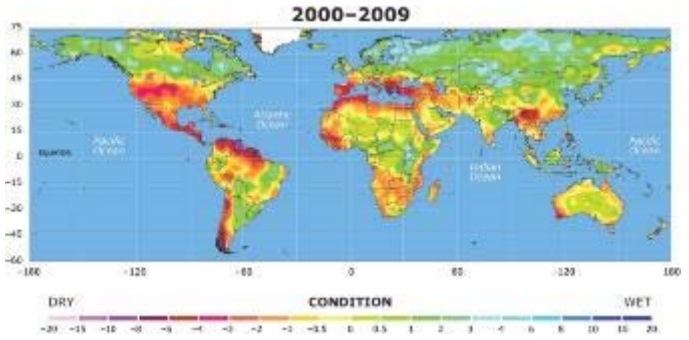


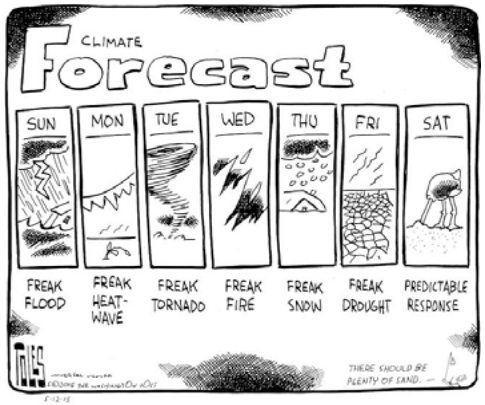
Chapra et al., 2017

Hydrologically: Things are getting more extreme

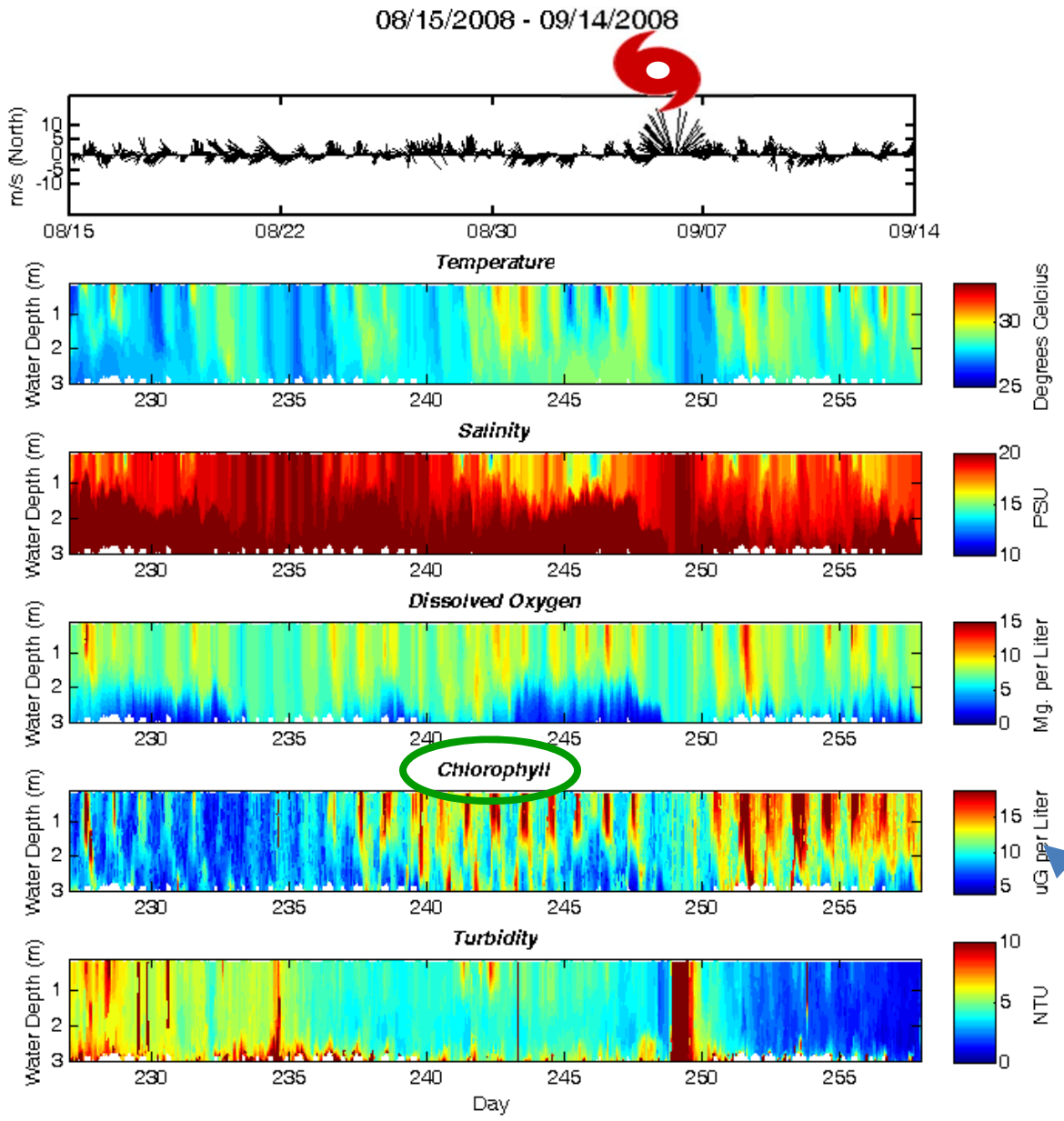
- **Storms, droughts more intense, extensive & frequent**





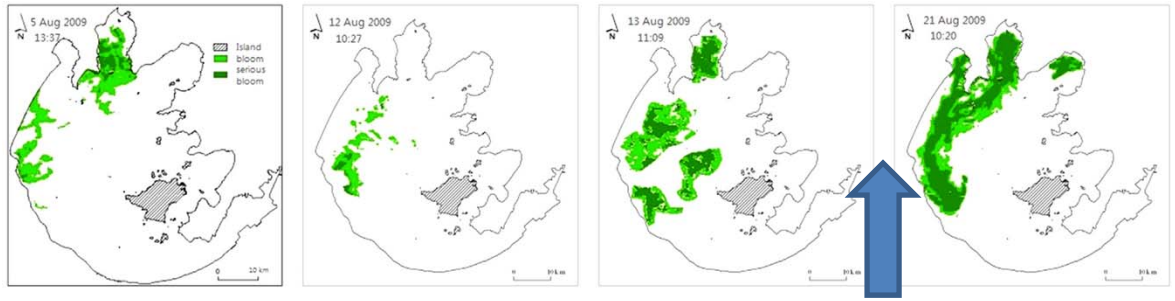


Hydrobiological impacts of Tropical Storm Hanna (8/15/08 – 9/14/08) on The New River Estuary, North Carolina, USA

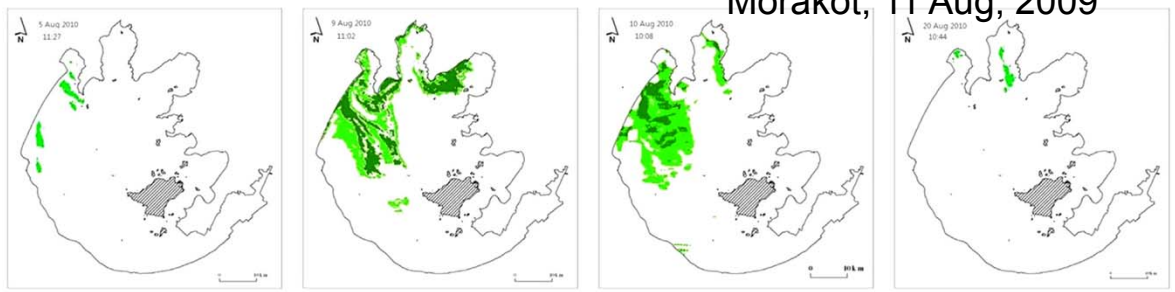


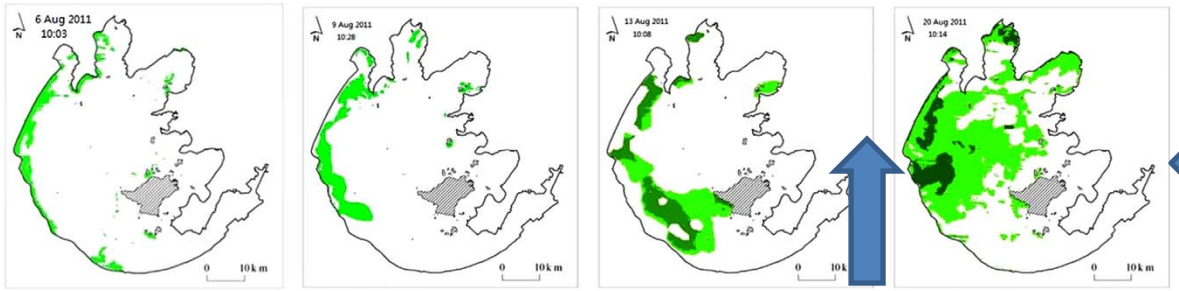
Impacts of Typhoon Passages on Cyano blooms in Lake Taihu, China, based on MODIS data

(Zhu et al., 2014)

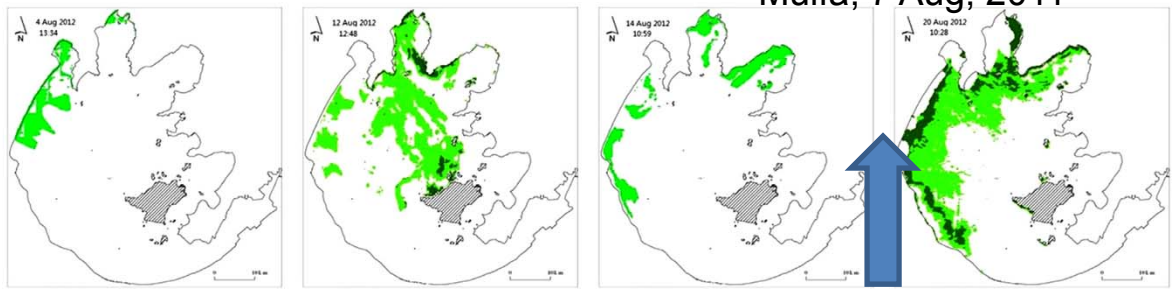


Morakot, 11 Aug, 2009





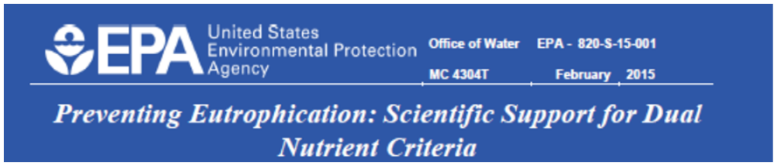
Muifa, 7 Aug, 2011



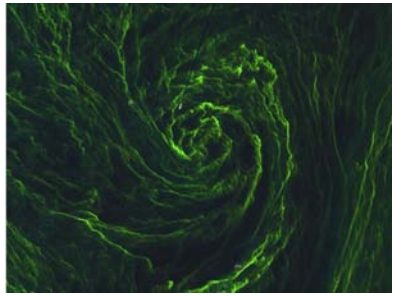
Haikiu, 8 Aug, 2012

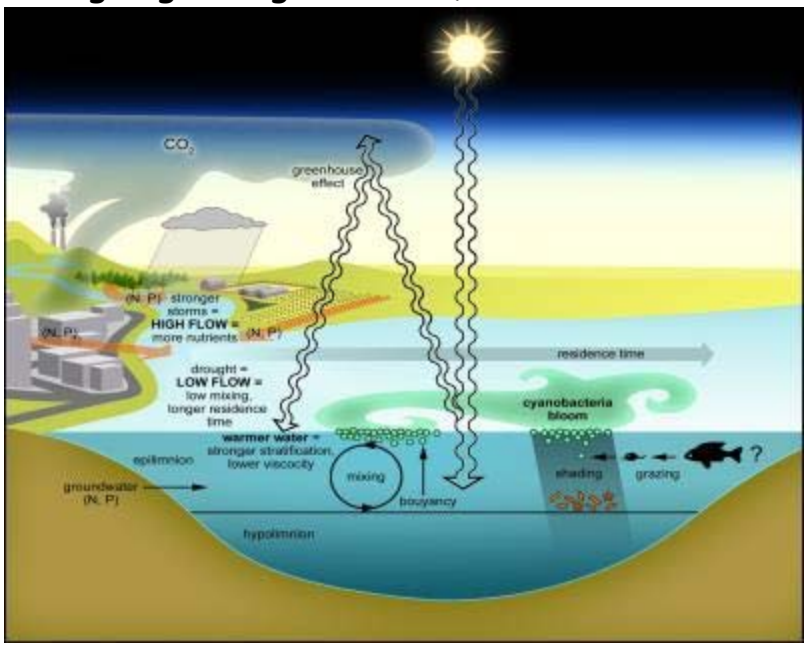
Conclusions/Recommendations for today and the future

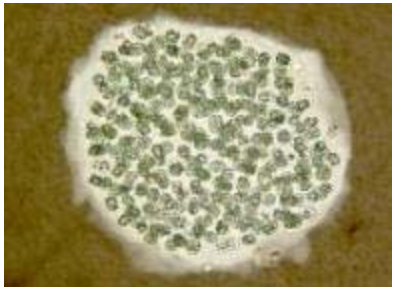
- Reduce both N & P inputs in most cases (P legacy a serious issue)



  - Nutrient-bloom threshold are system-specific
    - However, in many cases >30% reductions should be targeted
  - May need to reduce N and P inputs even more in a warmer, stormier world
    - Blooms "like it hot"
    - Episodic events favor CyanoHABs
- Impose nutrient input restrictions year-round
  - Residence time is long in many lakes (usually > 6 months)
  - Warmer, longer growing seasons (earlier ice off, later ice on)







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A. Joyner
T. Otten
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K Rossignol
S. Wilhelm
H. Xu
G Zhu
ModMon and
TLLER “crews”

Thanks!
www.unc.edu/ims/paerllab/research/cyanohabs/

Dimensions in Biodiversity Program

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U.S. EPA - Science To Achieve Results (STAR) Program
Grant # 82667701

Additional support: Nanjing Instit. of Geography and Limnology, Chinese Academy of Sciences/NIGLAS, Ministry of Science & Technology

Determining N&P reductions needed to control blooms: Use of dilution bioassays

Sampling

Distribution

Nutrient addition

Incubation

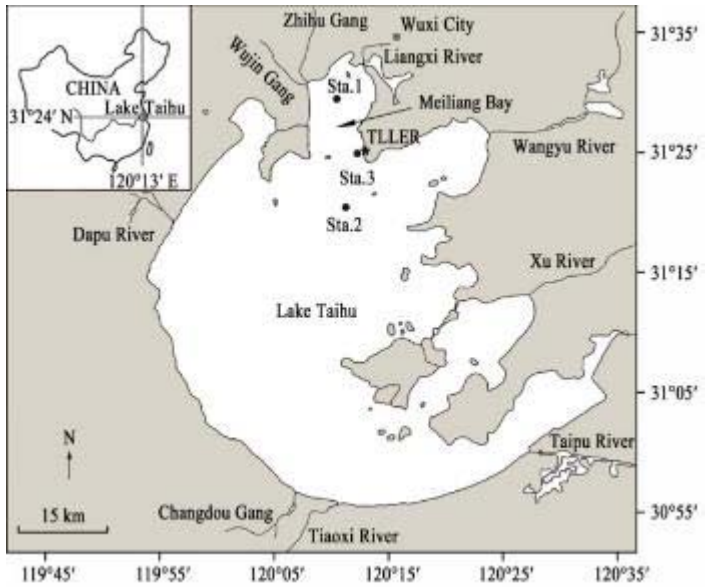
Nutrient dilution bioassays:

1. 0% (lake water, no dilution)
2. 30% dilution
3. 50% dilution
4. 70% dilution

N was added as KNO_3, and P was added as $K_2HPO_4 \cdot 3H_2O$.

Containers were incubated in the surface water to maintain ambient conditions.

Testing fast response of phytoplankton to the change in ambient conditions

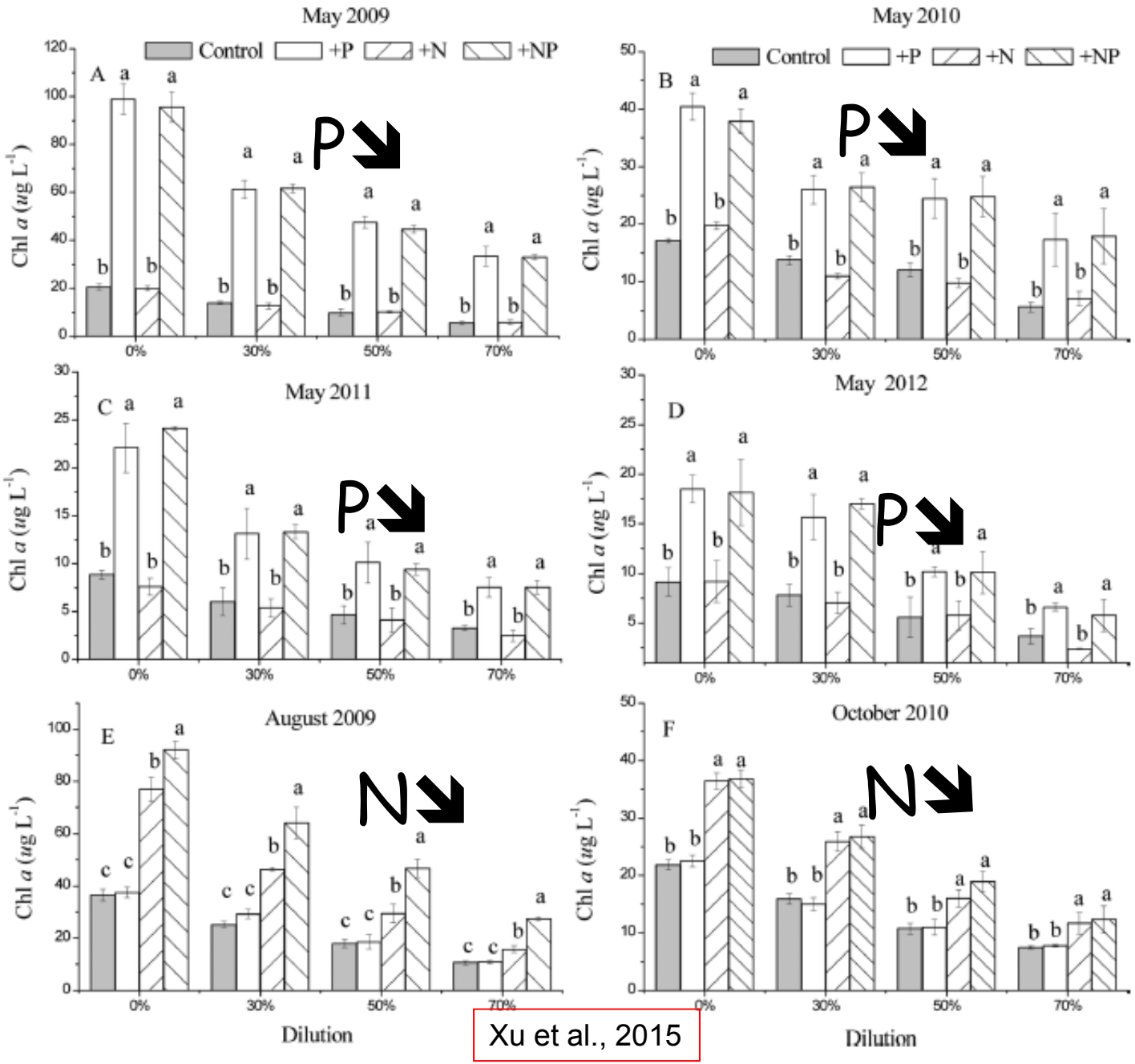


Xu et al., 2015

Nutrient Dilution Bioassays: How much N & P reduction is needed to control blooms?

30-50% for P

50-70% for N



Xu et al., 2015

Impact of Harmful Algal Blooms on Human and Animal Health

Elizabeth D. Hilborn, DVM, MPH, DACVPM

US Environmental Protection Agency

Office of Research and Development

Environmental Public Health Division

Office of Water and Region 4

Harmful Algal Blooms Southeastern Regional Workshop

Pre- Workshop Webinar

May 8, 2018

United States
Environmental Protection
Agency

Disclaimer: This presentation does not necessarily reflect EPA policy.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

There are no conflicts of interest.

Harmful algal blooms and health

United States Environmental Protection Agency

Marine and freshwater blooms

- Accumulations of phytoplankton

Freshwater

- Health impacts from direct exposure to blooms/toxins
- Poorly characterized effects from aquatic animal consumption

Marine

- Health impacts from aquatic animal consumption and from blooms/toxins
- Fish is the number one category of food implicated in food-borne outbreaks
    - Scromboid/histamine poisoning is leading etiology

Marine Blooms

Photo credit M. Gaskins, whoi.edu

Toxic marine phytoplankton

- Dinoflagellates
  - Azaspiracid SP
  - Ciguatera
  - Diarrhetic SP
  - Neurotoxic SP
  - Paralytic SP
- Diatoms
  - Amnesic SP
- Cyanobacteria
  - Dermal effects
  - Other effects?

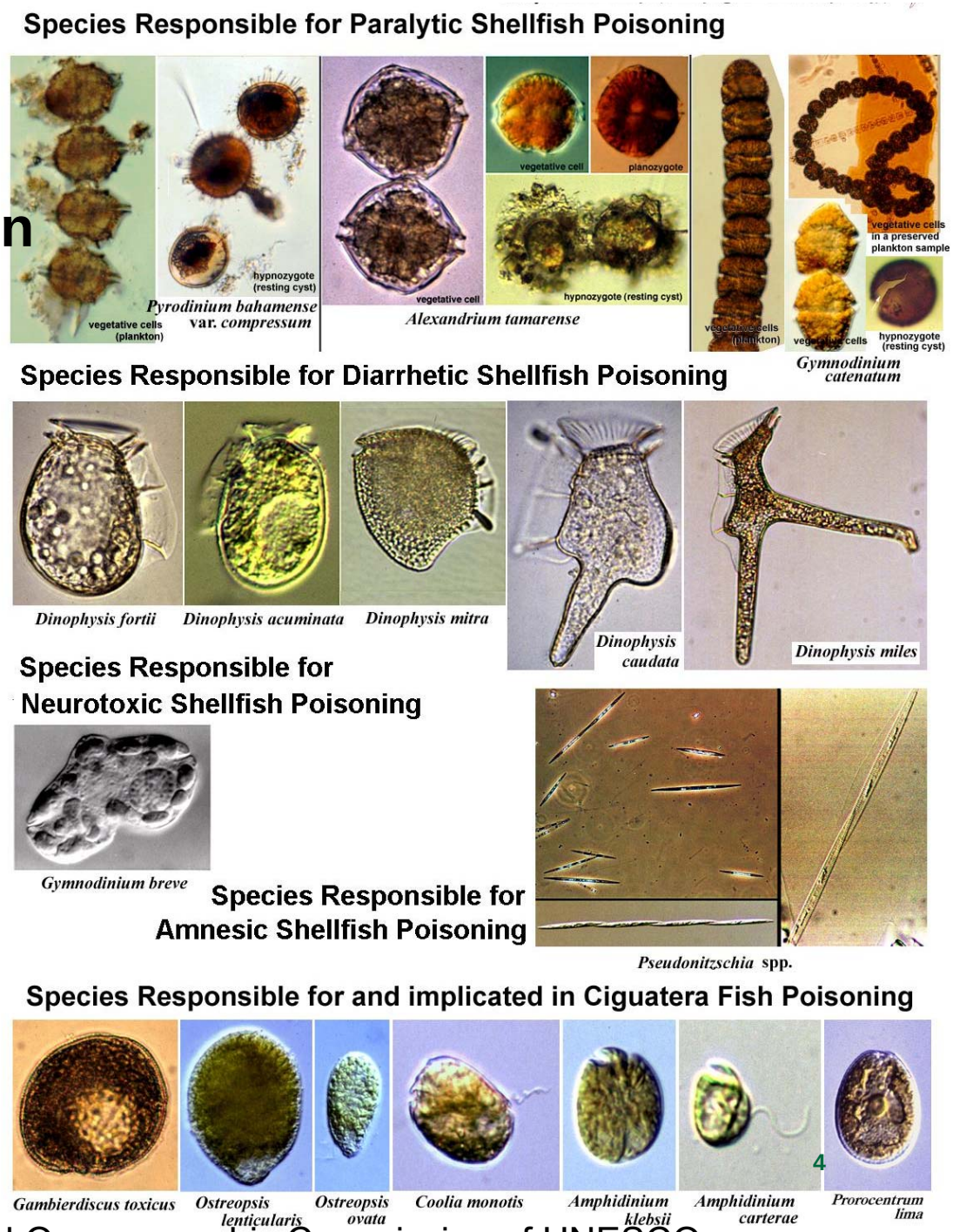


Image credit: Y. Fukuyo, Intergovernmental Oceanographic Commission of UNESCO

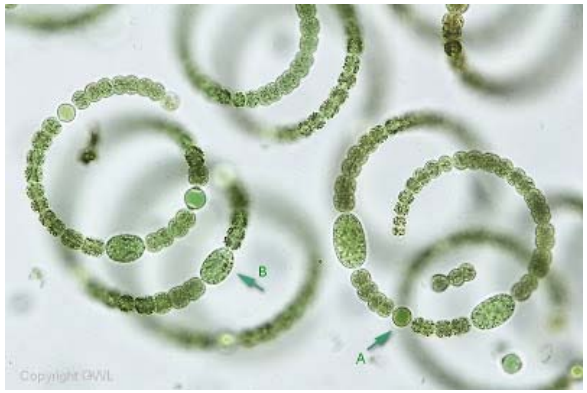
Brevetoxins associated with respiratory illnesses

https://algalredtides.wordpress.com/2014/03/07/other-human-effects/

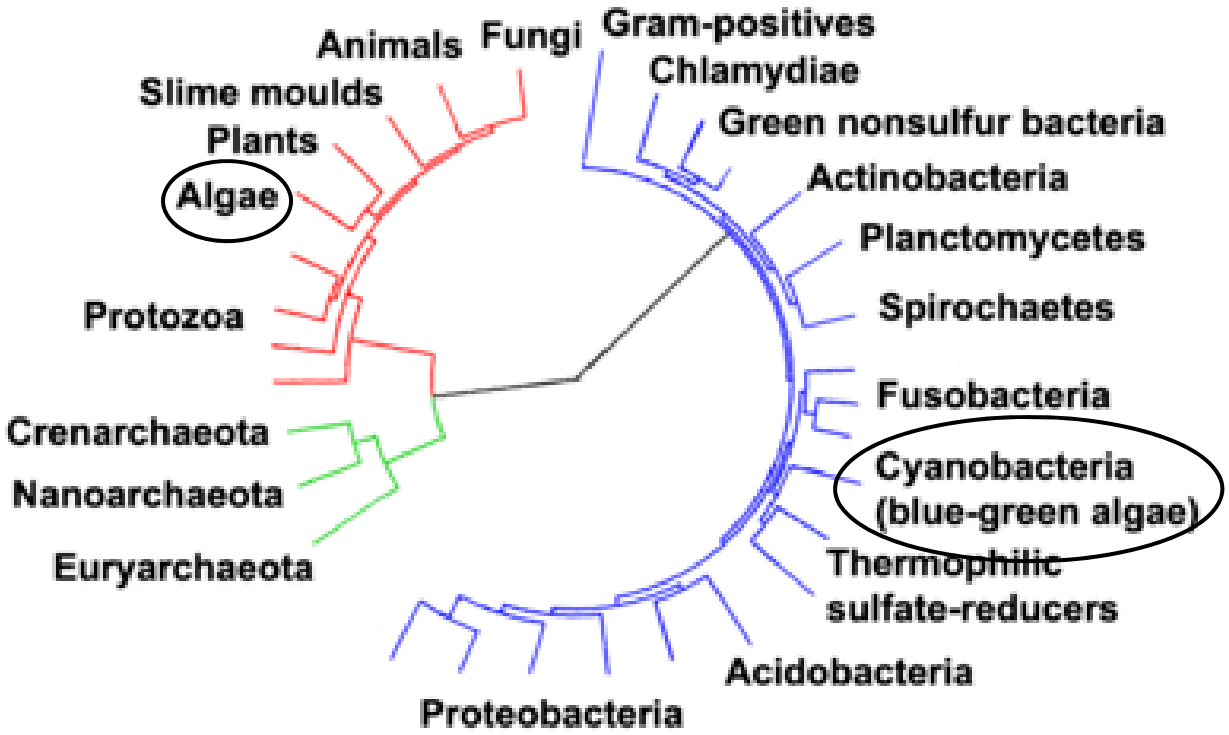

Freshwater Blooms

What are Cyanobacteria?

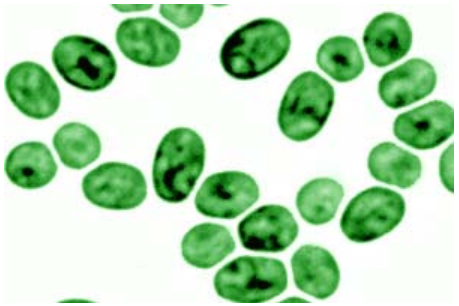
- Also known as:
  - Blue-green algae
  - Harmful algal blooms
  - Toxic algae



Anabaena, Marta Demarteau



- **Cyanobacteria are not algae**
- **They are photosynthesizing bacteria**

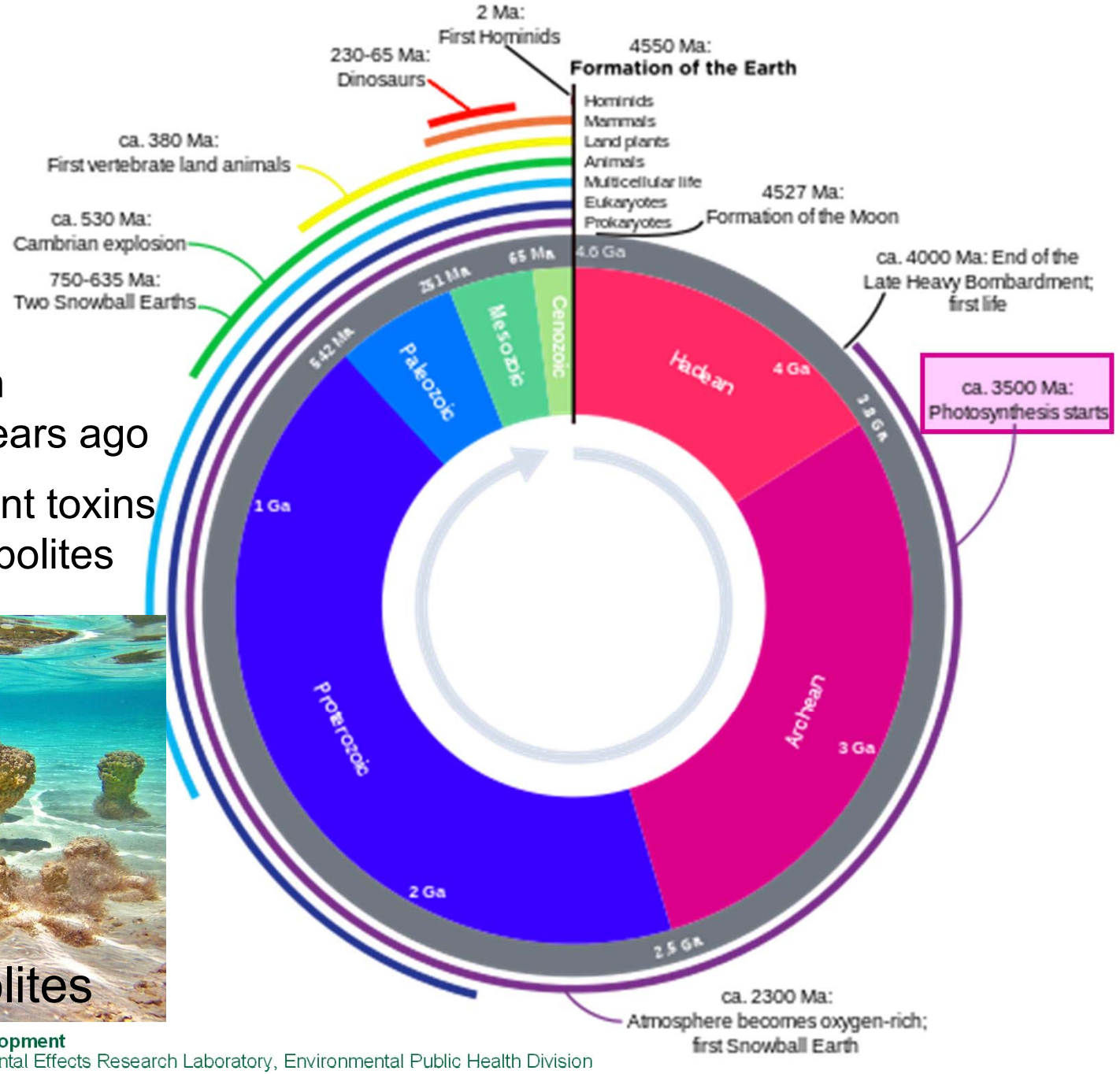


Cyanothece, Pakrasi Lab

United States Environmental Protection Agency

Cyanobacteria are ancient

- Established oxygen atmosphere 3.5b years ago
- Many produce potent toxins as secondary metabolites



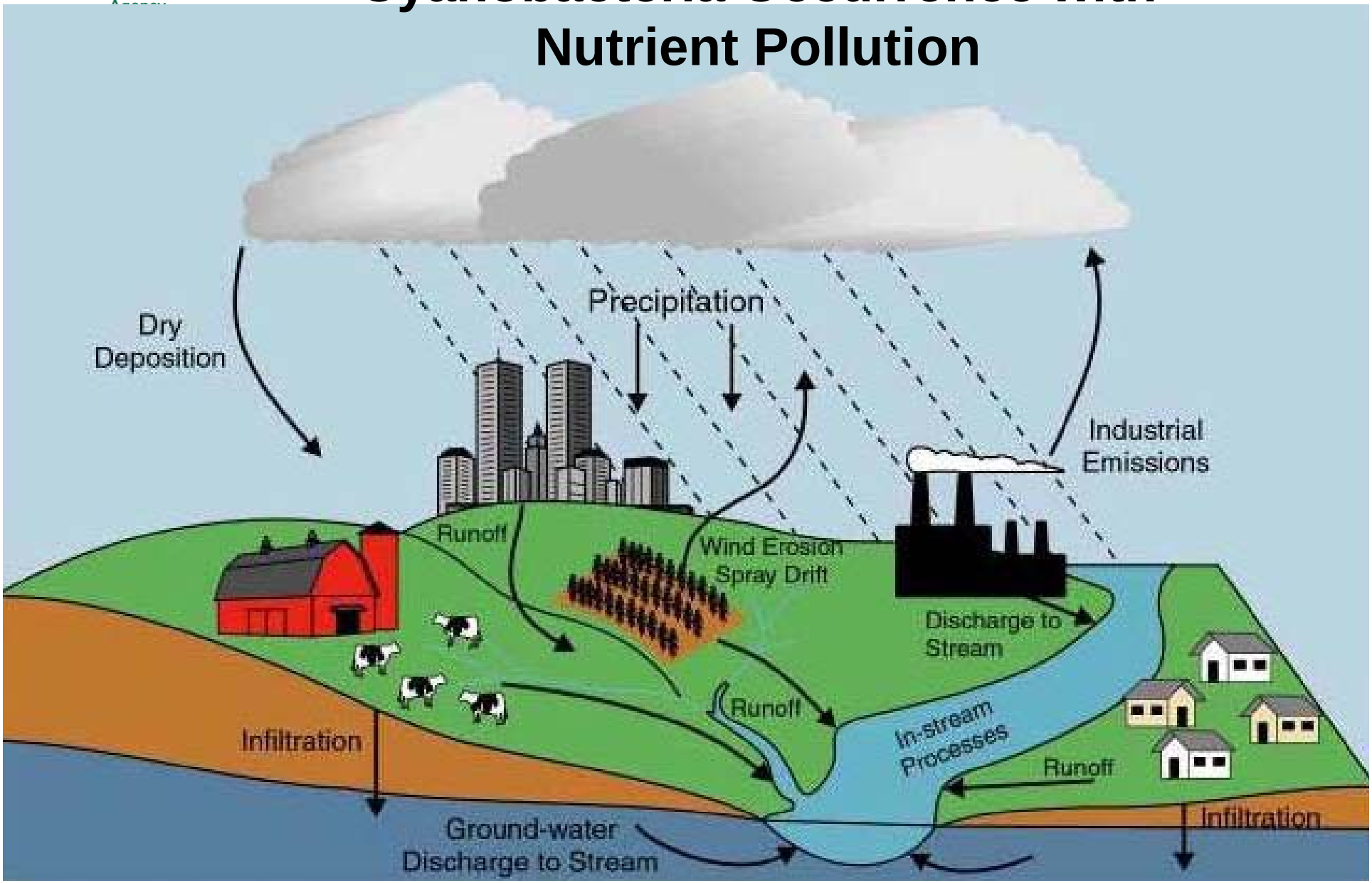
United States Environmental Protection Agency

Cyanobacteria are Common Contaminants

- Warm, stable, eutrophic surface waters
- Nuisance for water managers: fouls beaches, taste and odor problems drinking water
- Nitrogen and phosphorous limited
- Persist in benthos during periods of suboptimal growth

Lake Meade (courtesy Sandy Donnelly)

Humans are Supporting Cyanobacteria Occurrence with Nutrient Pollution



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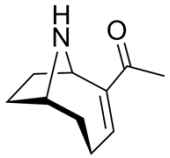
Cyanobacteria can produce potent toxins

- Anatoxins
- Aplysiatoxins
- Cylindrospermopsins
- Lipopolysaccharide (endotoxin)
- Lyngbya toxins
- Microcystins
- Nodularin
- Saxitoxins

>> Many more bioactive compounds

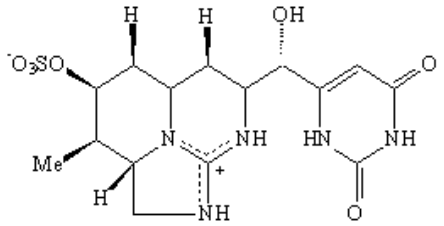
Cyanotoxins - Health Effects

- **Anatoxin-a** - Neurotoxic alkaloid



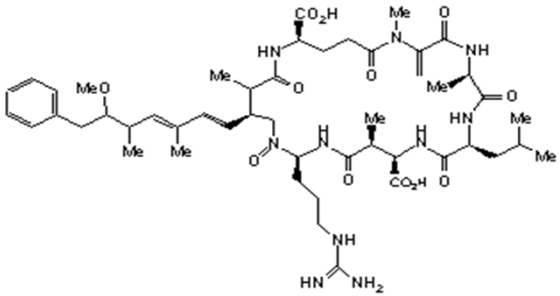
  - Mimics the effects of acetylcholine
  - Convulsions, diarrhea, vomiting, “very fast death factor”

- **Cylindrospermopsin** - Cytotoxic alkaloid



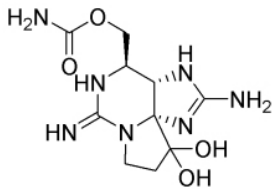
  - Affects multiple tissues
  - Inhibits protein synthesis, toxic metabolites

- **Microcystins -** Hepatotoxic cyclic peptides



  - Potent protein phosphatase inhibitors

- **Saxitoxins** – Neurotoxic nonterpene alkaloids
  - Sodium channel blocker, agents of Paralytic Shellfish Poisoning



Sources of Exposure to Cyanotoxins

- Drinking and recreational water
- Cyanobacterial scums
- Hemodialysis treatment for renal insufficiency
- Cyanobacteria-based supplements
- Aquatic foods
- Ambient water aerosols
- Produce

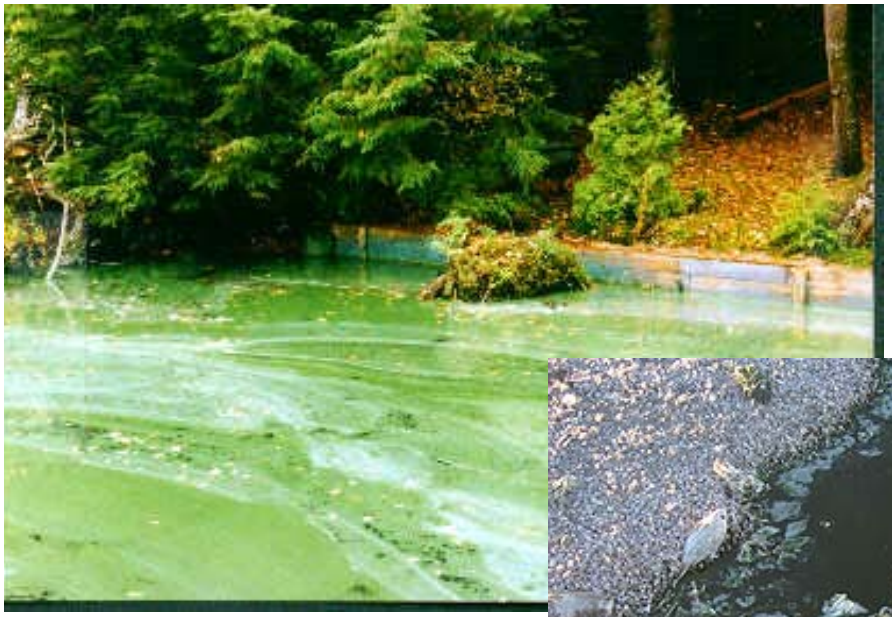
Potentially lethal cyanobacteria scums near shore

Photos: Courtesy Hans Paerl, UNC; Inside Edition; University of Arkansas, Division of Agriculture

Animals are at risk from direct exposure to cyanobacteria

Photos: Umwelt Bundesamt, Berlin, DE; US Fish and Wildlife Service; http://news.psu.edu/story/361695/2015/06/25

Animals are at risk from indirect exposure to cyanobacteria



Clostridium botulinum
Avian botulism

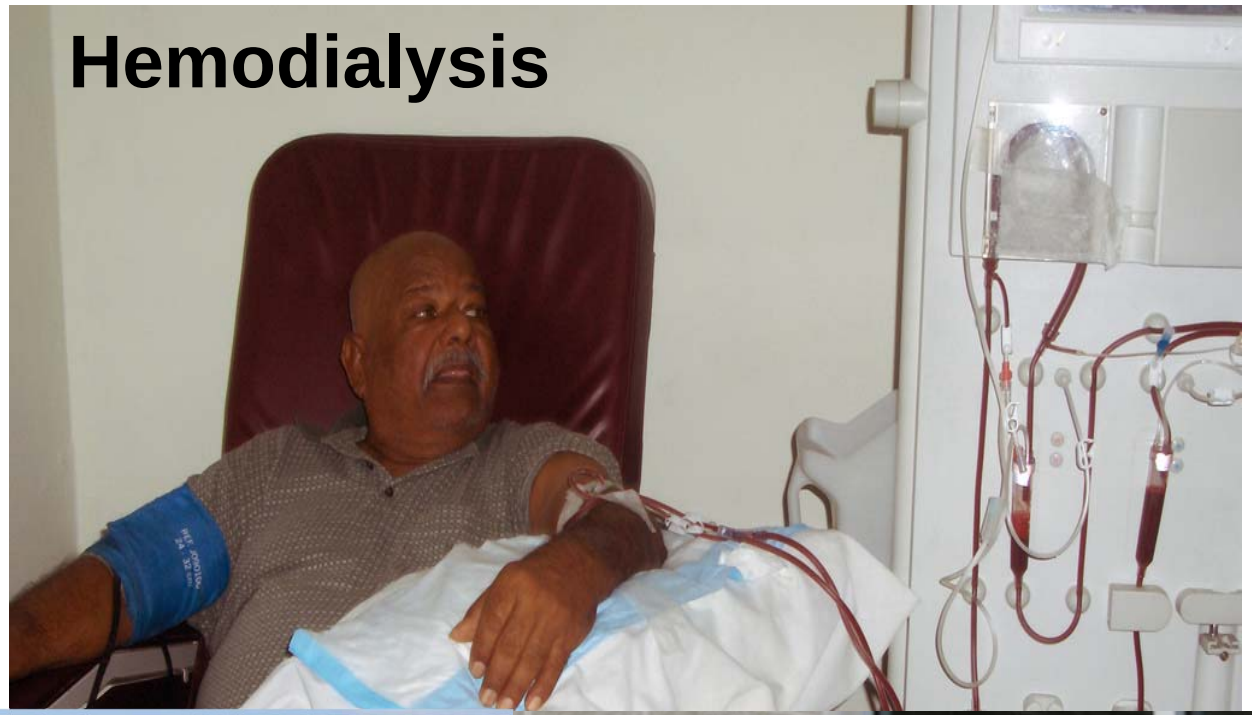
Photos courtesy of: Ohio Department of Environment, US; Nathan Lab, CA, US; US Fish and Wildlife Service

Office of Research and Development
National Health and Environmental Effects Research Laboratory, Environmental Public Health Division

People have been sickened from water

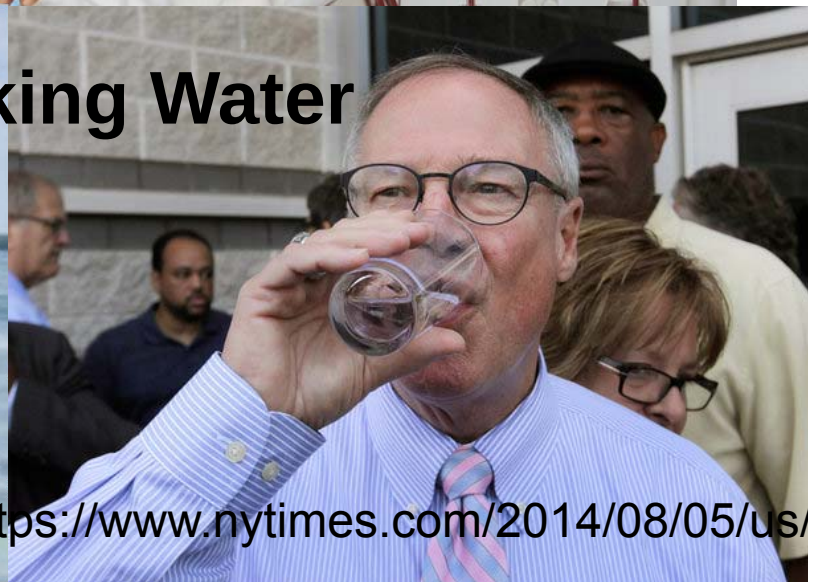
United States Environmental Protection Agency

Hemodialysis



Recreation

Drinking Water



Courtesy Ohio EPA; https://www.nytimes.com/2014/08/05/us/

Severe impacts on wildlife

United States Environmental Protection Agency

Severe impacts on livestock

Blue-green algae bloom kills 32 cattle in S. Oregon

By Aliya Hall • Capital Press
Published on July 12, 2017 10:25AM
Last changed on July 12, 2017 10:55AM

https://dpir.nt.gov.au

Severe impacts on pets

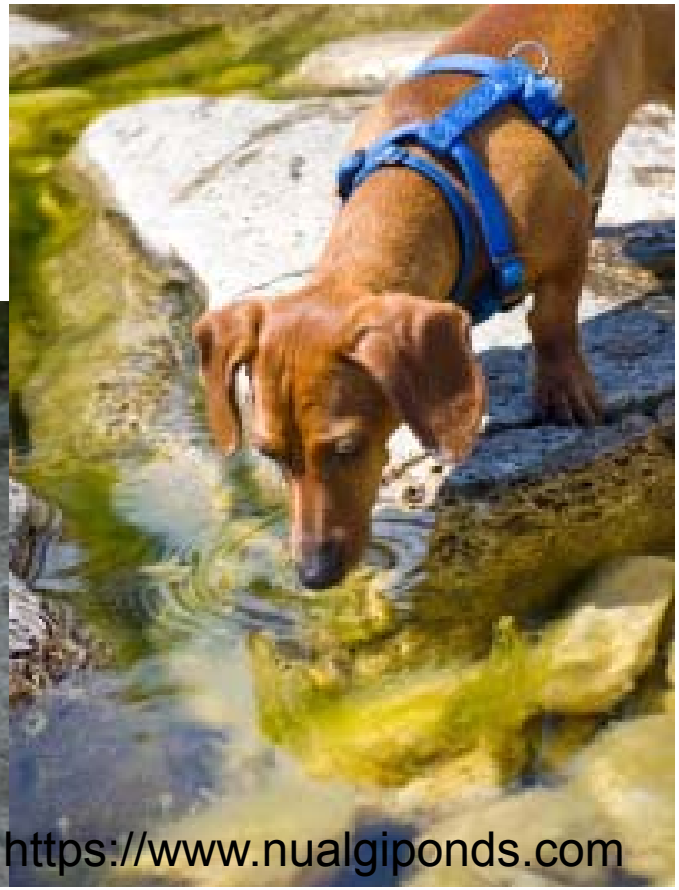
WATER & DROUGHT

JULY 02, 2017 1:53 PM

Toxic algae bloom kills two dogs in Napa as warnings proliferate

BY DON SWEENEY
dsweeney@sacbee.com

http://www.democratandchronicle.com/ Carlos Ortiz



https://www.nualgiponds.com

Potentially lethal cyanobacteria toxin concentrations can occur without blooms

Photo source: https://www.gopetplan.com/blogpost/pythiosis

United States Environmental Protection Agency

Canine Cyanotoxin Poisonings in the United States (1920s–2012): Review of Suspected and Confirmed Cases from Three Data Sources

Lorraine C. Backer [1,*], Jan H. Landsberg [2], Melissa Miller [3,4], Kevin Keel [4] and Tegwin K. Taylor [3]

Toxins **2013**, *5*, 1597-1628; doi:10.3390/toxins5091597

- Group identified 368 cases of cyanotoxin poisoning associated with dogs throughout the U.S.
  - Active surveillance
  - Medical record review for acute hepatitis
  - Historical reports (media, state/federal, other)

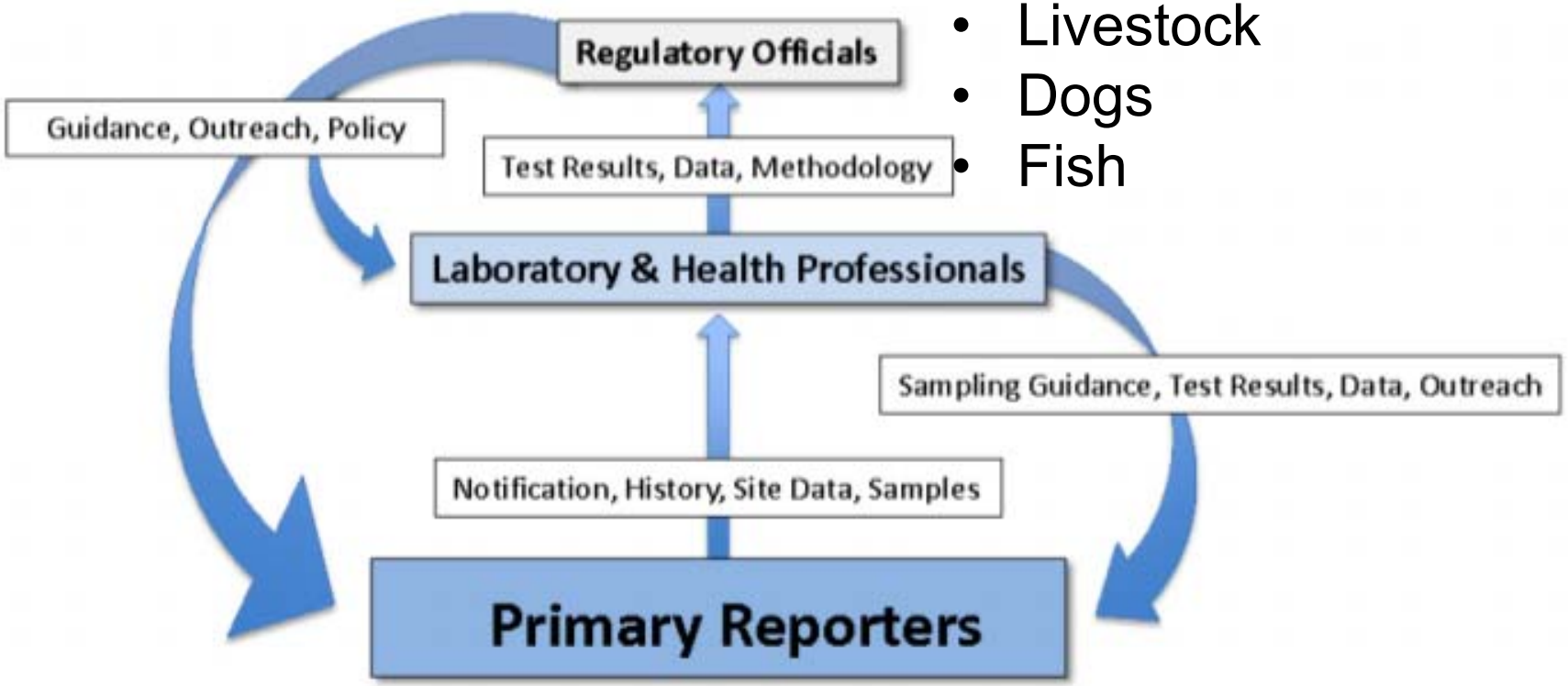
One Health and Cyanobacteria in Freshwater Systems: Animal Illnesses and Deaths Are Sentinel Events for Human Health Risks

Toxins **2015**, *7*, 1374-1395; doi:10.3390/toxins7041374

Elizabeth D. Hilborn [1,*] and Val R. Beasley [2]

Most useful sentinel events:

- Livestock
- Dogs
- Fish

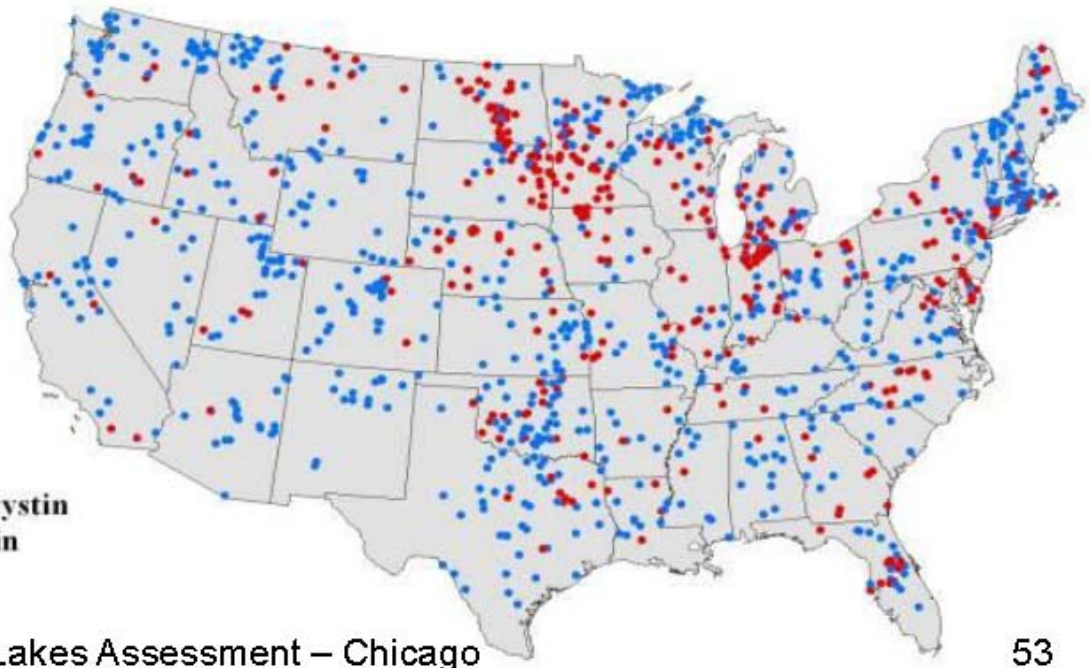


Microcystin Detections, National Lake Assessment Survey, 2007

Concentration (ppb MCLR equivalents)	Study Lakes
Mean	3.0 (~ 1.0)
Median	0.52 (< 0.10)
Minimum	0.10 (< 0.10)
Maximum	230

1 Values outside parenthesis are summary statistics for detections only. Values inside parenthesis include non-detections in summary statistics.

% Overall Detections (with Reference and Resampled Lakes: 32 % (401/1238)



USGS

● No Detectable Microcystin
● Detectable Microcystin

Courtesy Neil Kamman

Human Illness, Animal Deaths, Freshwater HABs, Kansas, 2011

- 13 cases human illness
  - Of 7 confirmed, adverse effects included:
  - Rash, gastrointestinal effects, eye and upper respiratory effects, fever, joint pain, pneumonia
- 5 dog deaths, 1 confirmed illness
  - Vomiting, diarrhea, lethargy, staggering, seizures
- Milford Lake monitored during
  - Maximum microcystins 1600µg/L

Trevino-Garrison et al. Toxins, 2015

Waterborne Disease Outbreaks

- NORS waterborne disease reports during 2009 - 2010
  - Recreational water associated outbreaks
  - Subset: algal bloom (HAB)-associated outbreaks

- HAB-associated outbreak
  - Two or more people were exposed to ‘algal blooms’ and subsequently reported illness
  - A shared location during recreational water activities
  - Environmental investigation
  - Information is at the outbreak level, no individual information

EPA United States Environmental Protection Agency

NORS National Outbreak Reporting System

Algal Bloom-Associated Outbreaks

- 11 reports from New York (3), Ohio (6), Washington (2)
  - –All outbreaks occurred at public or private lakes

- Sixty-one people became ill, no known deaths
  - –59% females
  - –66% ≤19 years of age
  - –59% sought health care*
  - – 7 (12%) visited emergency room*
  - – 2 (3%) hospitalized*

*** >1 category / person**

Multiple Health Effects Reported Among Algal- associated Outbreaks

- **In order of most commonly to least commonly reported effects:**
  - Skin, Gastrointestinal effects
  - Respiratory, Nonspecific effects
  - Ear effects
  - Nervous system effects
  - Muscles, Joint / Bone and / or Eye effects

- **Most commonly to least commonly reported toxins:**
- Microcystins
- Anatoxin-a
- Saxitoxins/cylindrospermopsin

Cyanotoxin* Analysis among Eight Outbreaks

Outbreak	Anatoxin-a	Cylindrospermopsin	Microcystins	Saxitoxins
1	-	-	112.5 µg /L	-
4	0.1µg /L	ND	4.6 µg /L	ND
5	-	-	> 1000 µg /L	-
6	ND	ND	0.2 µg /L	0.03 µg /L
7	-	ND	20.8 µg /L	ND
8	15.0 µg /L	9.0 µg /L	> 2000 µg /L	0.09 µg /L
9	0.2 µg /L	0.3 µg /L	0.3 µg /L	ND
10	-	-	< 6.0 µg /L	-

* Maximum toxin values, +/- 1 day outbreak period

Hilborn et al. MMWR January 10, 2014

Associated Animal Illness, Death

Affected animals	Anatoxin-a	Cylindrospermopsin	Microcystins	Saxitoxins
Fish kill, dog deaths	ND	ND	0.2 µg /L	0.03 µg /L
Heron illness, dog deaths	15.0 µg /L	9.0 µg /L	> 2000 µg /L	0.09 µg /L

Photos: National Wildlife Federation; https://clearlakecyanobacteria.wordpress.com/

Limitations

- Voluntary reporting
- Underestimate of occurrence
- No individual exposure or health information
- Limited supporting evidence from water, none from biological samples

EPA
United States
Environmental Protection
Agency

Challenges for Health Effect Attribution

- Lack of provider awareness
- Nonspecific health effects
- Lack of diagnostic tools
- Exposure to mixtures

Photo: http://blog.duncanseawall.com

Summary

- Documented exposures to cyanotoxins are uncommonly investigated and reported
- Toxins' health effects are fairly to poorly characterized
- Consumption of contaminated water is a high risk exposure
- Children and animals may be more likely to become ill
- Onset of illness may be rapid
- Multiple health effects may be associated with exposure
- Analytic tools for detecting toxins in water and biological samples are needed

United States Environmental Protection Agency

University of Pennsylvania

Val Beasley

Environmental Protection Agency

Tim Wade (NHEERL)

Centers for Disease Control and Prevention

Virginia Roberts, Michele Hlavsa, Jonathan Yoder (NCEZID)
Lorrie Backer (NCEH)

State Partners

Erin Deconno, Jessica Egan, James Hyde, David Nicholas, Eric Wiegert (New York); Laurie Billing, Mary Diorio, Marika Mohr (Ohio); Joan Hardy (Washington)

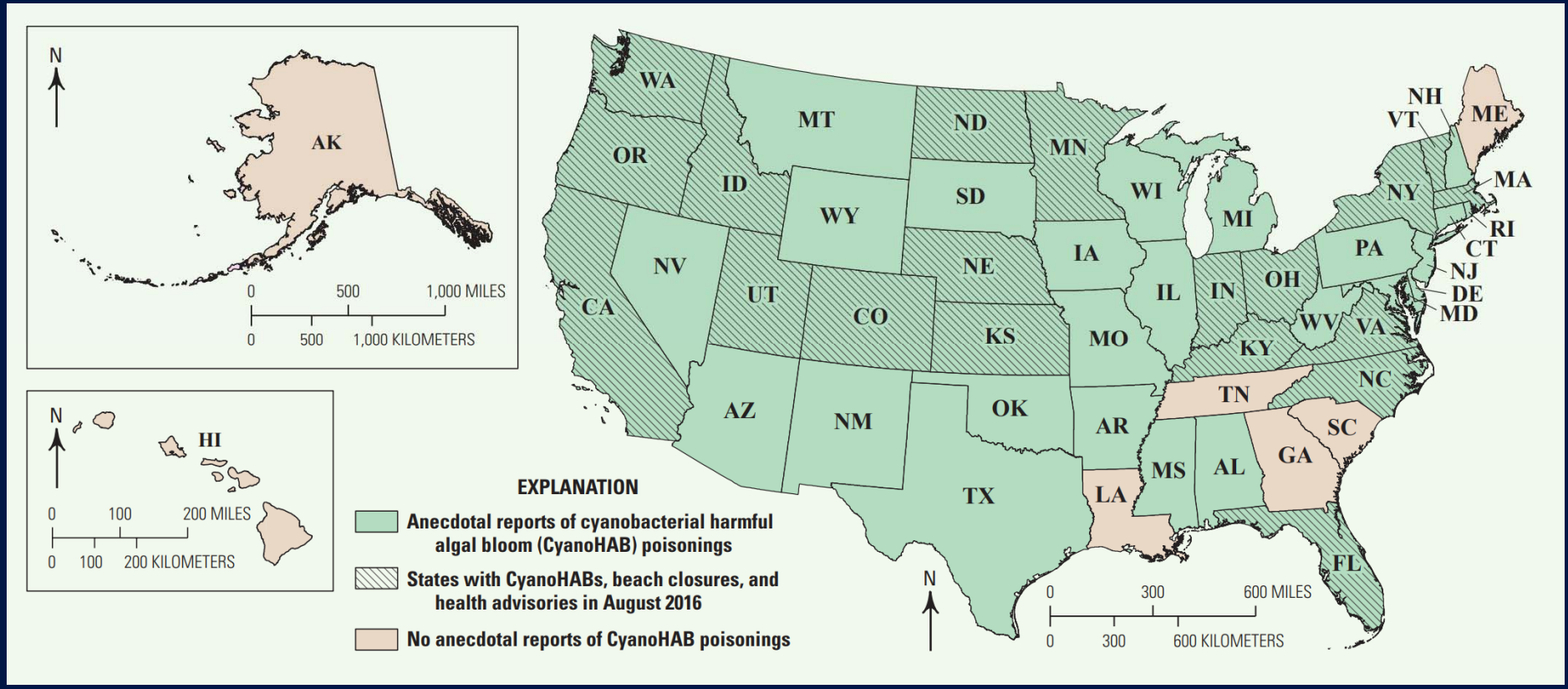
USGS
science for a changing world

Cyanotoxins in Freshwaters of the United States: Occurrence and Emerging Technologies

Jennifer L. Graham, Keith A. Loftin, and Guy M. Foster
U.S. Geological Survey

EPA Region 4 HAB Workshop
May 8, 2018

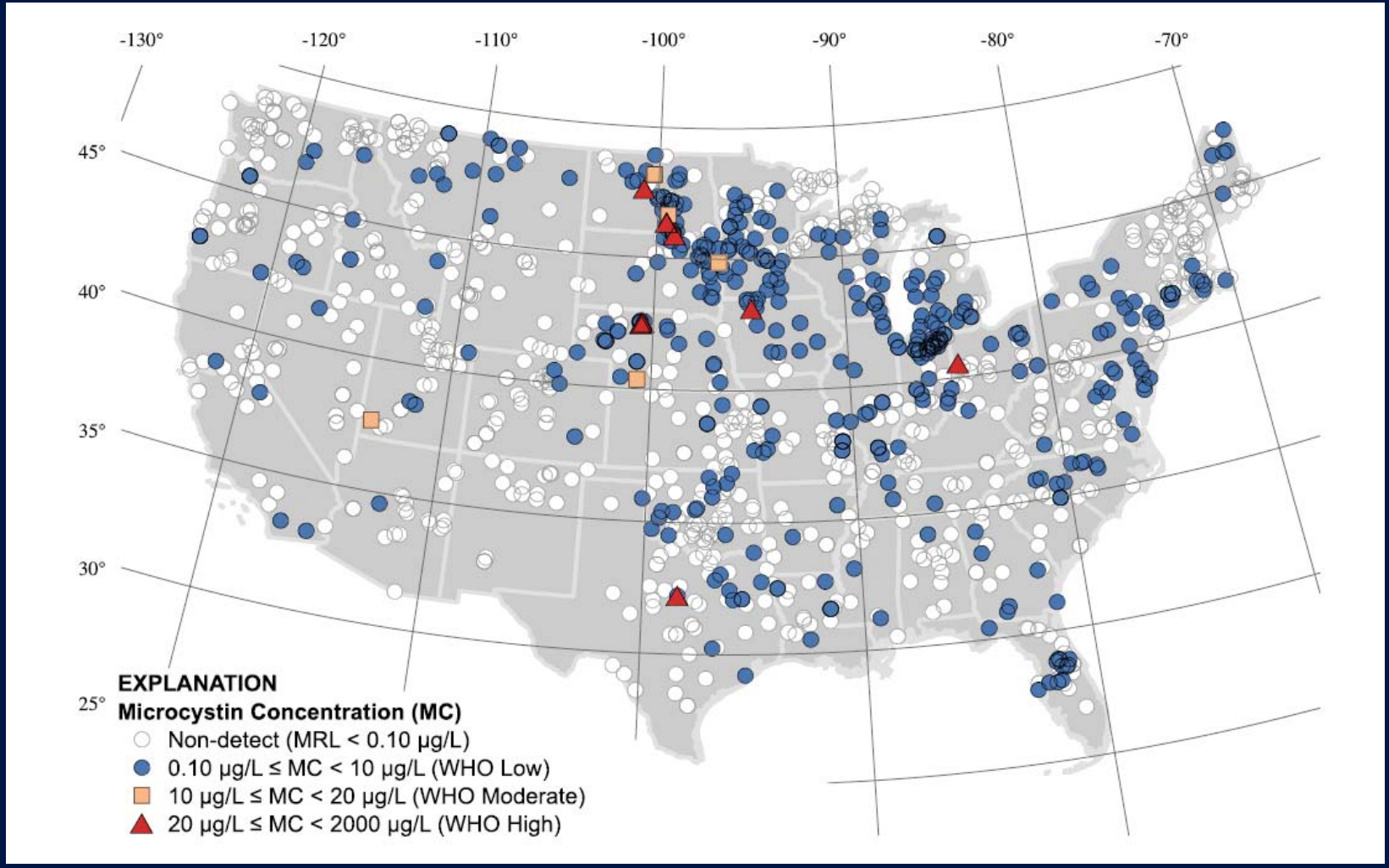
In August 2016, At Least 19 States Had Beach Closures or Health Advisories



USGS
science for a changing world

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

In the 2007 National Lakes Assessment, Microcystins Were Detected by ELISA in About 32% (n=1252) of Analyzed Samples



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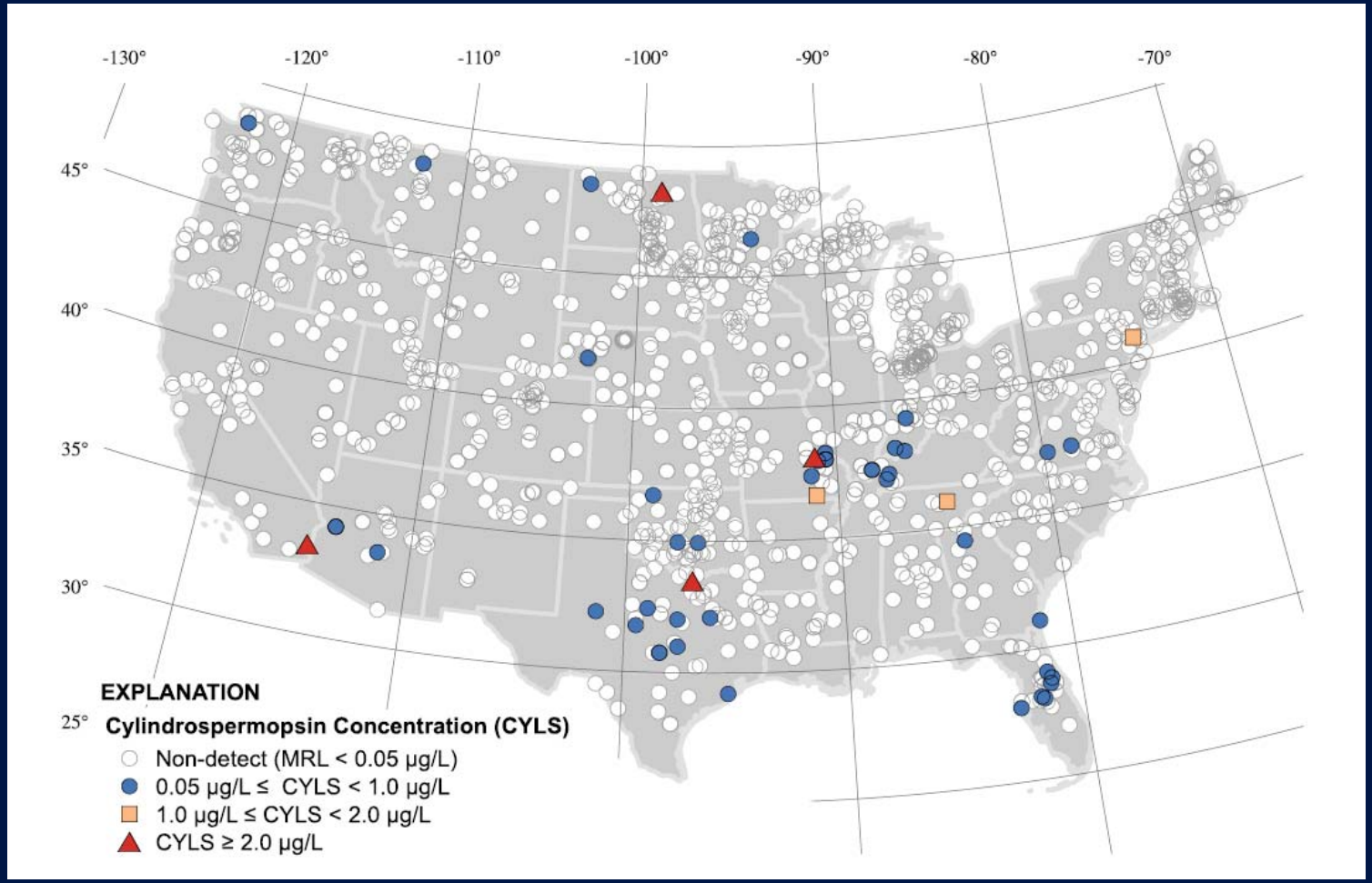
science for a changing world

Loftin and others, 2016, Harmful Algae

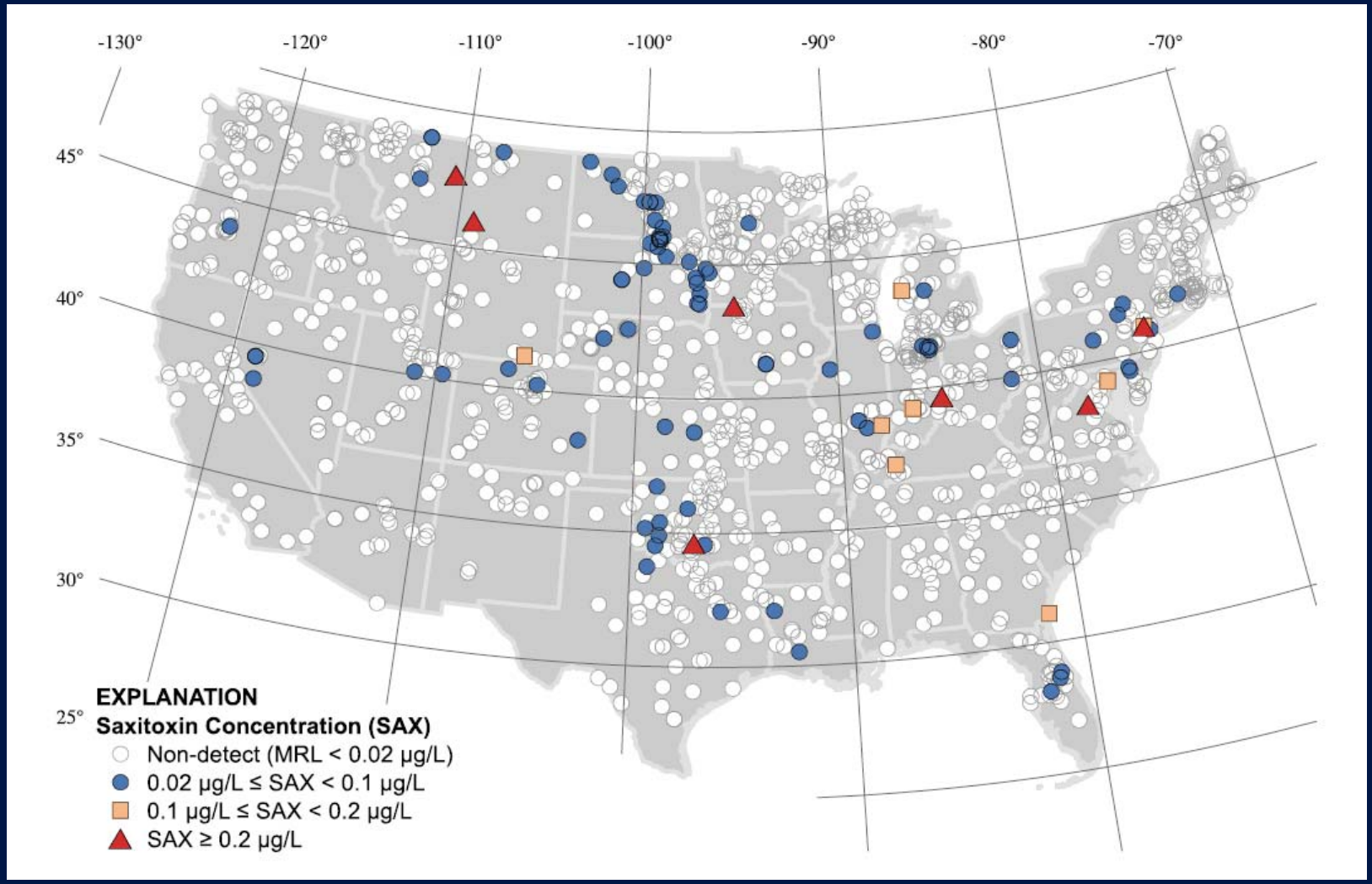
In the 2007 National Lakes Assessment, Cylindrospermopsins Were Detected by ELISA in About 4% (n=1252) of Analyzed Samples



USGS science for a changing world

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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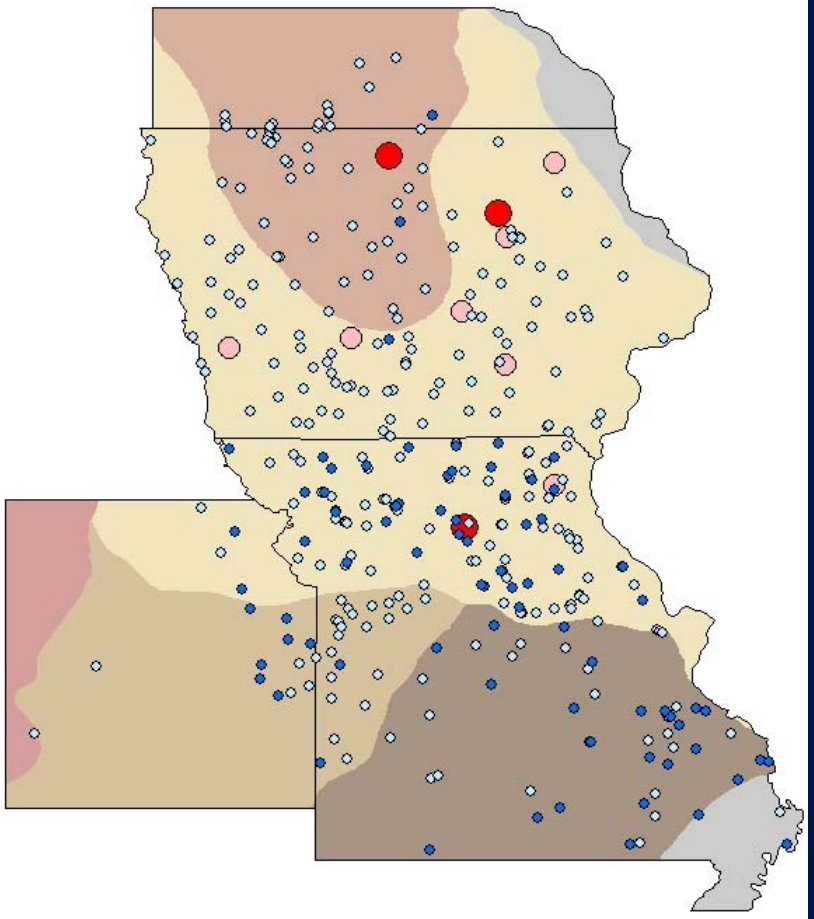
Loftin et al., 2016, Harmful Algae

Microcystins are Widespread and Common in the Midwest

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

CONCENTRATION/RISK

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



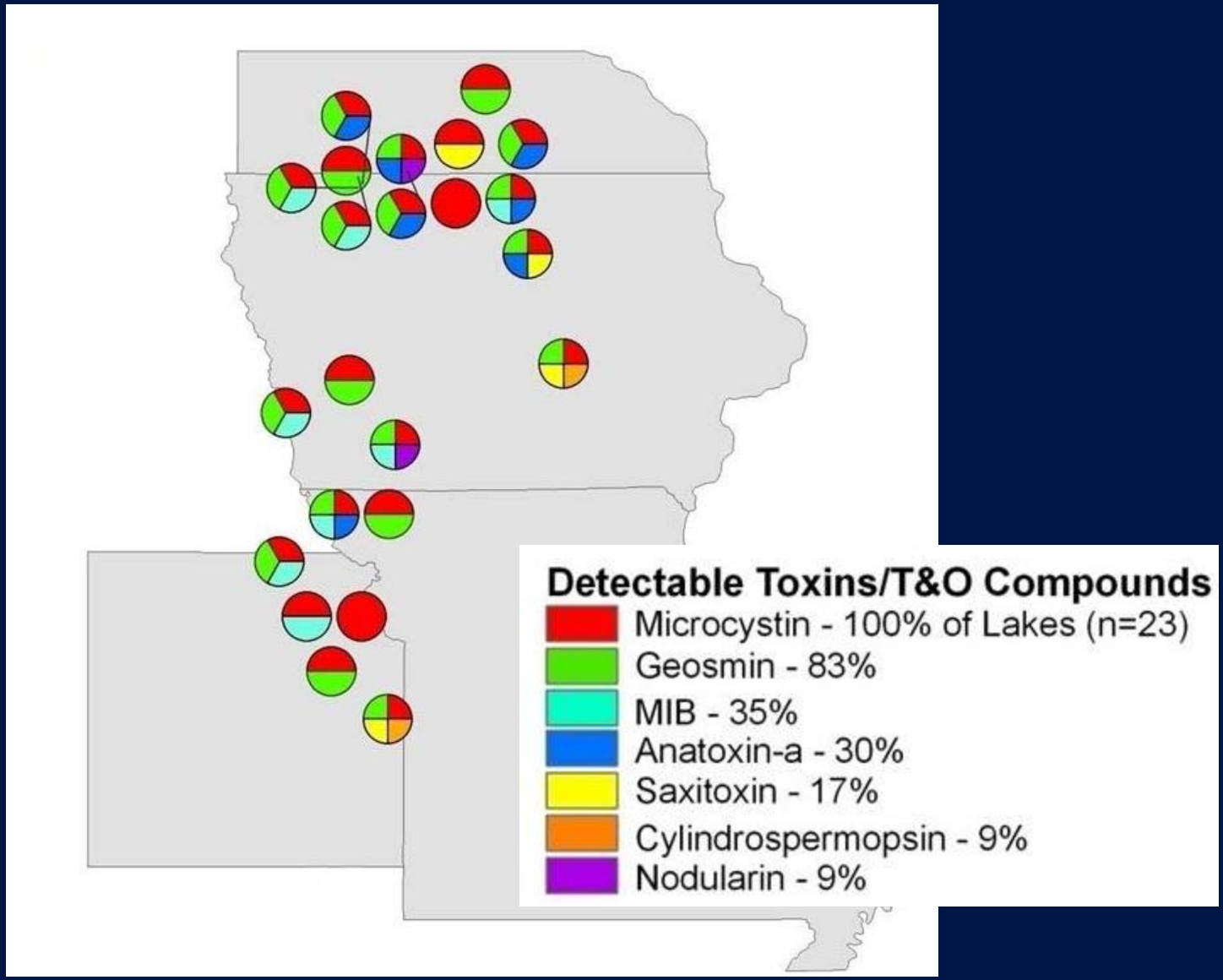
78% of lakes had detections (n=359)

Maximum concentration: 52 µg/L

USGS science for a changing world

Graham and others 2004, 2006, and 2009

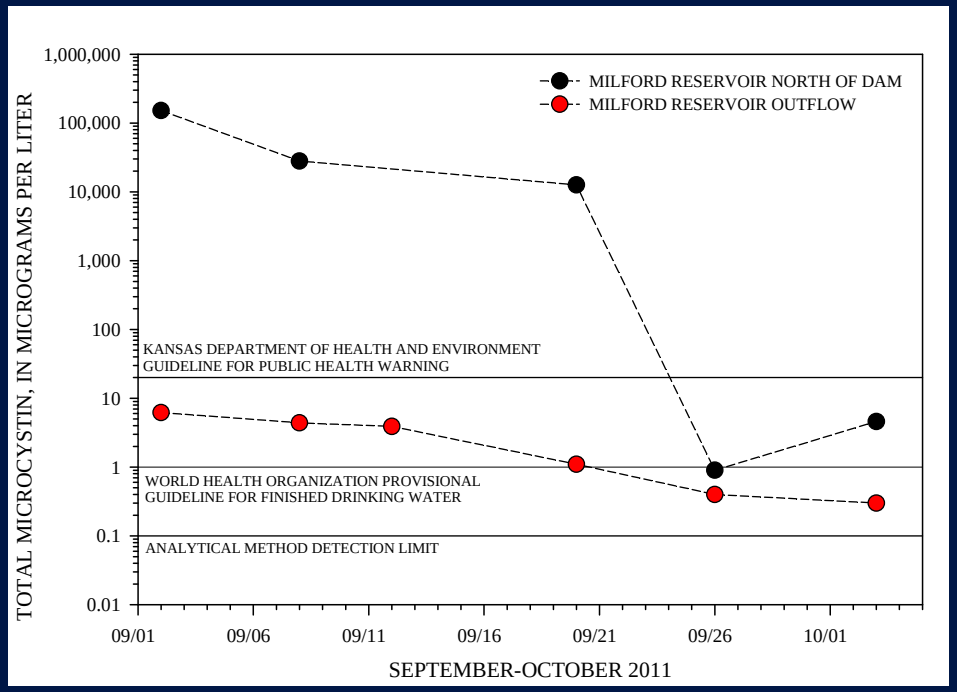
Multiple Toxins and Taste-and-Odor Compounds Frequently Co-Occur in Cyanobacterial Blooms

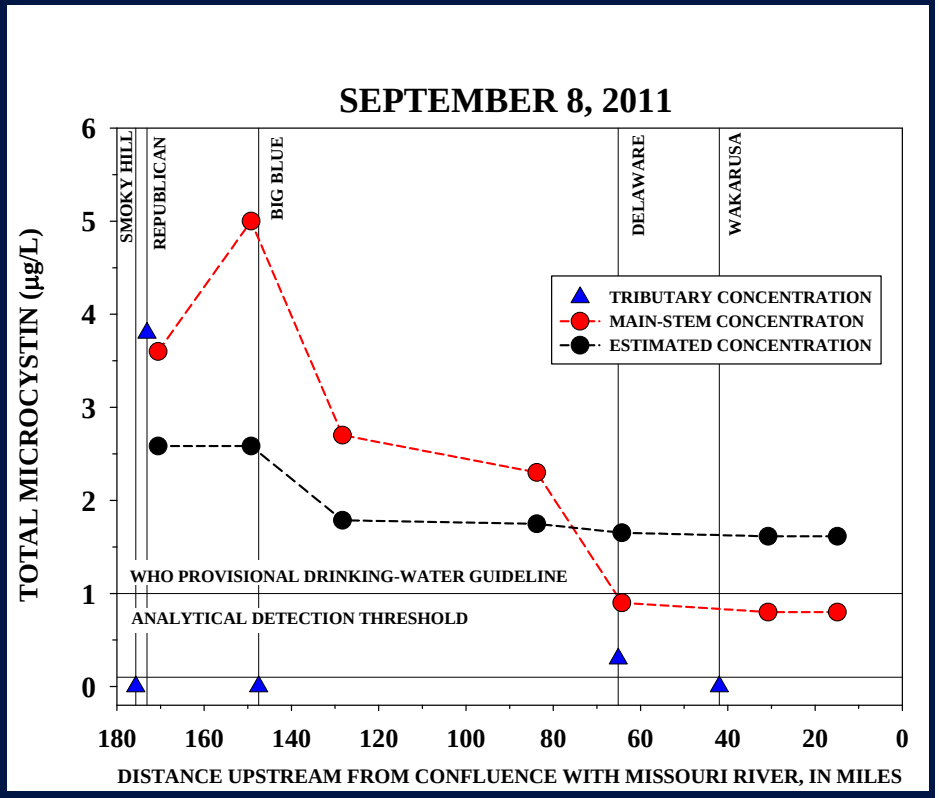


USGS
science for a changing world

Graham and others, 2010, ES&T

Cyanobacteria and Associated Compounds May Be Transported for Relatively Long Distances Downstream from Lakes and Reservoirs

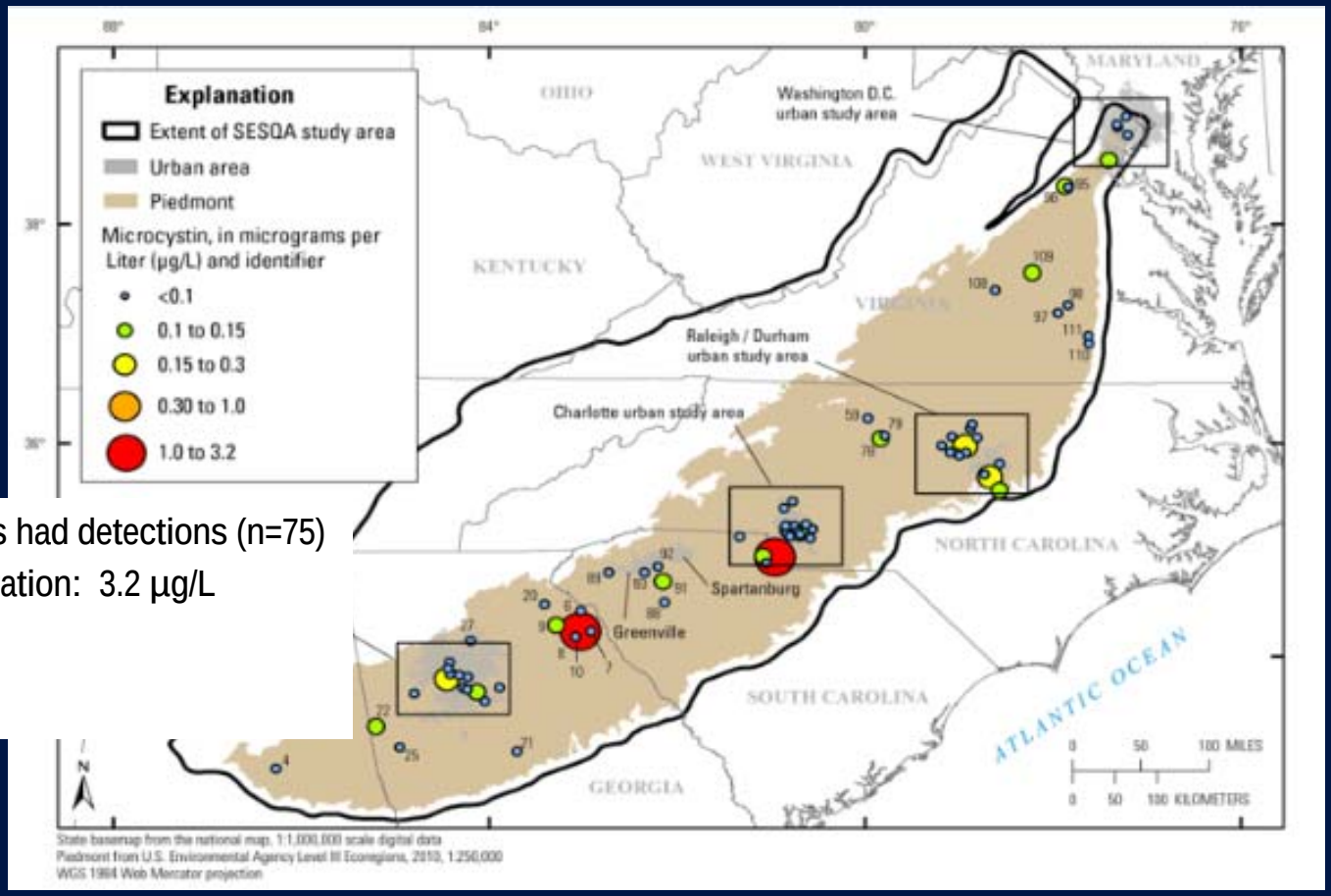




USGS
science for a changing world

Graham and others, 2012, USGS SIR 2012-5129

Microcystins Occurred in 39% of Small Stream Sites Sampled in the Southeastern United States



39% of stream sites had detections (n=75)

Maximum concentration: 3.2 µg/L

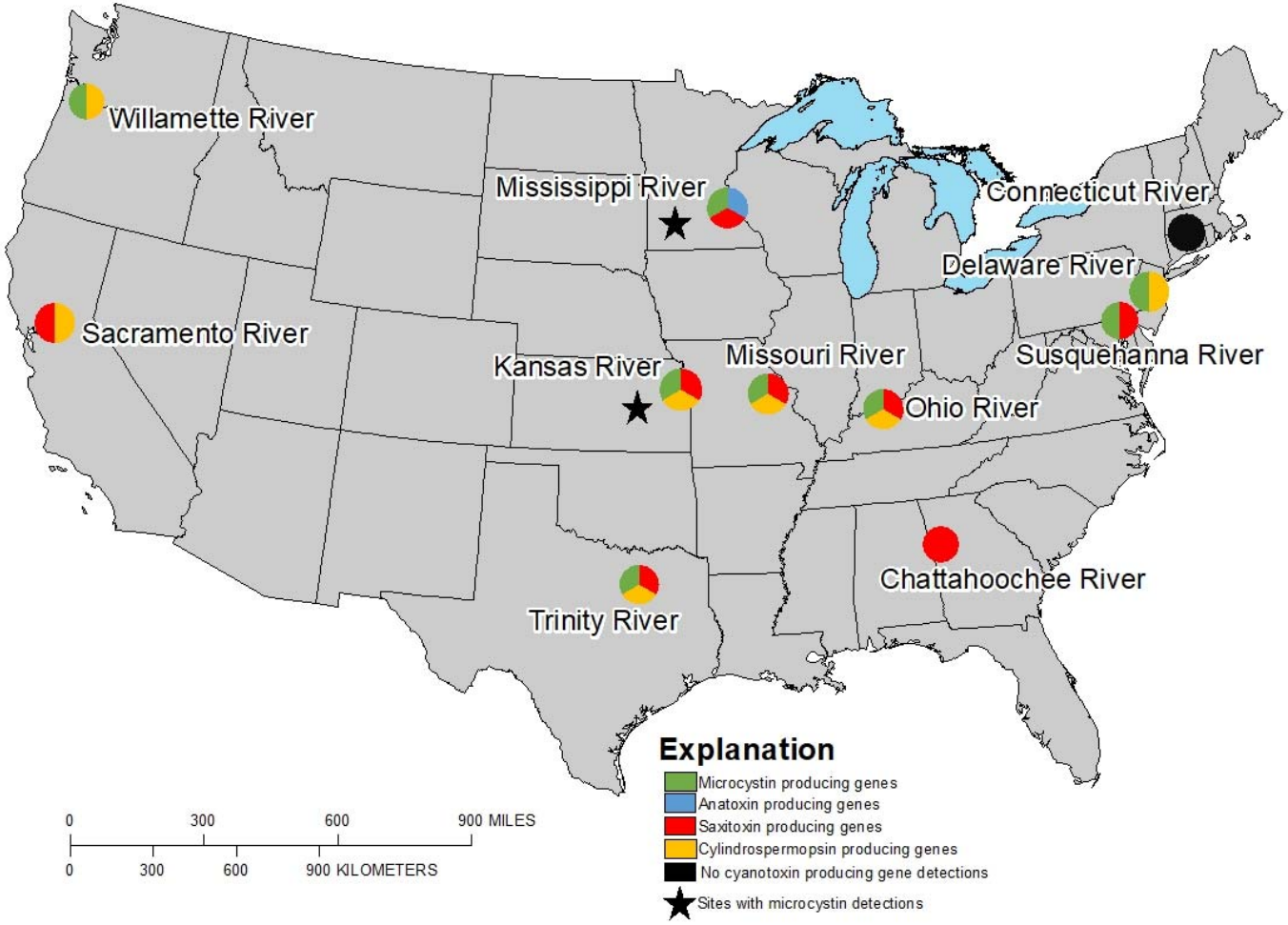
Median: 0.11 µg/L

Mean: 0.29 µg/L

USGS science for a changing world

Loftin and others, 2016, Environmental Toxicology and Chemistry

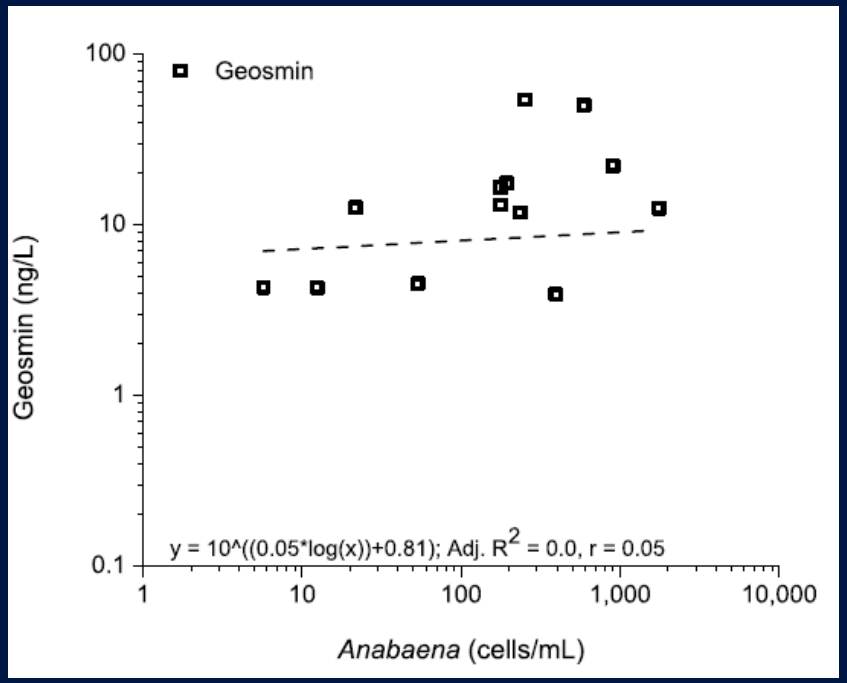
The *Potential* for Cyanotoxin Production Was Detected at All Large River Sites Except One During June-September 2017

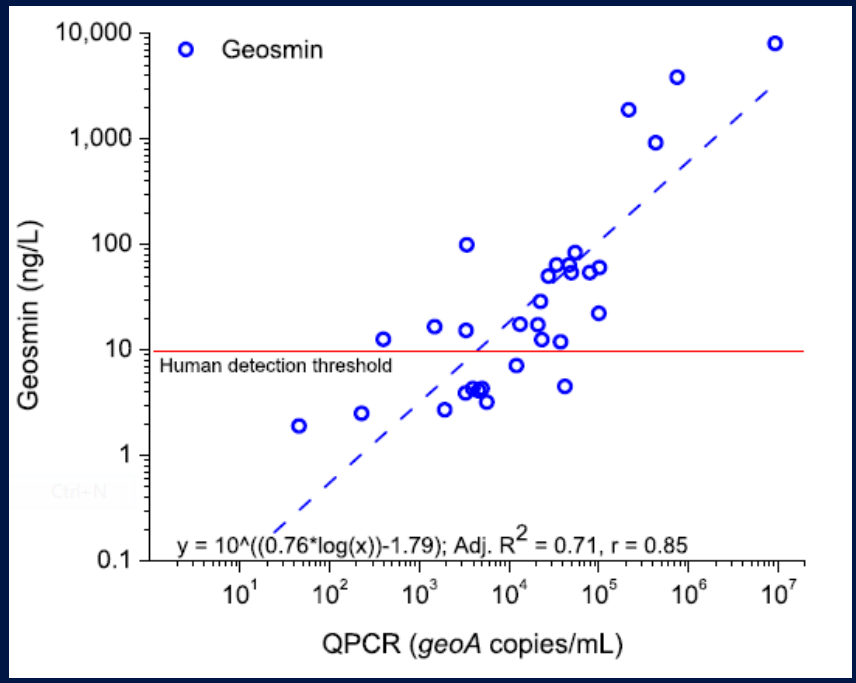


USGS science for a changing world

Graham and others, in preparation

Genetic Data Improve Understanding of the Occurrence of Cyanobacteria and Associated Compounds





USGS science for a changing world

Otten et al., 2016, Applied and Environmental Microbiology


Emerging technologies allow integrated studies ranging from cells to satellites
USGS
USGS 391259097001800 MILFORD LK NR WAKEFIELD, KS
Phycocyanins (cyanobacteria), water, in situ fluorescence, excitation at 590 +-15 nm, emission at 685 +-20 nm, relative fluorescence units (RFU)
70
60
50
40
30
20
10
0
Jul 11 2016
Jul 12 2016
Jul 13 2016
Jul 14 2016
Jul 15 2016
Jul 16 2016
Jul 17 2016
Jul 18 2016
---- Provisional Data Subject to Revision ----
USGS
6
ECOMAPPER

Aerial- and Ground-Based Cameras Show Potential as Early Warning Indicators

Ohio River

Courtesy of E. Emory

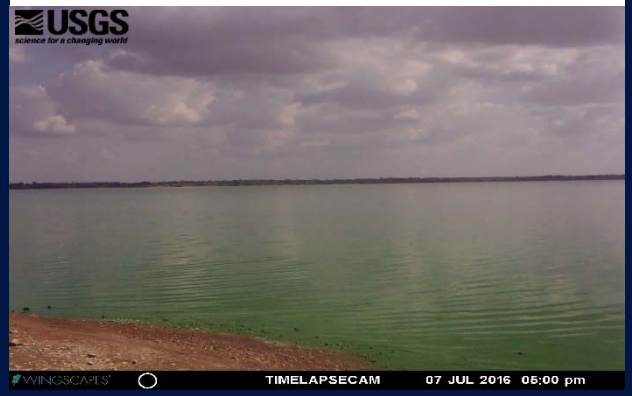
Courtesy of C. Smith

Willow Creek Reservoir, OR

USGS
science for a changing world

Time-Lapse Cameras Capture Temporal Variability at Sites of Interest

July 7, 2016 at 5:00 pm



July 7, 2016 at 6:00 pm

July 20, 2016 at 3:54 pm

July 20, 2016 4:09 pm

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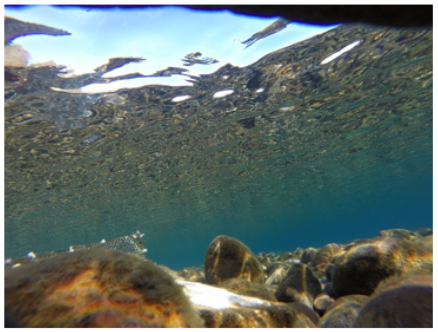
science for a changing world

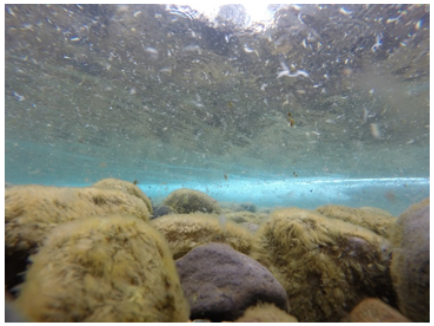
Underwater Cameras Capture Periphyton Growth at Locations that Are Otherwise Difficult to Sample

Nov 14, 2015

Dec 19, 2015



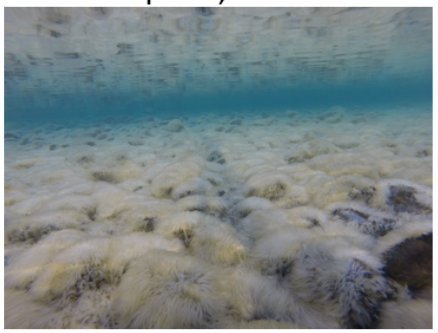
Jan 5, 2016



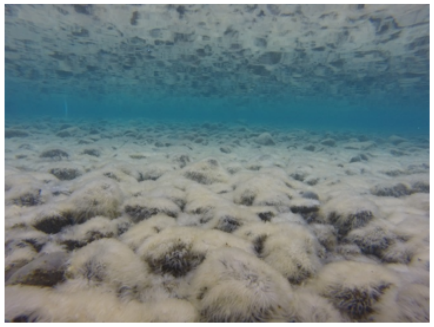
Feb 3, 2016

March 11, 2016

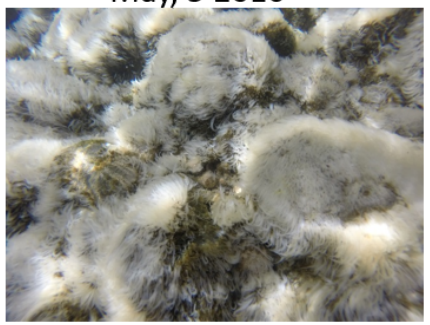
April 1, 2016



Apr, 28, 2016



May, 5 2016



May, 29 2016

June 9, 2016

June 19, 2016

USGS science for a changing world

Courtesy of R. Naranjo
"Whiskey is for drinking, peri is for phyton"

Water-Quality Sensors Show Promise as Early Warning Tools

ENVIRONMENTAL ISSUES | WATERTECH ENEWS

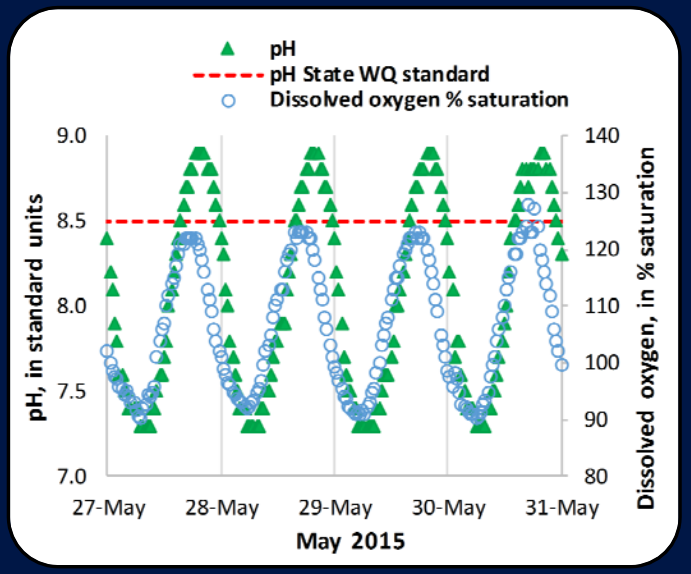
STUDY SHOWS HOW ALGAL BLOOMS CAN BE RAPIDLY PREDICTED

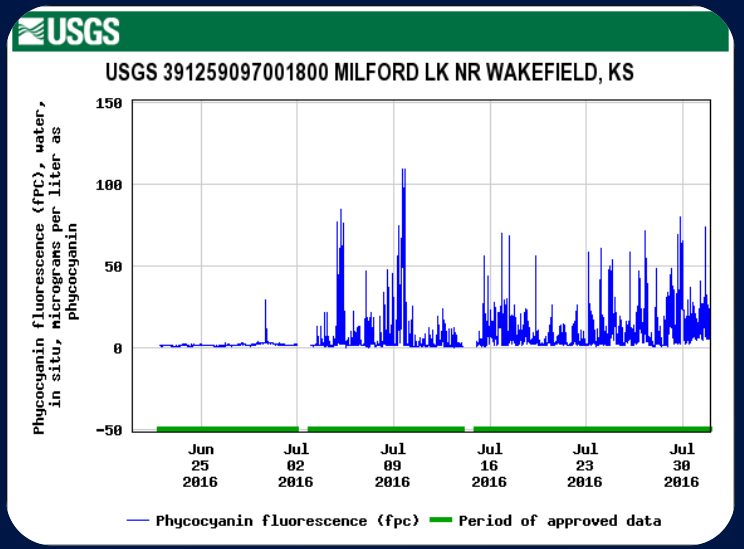
After collecting weekly to monthly data for two recreational seasons, the scientists identified factors that could be used to predict microcystin concentrations at a variety of freshwater sites.

https://waterwatch.usgs.gov/wqwatch

Diurnal or Noisy Patterns in Dissolved Oxygen, pH and Algal Fluorescence May Be Indicative of Potentially Harmful Algal Blooms

Courtesy of L. King





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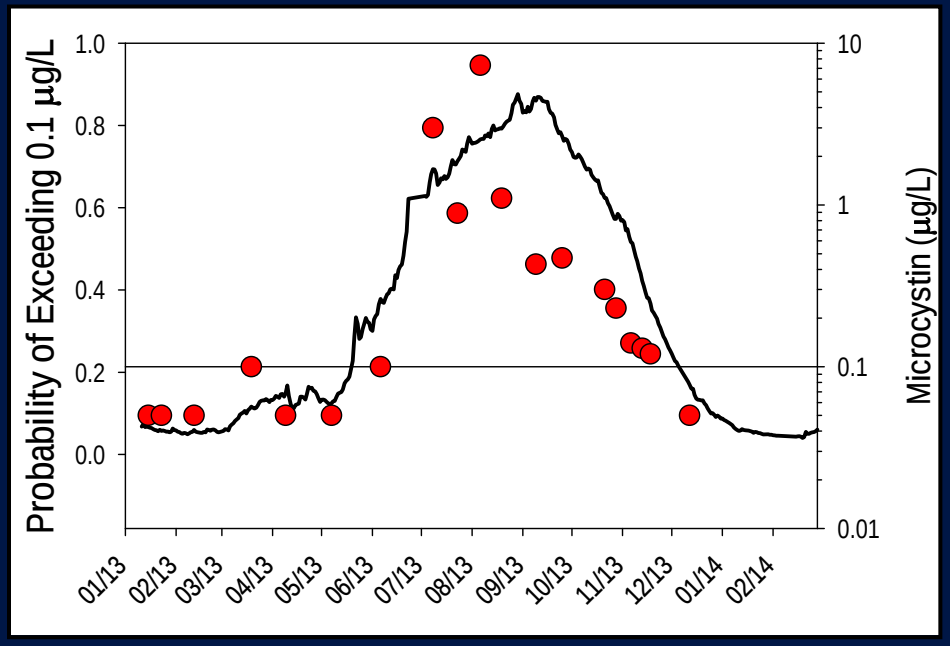
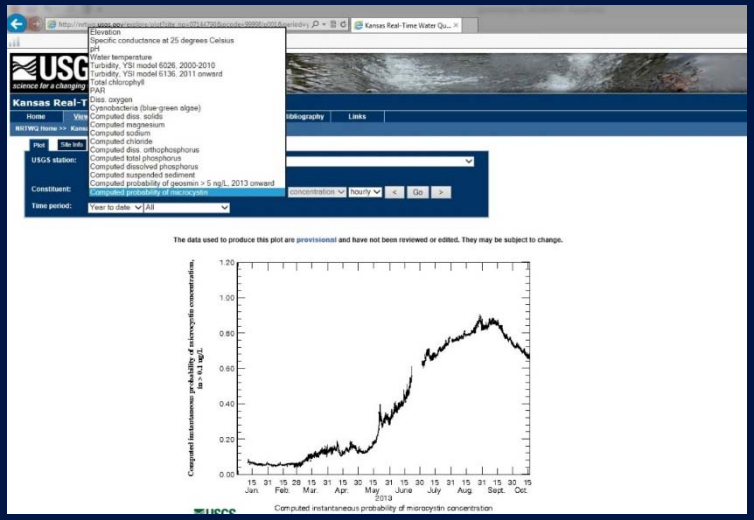
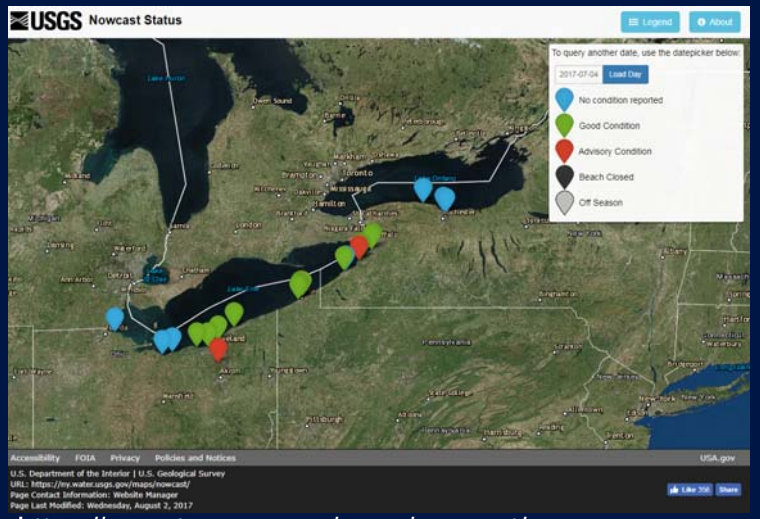
Continuous Water-Quality Monitors Can Be Used to Develop Models to Compute Probability of Cyanotoxin Occurrence in Real Time



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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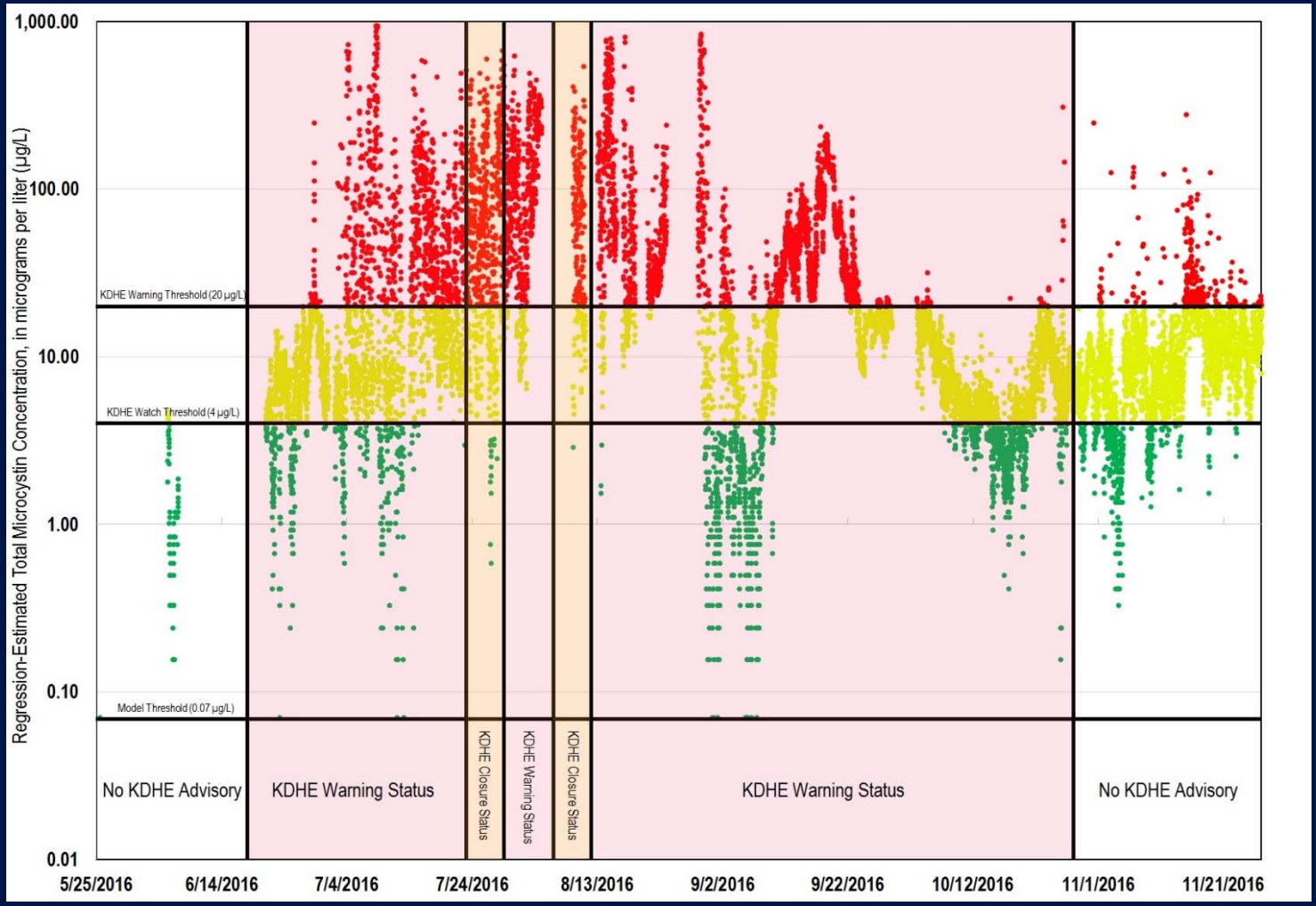
Continuous Water-Quality Monitors Can Be Used to Develop Models to Compute Cyanotoxin Concentrations in Real Time



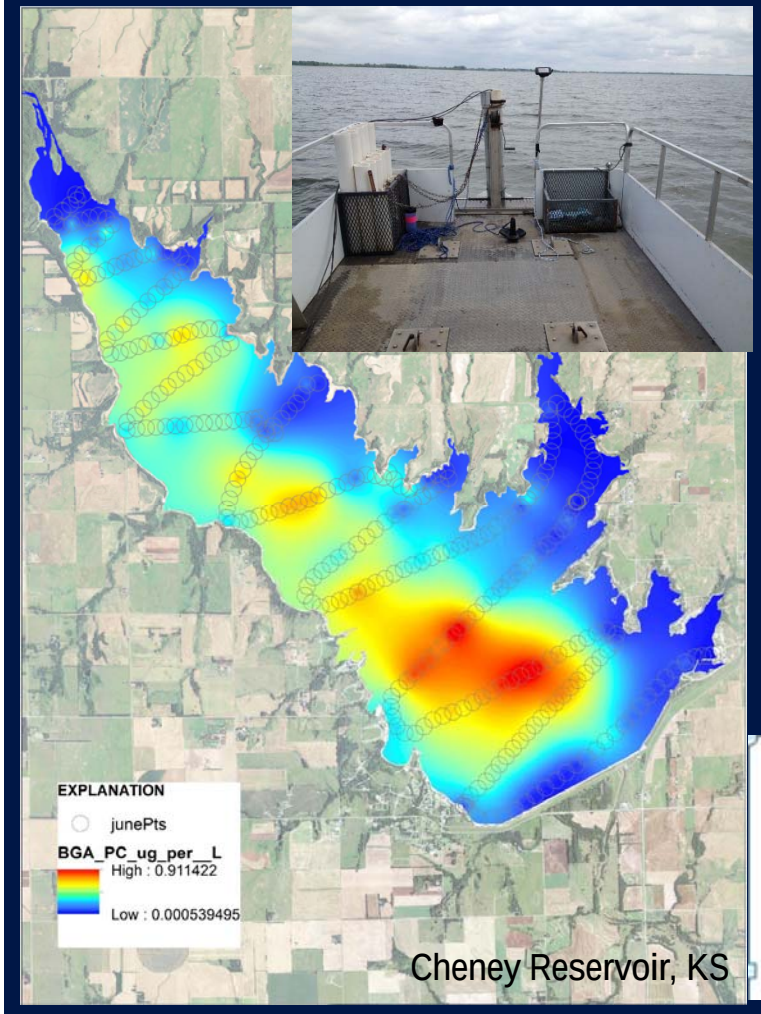
Milford Lake at Wakefield, Data for Explanatory Variable (phycocyanin RFU)
Can Be Found At:
https://waterdata.usgs.gov/nwis/uv?site_no=391259097001800
Foster and others, in review

USGS science for a changing world

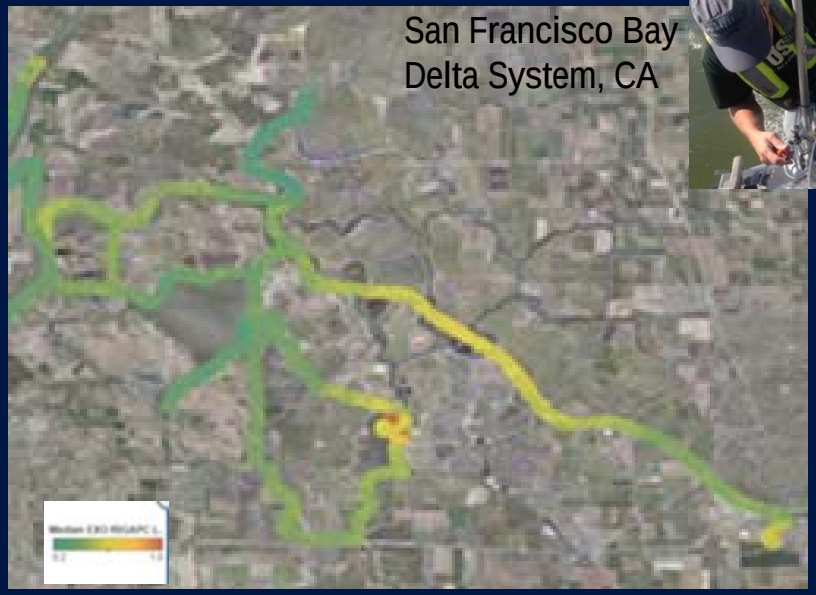
Kansas Department of Health and Environment

January 2016

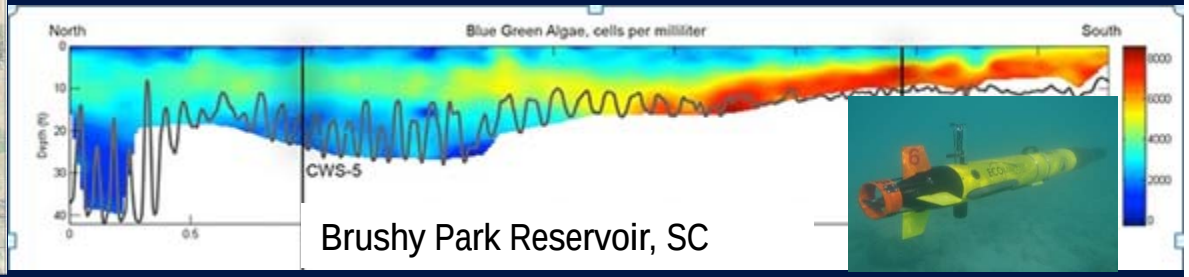
New Sensor Technologies Allow New Applications, Such as High Resolution Spatial Data Collection



Cheney Reservoir, KS



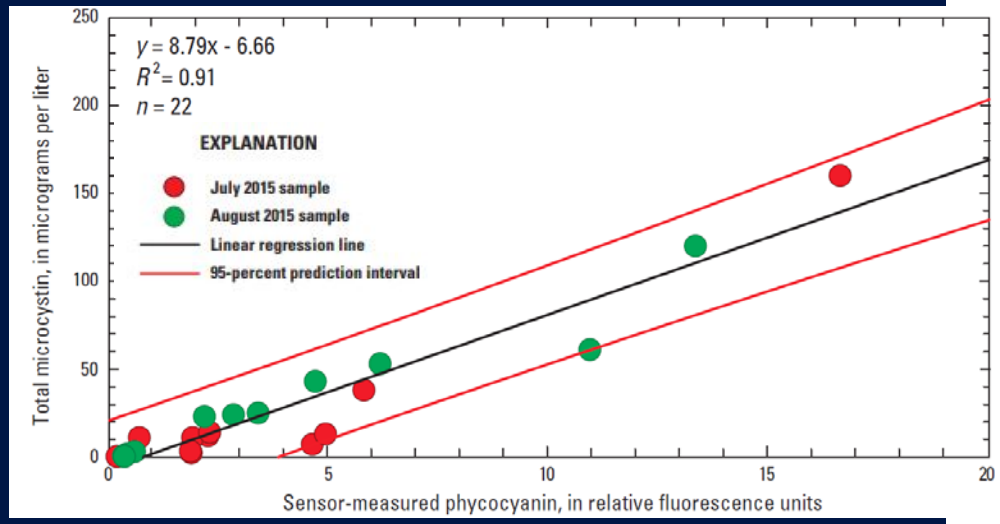
San Francisco Bay Delta System, CA

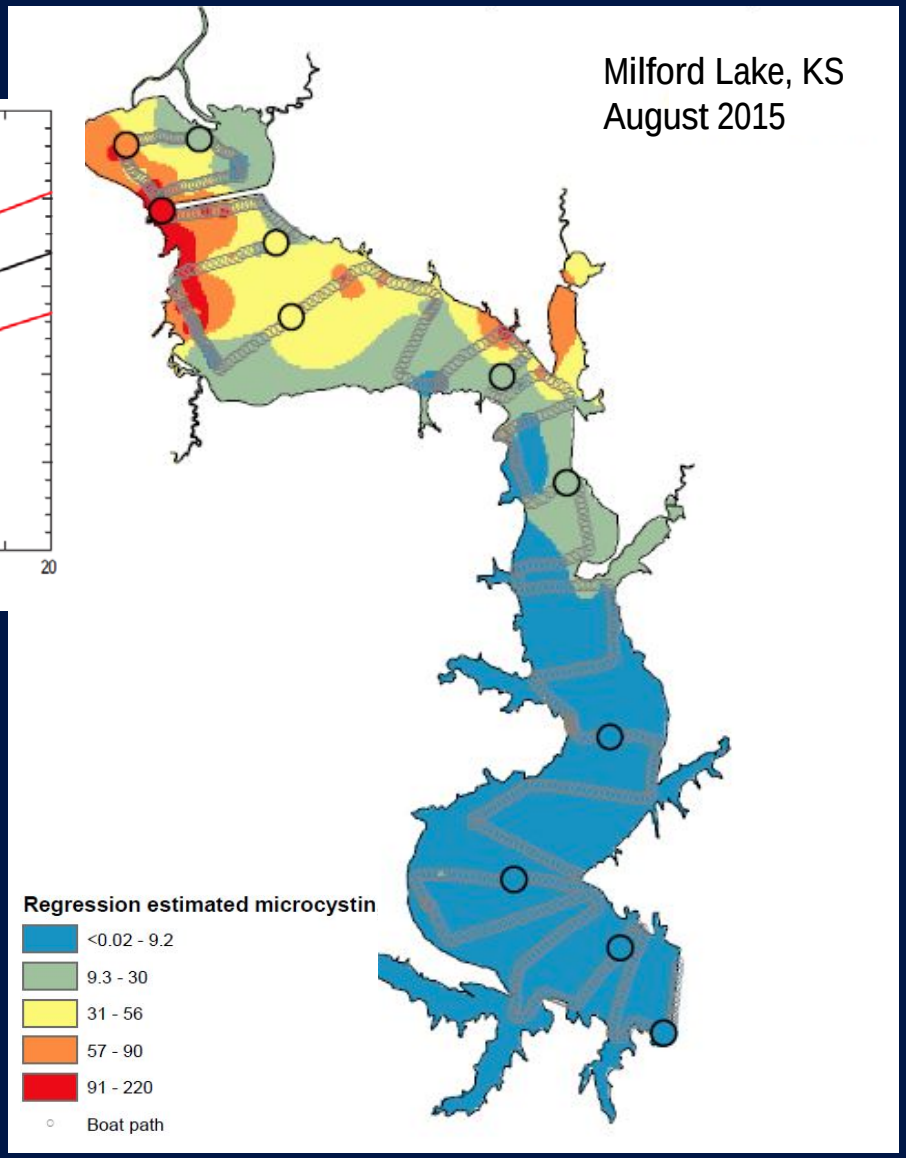


Brushy Park Reservoir, SC

Foster, KSWSC
Bergamaschi, CAWSC
Journey, SAWSC

Surrogate Relations Can Be Developed to Map Spatial Variability in Cyanotoxin Concentrations





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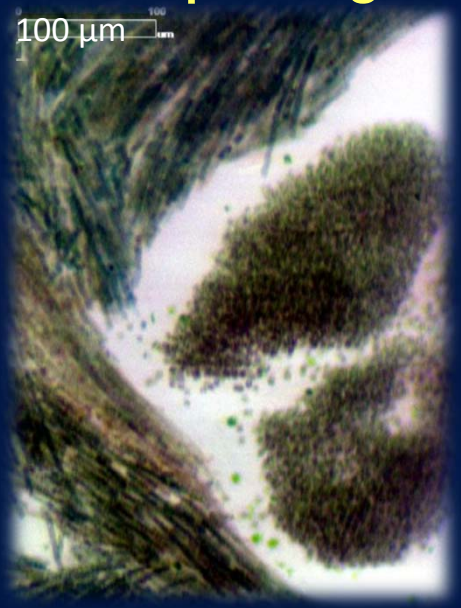
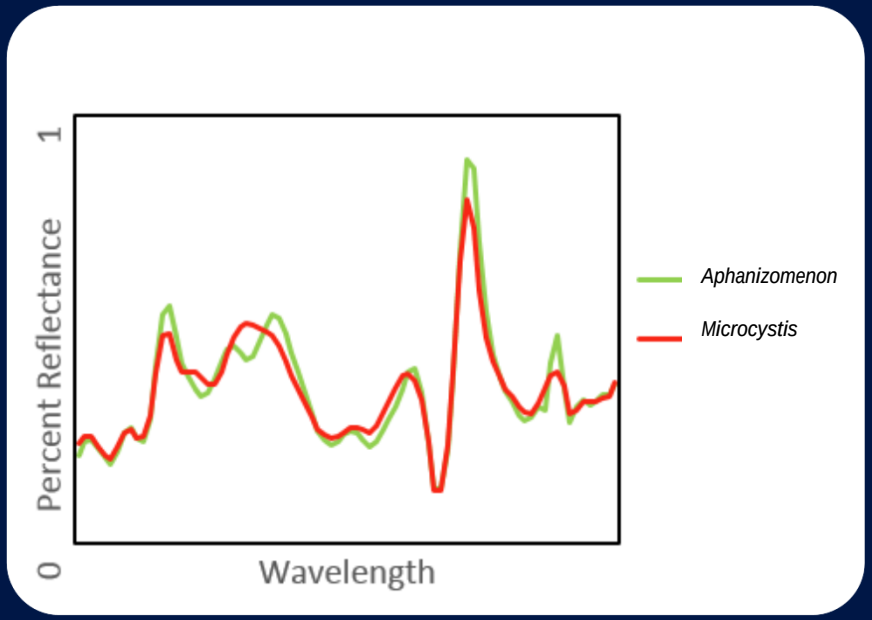
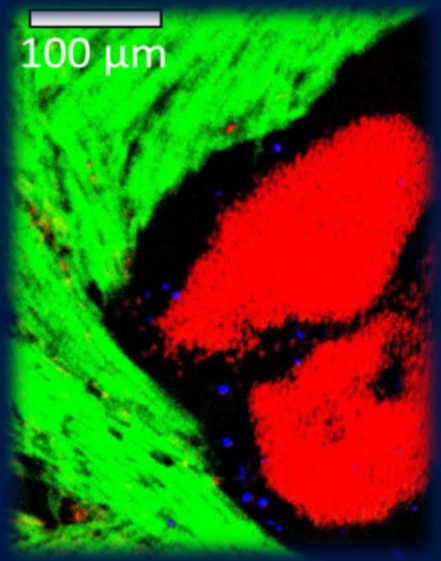
Kansas Department of Health and Environment

Foster and others, 2016
https://pubs.er.usgs.gov/publication/sir20165168

Hyperspectral Microscopy Can Potentially Be Used to Identify Unique Signatures of Harmful Algal Bloom Forming Taxa







USGS science for a changing world

PML Physical Measurement Laboratory

NIST National Institute of Standards and Technology U.S. Department of Commerce

Courtesy of T. Slonecker and N. Simon, USGS

Hyperspectral Microscopy Can Potentially Be Used to Identify Unique Signatures of Harmful Algal Bloom Forming Taxa

USGS science for a changing world

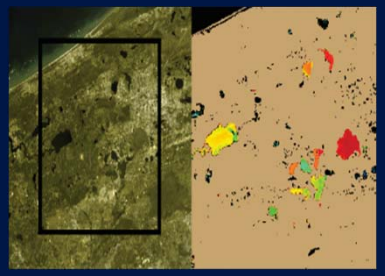
PML

NIST National Institute of Standards and Technology U.S. Department of Commerce

Courtesy of T. Slonecker and N. Simon, USGS

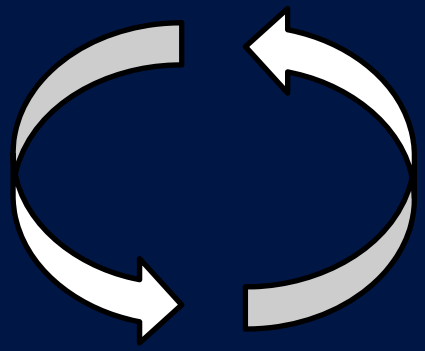
Tools to Utilize Satellites for Inland HAB Monitoring are Being Developed

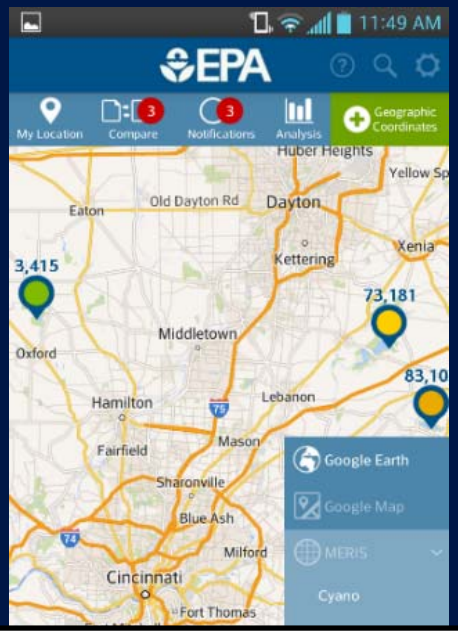
Cyanobacteria Assessment Network (CyAN) Project

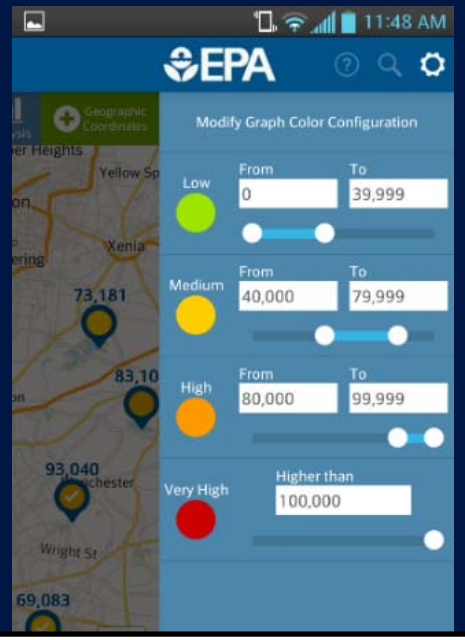


Remote Sensing

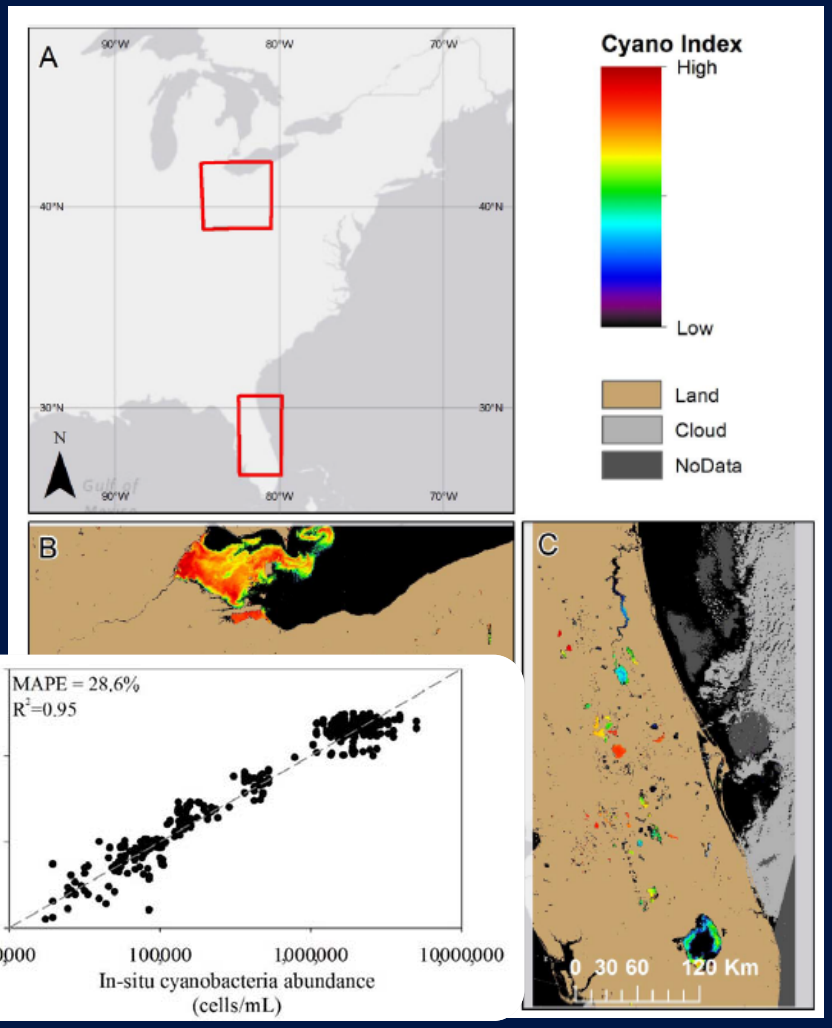
Field Data

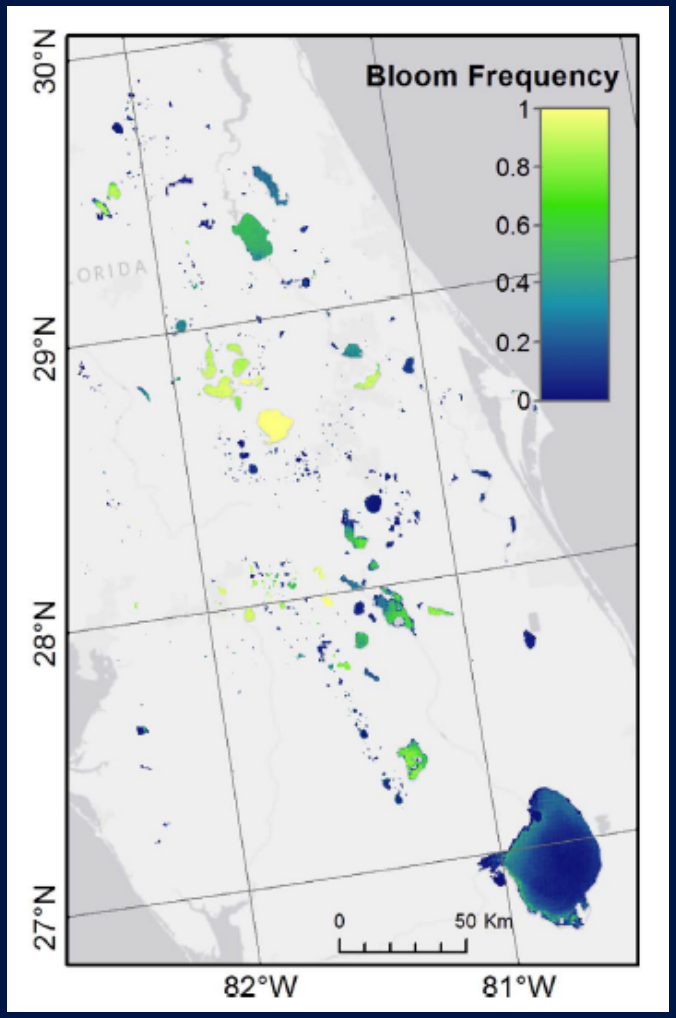






Satellite Imagery May Capture Spatial and Temporal Variability Across a Regional Scale





USGS science for a changing world

CYAN

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

Integrated Approaches are Essential to Understand, Quantify, and Mitigate Harmful Algal Blooms

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

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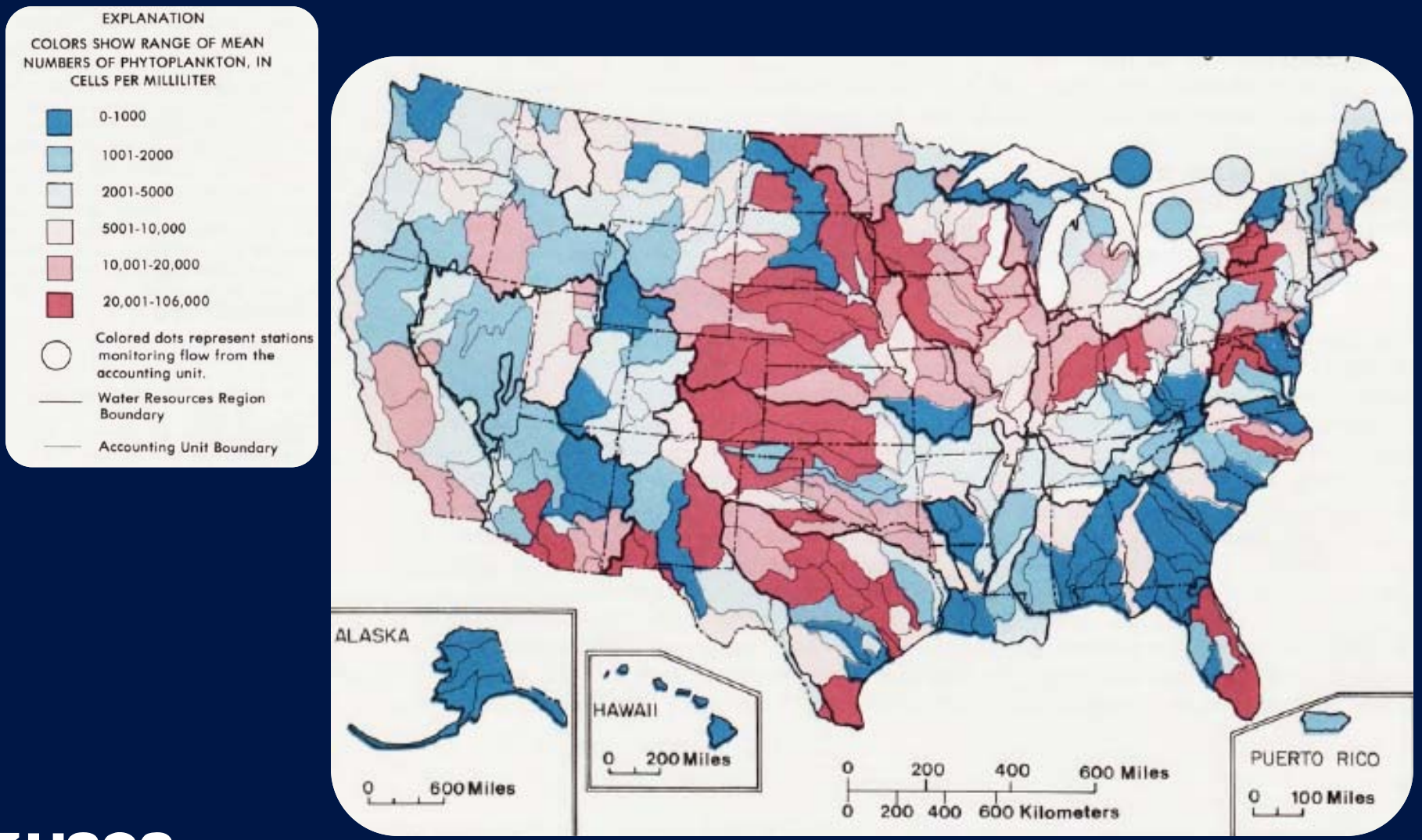
Legacy Data Are Essential to Understanding Status and Trends



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USGS WY1975 NASQAN Data, *n*=345
After Briggs and Ficke, 1977

USGS:

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

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

https://www2.usgs.gov/envirohealth

jlgraham@usgs.gov

kloftin@usgs.gov

gfoster@usgs.gov

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EPA United States Environmental Protection Agency

Recent intensification of harmful cyanobacteria blooms in Midwestern reservoirs

Environmental Protection Agency
Nate Smucker
Jake Beaulieu
Chris Nietch
U.S. Army Corps of Engineers
Jade Young

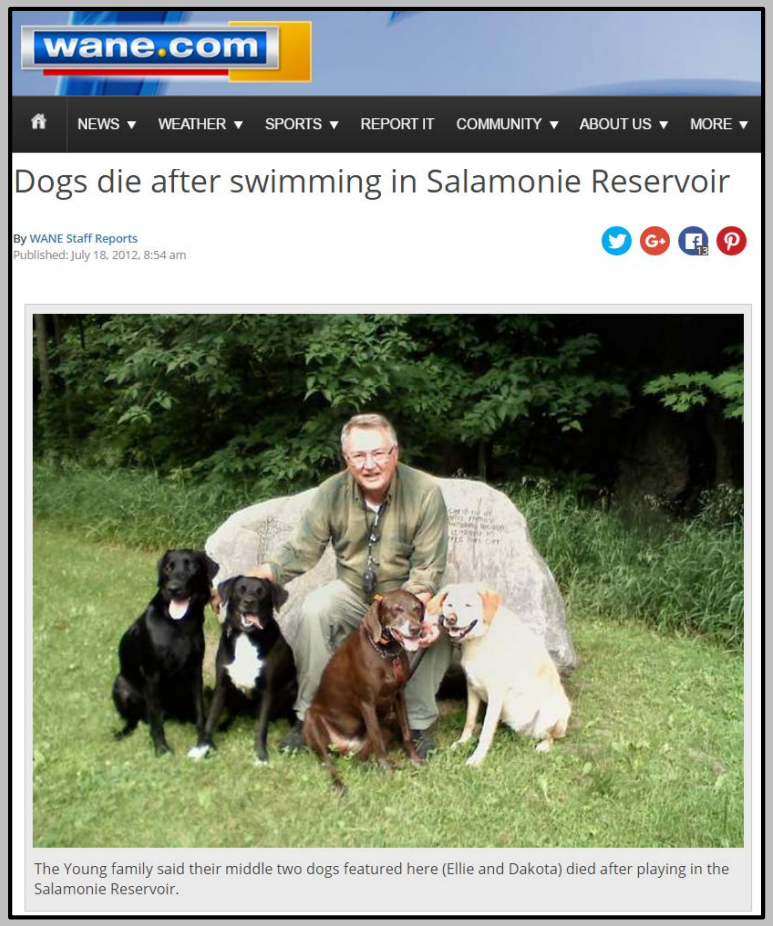
The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

Office of Research and Development
National Exposure Research Laboratory
Systems Ecology Division

May 8, 2018

smucker.nathan@epa.gov

Recent observations of cyanobacteria blooms and related issues in the region



Unknown if these incidents were new or getting worse? How common were they?

World Health Organization recommendations for recreational exposure

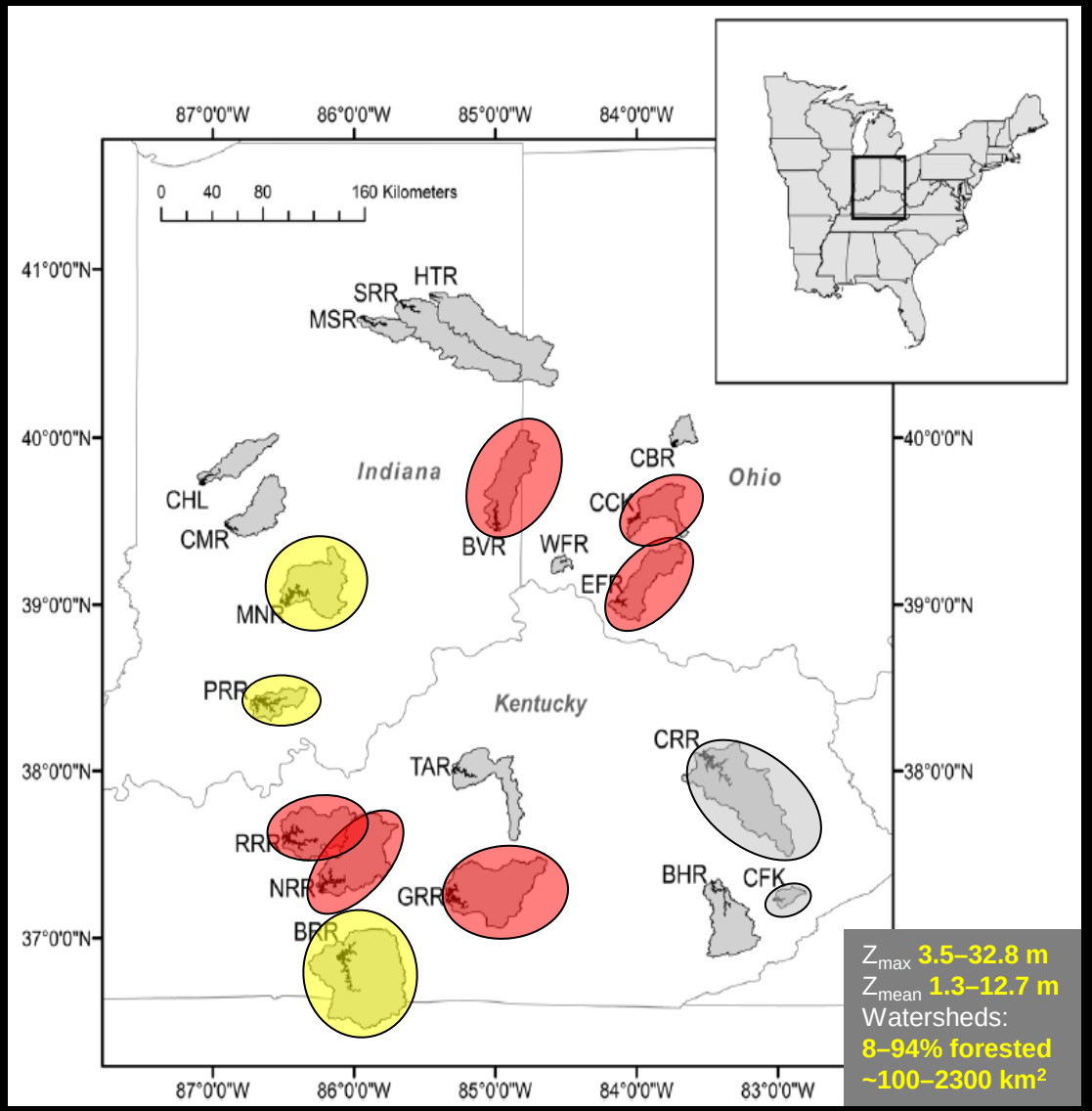
(https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations)

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	<10	<10
Moderate	20,000-100,000	10-20	10-50
High	100,000-10,000,000	20-2,000	50-5,000
Very High	> 10,000,000	>2,000	>5,000

U.S. Army Corps of Engineers monitoring program (Louisville District)

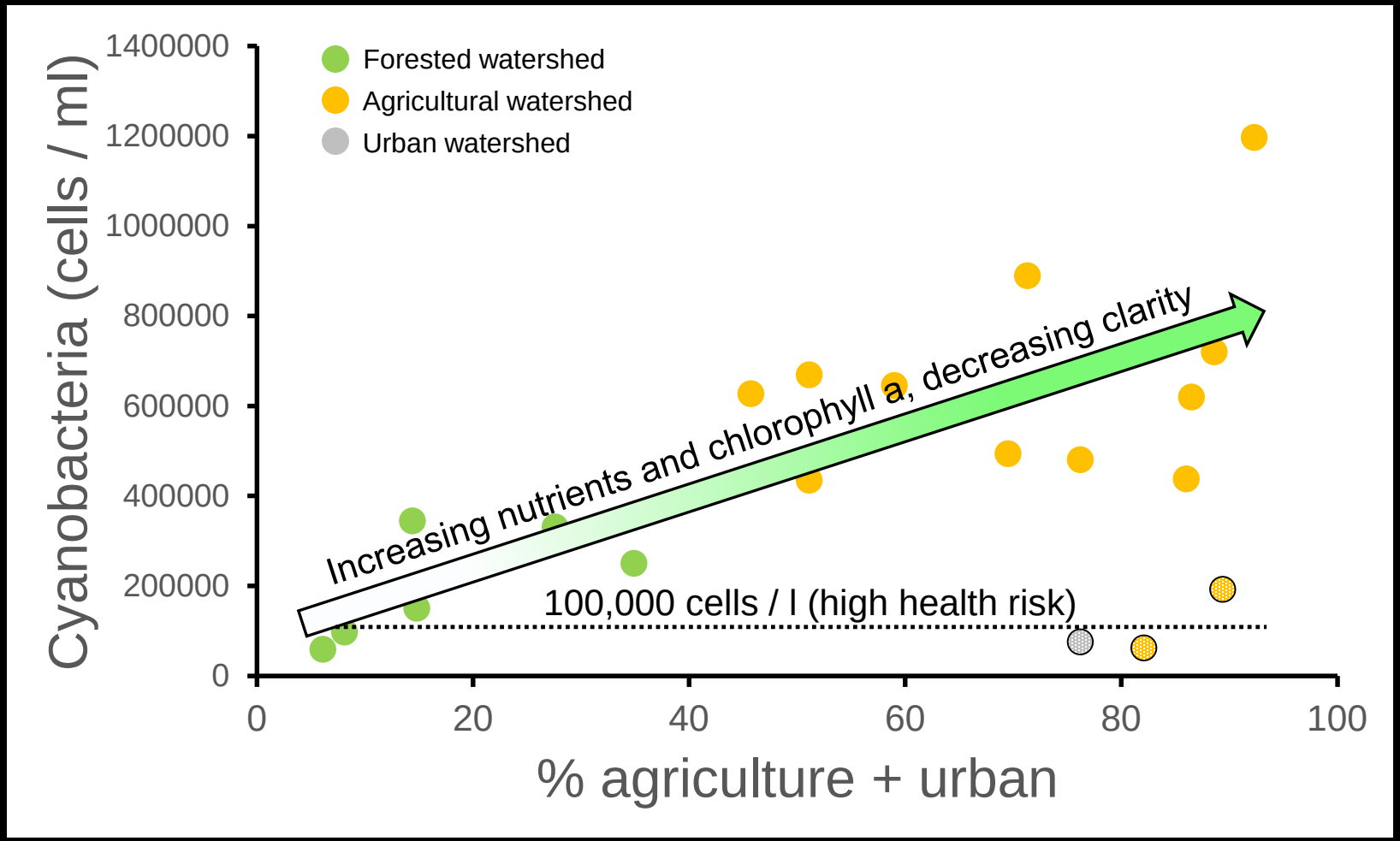
- 20 reservoirs (built 1953-1983)
  - **All flood control, but also recreation, fish and wildlife, to provide high water quality, and 11 for drinking water**
  - **24 million visits / year**
- Monitoring since 1988
  - Deepest point and frequently a few other stations
  - Multiple depths sampled
  - Cyanobacteria, DO, and temperature
  - Nutrients since 1999

Summer most consistent and we focused on yearly maximums + monthly means of cyanobacteria



Drinking water sources circled (gray = low, yellow = moderate, and red = high health risk [based on cell densities])

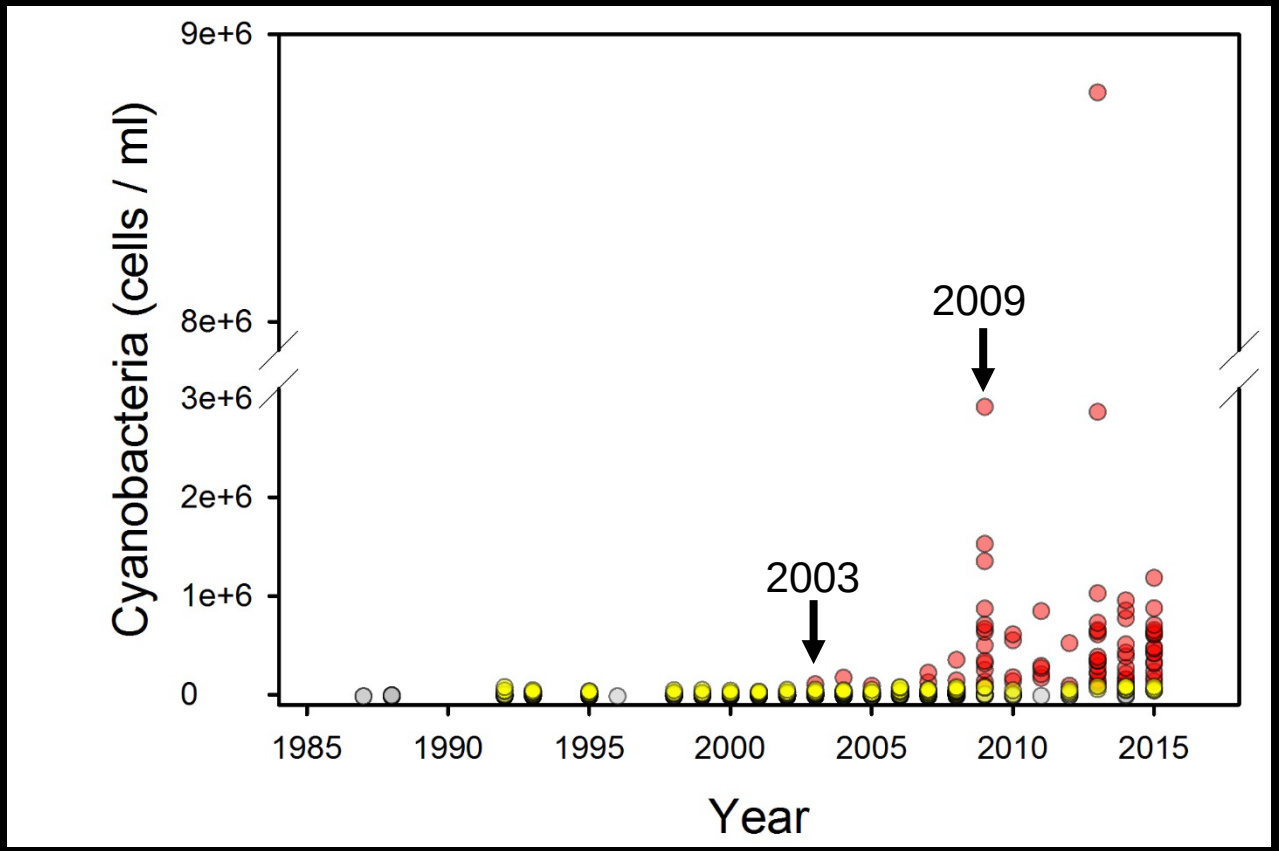
2015 – increase in maximum cyanobacteria cell densities associated with less forest cover



62,000 → 1.2 million cells per liter ($R^2 = 0.62$)

High cell densities of cyanobacteria have not always been the case

More reservoirs experiencing conditions with moderate to high relative risk to human health in recent years



Summer maximum cell densities (*n* = 391)
(gray = low, yellow = moderate, and red = high health risk [based on cell densities])

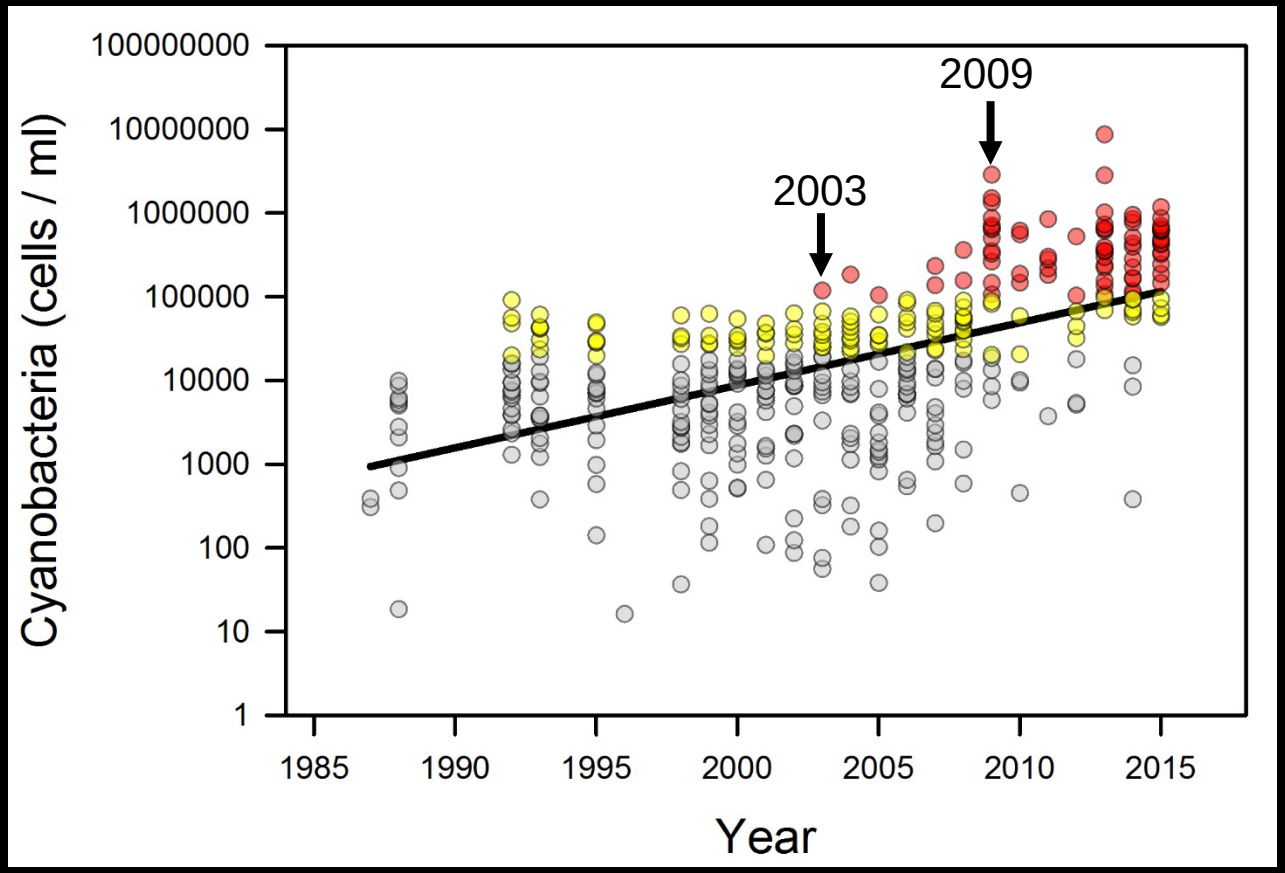
Most abundant taxa capable of toxins:

Pseudanabaena
Cylindrospermopsis
Aphanocapsa
Planktothrix
Aphanizomenon
Microcystis
Anabaena

Hepatotoxins
Neurotoxins
Dermatoxins
Taste and odor

High cell densities of cyanobacteria have not always been the case

More reservoirs experiencing conditions with moderate to high relative risk to human health in recent years



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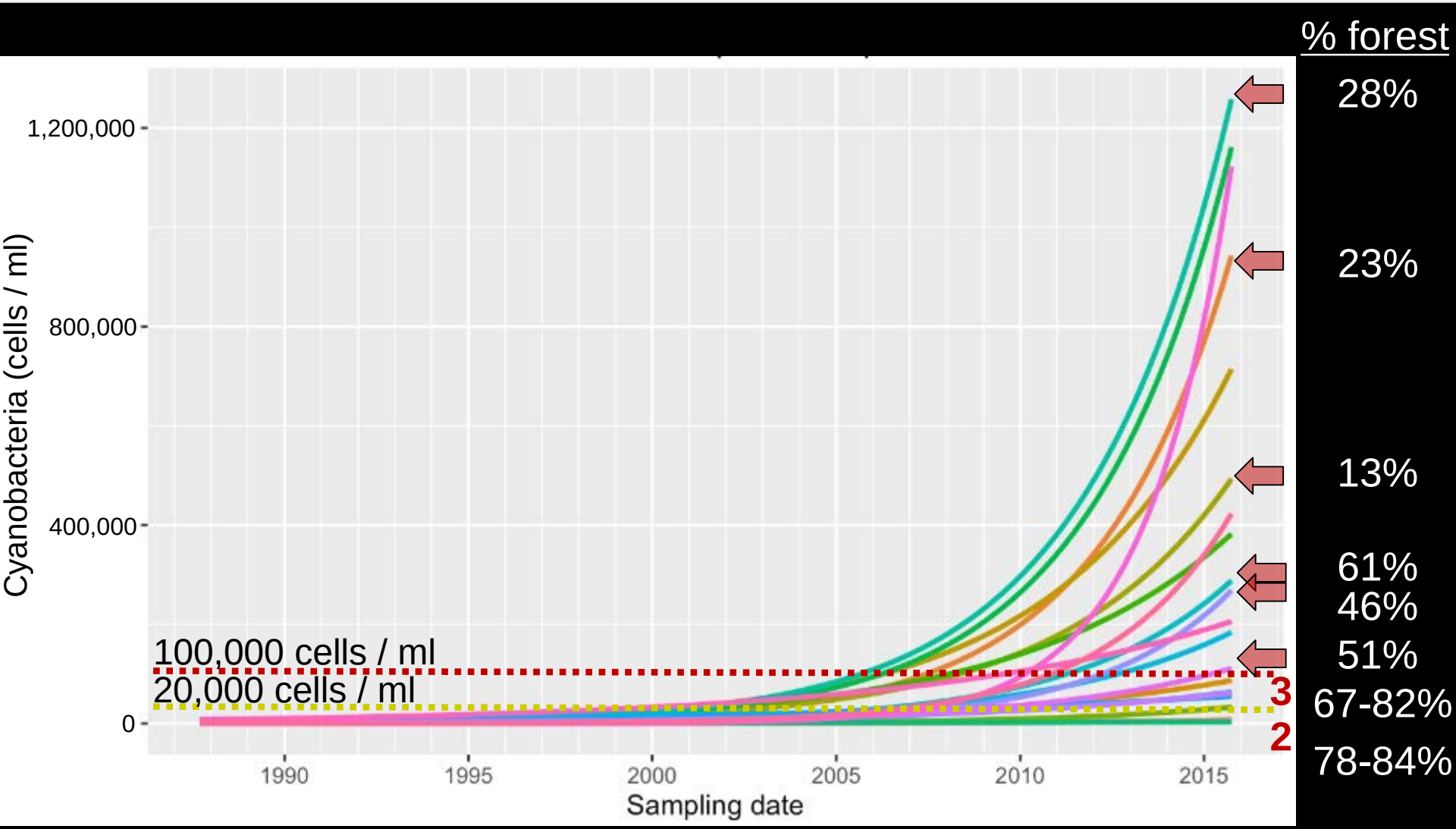
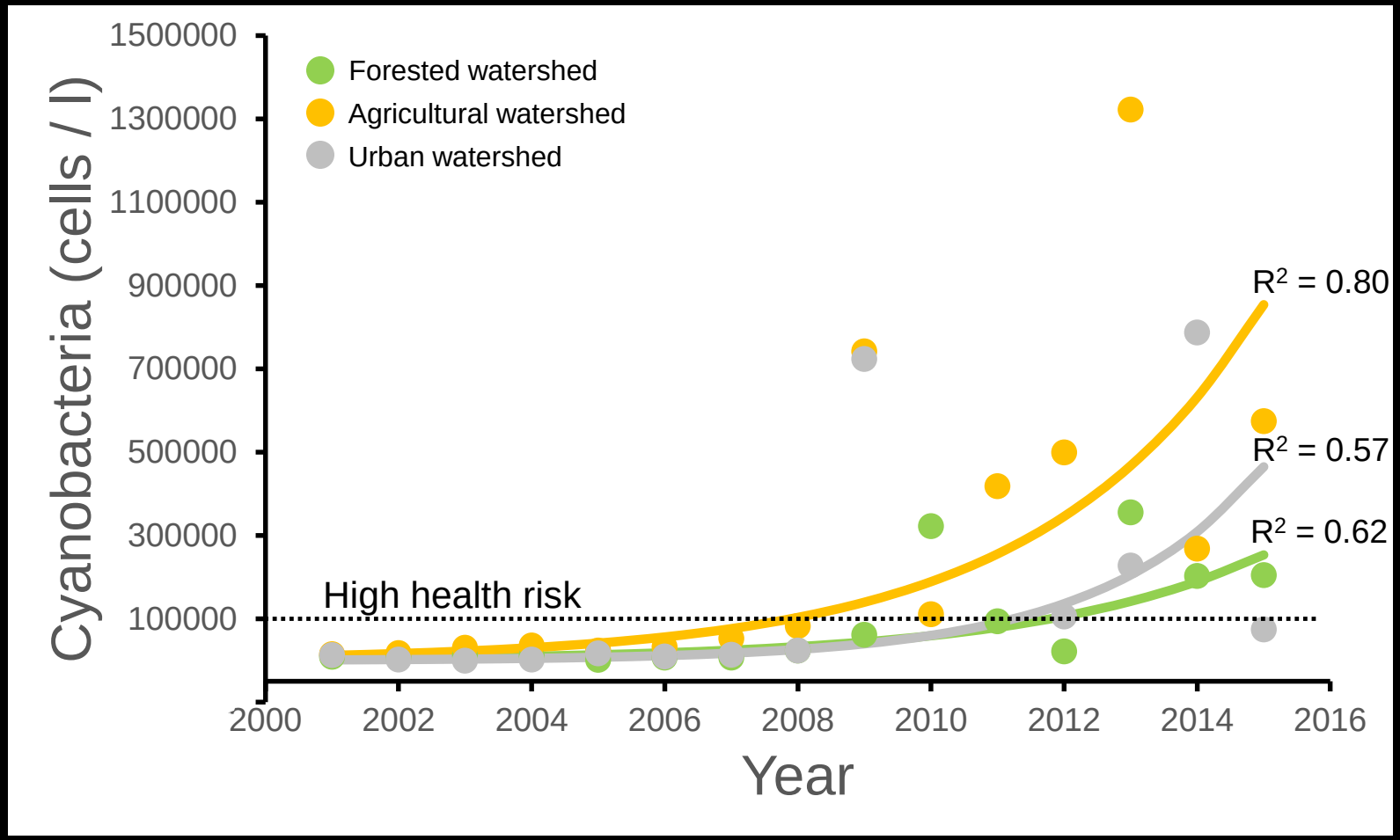
Hepatotoxins
Neurotoxins
Dermatoxins
Taste and odor

Statistical models showing general trends for each of the 20 reservoirs



Drinking water sources marked by red arrows and numbers

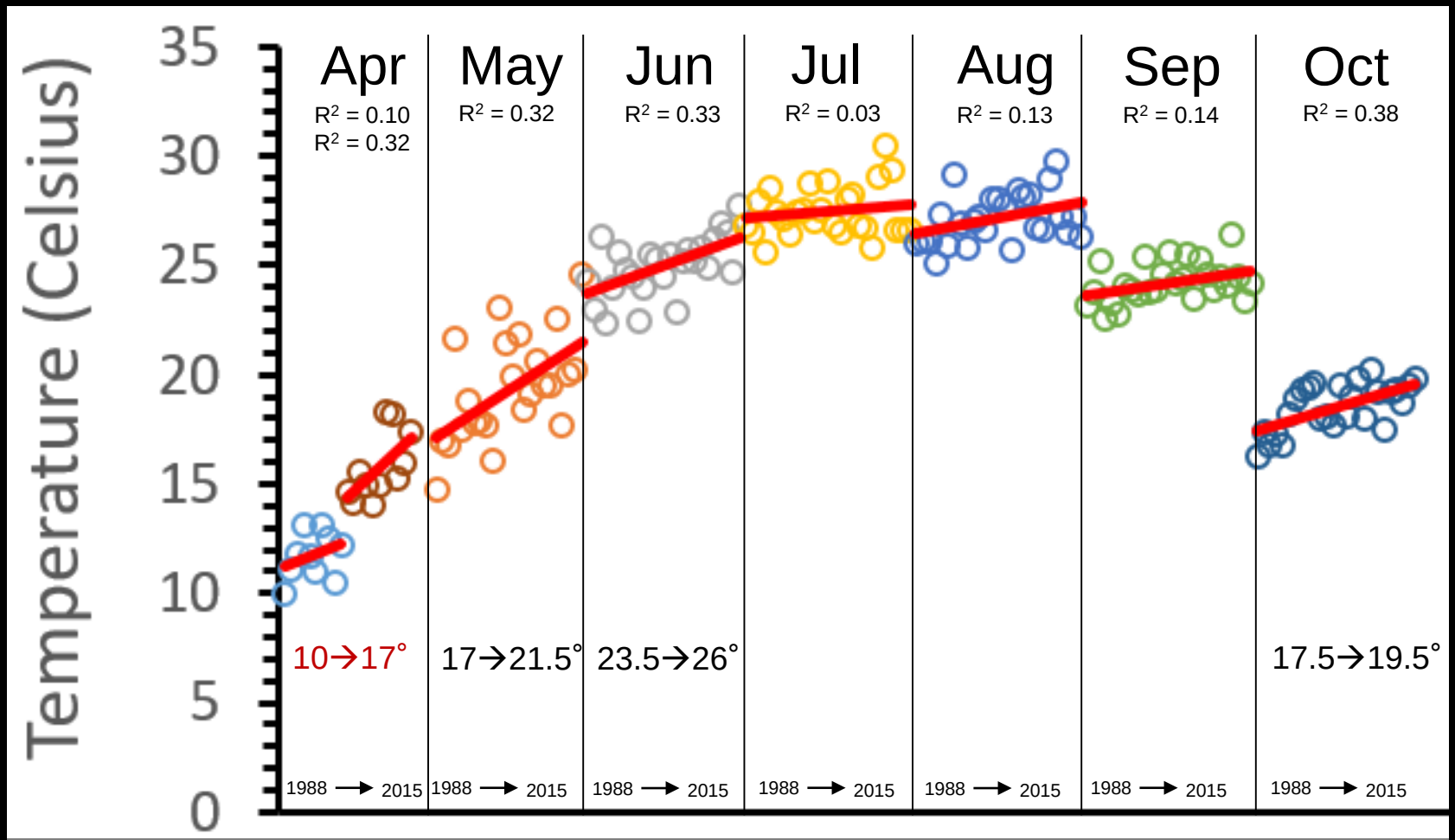
Models showing the general trends for reservoirs with forested, agricultural, and urban watersheds



Yearly averages of summer maximums

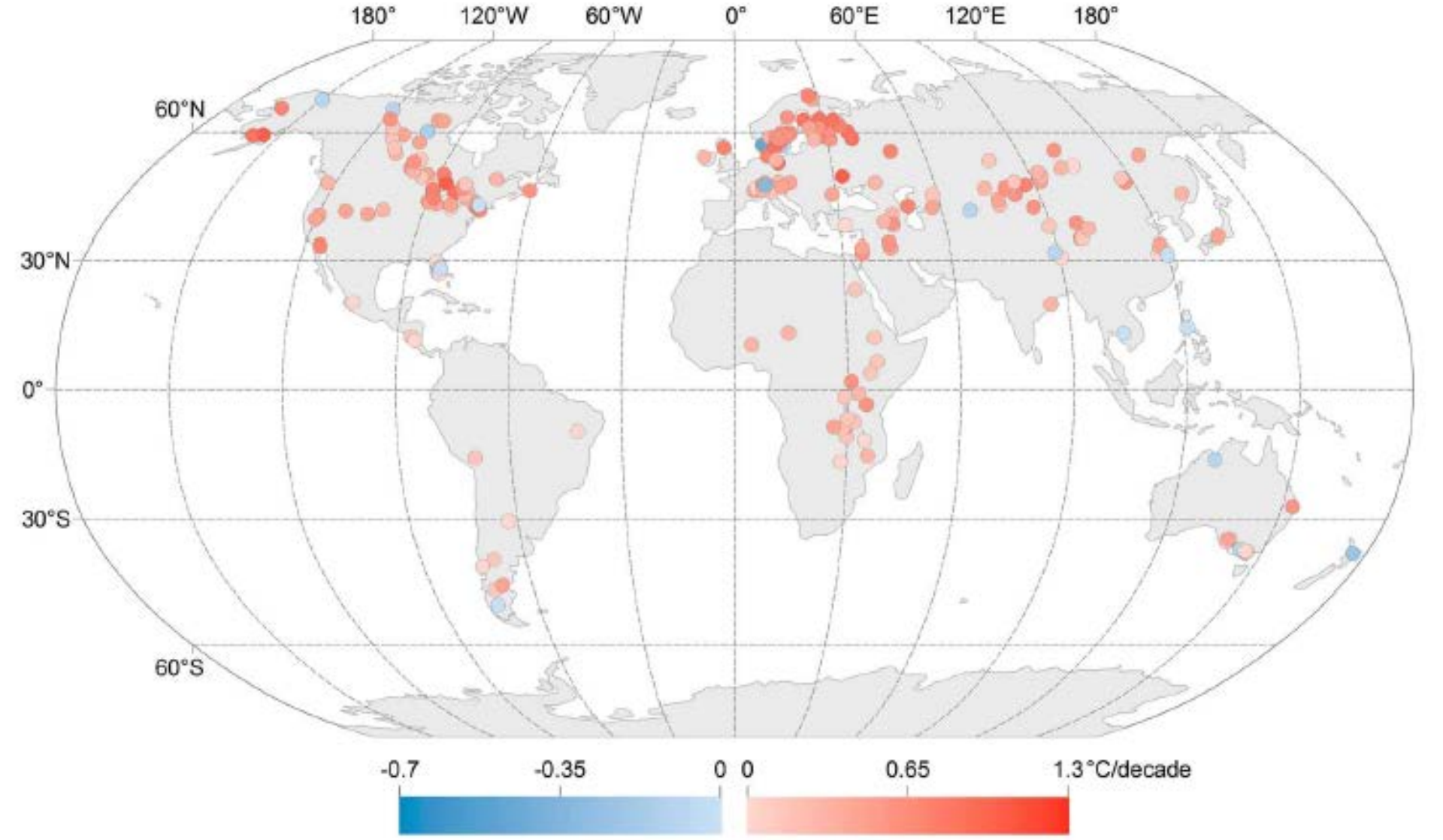
Surface water temperatures have gotten warmer in the Spring and Fall

Yearly means of all 20 reservoirs



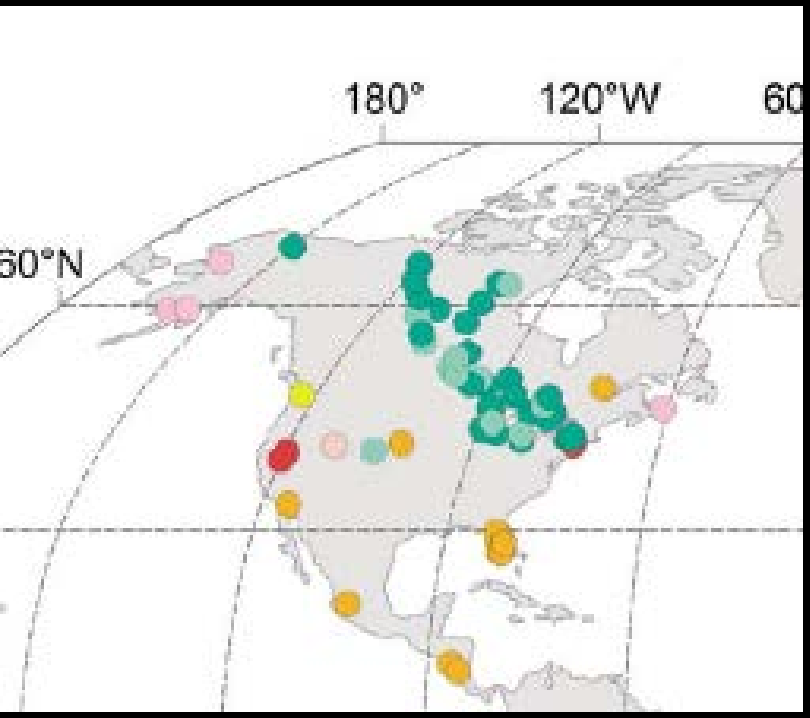
Earlier warming of surface waters associated with earlier increased and prolonged cyanobacteria dominance?

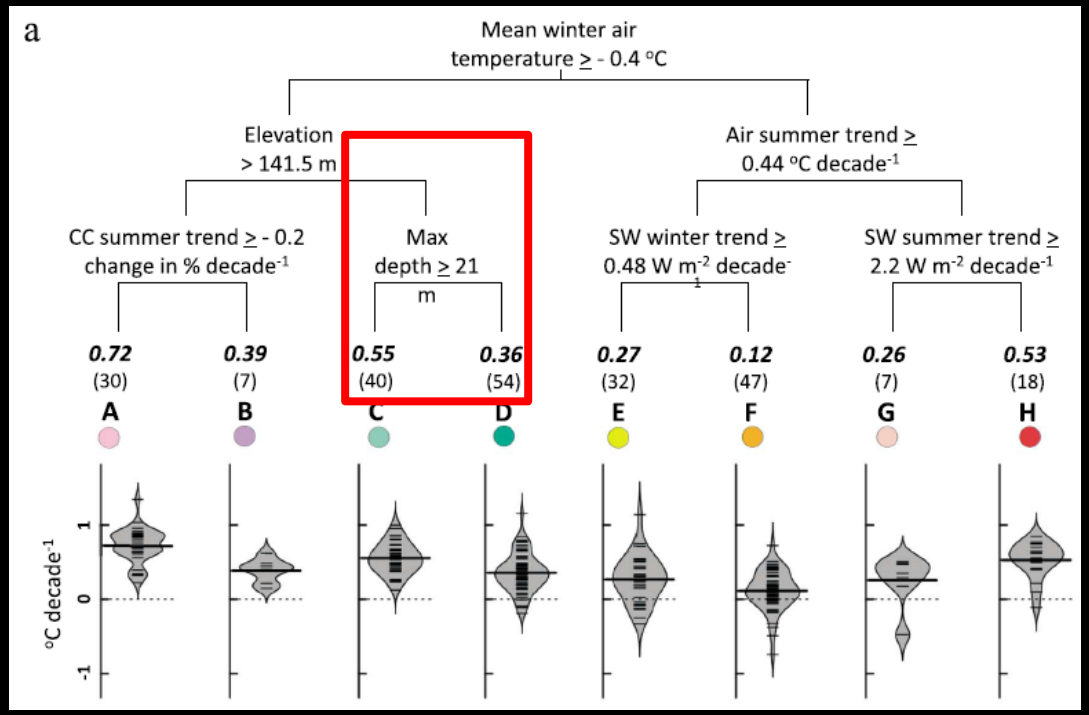
Global trend of warmer lake surface temperatures



O'Reilly et al. (2015) Rapid and highly variable warming of lake surface waters around the globe (Jul-Aug-Sep temperatures)

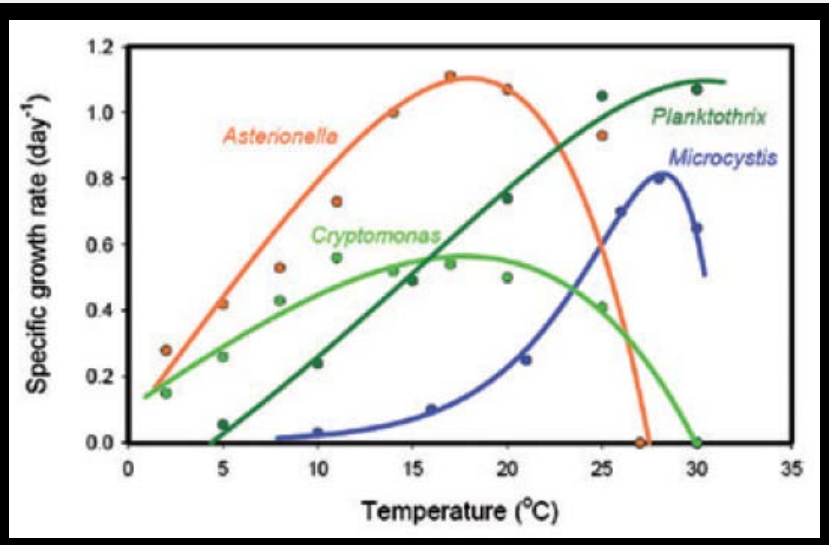
Regional trends of warmer lake surface temperatures

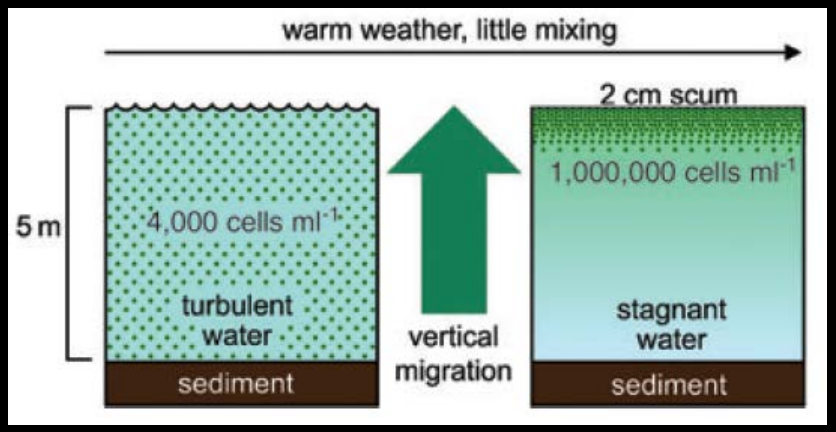


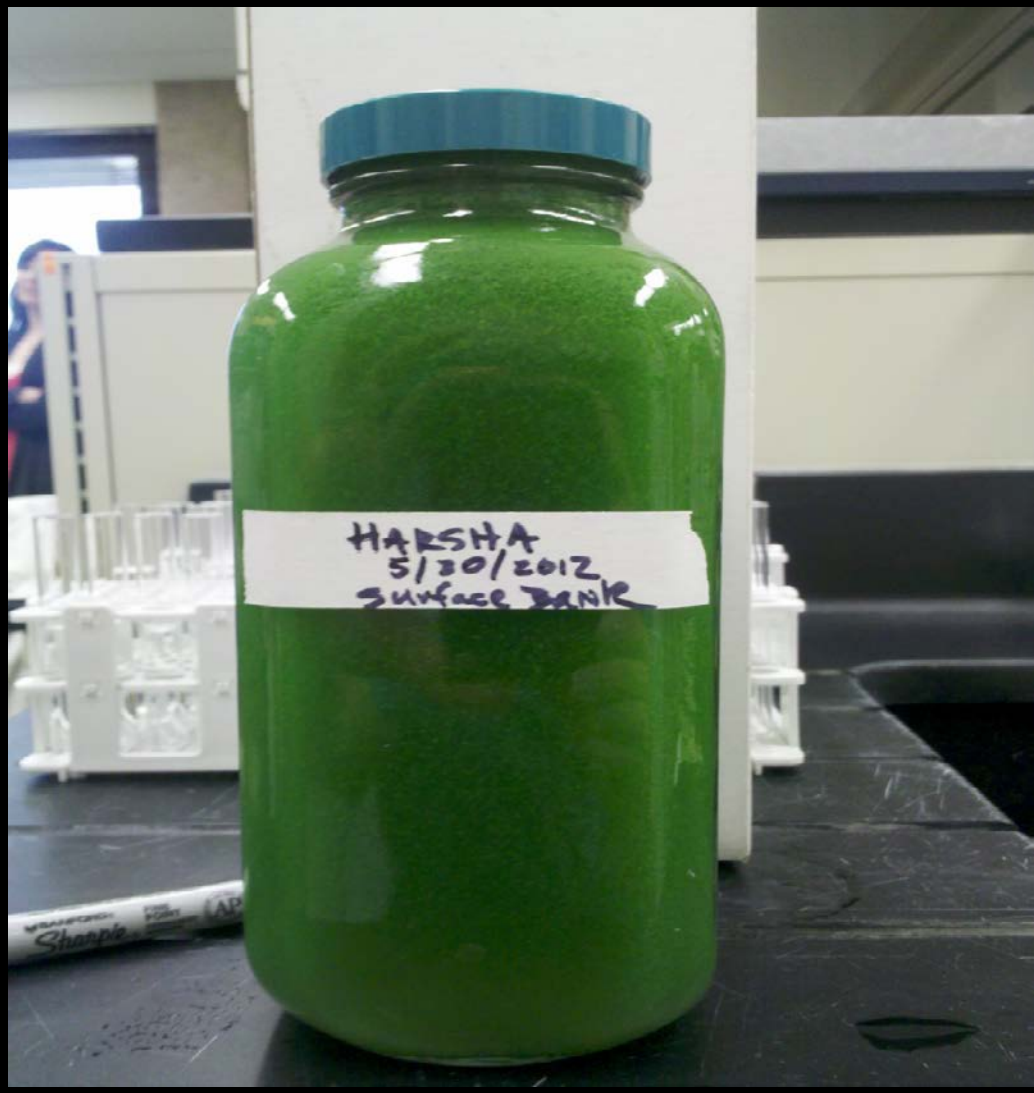


O'Reilly et al. (2015) Rapid and highly variable warming of lake surface waters around the globe (Jul-Aug-Sep temperatures)

Cyanobacteria like it warm

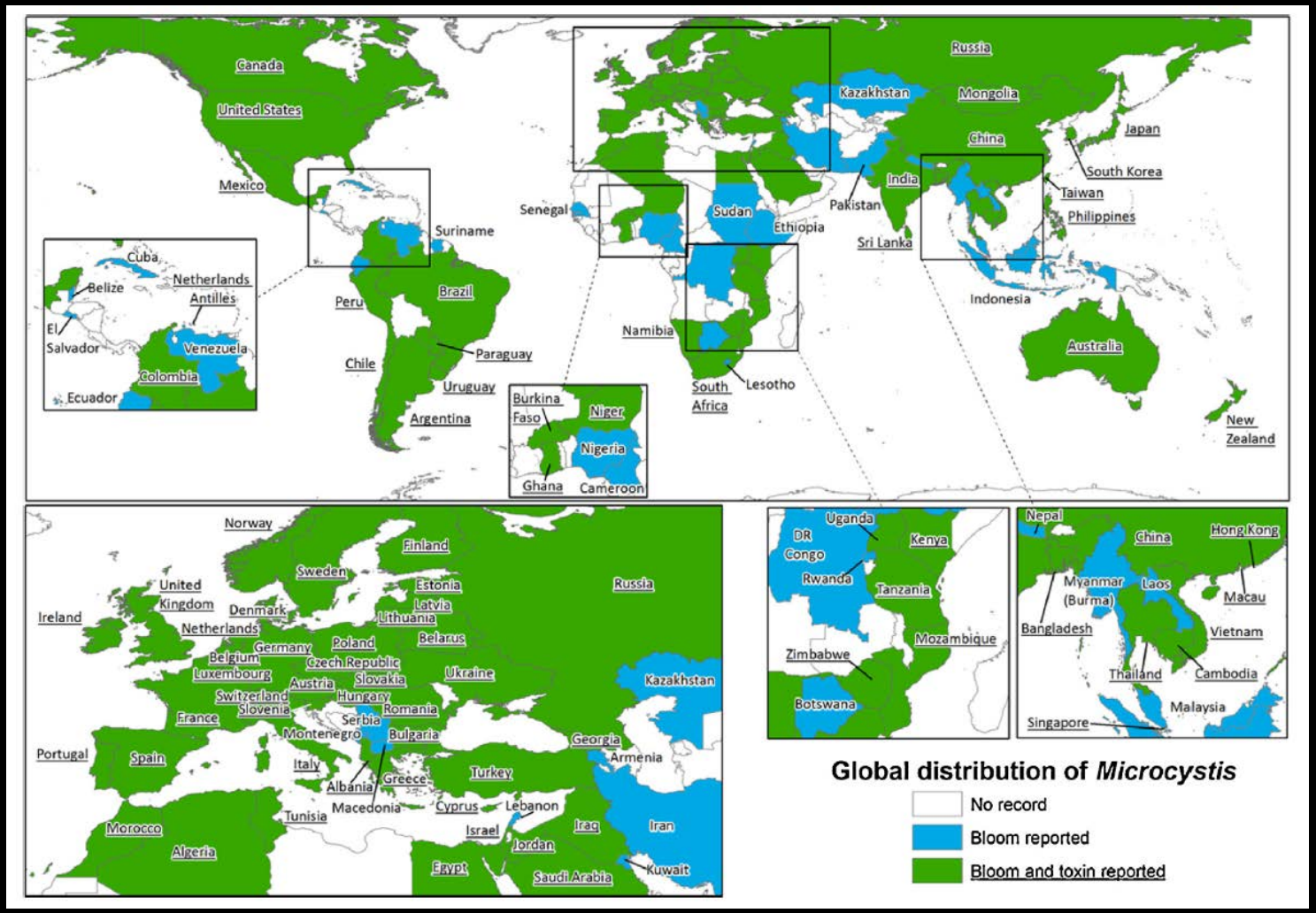






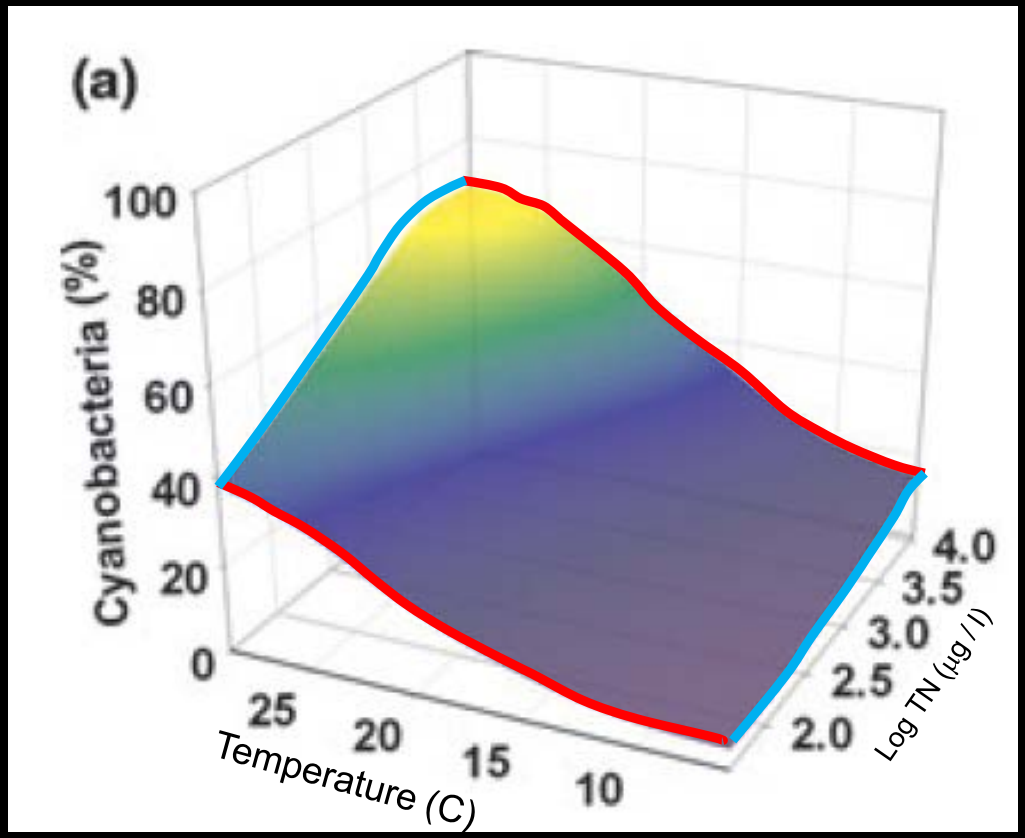
Paerl & Huisman (2009) Climate change: a catalyst for global expansion of harmful cyanobacterial blooms

Globally widespread observations of blooms (only Microcystis shown)



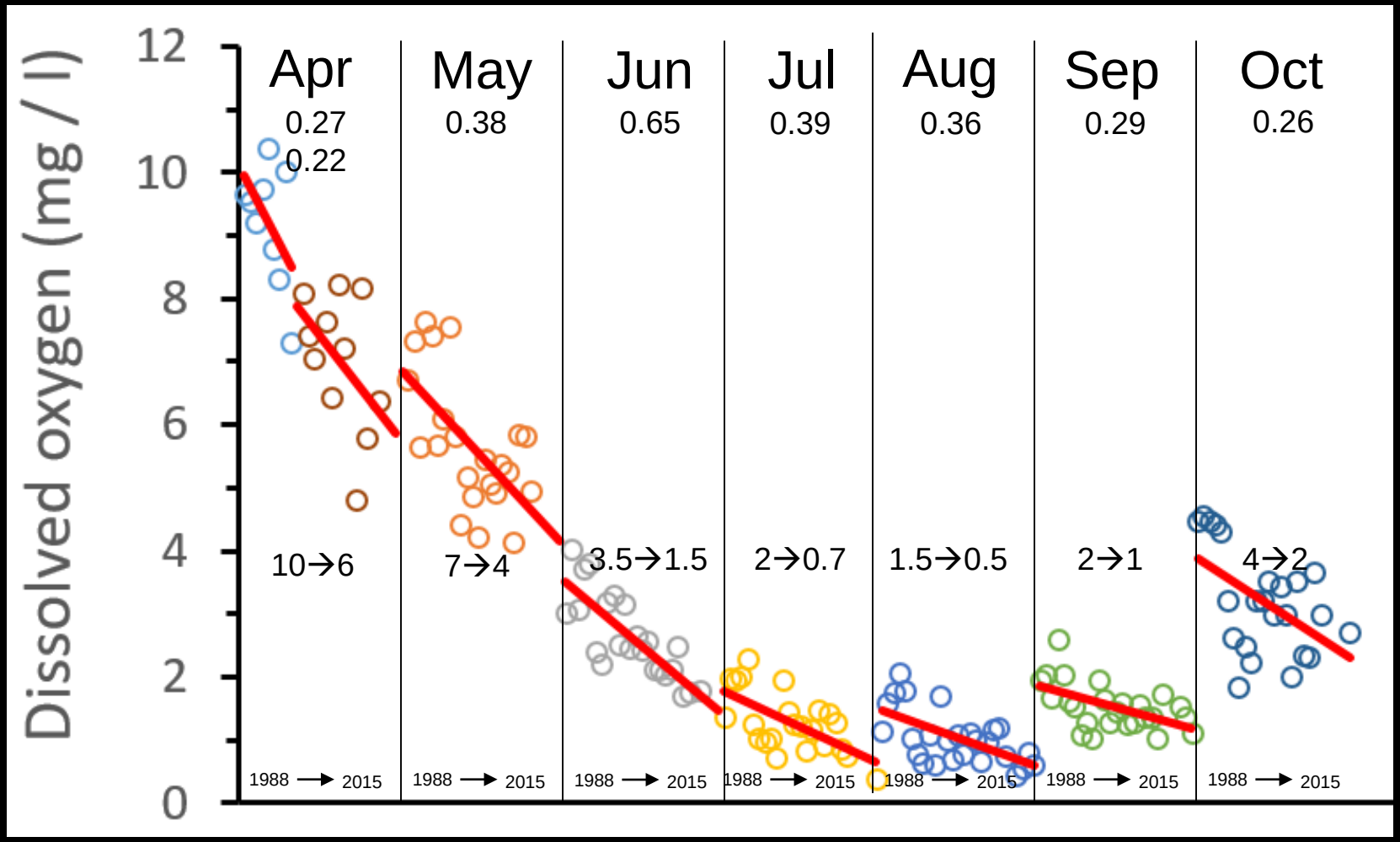
Harke et al. (2016) A review of the global ecology, genomics, and biogeography of the toxic cyanobacterium, Microcystis spp.

Possible interactions between temperatures and nutrients



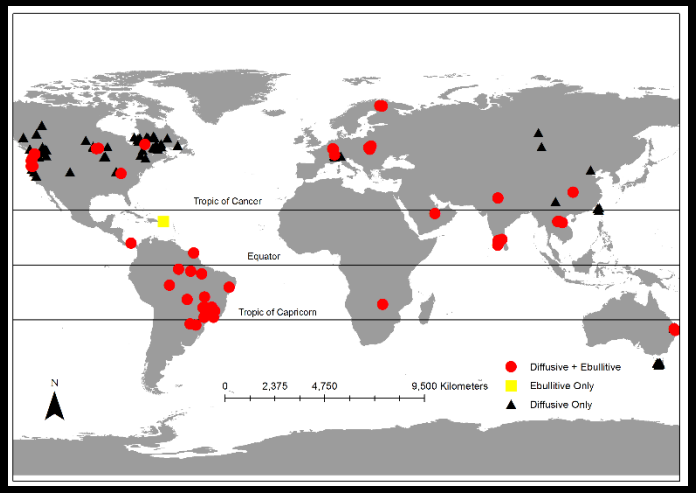
Kosten et al. (2012) Warmer climates boost cyanobacterial dominance in shallow lakes

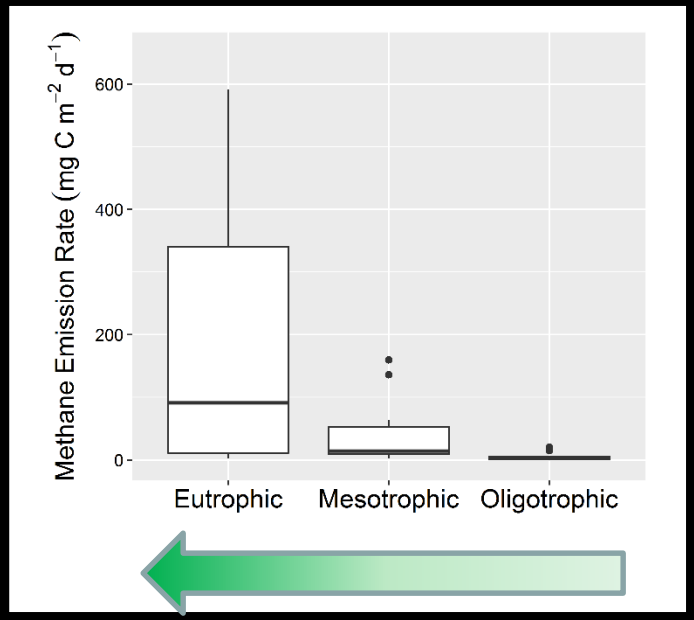
Hypolimnion dissolved oxygen has decreased



Decades of P loading and accumulation in sediments increasingly being released under more severe and longer hypoxic conditions?

Other implications of algal blooms
Methane and water quality: global scale





Deemer et al. 2016. Bioscience

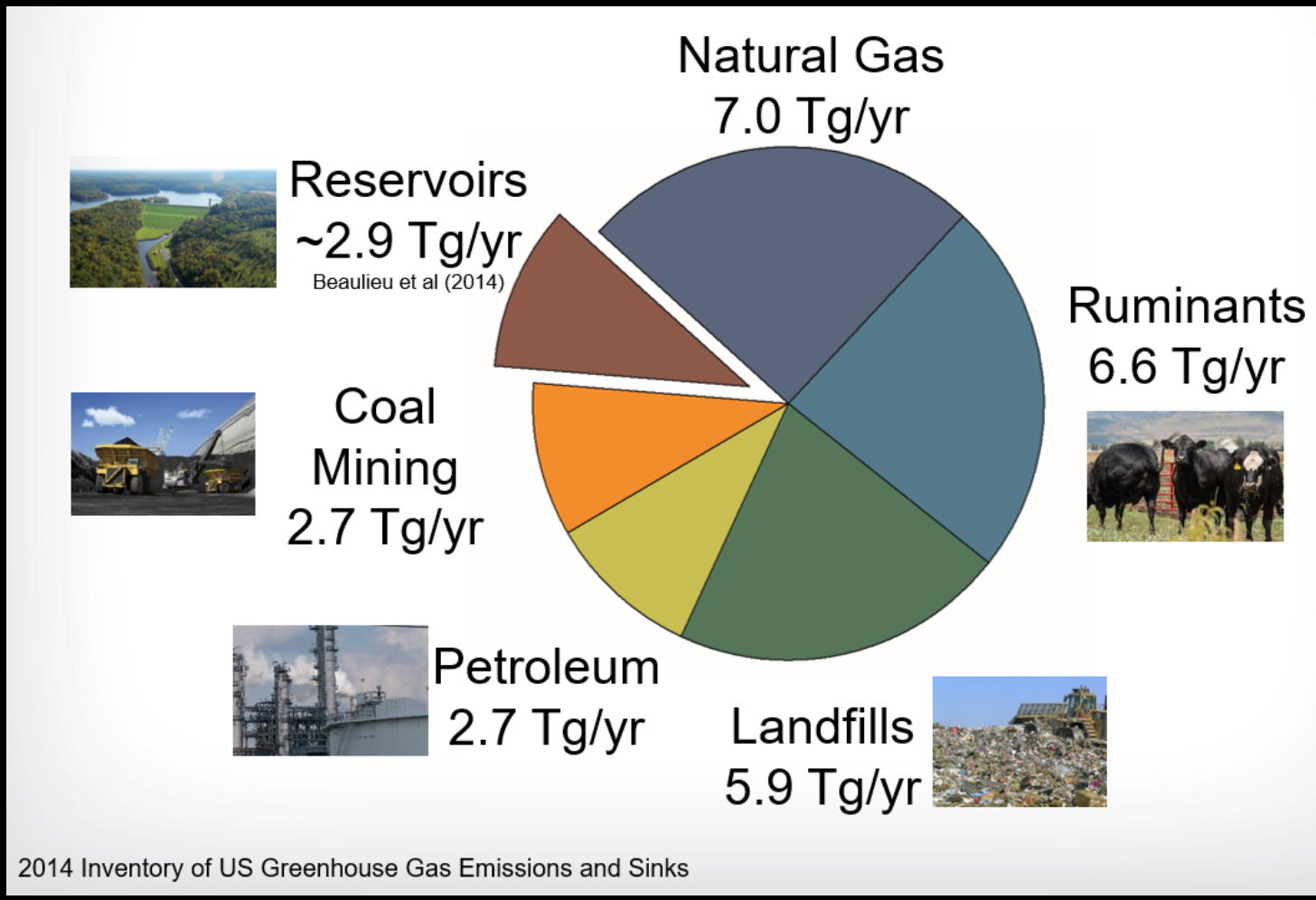
Nutrients

Algal blooms

CH_4 production

Slide provided by Jake Beaulieu (EPA)

Other implications of algal blooms
US Anthropogenic CH_4 Budget



An example of stakeholder engagement and collaboration to improve water quality



Leverages monitoring and management effort to:

- Ensure water safety from harmful algae in the short term
- Maintain a network of sample sites that help promote a watershed approach and allows for the consideration of market-based options for nutrient abatement.

Since 2009 the East Fork Watershed Cooperative has pooled its resources to:

- Document historical changes in water quality and coincident shifts in algal communities
- Establish a water monitoring infrastructure and facilitate focused research studies.
- Support the development, testing and validation of models that are used to integrate and scale the monitoring data
- Engage a broader stakeholder community to promote watershed protection education and increase adoption rate of management practices (BMPs)

nietch.christopher@epa.gov

Discussion

- Inform predictive models of bloom dynamics and severities
- Examine economic effects and how beneficial uses are affected
- Inform best management practices and source water protection in the future and predict their effectiveness
- How do the coincident rise in reservoir temperatures and exacerbation of hypoxia affect our ability to predict the effectiveness of nutrient management plans?

smucker.nathan@epa.gov

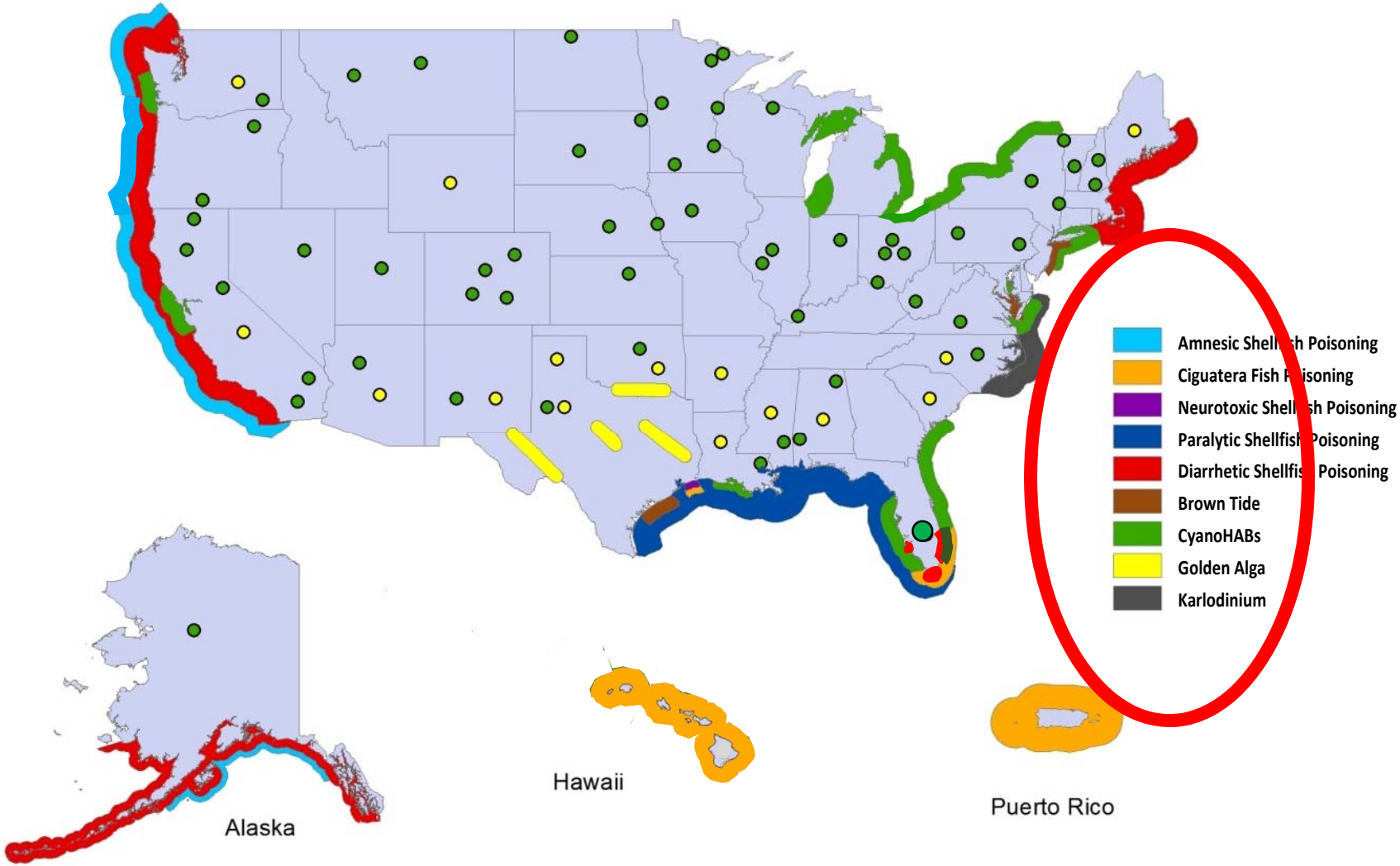
NOAA Harmful Algal Bloom Program

National Perspectives

EPA Region 4 HAB Webinar
May 8, 2018

Marc Suddleson
Manager, MERHAB Sponsored Research Program
Co-manager, HAB Rapid Response

Harmful Algal Blooms – A National Problem



Harmful Algal Booms - Impacts

	Name	Human & Animal* Poisoning	Fish Kills	Water Discoloration
	Amnesic Shellfish Poisoning (ASP)	Yes**	No	No
	Ciguatera Fish Poisoning (CFP)	Yes	No	No
	Neurotoxic Shellfish Poisoning (NSP)	Yes**	Yes	Yes
	Paralytic Shellfish Poisoning (PSP)	Yes**	Yes	Yes
	Diarrhetic Shellfish Poisoning (DSP)	Yes	No	No
	Brown Tide	No	Yes	Yes
	CyanoHABs	Yes**	Yes	Yes
	Golden Alga	No	Yes	Yes
	Karlodinium	No	Yes	Yes

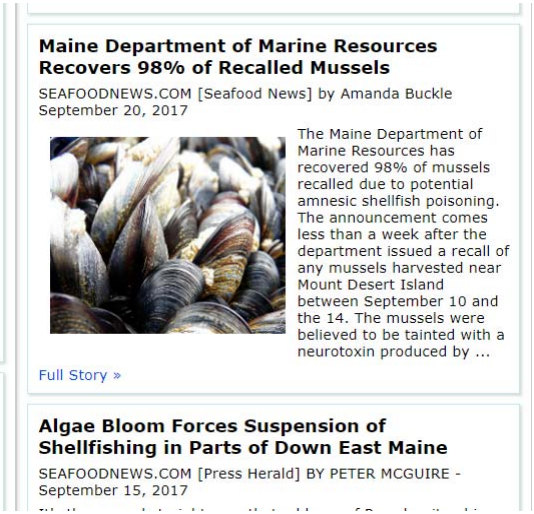
*Mammals, birds, turtles, often protected species

**Can cause human or animal deaths

Measuring HAB Impacts – Economics

$82 - $100M per year for U.S.

- This is likely an underestimate:
  - $49.6M – Lost income during historic 2005 red tide in Maine alone
  - $20.4 M—WA Lost spending when recreational clamming season closed for season
  - $10.3 M—2011 TX red tide drop in oyster landings
  - $2-6M/event –Lost profits from WA net pen fish kills (*heterosigma*).



Maine Department of Marine Resources Recovers 98% of Recalled Mussels

SEAFOODNEWS.COM [Seafood News] by Amanda Buckle
September 20, 2017

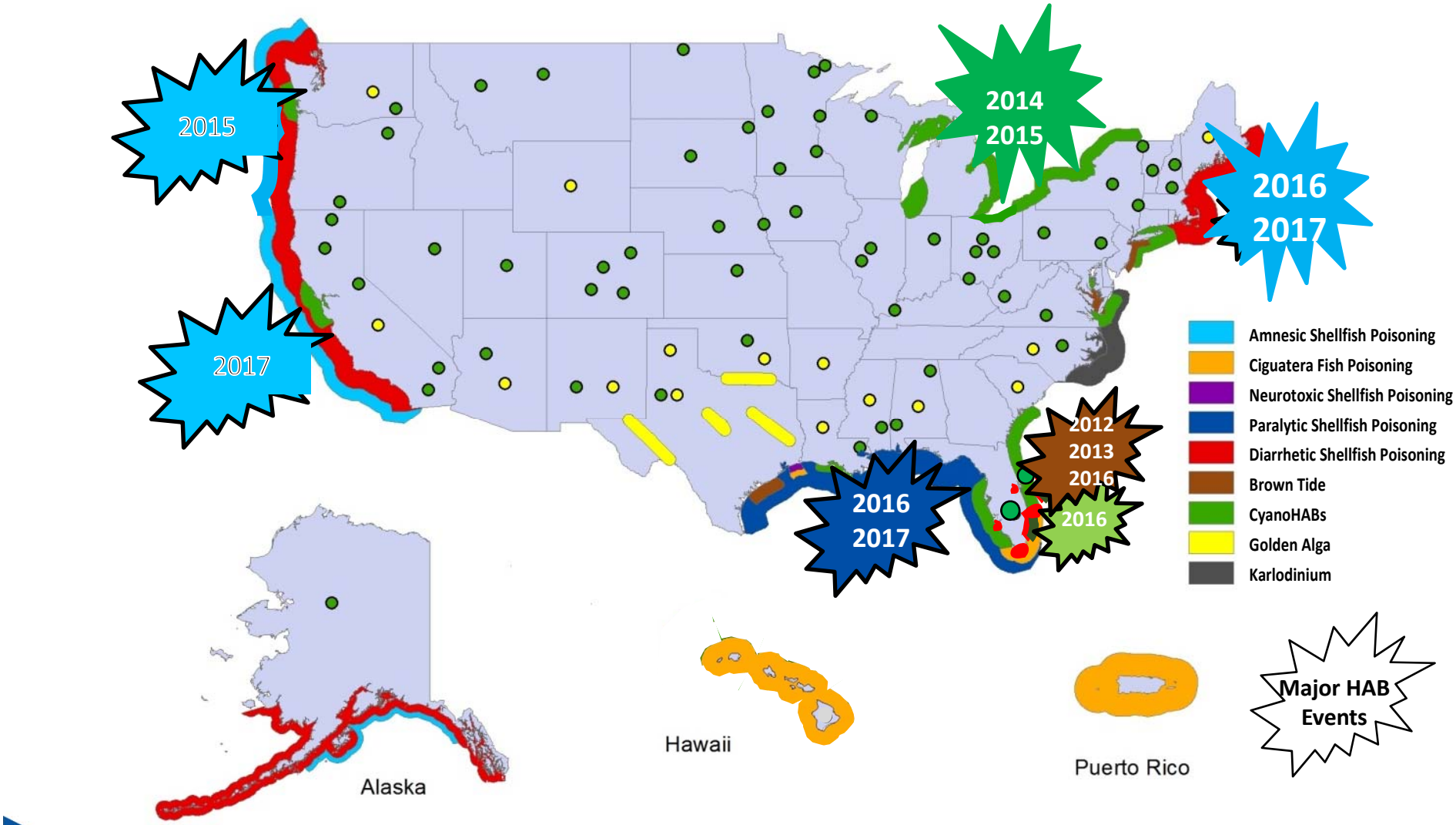
The Maine Department of Marine Resources has recovered 98% of mussels recalled due to potential amnesic shellfish poisoning. The announcement comes less than a week after the department issued a recall of any mussels harvested near Mount Desert Island between September 10 and the 14. The mussels were believed to be tainted with a neurotoxin produced by ...

Full Story »

Algae Bloom Forces Suspension of Shellfishing in Parts of Down East Maine

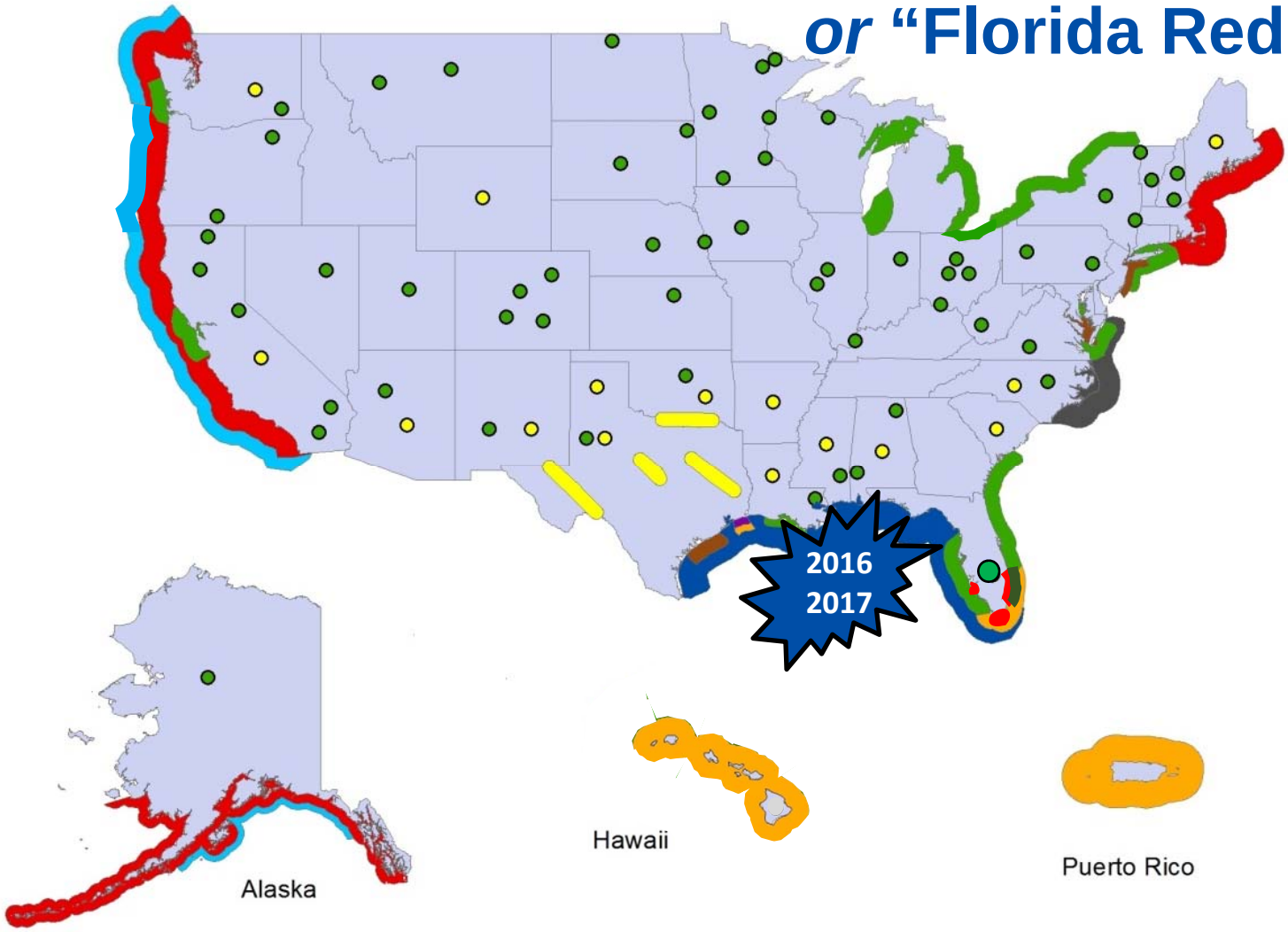
SEAFOODNEWS.COM [Press Herald] BY PETER MCGUIRE -
September 15, 2017

Harmful Algal Blooms – Major Events Since 2014



HABs – Expansion of Known HABs - **NSP**

***or* "Florida Red Tide"**



NSP\Red Tide Impacts

Impacts

Discolored water

Toxic shellfish

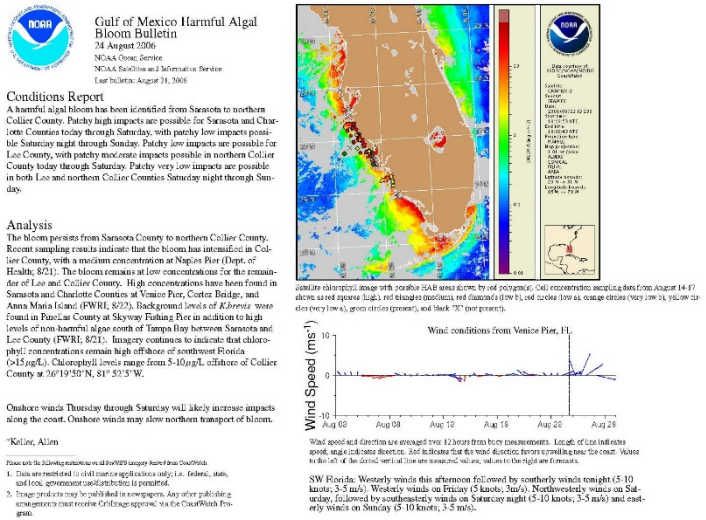
Mortality Endangered Species

Dead fish

Respiratory irritation

2016 Gulf-Wide NSP\Red Tide - NOAA Response

Operational HAB Forecasts FL & TX



Gulf of Mexico Harmful Algal Bloom Bulletin
24 August 2006
NOAA Ocean Service
NOAA Satellites and Information Service
Last bulletin: August 21, 2006

Conditions Report

A harmful algal bloom has been identified from Sarasota to northern Collier County. Patchy high impacts are possible for Sarasota and Charlotte Counties today through Saturday, with patchy low impacts possible Saturday night through Sunday. Patchy low impacts are possible for Lee County, with patchy moderate impacts possible in northern Collier County today through Saturday. Patchy very low impacts are possible in both Lee and northern Collier Counties Saturday night through Sunday.

Analysis

The bloom persists from Sarasota County to northern Collier County. Recent sampling results indicate that the bloom has intensified in Collier County, with a medium concentration at Naples Pier (Dept. of Health; 8/21). The bloom remains at low concentrations for the remainder of Lee and Collier County. High concentrations have been found in Sarasota and Charlotte Counties at Venice Pier, Cortez Bridge, and Anna Maria Island (FWRI, 8/22). Background levels of *K.brevis* were found in Pinellas County at Skyway Fishing Pier in addition to high levels of non-harmful algae south of Tampa Bay between Sarasota and Lee County (FWRI, 8/21). Imagery continues to indicate that chlorophyll concentrations remain high offshore of northwest Florida (>15 µg/L). Chlorophyll levels range from 5-10 µg/L offshore of Collier County at 26°19'50"N, 81° 52'5"W.

Onshore winds Thursday through Saturday will likely increase impacts along the coast. Onshore winds may slow northern transport of bloom.

-Keller, Allen

Please note the following restrictions on all NowCWF imagery derived from CoastWatch.

1. Data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Image products may be published in newspapers. Any other publishing arrangements must receive CoastWatch approval via the CoastWatch Program.

Satellite chlorophyll image with possible HAB areas shown by red polygon(s). Cell concentration sampling data from August 14-17 shown as red squares (high), red triangles (medium), red diamonds (low 1), red circles (low 2), orange circles (very low 2), yellow circles (very low 1), green circles (present), and black "X" (not present).

Wind conditions from Venice Pier, FL

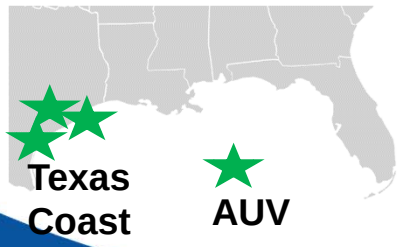
Wind Speed (ms^{-1})

Aug 03 Aug 08 Aug 13 Aug 18 Aug 23 Aug 28

Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed, angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values, values to the right are forecasts.

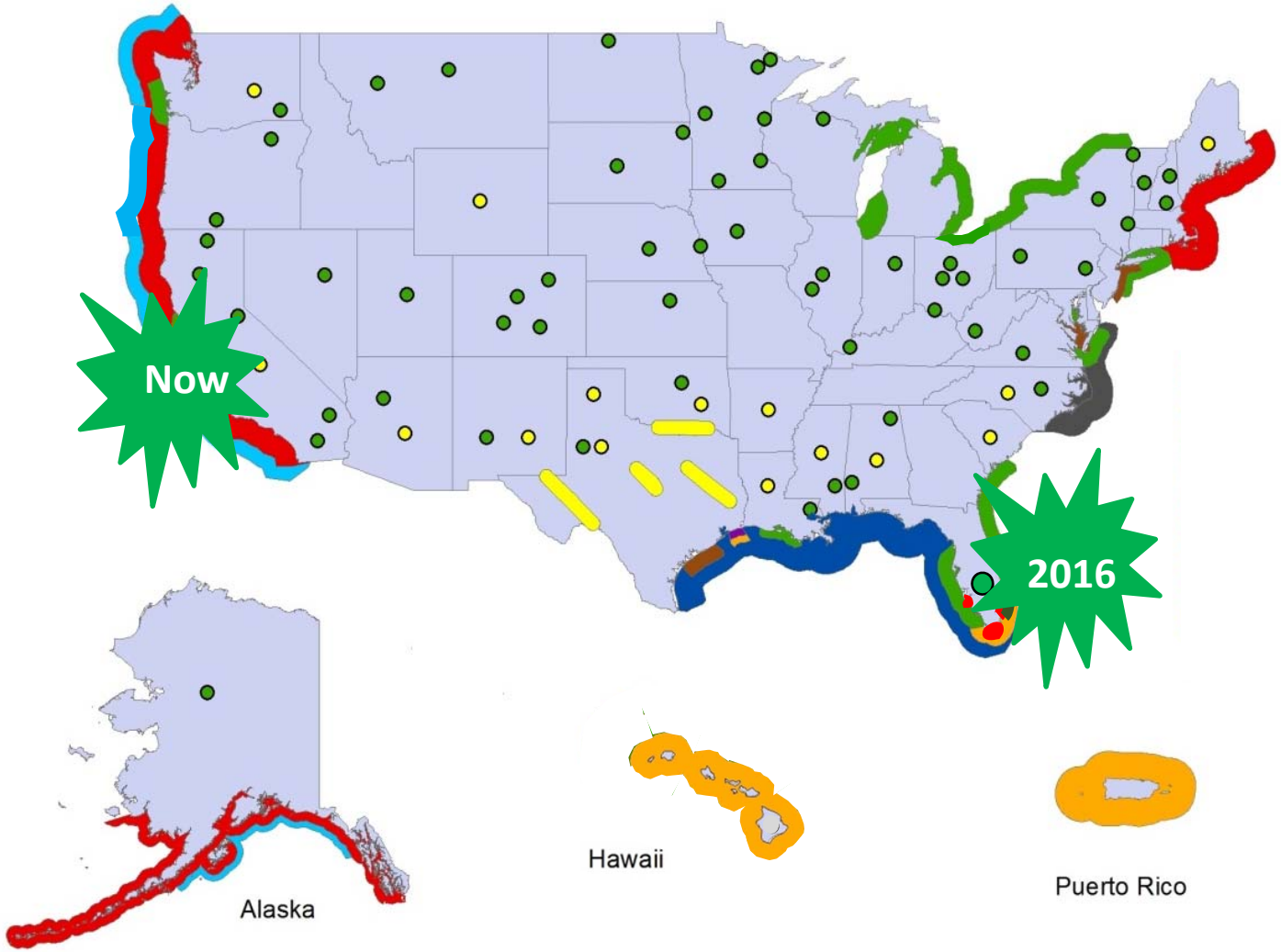
SW Florida: Westerly winds this afternoon followed by southerly winds tonight (5-10 knots; 3-5 m/s). Westerly winds on Friday (5 knots; 3m/s). Northwesterly winds on Saturday, followed by southeasterly winds on Saturday night (5-10 knots; 3-5 m/s) and easterly winds on Sunday (5-10 knots; 3-5 m/s).

Developing Monitoring Network—Microscope in a Can



- **Active Research & Response**
  - Improving routine HAB monitoring
  - Operational Forecast: FL and TX
  - Developing Seasonal Forecast
- **During bloom**
  - Updates to State and County responders
  - Guidance to State HAB Monitors

Emerging Coastal Issue - CyanoHABs



2016 CyanoHABs in St. Lucie Estuary, FL

NOAA Response

- **Assist local counties**
- **Improve remote sensing**
- **Research to understand bloom & toxin production**

CYAN

CyanoHAB Toxins in Many U.S. Estuaries

Sea Otter
California's CyanoHAB Sentinel

Emerging Issue

How widespread?

Is it a human health threat?

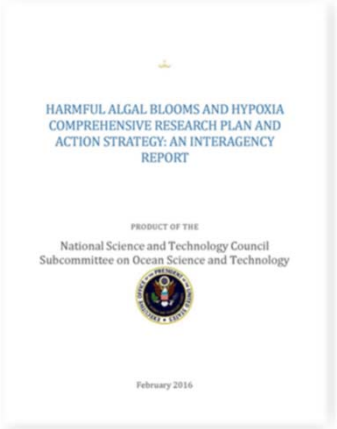
No guidance for toxins in shellfish!

NOAA Response

- **Assess magnitude of problem in California estuaries**
- **Fund state, tribes, feds (USGS and EPA) partnership**
- **Adapt new monitoring tools (SPATT)**

Harmful Algal Bloom and Hypoxia Research and Control Act 2014 (HABHRCA)

- Improve interagency coordination
- Conduct research – (competitive and internal)
  - Understand causes & impacts
  - Develop better monitoring, prediction and response
  - Understand roles of climate, nutrients
  - Toxins in foods and water
  - Methods for HAB suppression, control
- Rapid Response to HAB events
- Reports to Congress
  - HABs and Hypoxia Comprehensive Research Plan & Action Strategy – Final Feb 2016
  - Great Lakes Research Plan and Action Strategy—in review.


HARMFUL ALGAL BLOOMS AND HYPOXIA COMPREHENSIVE RESEARCH PLAN AND ACTION STRATEGY: AN INTERAGENCY REPORT

PRODUCT OF THE
National Science and Technology Council
Subcommittee on Ocean Science and Technology

February 2016

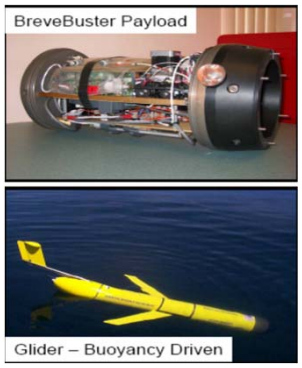
http://coastalscience.noaa.gov/research/habs/habhrca

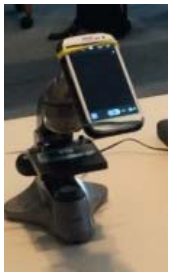
Harmful Algal Bloom and Hypoxia Research and Control Act 2014 (HABHRCA)

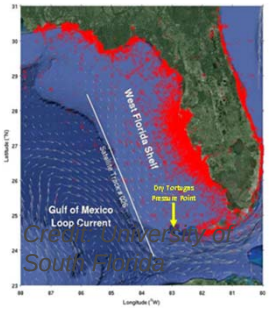
- Competitive HAB research programs $
  - ECOHAB—Determine causes & impacts of HABs
  - **MERHAB**—Build HAB response capacity though managers, researchers, & shellfish industry partnership projects
  - PCMHAB—develop, demonstrate and transition HAB prevention, mitigation, and control technologies. Assess costs associated with HABs
- Rapid Response to HAB events $
- Internal HAB science
  - Algal Taxonomy, Identification Physiology, Molecular Ecology
  - Biotoxin Measurement & Impacts
  - Sensors and Detection
  - Marine Biotoxin Measurement & Impacts
- HAB Forecasting
- Phytoplankton Monitoring Network

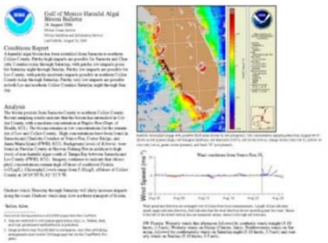
National HAB Program - Accomplishments

- Guidelines for freshwater toxins, health advisories
- Enhanced HAB Detection
  - low cost\simple screening
  - Better regulatory confirmation
  - Real-time HAB sensors
- HAB modeling & forecast products
- Timely HAB event response
- Understanding effects of HAB toxins on human, animal health





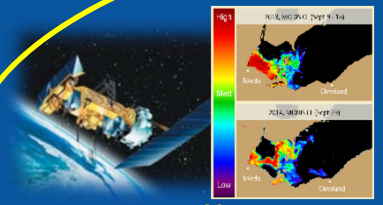




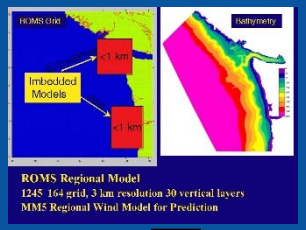
National HAB Forecast & Regional Observing Systems

Sensors

Monitoring Programs

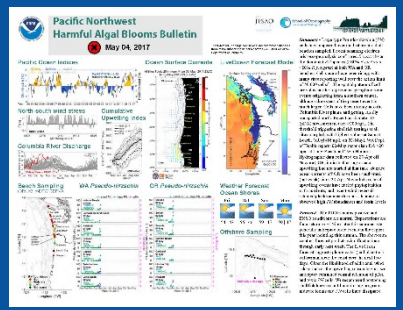


Satellite Observations



Models

HAB Forecast



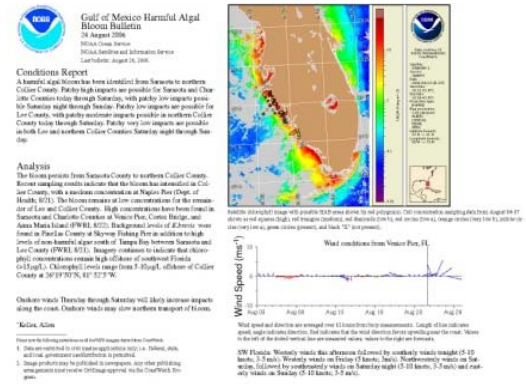
Analysis and Interpretation

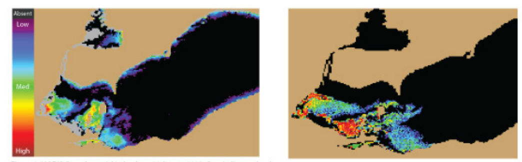
Public Warning & Outreach

Info Supports Management & Industry

NOAA HAB Operational Forecast (HABOFS)

- Operational 24/7
  - o FL *Karenia*—weekly+
  - o TX *Karenia*—weekly+
  - o Lake Erie cyanobacteria seasonal & weekly
- In transition to operational
  - o Gulf of Maine *Alexandrium*
  - o Puget Sound & Washington coast
  - o California coast
- In development
  - o Alaska *Alexandrium*
  - o Puget Sound
  - o Chesapeake Bay





Experimental Lake Erie Harmful Algal Bloom Bulletin
National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory
23 August 2013; Bulletin 15

Microcystin concentrations in some areas of the bloom near Maumee Bay may reach 56 ug/L. Dense cyanobacteria is present along some of the western shore. There may be small patches of scum from the Bass Islands west to Maumee Bay.

Slight eastward transport is forecasted for the next few days. Winds today >15 knots could possibly cause mixing of the bloom. Low winds (<8 knots) are expected over the weekend which could cause the bloom to intensify at the surface and produce patchy areas of scum.

- Dupuy, Stumpf, Tomlinson

Figure 1. MODIS Cyanobacterial Index from 20 August 2013. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 35,000

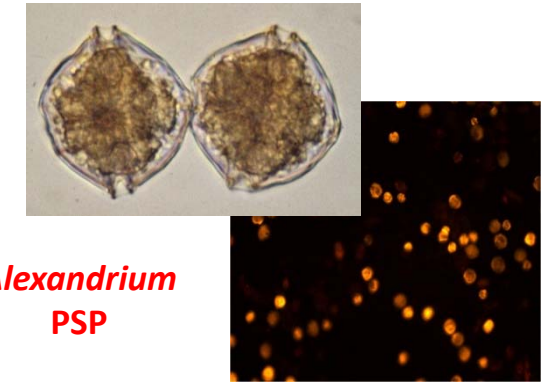
Figure 2. Nowcast position of bloom for 23 August 2013 using GLCFS modeled currents to move the bloom from the 20 August 2013 image.

- Need HAB Observing System
  - ○ Develop HAB toxin/cell-specific sensors

http://tidesandcurrents.noaa.gov/hab/

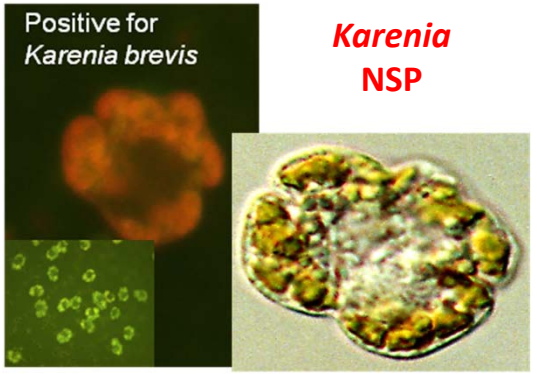
Improving HAB Response

- Risk Assessment before HAB occurs—
  Develop meaningful contingency plans
  - Coastal
  - Freshwater
    Plan for future HAB expansion
- Support to state & tribal agencies
  - Work with ISSC to approve new methods
  - Equipment and training to adopt new methods
  - Rally against program cuts – common in years with no HABs.



Alexandrium
PSP

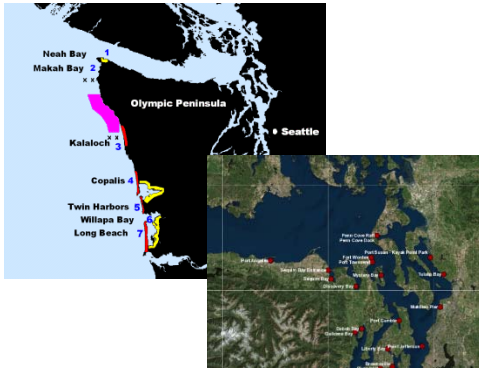
U.S. HAB ID Training Course



Karenia
NSP

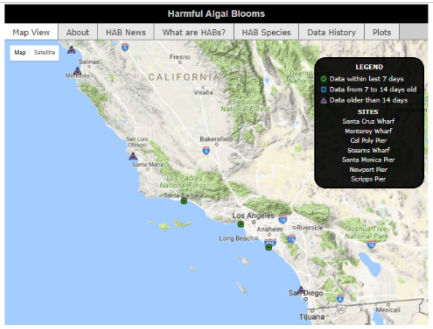
Improving HAB Response

- Support and Expand Regional Monitoring Networks
  - Engage citizen, tribal and industry monitoring partners
  - Monitoring for HAB early warning
  - Stakeholders help guide research
  - Share toxin analysis capabilities



WA – ORHAB & Soundtoxins

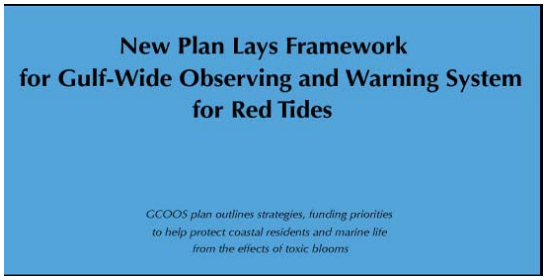
FL - FWC, Mote, USF, START + GOMA



CA - CalHABMAP

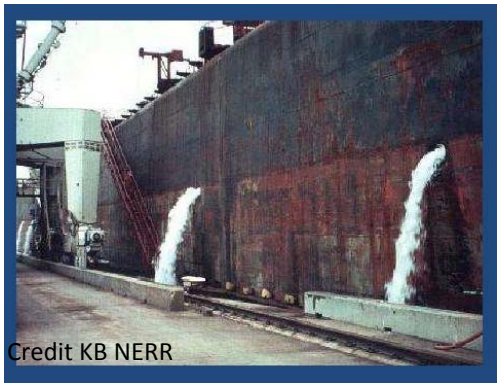
Improving HAB Response

- Encourage NOAA IOOS and Regional Association involvement (e.g. adding HAB sensors, serving\displaying data)
- Support NOAA HAB Forecasting System and Ecological Forecasting Services
- Educate impacted industries (e.g. aquaculture) about out HAB-related disruptions & ID research needs and solutions to mitigate and prevent HAB impacts



Improving HAB Response

- Urge state participation in CDC One Health Harmful Algal Bloom System (OHHABS)
  - 1st national system to report HABs and associated human and animal health impacts
  - Voluntary
  - Track severity of problem to support efforts to prevent blooms and illnesses
- Reduce human activities that increase HABs
  - Reduce nutrient inputs
  - Prevent warming of water bodies
  - Be careful of hydrographic changes
  - Prevent HABs as invasive species


Credit KB NERR

Conclusions

- HABs impact all U.S. coastal areas
- New HAB problems emerging
- NOAA response
  - Understand causes & impacts to improve prevention, control, & mitigation
  - Develop HAB forecasts and improve monitoring to provide early warning

For More Information

- NOAA HAB Programs
  - Research https://coastalscience.noaa.gov/research/habs/
  - HAB forecasting: http://tidesandcurrents.noaa.gov/hab/overview.html
  - Event Response https://coastalscience.noaa.gov/research/habs/response/default
- HABHRCA https://coastalscience.noaa.gov/research/habs/habhrca
- HAB National Office: http://www.whoi.edu/redtide/
- US HAB Training at Bigelow https://ncma.bigelow.org/training-courses
- Interstate Shellfish Sanitation Commission: http://www.issc.org/
- IOOS Regional Associations: http://www.ioosassociation.org/
- GCOOS http://gcoos.org/ AND SECOORA http://secoora.org/
- Primer on Gulf of Mexico HABs http://gcoos.tamu.edu/documents/HabPrimer-10162013.pdf
- Harmful Algal Blooms Observing System (HABSOS) https://habsos.noaa.gov/

Contact Information:
Marc.Suddleson@noaa.gov
(240) 533-0305

Harmful Algal Blooms and Public Health Surveillance: The One Health Harmful Algal Bloom System (OHHABS)

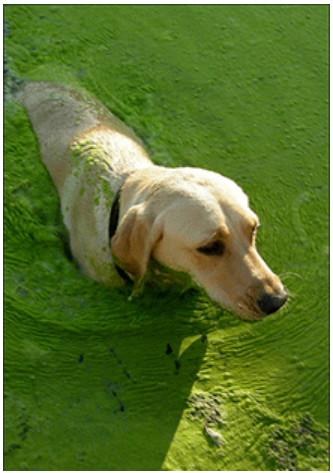
Virginia Roberts, MSPH
Epidemiologist

EPA Region 4 Harmful Algal Bloom Virtual Workshop

May 8th, 2018

HABs and Public Health

- People can get sick from HAB toxins if they ingest them, inhale them, or if they expose their skin to them through activities like swimming.
- One Health issue – humans, animals, and the environment
- Emerging public health issue
  - Warming climate, nutrient pollution
- Challenges: identifying and characterizing HAB-associated illnesses



Source: Jill Siegrist

Source: USGS

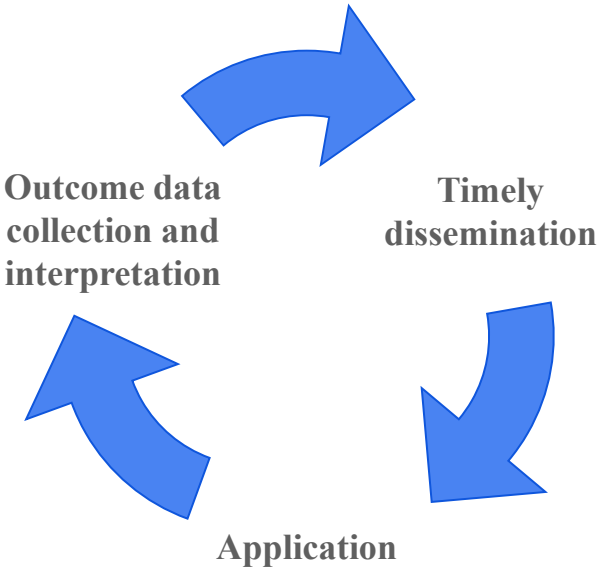
Source: David Zapotosky

An Emerging Public Health Issue

- Challenges: identifying and characterizing HAB-related illnesses
- Questions include:
  - Frequency and geographic distribution
    - How many cases of illness annually? Where? When?
    - Illnesses occurring more/less frequently?
  - Illness characterization
    - What are the symptoms of HAB-associated illness?
      - How does this differ by the type or amount of toxin?
    - How to interpret clinical, epidemiological, and environmental data?
      - Suspect, probable, confirmed case of illness?
  - Risk factors
    - How do factors such as age, route of exposure, and immune status affect susceptibility?
  - Prevention efforts—needs? impacts?

Public health surveillance can help to answer these questions

- **Public health surveillance:**
  - ***The ongoing, systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice.***



Teutsch and Churchill , Principles and Practice of Public Health Surveillance. 2000. Oxford University Press

Public health surveillance for HABs and associated illnesses

- NORS (web-based, national)
  - Voluntary state and territorial reporting of outbreak data (≥ 2 human illnesses) since 2009
  - Waterborne and foodborne HAB-associated outbreaks
  - Data collected via separate systems from 1970s-2008

NORS
National Outbreak Reporting System

- HABISS (web-based, select states)
  - 2009-2013
  - Enhanced surveillance for HABs, human illness, animal illness

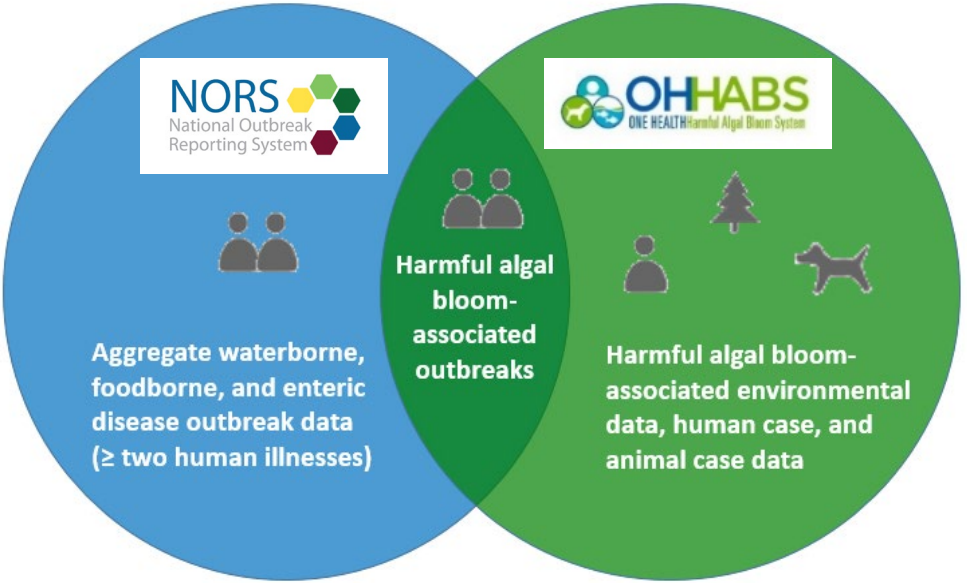
- OHHABS (web-based, national) Launched in 2016
  - Voluntary state and territorial reporting of HABs, human illness, animal illness
  - Launched in 2016

OHHABS
ONE HEALTH Harmful Algal Bloom System

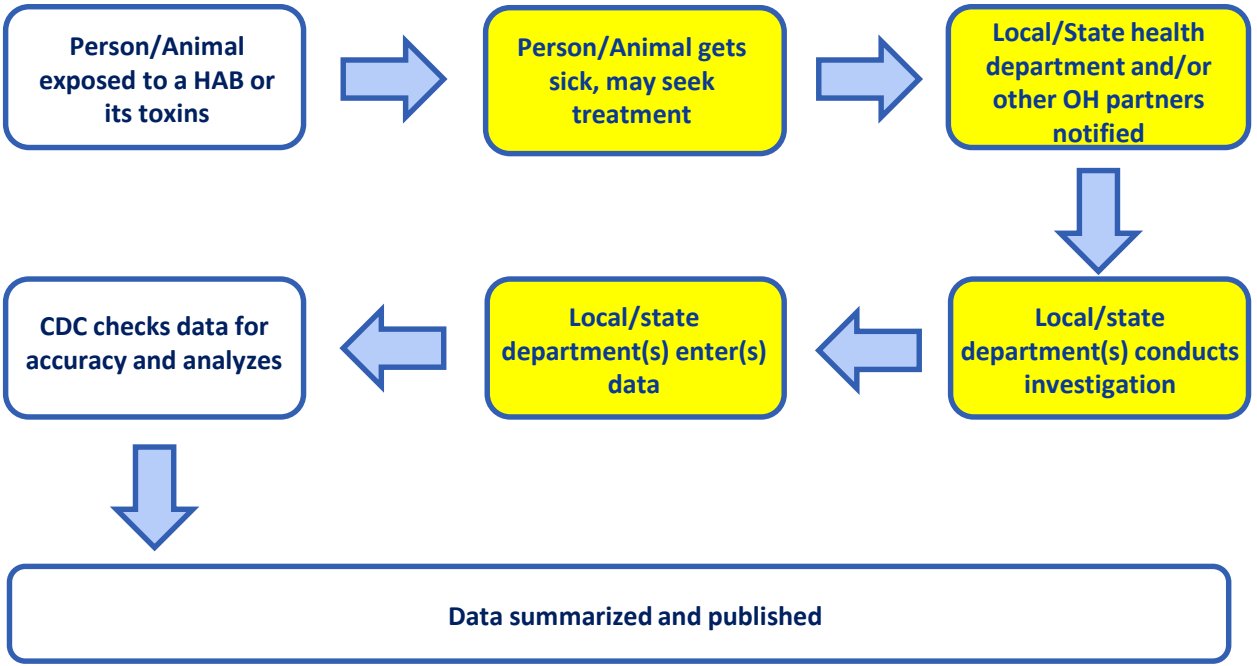
- Voluntary reporting to CDC
  - Nationally available to local, state, and territorial public health partners
  - Their designated environmental health and animal health partners
- Electronic reporting
  - Web-based, password-protected system
  - Systematic data collection
- One Health surveillance for fresh and marine water events
  - HAB events (environmental data)
  - HAB-associated human cases of illness
  - HAB-associated animal cases of illness
- Reporting frequency
  - Event-based, not routine water monitoring
  - Not a real-time notification or case investigation system
  - Passive surveillance

One Health Harmful Algal Bloom System (OHHABS)

- **Web-based reporting system linked to NORS**
  - OHHABS and NORS are linked in two ways:
    1. Share technical reporting features (same web platform, reporting structure)
    2. Collect different types of data about HAB-associated outbreaks



General HAB-associated Illness Reporting Process



Data uses:

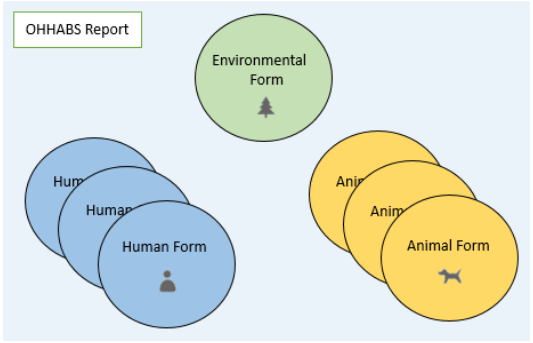
Summary reports, other publications, data and statistics

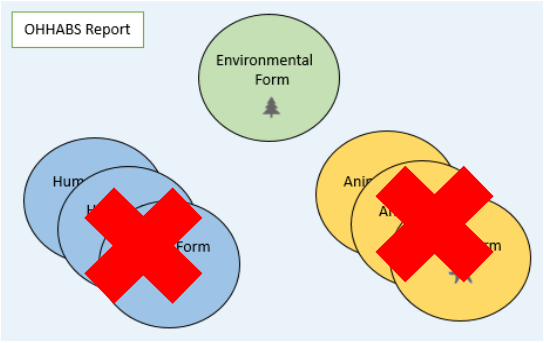
Development and support of programs, health promotion, and policies

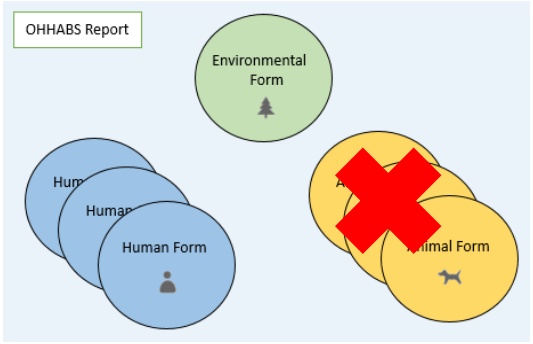
Factors influencing HAB-associated illness detection, investigation, and reporting

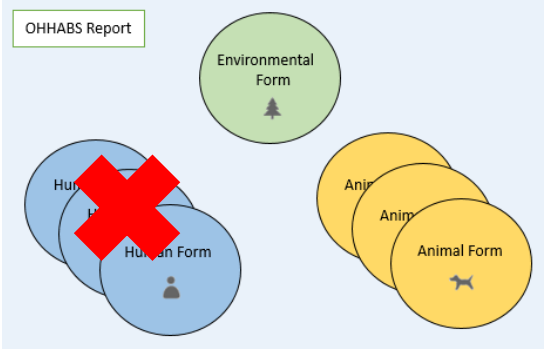
- Resources
  - Limited state funding for surveillance and reporting
- Awareness
  - Knowledge of exposure, routes, and symptoms
  - May be difficult to detect and link back to a specific exposure
- Communication
  - Animal health and environmental health partners may be the first/only ones to be notified
  - Capacity for communication with public and across disciplines
- Laboratory testing
  - Limited environmental testing capability in states
  - Availability of clinical testing for chemicals/toxins
- Reporting requirements
  - Waterborne and foodborne outbreaks are nationally notifiable
    - Nationally notifiable ≠ required to report
  - HAB-associated illnesses (single cases) are not nationally notifiable

How Are Events and Cases Reported in OHHABS?









What Data Can be Reported?

Form Type	Types of Data Collected*
Environmental Form	• Location of the HAB event • Observed water body characteristics • Advisories and health warnings • Laboratory testing – event sample testing • Pathogens or toxins detected • Other data systems that contain associated information • Seafood catch or harvest location for HAB-associated foodborne illnesses
Human Form	• General case information (e.g., sex, age in years) • Exposures (e.g., activities, duration) • Signs and symptoms of illness • Medical and health history • Clinical testing • Pathogens or toxins detected in clinical samples
Animal Form	• General case information (e.g., type of animal, single/group of animals) • Exposures (e.g. activities, duration) • Signs of illness • Health information (e.g., veterinary treatment) • Clinical testing • Pathogen or toxins detected in clinical samples

*No personally identifiable information

How are OHHABS Events and Cases Classified?

1. HAB event definitions

Definition	Criteria		
HAB Event	**Laboratory-based HAB data[1]**	**Observational or environmental data[2]**	**Associated illness**
1. Suspect		Required to have 1	
2. Confirmed	Required		
3. Confirmed		Required	Required

[1] Laboratory detection (e.g., microscopic confirmation or DNA analyses) of cyanobacteria, other potentially toxin-producing algae, or algal/cyanobacterial toxins in a water body or finished drinking water supply

[2] Observational (e.g., scum, algae, water color change, sheen, photographic evidence, satellite data) or environmental (e.g., pH, chlorophyll, nutrient levels) data from a water body to support the presence of an algal bloom

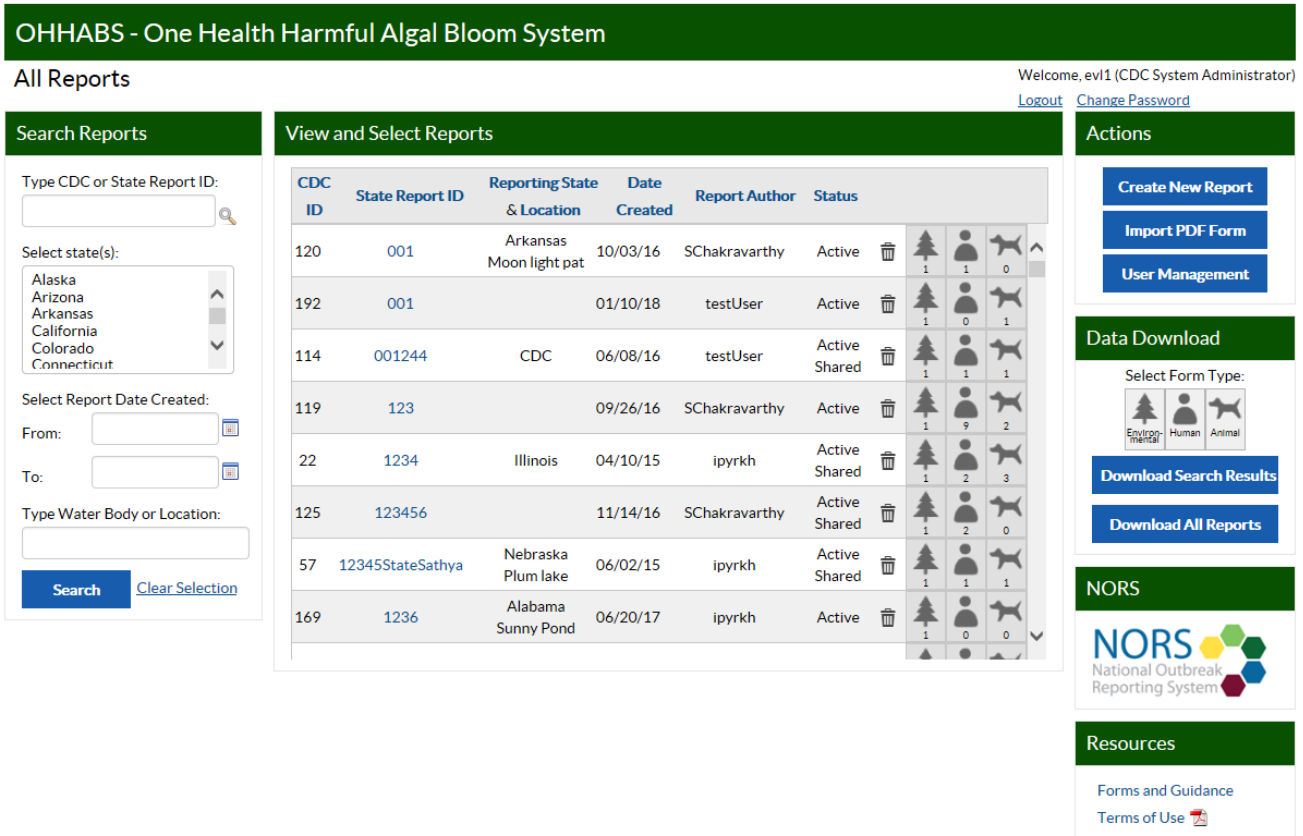
Blue shaded cells: you must have at least one of the criteria described in the shaded cell.

2. HAB-associated case definitions—human

Definition	Criteria							
Human HAB-associated Case	**Exposure[1]**	**Signs/ symptoms[2]**	**Public health assessment[3]**	**Professional medical diagnosis[4]**	**Other causes of illness ruled out**	**Observational or environmental data[5]**	**Laboratory-based HAB data[6]**	**Clinical data[7]**

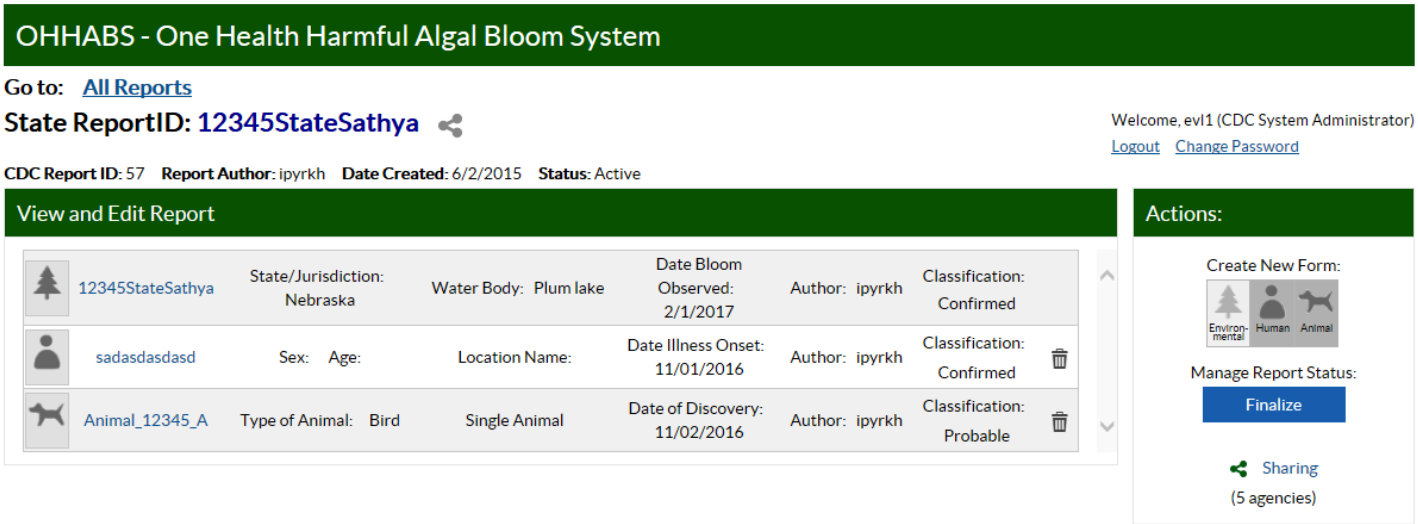
https://www.cdc.gov/habs/pdf/ohhabs-case-and-event-definitions-table.pdf

OHHABS Landing Page*



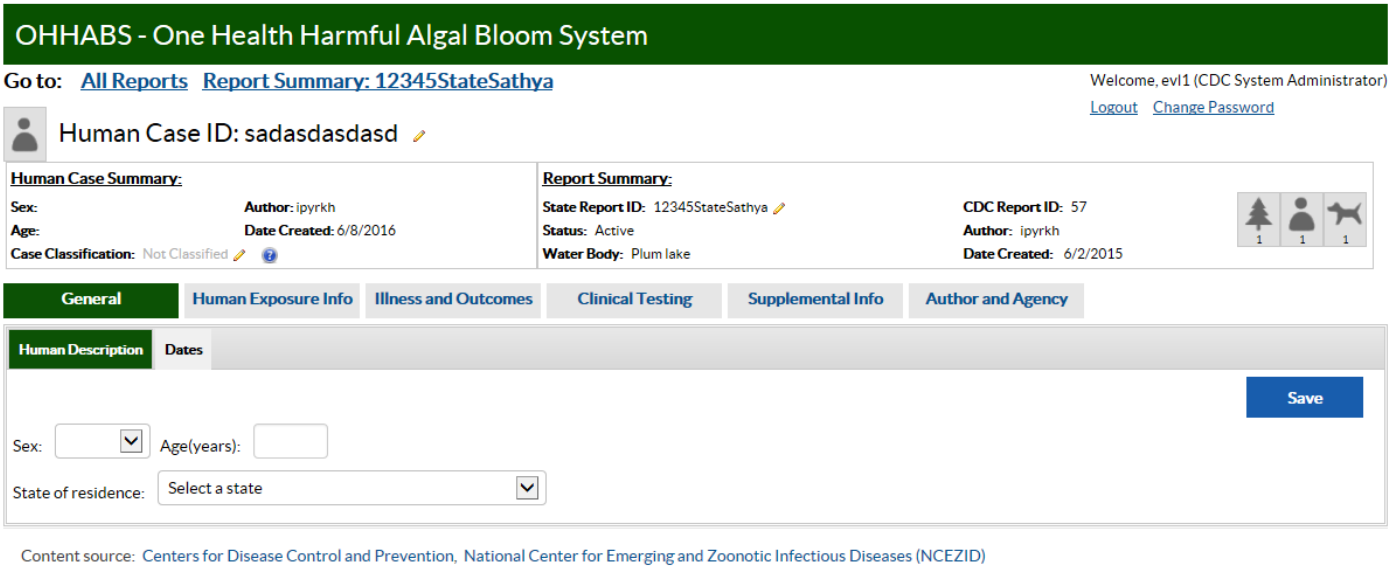
*Example using test system data

Report Summary*



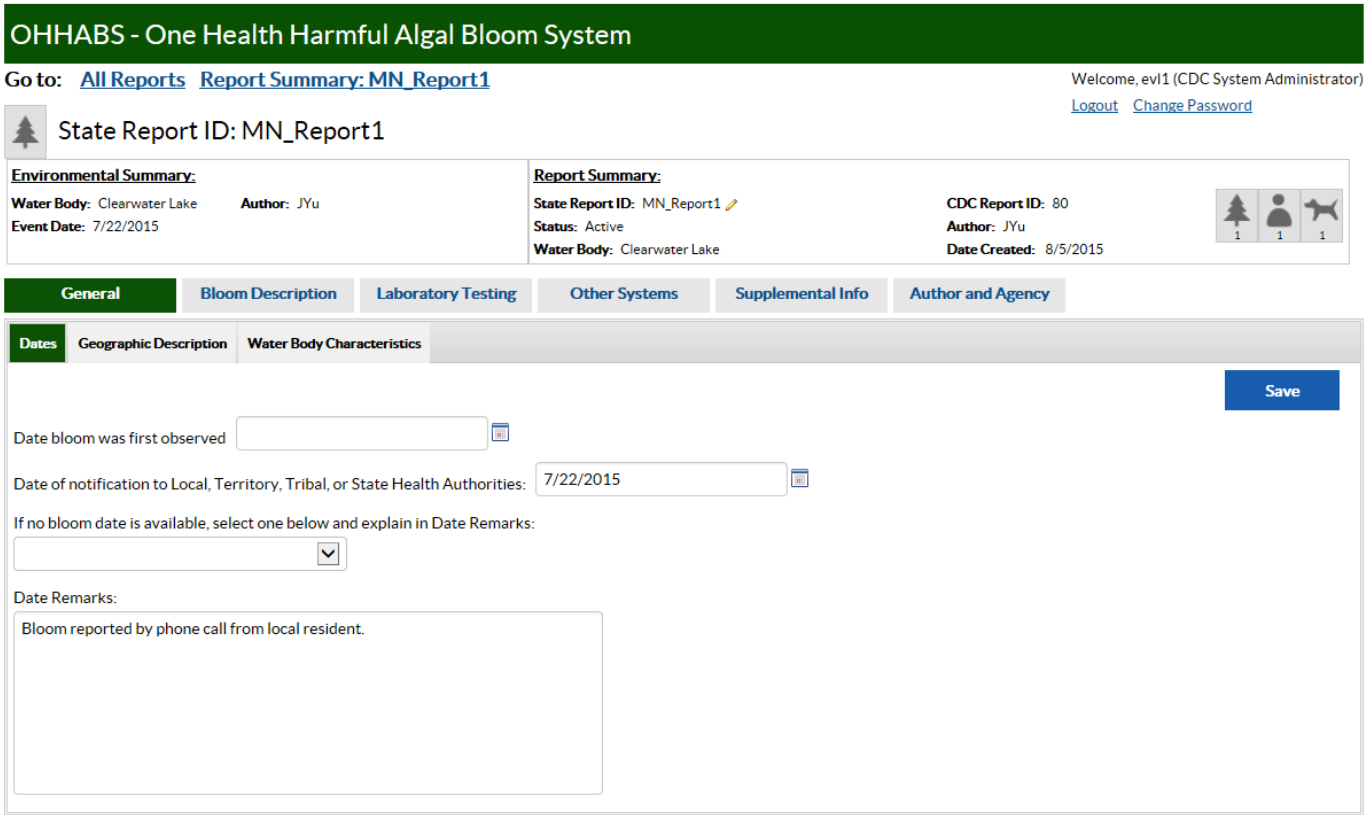
*Example using test system data

Human Case Form*



*Example using test system data

Environmental Form*

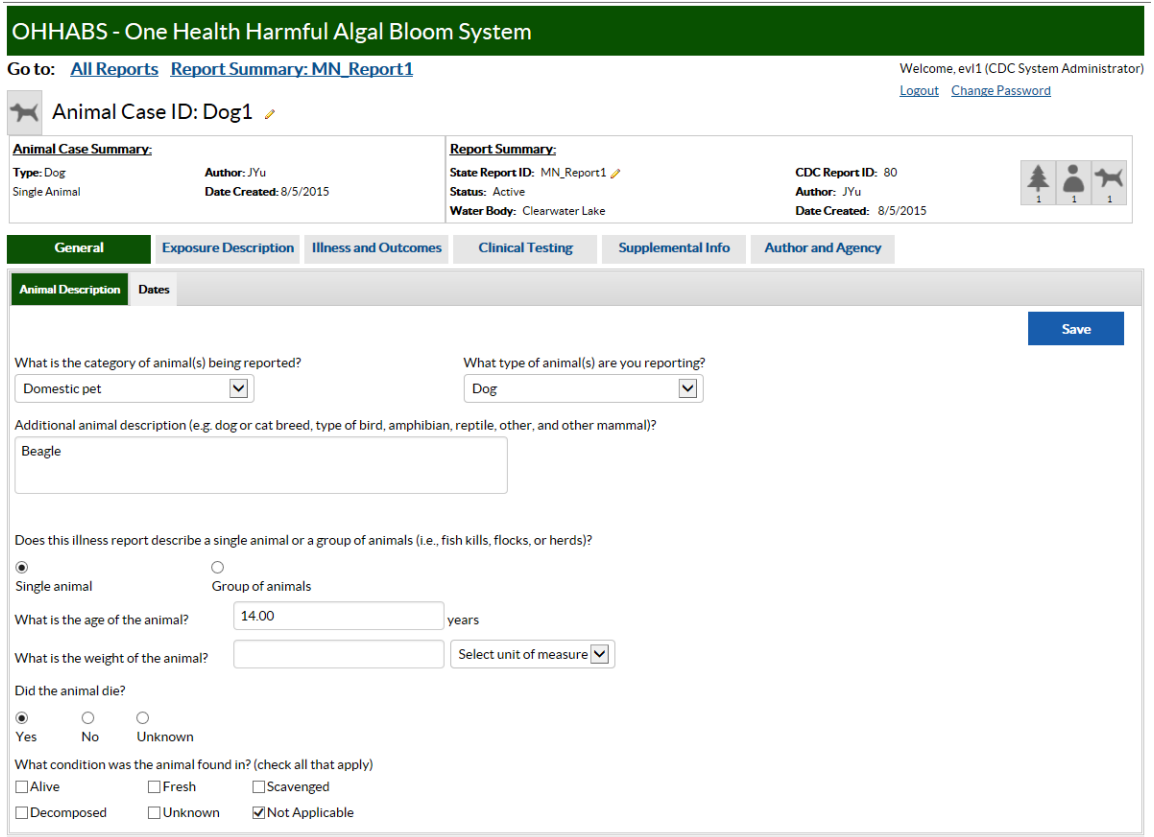


*Example using test system data

Human Case Form*

*Example using test system data

Animal Case Form*



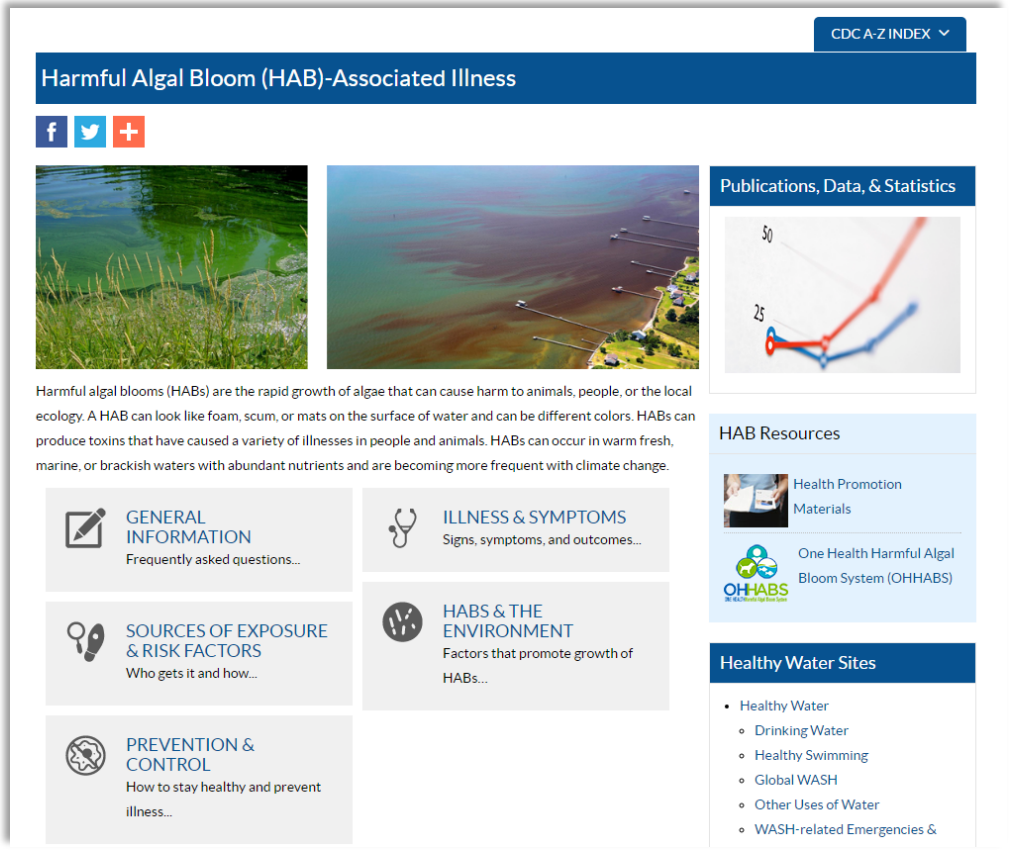
*Example using test system data

Related Resources

- **OHHABS resources at www.cdc.gov/habs/ohhabs**
  - Guidance documents
  - Case and event definitions
  - Static and fillable PDF forms
- **Training webinars—recordings available upon request**
- **Harmful Algal Bloom – Associated Illness website for the general public at www.cdc.gov/habs**
- **Health promotion materials at www.cdc.gov/habs/materials/index.html**
  - OHHABS partner toolkit (fact sheet, slides, newsletter article, resources list)
  - Cyanobacterial Fact Sheet
  - Poster
  - Reference Cards for veterinarians, physicians, and the general public
- **For more information: NORSWater@cdc.gov**

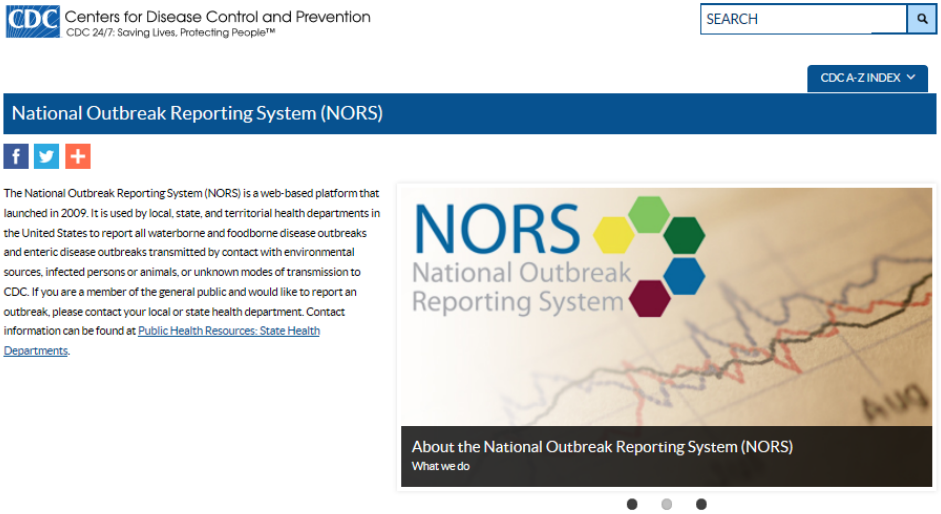
Harmful Algal Bloom-Associated Illness website

www.cdc.gov/habs



NORS Informational Website

https://www.cdc.gov/nors/



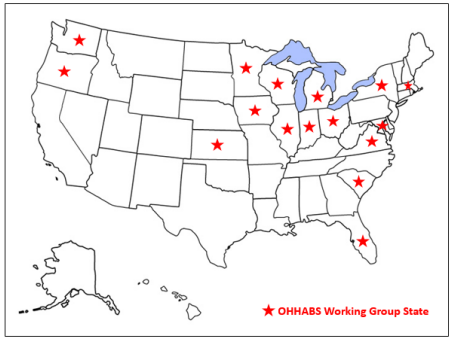
Looking Ahead

- **OHHABS = One Health surveillance**
  - **OHHABS can link human and animal illness data with HAB events**
  - **Data to inform prevention and mitigation of HAB-associated health effects**
- **Surveillance capacity extends beyond an electronic system and may rely on more than the traditional infectious disease or human illness partnerships for foodborne and waterborne disease prevention.**

Acknowledgements

- Great Lakes Restoration Initiative (GLRI)
  - Regional Working Group

- OHHABS Working Group
  - State Partners
  - Federal and other partners



- CDC Health Surveillance Partners
  - CDC/National Center for Emerging and Zoonotic Diseases
  - CDC/National Center for Immunization and Respiratory Diseases
  - CDC/National Center for Environmental Health
  - IT Development: Northrup Grumman

NORS
National Outbreak Reporting System

Thank you! Questions?

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

EPA
United States
Environmental Protection
Agency

Cyanobacteria Monitoring & Applications using Satellite Sensing

Blake Schaeffer and CyAN Team

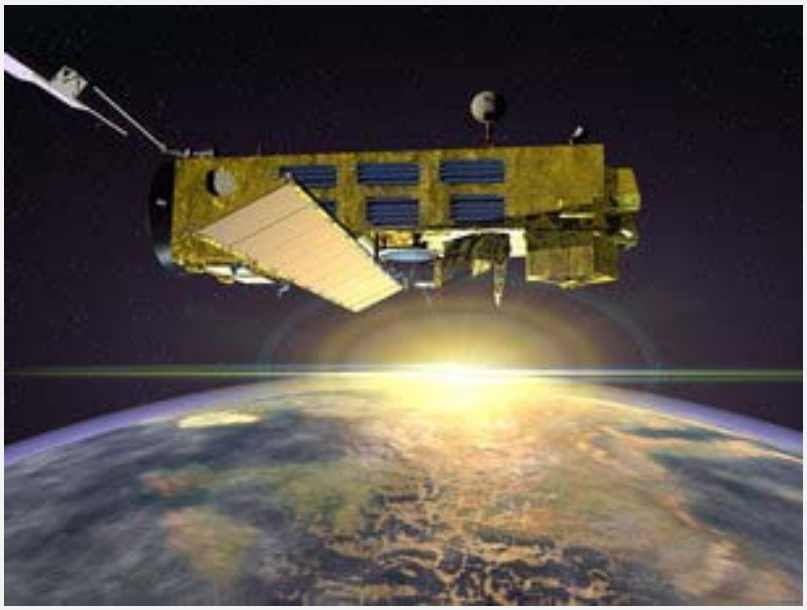
May 8, 2018

EPA
United States
Environmental Protection
Agency

AquaWatch

The GEO Water Quality Initiative

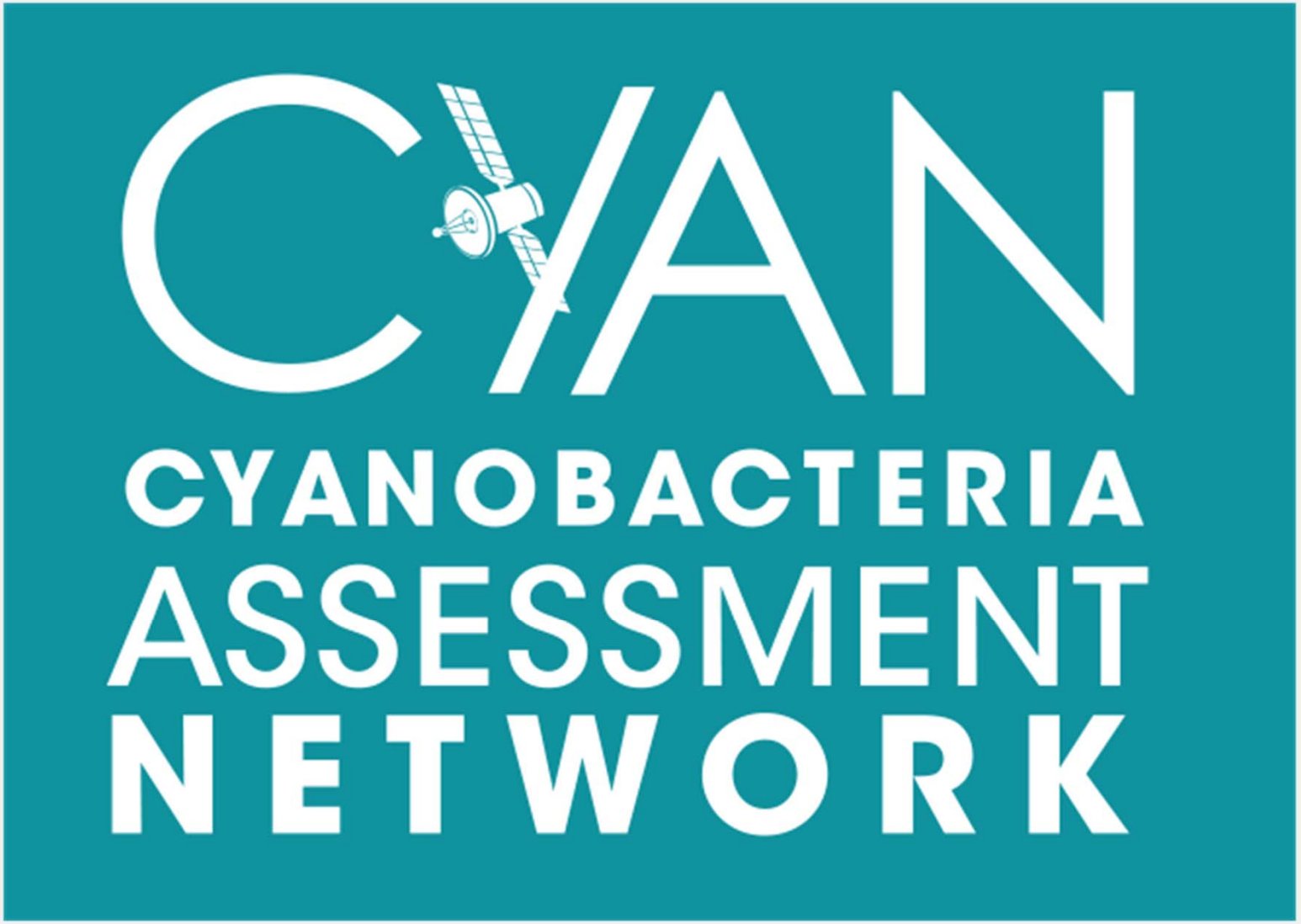
EPA
United States
Environmental Protection
Agency



ESA Envisat

ESA Sentinel-3

EPA
United States
Environmental Protection
Agency



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

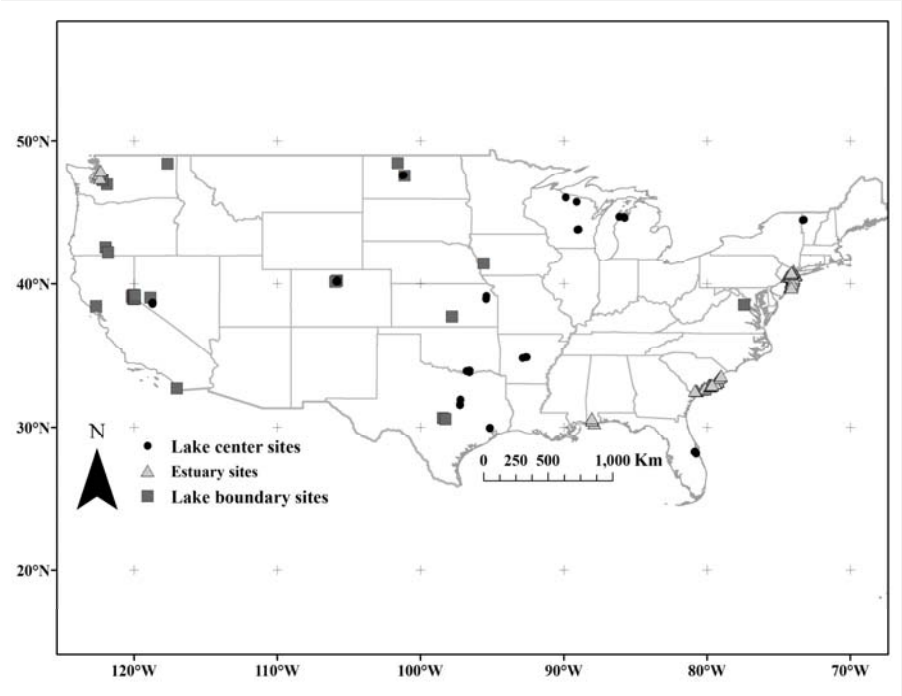
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

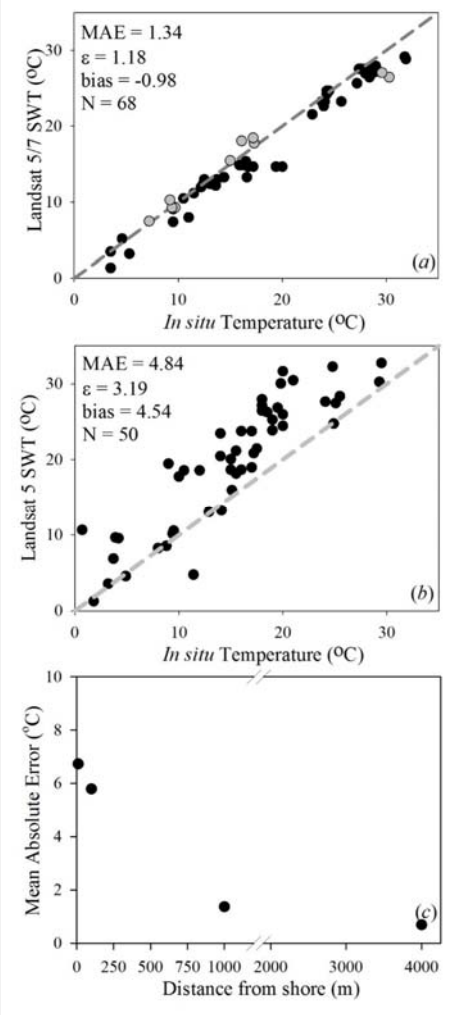
USGS
science for a changing world

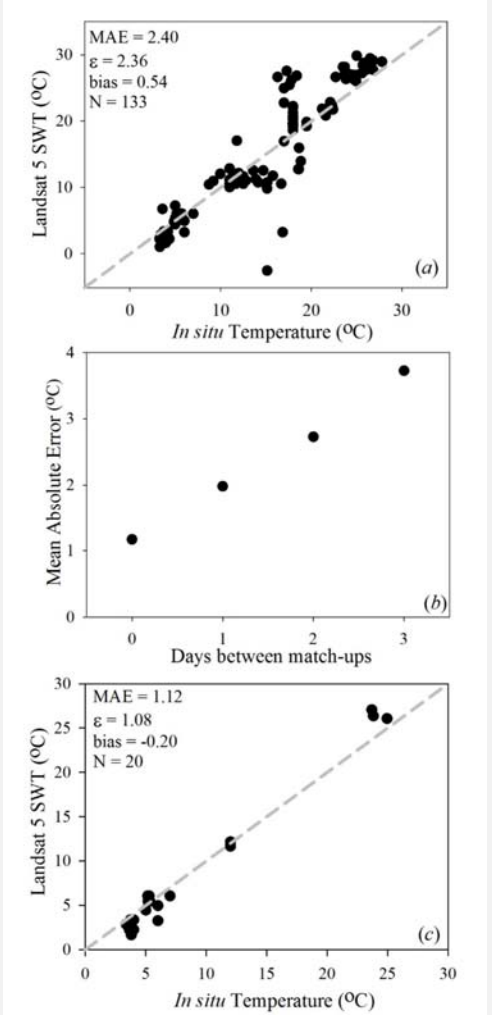
NASA

Schaeffer et al. 2015. Agencies collaborate, develop a cyanobacteria assessment network. Eos. 96:16-20.

Surface Water Temperature

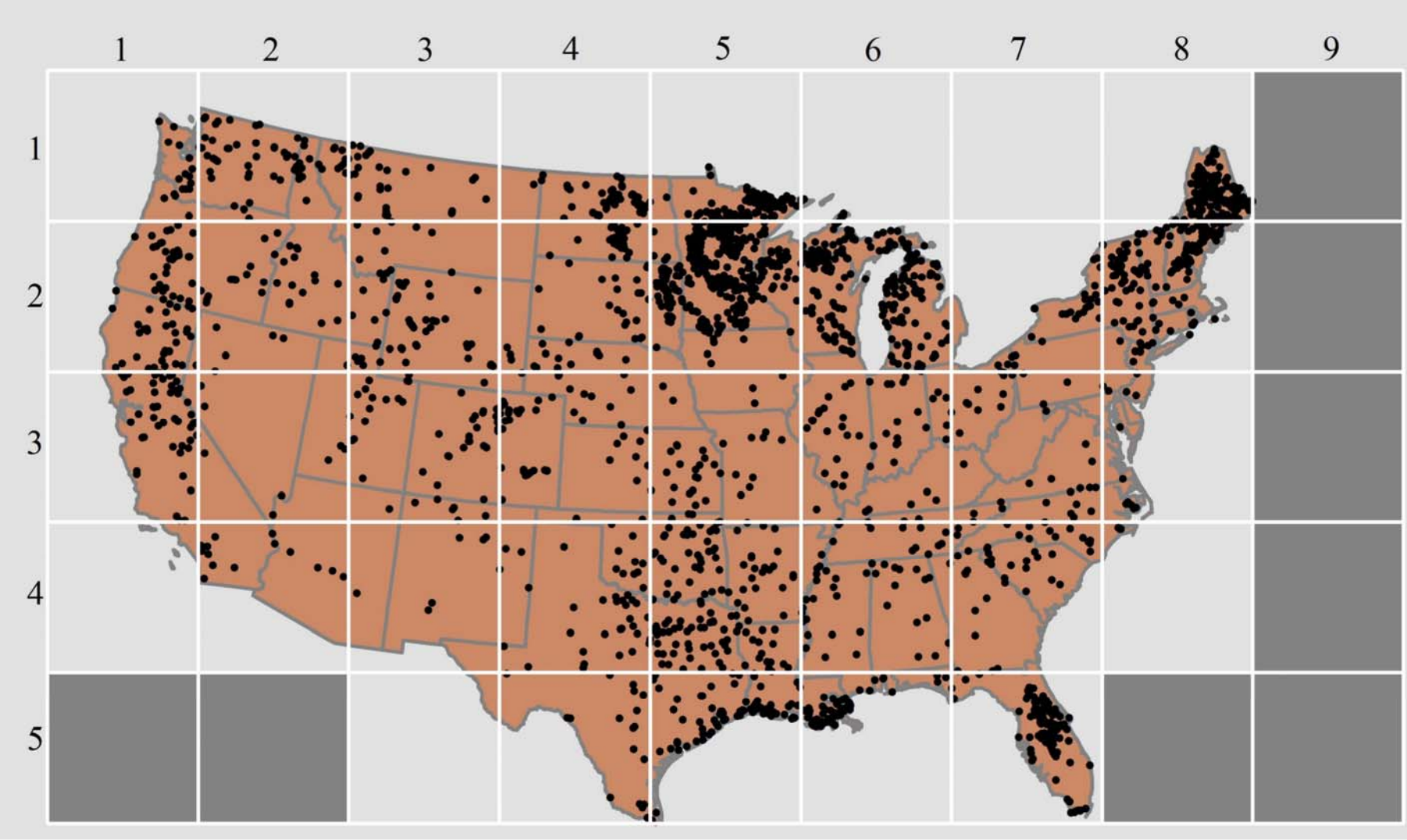






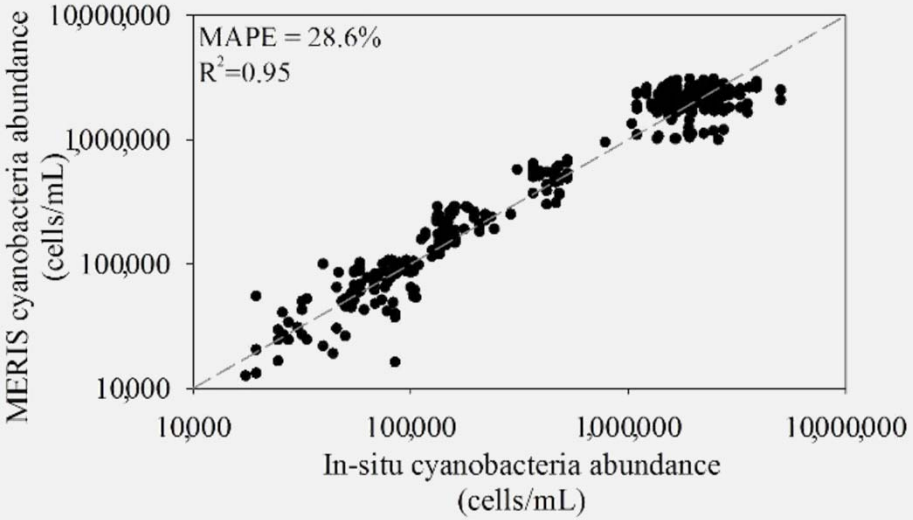
USGS will host starting Summer 2018

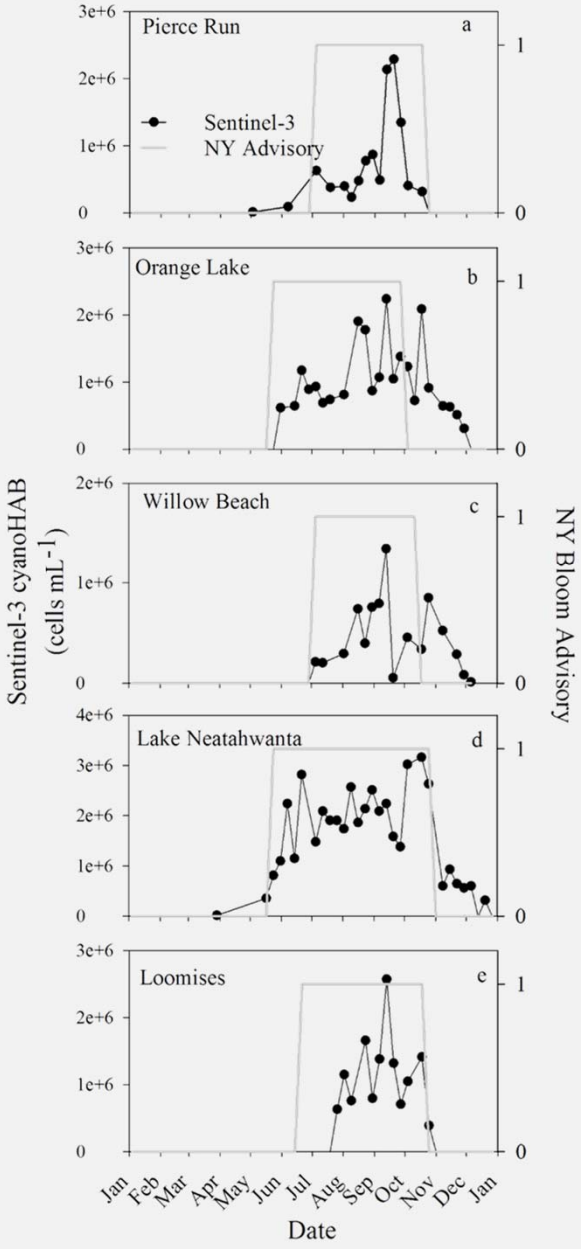
Schaeffer et al. (*In Review*). International Journal of Remote Sensing.



Source: Clark et al. 2017. Ecological Indicators. 80:94-95.

Schaeffer et al. (*In Review*). Environmental Modelling and Software.





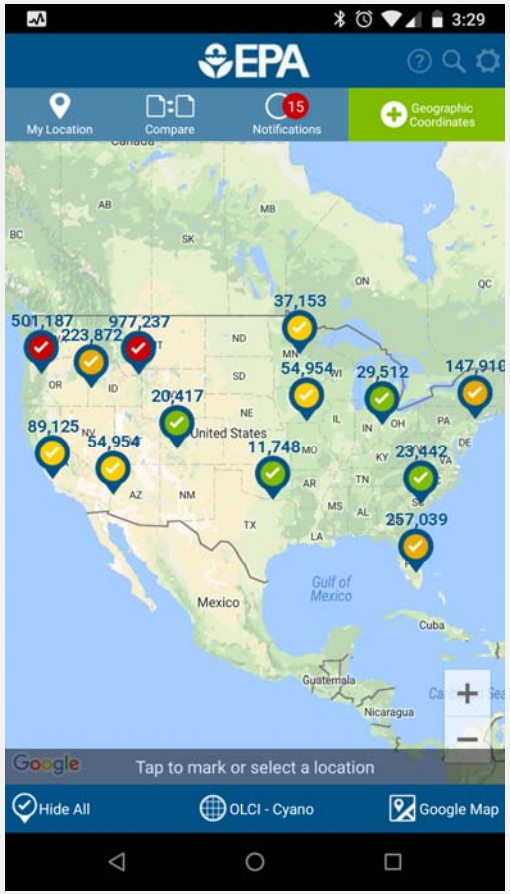
Source: Clark et al. 2017. Ecological Indicators. 80:94-95.

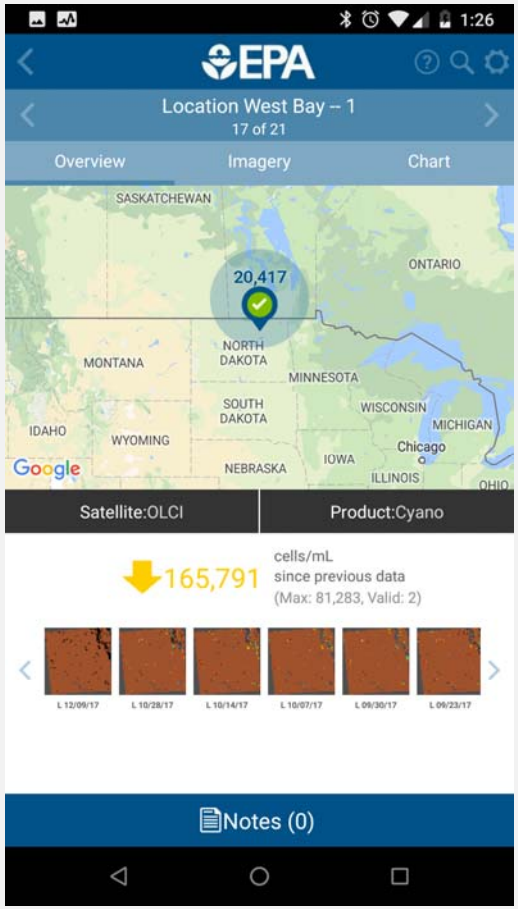
Schaeffer et al. (*In Review*). Environmental Modelling and Software.

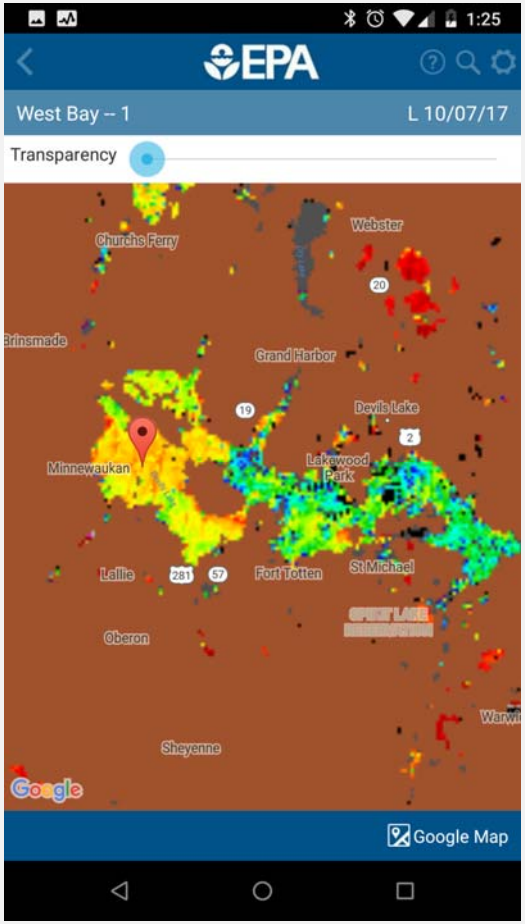
United States Environmental Protection Agency

Known Issues

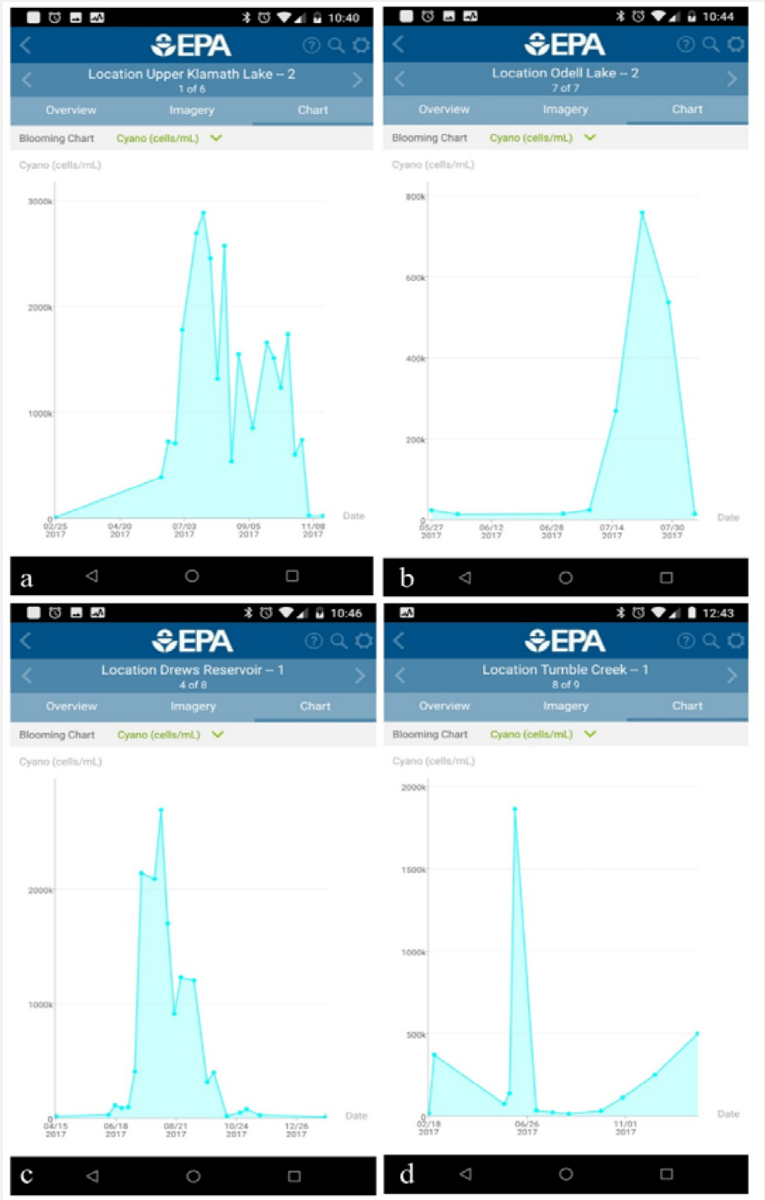
Android Mobile Application

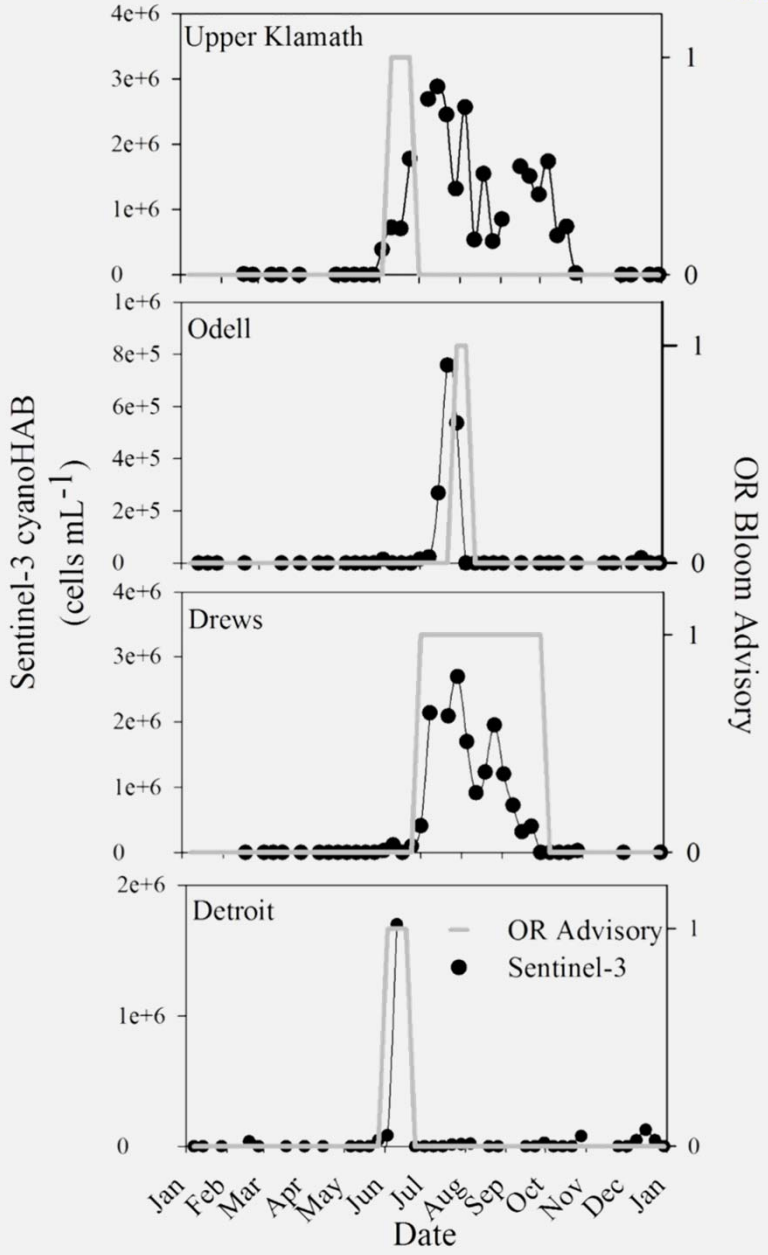






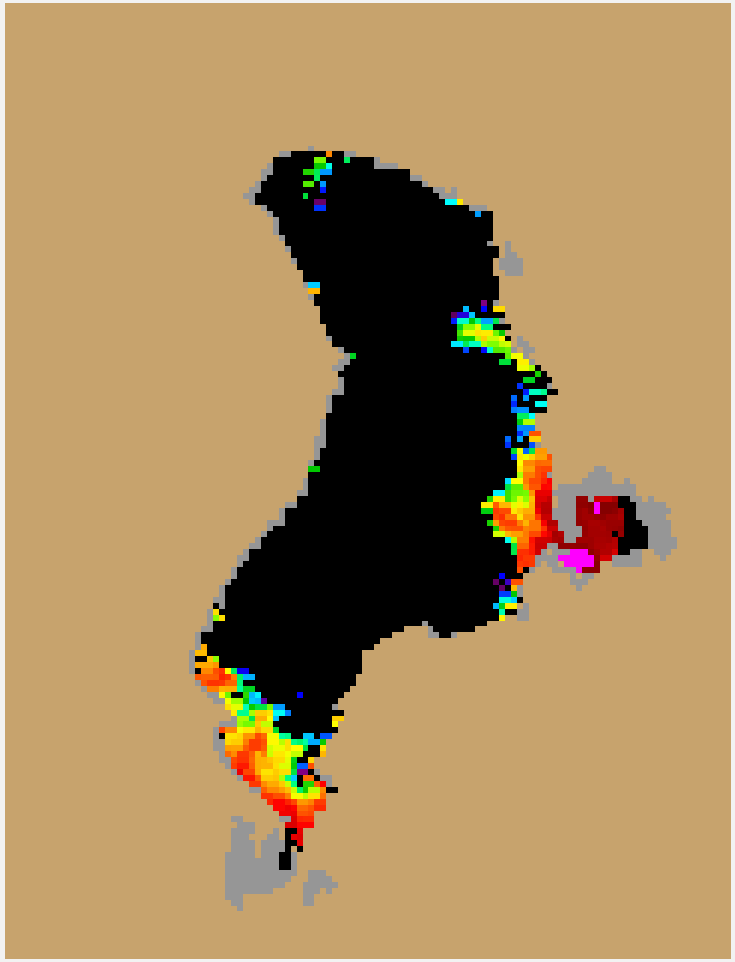
Webinar Training May 1, 2018 2:00pm



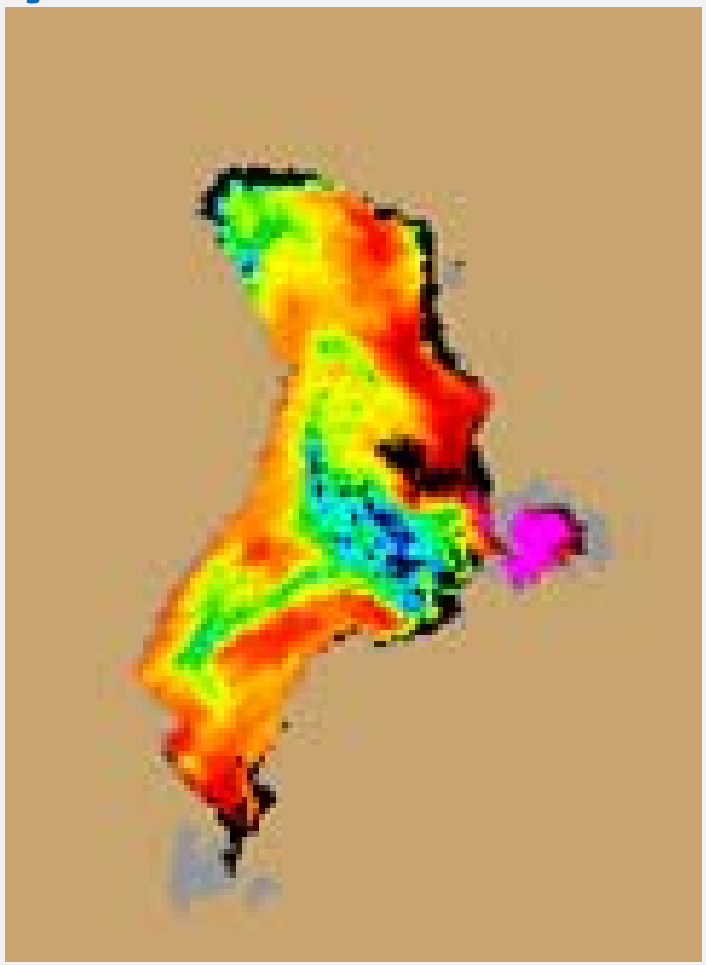


Schaeffer et al. (*In Review*). Environmental Modelling and Software.

Utah DEQ Case Study



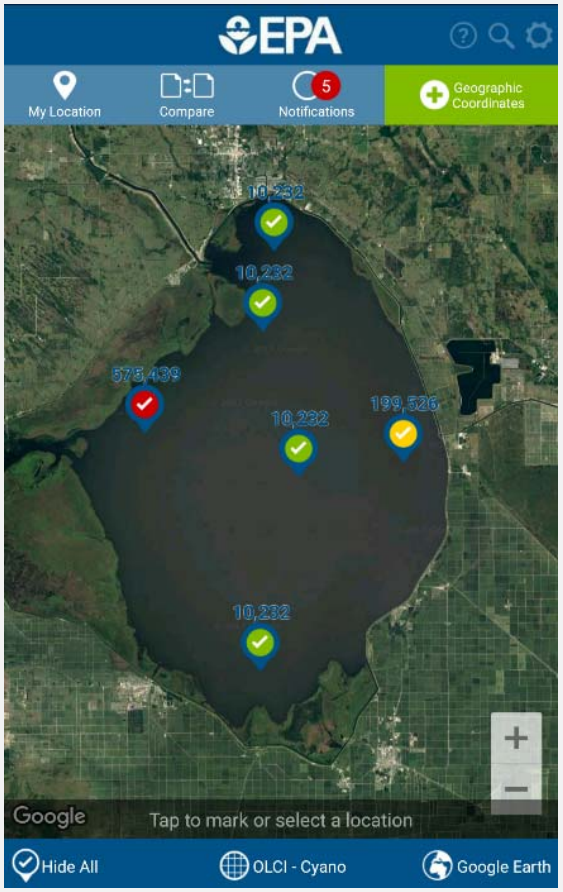
June 18, 2017

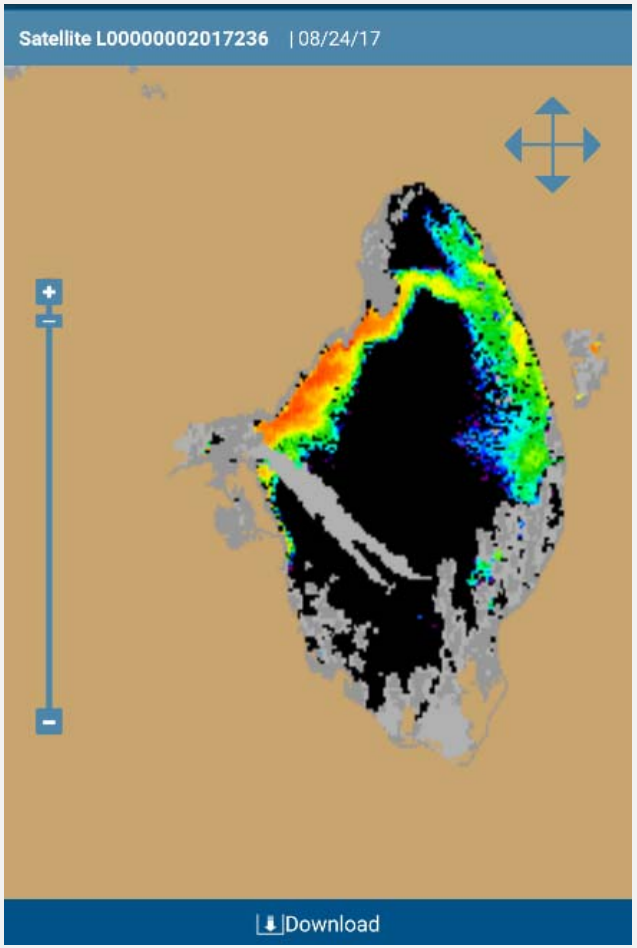


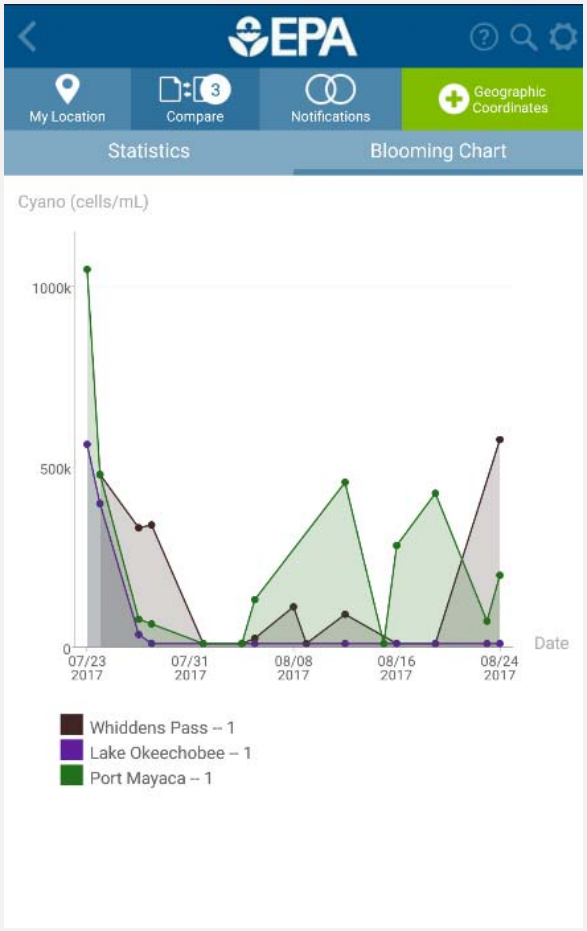
July 3, 2017

Sentinel-3 OLCI imagery from ESA and processed by NOAA

USACE Florida Case Study







Sentinel-3 OLCI imagery from ESA
CyAN app supported by NERL/CED/WEB & OSIM

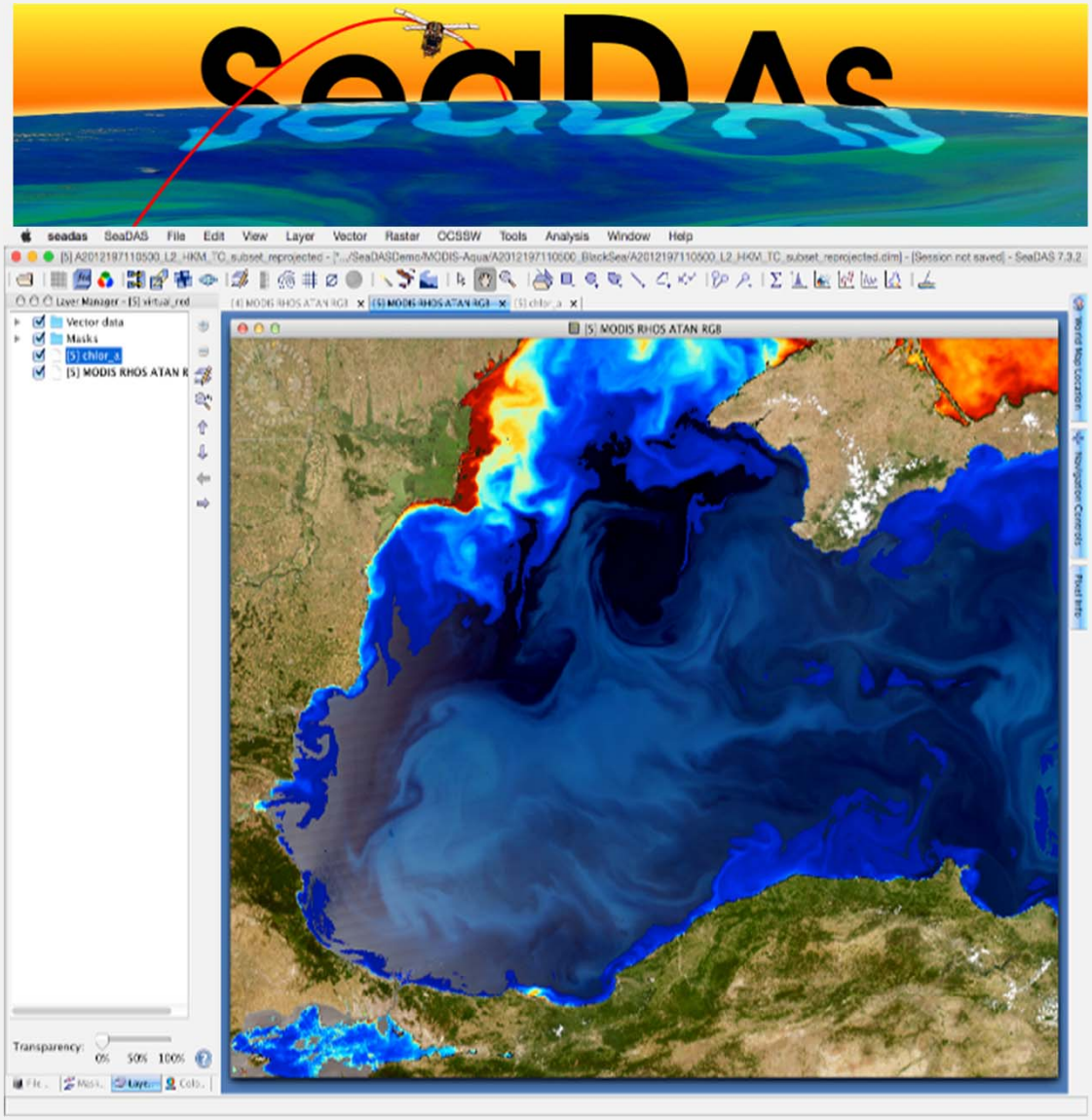
EPA United States Environmental Protection Agency

USGS science for a changing world

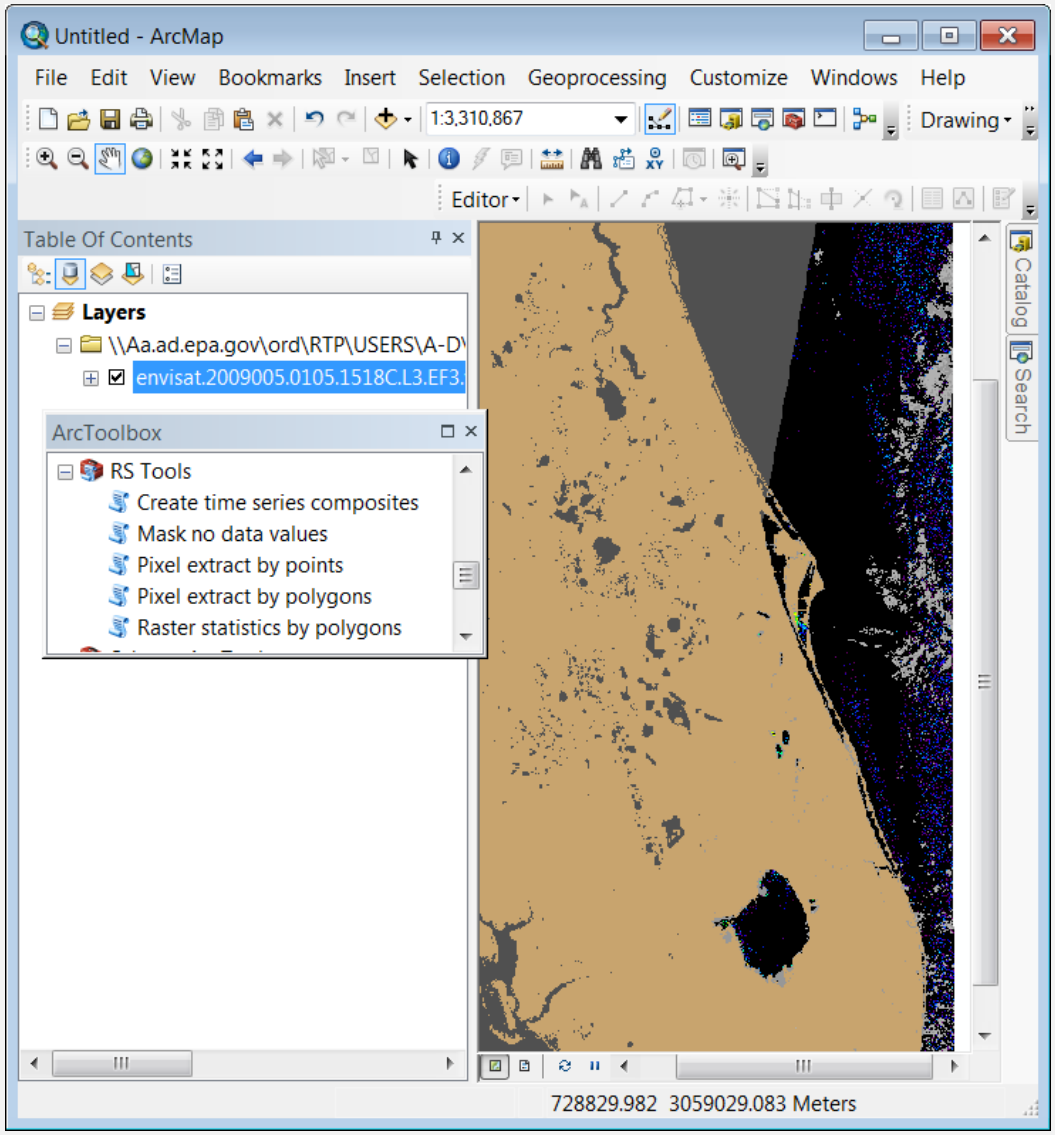
NASA

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

Webinar Training May 23, 2018 2:00pm



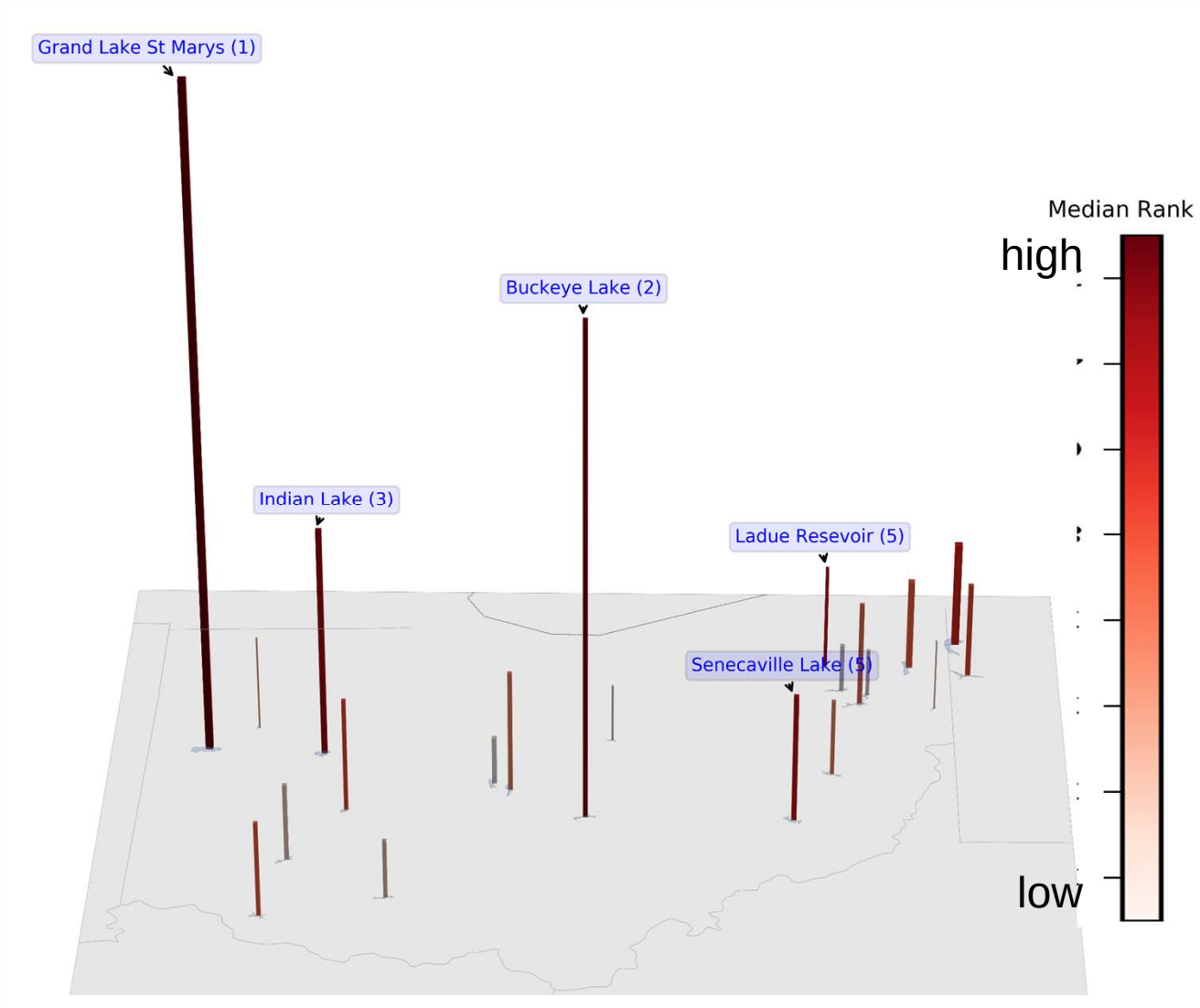
Webinar Training April 24, 2018 2:00pm



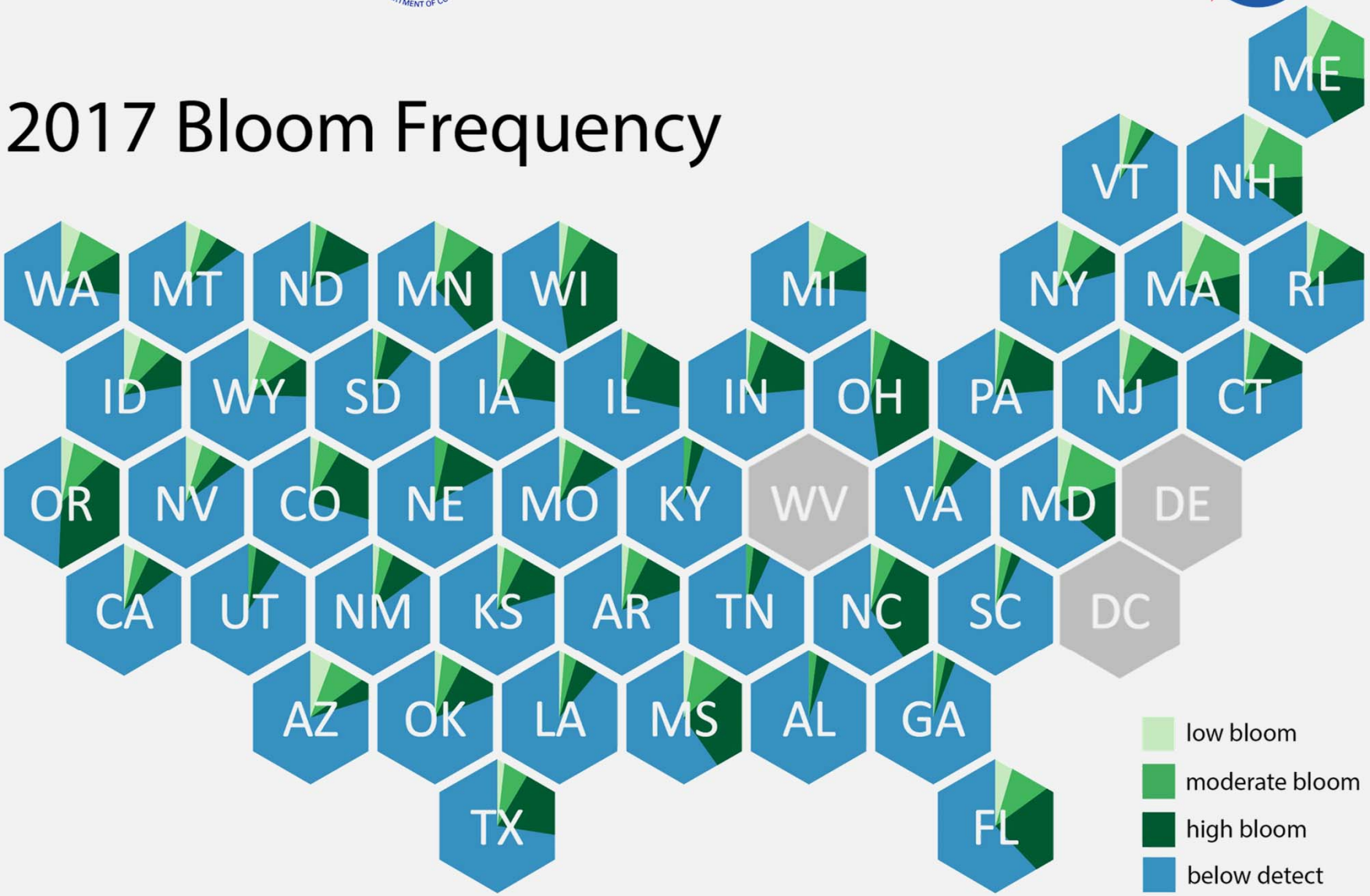
Severity metric

Severity captures magnitude of biomass.

Ohio shown



2017 Bloom Frequency



Source: Clark et al. 2017. Ecological Indicators. 80:94-95.

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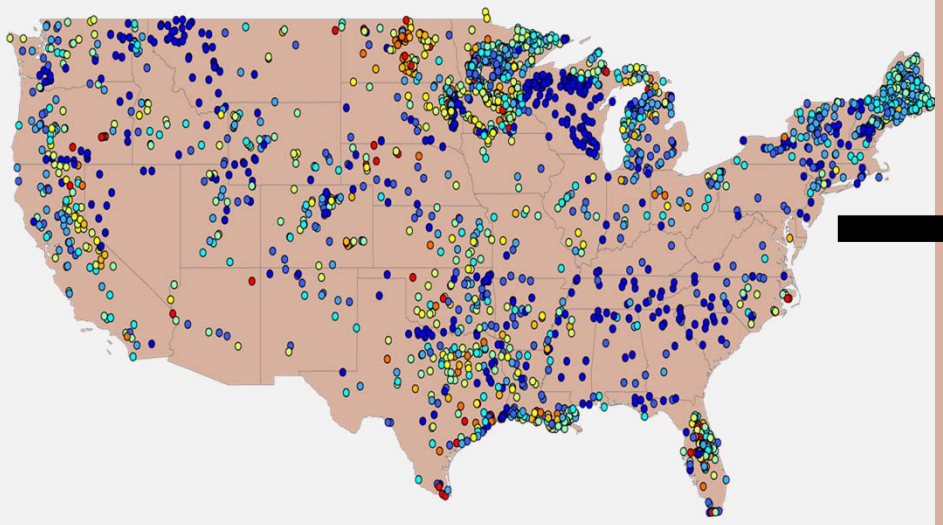
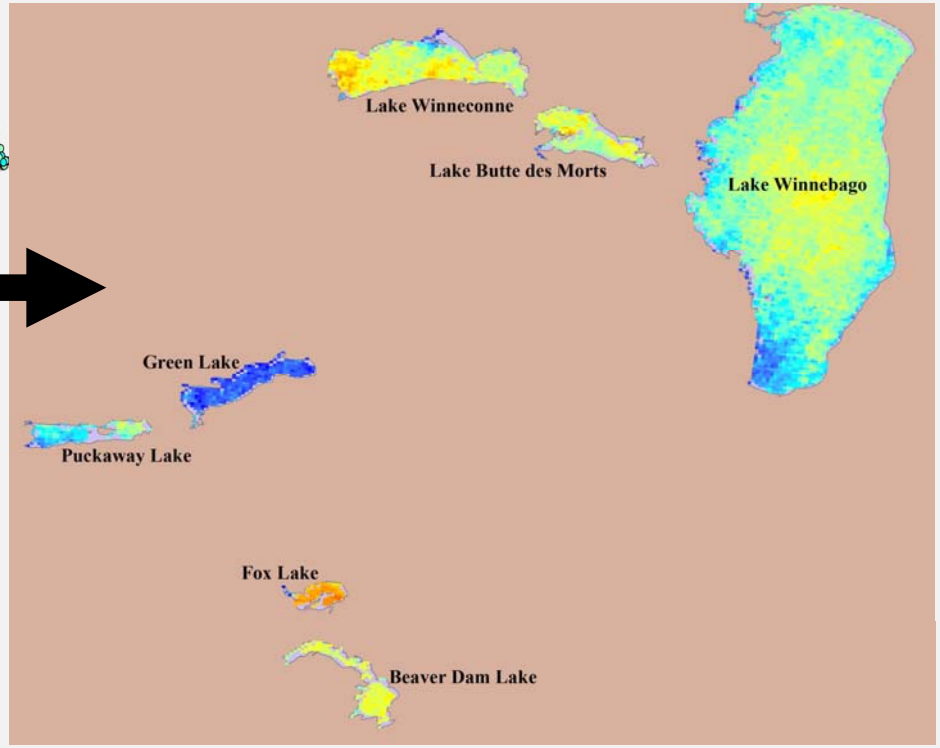
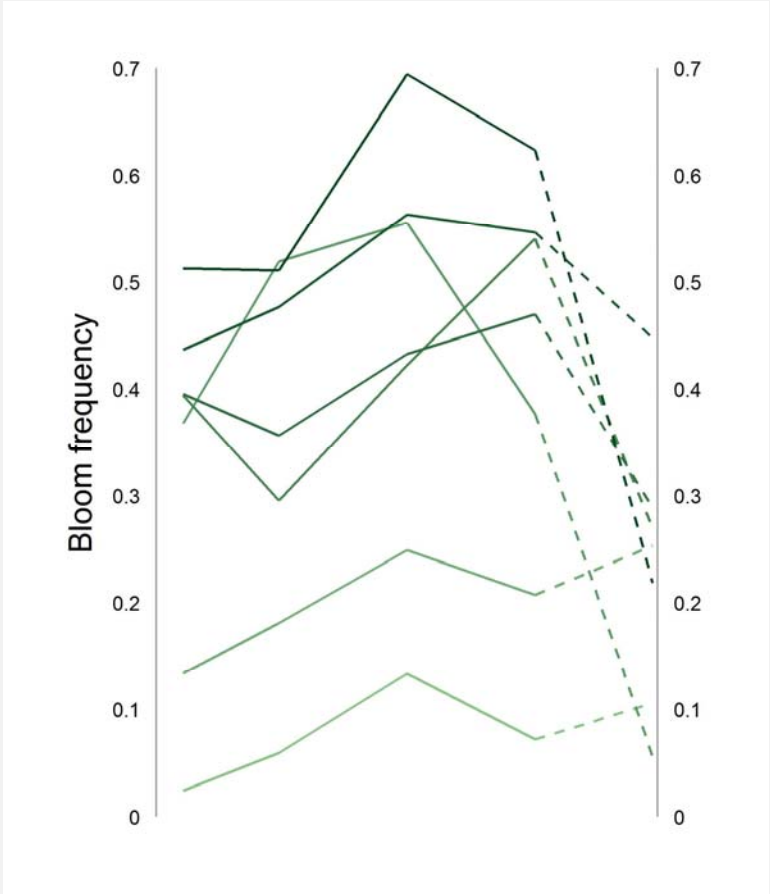
NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

2011 Lake Freq

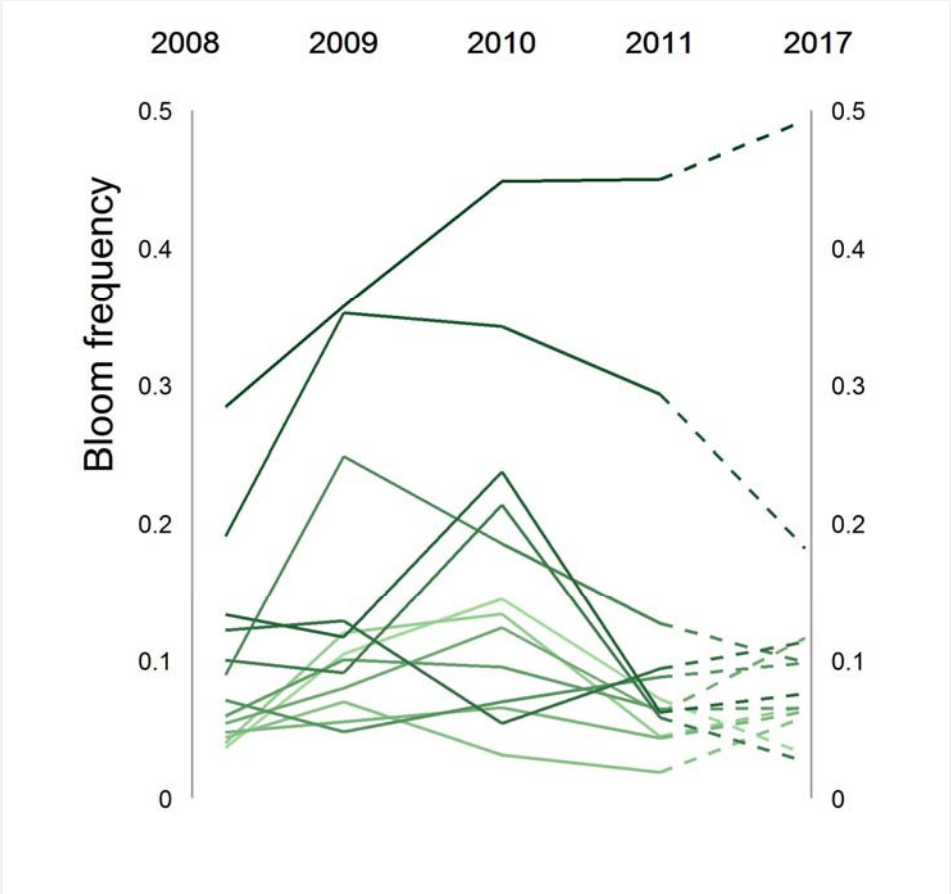


2011 Pixel Freq



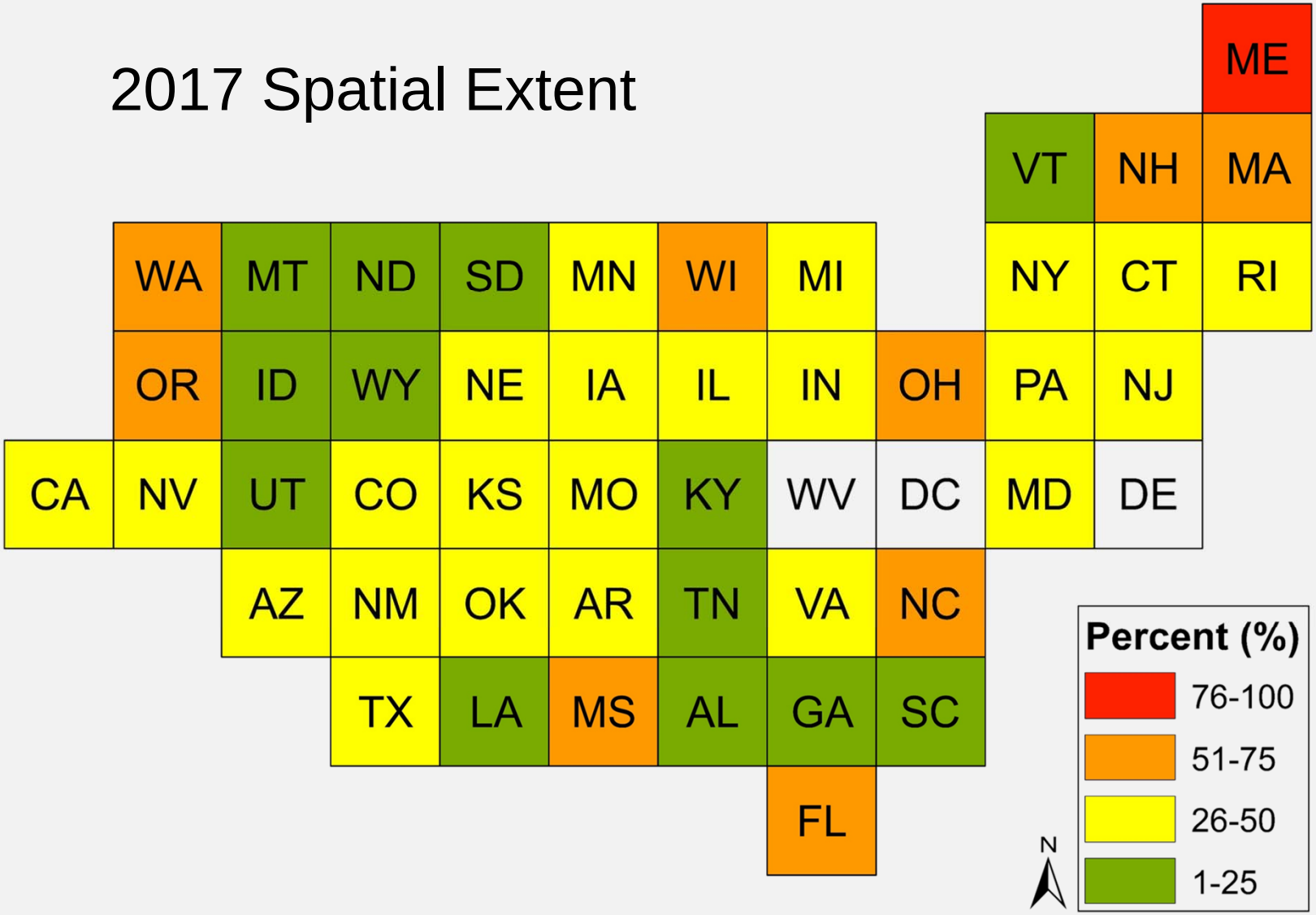


Florida



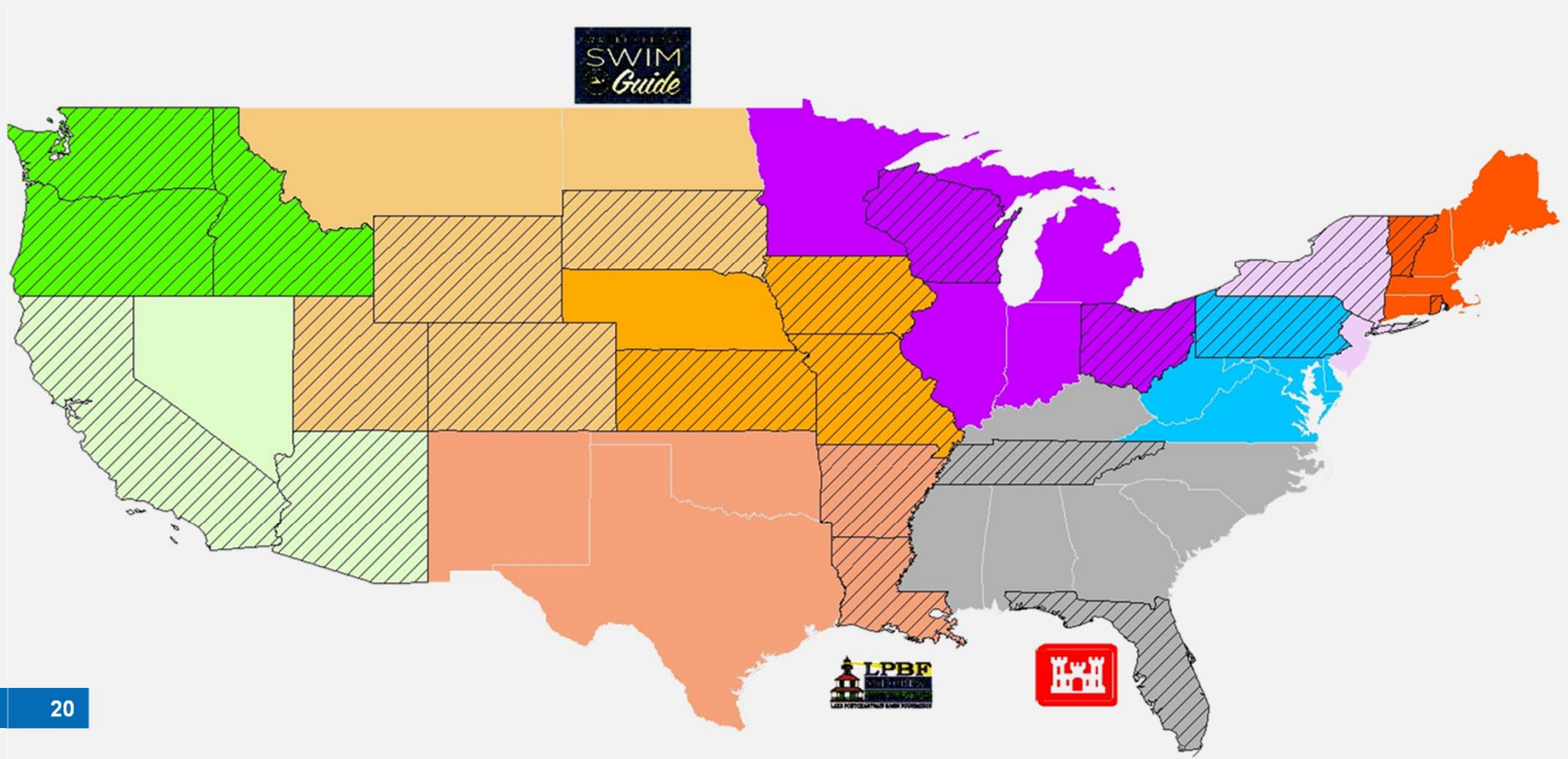
Ohio

2017 Spatial Extent



Source: Urquhart et al. 2017. Harmful Algae. 67: 144-152.

Collaborators



Impact

- Consistent approach for determining cyanoHAB change, year-to-year, with long-term operational satellites
- Quantify cyanoHAB spatial extent and frequency of occurrence
- Support management of recreational waters and drinking water sources

For More Information

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www.epa.gov/cyanoproject

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