EPA Region 4 Harmful Algal Bloom Southeastern Regional Workshop Agenda

Day 2 – Tuesday, May 15, 2018

Recording: http://epawebconferencing.acms.com/p5xr072366s/

Freshwater HABs Guidelines and Management Strategies		
Time	**Presentation Title**	**Presenter**
8:00 – 8:15 am	Registration	EPA
8:15 – 8:30 am	Welcome and Introductions	Region 4, EPA
8:30 – 9:00 am	Development of Recreational Ambient Water Quality Criteria and/or Swimming Advisories for Cyanotoxins	John Ravenscroft, EPA
9:00 – 9:30 am	Via Webinar: Progress in HAB Mitigation for Aquatic Systems?	Kevin G. Sellner, Hood College
9:30 – 9:50 am	Q&A and Open Discussion	EPA
9:50 – 10:00 am	Break	
Overview of States HABs Experience and Programs		
10:00 – 10:20 am	Public Health Response to Freshwater HABs in Florida	Andrew Reich, FDOH
10:20 – 10:40 am	North Carolina Algal Bloom Assessment Program	Leigh Stevenson, NCDENR
10:40 – 11:00 am	Status of HABs and Cyanotoxins Monitoring and Response in South Carolina	David Chestnut, SCDHEC
11:00 – 11:20 am	Harmful Algal Bloom Response and Challenges in Kentucky	Melanie Arnold, KYDEP
11:20 – 11:40 am	Overview of Mississippi Harmful Algal Blooms	Pete Howard, MDEQ
11:40 – 12:00 pm	HABs and Toxins in Georgia	Victoria Adams, GAEPD
12:00 – 12:20 pm	HABs and Toxins in Tennessee	Jennifer Dodd, TDEC
12:20 – 12:40 pm	Q&A and Open Discussion	EPA
12:20 – 2:00 pm	Networking Lunch – States HABs Experiences Discussion	

Surface Water Blooms Monitoring		
2:00 - 2:30 pm	Forecasting Toxic Cyanobacterial Blooms throughout the Southeastern U.S.	Alan Wilson, Auburn University
2:30 – 2:50 pm	Consider the Source: Tools and Resources for Source Water Protection	James (Bo) Williams, EPA
2:50 – 3:10 pm	Cyanobacterial Ecological Strategies and how these Impact Monitoring Techniques	Barry Rosen, USGS
3:10 – 3:25 pm	Break	
3:25 – 4:30 pm	PMN and Basic Cyanobacteria ID Workshop	Jennifer Maucher, NOAA
4:30 – 4:50 pm	Field Test Strips and ELISA Kits: Screening for Algal Toxins	Sue Dye, EPA
4:50 – 5:00 pm	Wrap up	EPA
5:00 pm	Adjourn and Networking Opportunity at Taco Mac in the CNN Center	

EPA Region 4 Harmful Algal Bloom
Southeastern Regional Workshop Agenda

Biographies of Presenters

Mr. John Ravenscroft is a microbiologist in EPA's Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. He is coordinating the development of the Agency's new recreational ambient water quality criteria for cyanotoxins. He also participated in developing recreational water quality criteria for fecal indicators and was a project lead for preparing technical support documents for use in criteria implementation. His interests include integrating quantitative microbial risk assessment frameworks to help inform science policy. Mr. Ravenscroft received a M.S. in Environmental Microbiology from West Virginia University and a B.S. in Biology from Frostburg State University. He is a Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) with the National Environmental Health Association.
Email: ravenscroft.john@epa.gov; Phone: 202-566-1101

Dr. Kevin Sellner: After serving as the first program manager for the interagency program ECOHAB and ~40 years working primarily in Chesapeake Bay, Kevin is now a Senior Scholar at Hood College's Center for Coastal and Watershed Studies designing and implementing multiple planktonic and benthic cyanobacteria projects for waters in western Maryland. His recent projects have explored several mitigation techniques for freshwater and brackish cyanobacteria blooms, including flushing, flocculation, acidification, barley straw (*Hordeum vulgare*) additions, low level algicide impacts, and peroxide loading to reduce microcystin-producing cyanobacteria. He has published >100 papers, reports, and factsheets with two recent reviews of prevention, control, and mitigation techniques for HABs in fresh and marine waters.
Email: sellner@hood.edu; Phone: 410-693-2067

Mr. Andrew Reich is the scientific advisor to the Chief of the Bureau of Environmental Health at Florida Department of Health. He has over 25 years of experience in public health addressing issues such as water quality, fish advisories, hazardous waste investigations, toxicology consultations, environmental contamination and disease outbreaks. For over 10 years Mr. Reich has lead the Department's effort to address adverse health impacts from exposures to toxic algal blooms in fresh water and marine environments. His efforts have led to an integrated and collaborative approach to environmental health response in Florida with federal, state, and local partners including NOAA, CDC, Army Corps of Engineers and the US Environmental Protection Agency. Mr. Reich has a Master's of Science degree in Public Health from the University of Alabama in Birmingham as well as a Master's in Medical Science from Emory University in Atlanta, Georgia with a concentration in Intensive Care Medicine.
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Ms. Leigh Stevenson is an Environmental Specialist with the North Carolina Division of Water Resources. She works as a phycologist within the Algal and Aquatic Plant Assessment Program. Since joining the division in June 2017, she has been actively involved in developing and integrating cyanotoxin monitoring into North Carolina's algal bloom response protocol. Leigh holds an MS in Environmental Science from Indiana University and a BS in Biochemistry from Ball State University.
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Mr. David Chestnut is currently a Senior Scientist with the South Carolina Department of Health and Environmental Control, Bureau of Water, where he has worked since 1985.
He received a Bachelor of Science degree in Biology from Northern Illinois University in 1980, graduating cum laude. In 1983 he received his Master of Science degree in Biology from the University of South Carolina in Columbia, SC. After graduating from USC he served as the Estuarine Macroinvertebrate Laboratory Manager for the Department of Research and Development at McNeese State University in Lake Charles, Louisiana. His primary responsibilities at SCDHEC include the design and oversight of the statewide Ambient Surface Water Quality Monitoring Program and the assessment of water quality data to support Clean Water Act reporting requirements [§305(b) and §303(d) reports] and other internal SCDHEC needs. Twice President of the Southeastern Water Pollution Biologists Association (SWPBA), Executive Committee member, three terms. Mr. Chestnut is currently a member of the National Water Quality Monitoring Council (NWQMC), a subgroup of the federal Advisory Committee on Water Information, representing the eight EPA Region 4 southeastern states. He serves on the NWQMC Water Information Strategies, Collaboration and Outreach, and Volunteer Monitoring workgroups. He is also a member of the EPA and States (through ACWA) Monitoring and Assessment Partnership workgroup. Mr. Chestnut is currently serving on the EPA National Aquatic Resource Survey steering committees for the National Lakes Assessment, River and Streams Assessment, and National Coastal Condition Assessment.
Email: CHESTNDE@dhec.sc.gov; Phone: 803-898-4066

Ms. Melanie Arnold is the supervisor of the Monitoring Section at the Kentucky Division of Water. She oversees a variety of monitoring programs including Probabilistic Bio-assessment Monitoring, Reference Reach Monitoring, Ambient Rivers, Ambient Lakes, 319 Non-point Source Monitoring, Fish Tissue Monitoring, and Harmful Algal Bloom Response for recreational waters.
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Mr. Pete Howard is an Environmental Scientist with the MS Dept of Environmental Quality, Field Services Division. He assists with monitoring a number of projects statewide to protect water quality. Pete has 29 years' experience including, Clean Lakes, Ambient Stream and Lake monitoring, WLAs, Restoration, spills, Special Studies, Deepwater Horizon TWG groups and Hurricane Katrina assessments. M.S. in Geography with emphasis in GIS and Water Resource Management from the University of Southern Mississippi and a B.S. in Geography from the University of Central Arkansas.
E-mail: phoward@mdeq.ms.us; Phone: 601-961-5701

Ms. Jennifer Dodd is a Deputy Director in TDEC's Division of Water Resources. Prior to that, from 1999 to 2012, she worked in TDEC's Pretreatment Program, serving as Pretreatment Coordinator for the State starting in 2003. Ms. Dodd received her Bachelor's degree in Chemistry from Warren Wilson College and her Master's degree in Environmental Science and Engineering from the Civil/Environmental Engineering Department of Virginia Tech.
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Dr. Alan Wilson received his Ph.D. in Applied Biology from Georgia Tech in 2006. After spending a year as a research investigator at the University of Michigan, Alan joined the faculty in the School of Fisheries at Auburn University in 2007 where he is currently an Associate Professor. Alan is broadly interested in understanding the ecology of cyanobacterial blooms in recreational, drinking, and aquaculture waterbodies. Alan has also developed a large-scale project with collaborators throughout much of the southeastern US to help develop models to forecast cyanobacterial blooms in this region. Lastly, during the past three years, Alan has also

been studying the factors responsible for off-flavor events in drinking water reservoirs. You can learn more about Alan's research at http://wilsonlab.com/
Email: aew0009@auburn.edu; Phone: 334-246-1120

Mr. James (Bo) Williams is a Biologist in the Drinking Water Protection Division of the U.S. Environmental Protection Agency's Office of Ground Water and Drinking Water in Washington, DC. As a member of the Source Water Protection program, he manages geospatial analyses and outreach in a variety of projects to protect sources of drinking water and is a representative on the national Source Water Collaborative. Prior to joining EPA, Bo worked as a field biologist with the California Department of Fish & Wildlife, Fisheries Restoration Program, and in watershed restoration and planning roles with non-profits in Michigan, California, and the DC area. Bo has an M.S. in Natural Resources and Environment from the University of Michigan and a B.A. in History from Kenyon College.
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Dr. Barry Rosen has worked on cyanobacteria for over four decades, with emphasis on physiological ecology. His title is Biologist with U.S. Geological Survey Southeast Regional Director's Office located on the campus of University of Central Florida, Orlando, Florida. He recently published: *Cyanobacteria of the 2016 Lake Okeechobee and Okeechobee Waterway harmful algal bloom,* Open-File Report 2017-1054 and has two other related publications near completion. He is involved in several research projects involving cyanobacterial taxonomy and cyanotoxins throughout the U.S. and is collaborating with scientists around the world. He is also the Southeast Regional Tribal Liaison for the USGS. He recently authored the *Field and Laboratory Guide to Freshwater Cyanobacteria Harmful Algal Blooms for Native American and Alaska Native Communities* report, Open-File Report 2015-1164.
Email: brosen@usgs.gov; Phone: 407-738-0669

Ms. Sue Dye is an Aquatic Ecologist at the EPA Region 4 Science and Ecosystem Support Division in Athens, Georgia, in the Ecology Section of the Field Services Branch. She conducts field investigations for Clean Water Act initiatives, including water quality studies and bioassessments in support of numeric nutrient criteria and TMDL development. She is also the manager of the SESD Algal Laboratory, where she analyzes samples for chlorophyll *a* and performs algal bioassays for estimation of trophic status and limiting nutrients. Before starting with EPA in 2007, she was a research coordinator at the Cary Institute of Ecosystem Studies in Millbrook, NY and at the Odum School of Ecology at the University of Georgia. Sue received a B.A. in Biology and Environmental Studies from Oberlin College and an M.S. in Ecology from UGA.
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Ms. Jennifer Maucher Fuquay has been a research scientist with NOAA's Marine Biotoxins Program in Charleston, SC since 2002. Jen is currently the Program Coordinator for NOAA's Phytoplankton Monitoring Network, and is responsible for outreach, training of volunteers, and most recently, led the expansion efforts of PMN into the monitoring of freshwater environments. Prior to becoming program coordinator for the PMN, she conducted laboratory research in the Marine Biotoxins Program which focused on investigation of maternal-fetal transfer of domoic acid, measuring ciguatoxins in endangered Hawaiian monk seals, and assessing the impacts of brevetoxins in naturally exposed sea turtles and birds. Additionally, since 2004, she has served as an adjunct faculty member in the biology department at Trident Technical College. Jen holds a MS in Marine Biology from the College of Charleston.
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Development of Recreational Ambient Water Quality Criteria and/or Swimming Advisories for Cyanotoxins

EPA Region 4 HAB Southeastern Regional Workshop

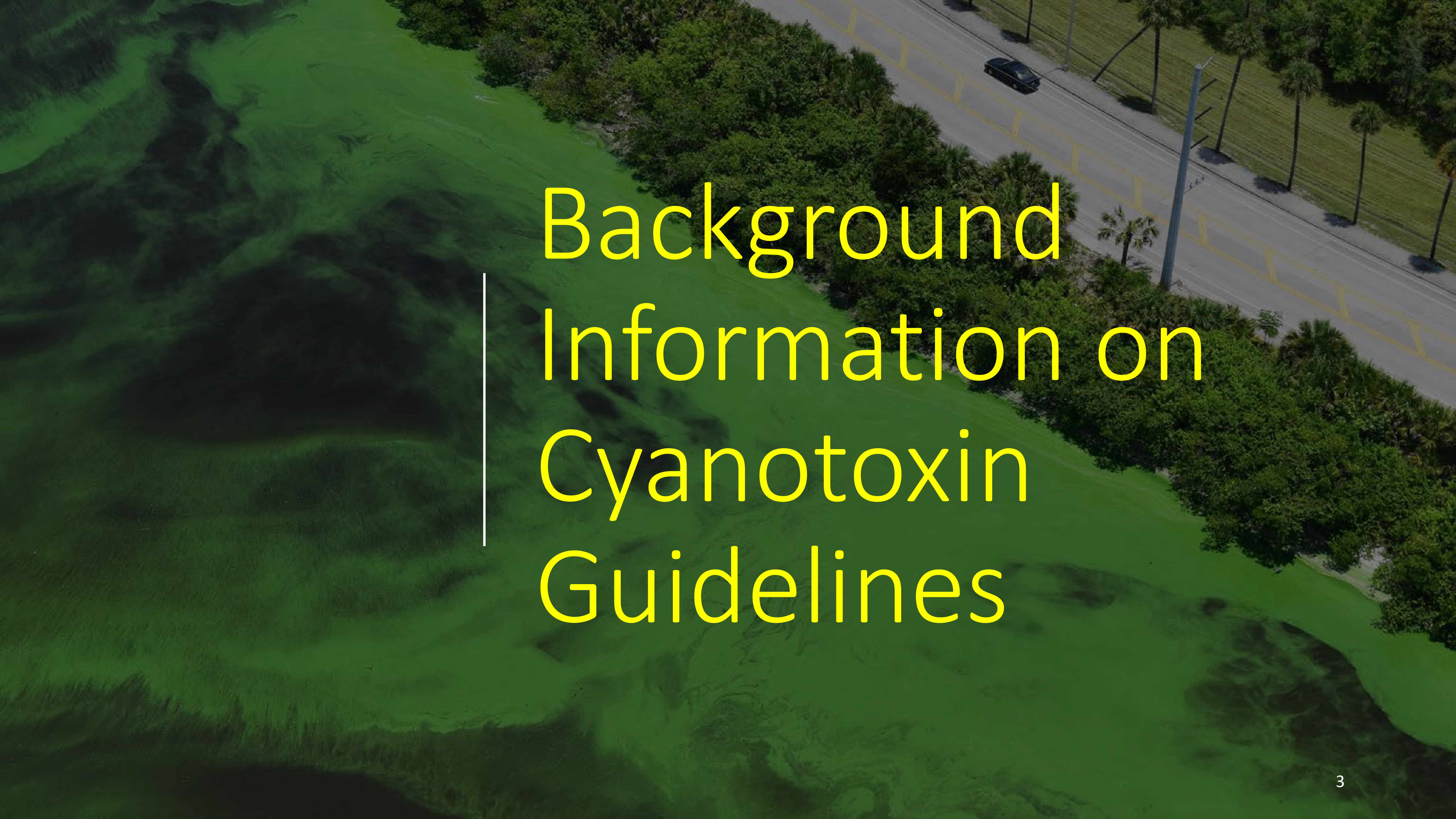
May 15, 2018

John Ravenscroft

U. S. EPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division

Presentation Outline

- **Background information on cyanotoxin guidelines**
- **Overview of the recreational AWQC or swimming advisories for cyanotoxins**
- **Implementation Tools for Cyanotoxins in Recreational Waters**



Background Information on Cyanotoxin Guidelines

EPA's Drinking Water Health Advisories

- In June 2015, EPA published Drinking Water Health Advisories for two cyanotoxins: Total Microcystins and Cylindrospermopsin.
- These 10–day health advisory values are based on consumption of finished drinking water containing these cyanotoxins.
- EPA recommended levels for two age groups: children pre-school age and younger (≤ 6yr); and, school-age children through adults (>6 yr).
- Insufficient information was available on anatoxin-a to develop a reference dose.

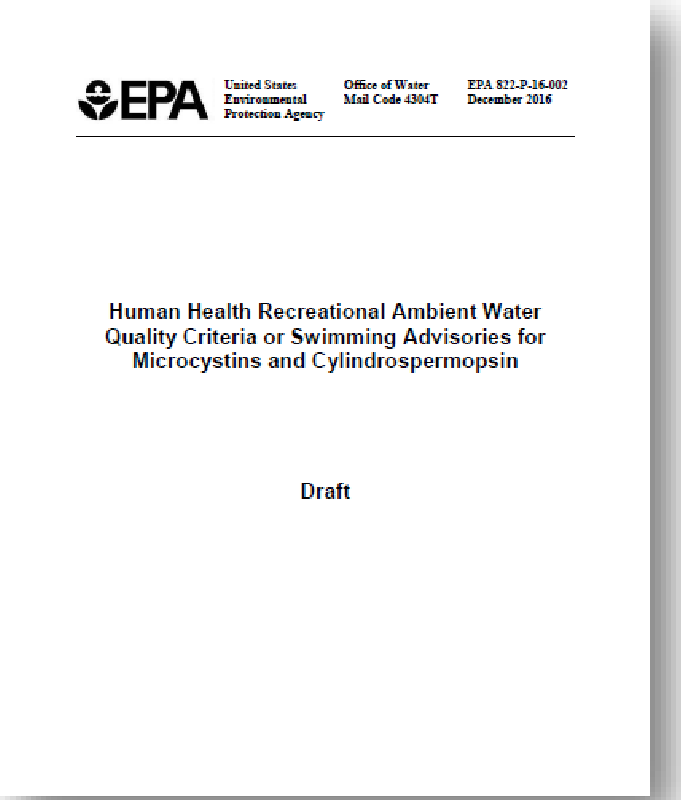
Toxin	Health Advisory Values ≤ 6 yr	Health Advisory Values > 6 yr
Microcystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3.0 µg/L

http://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations

Guidelines for Recreational Waters

- WHO (2003) “Guidelines for Safe Recreational Water Environments”.
- Existing state guidelines for recreational waters are variable and provide inconsistent levels of public health protection from state to state.
- EPA initiated development of CWA Section 304(a) recreational criteria or swimming advisories that reflect the latest science to protect primary contact recreation.
- Draft document posted for public comment 12/2016.

EPA's DRAFT Recreational Criteria or Swimming Advisory Values

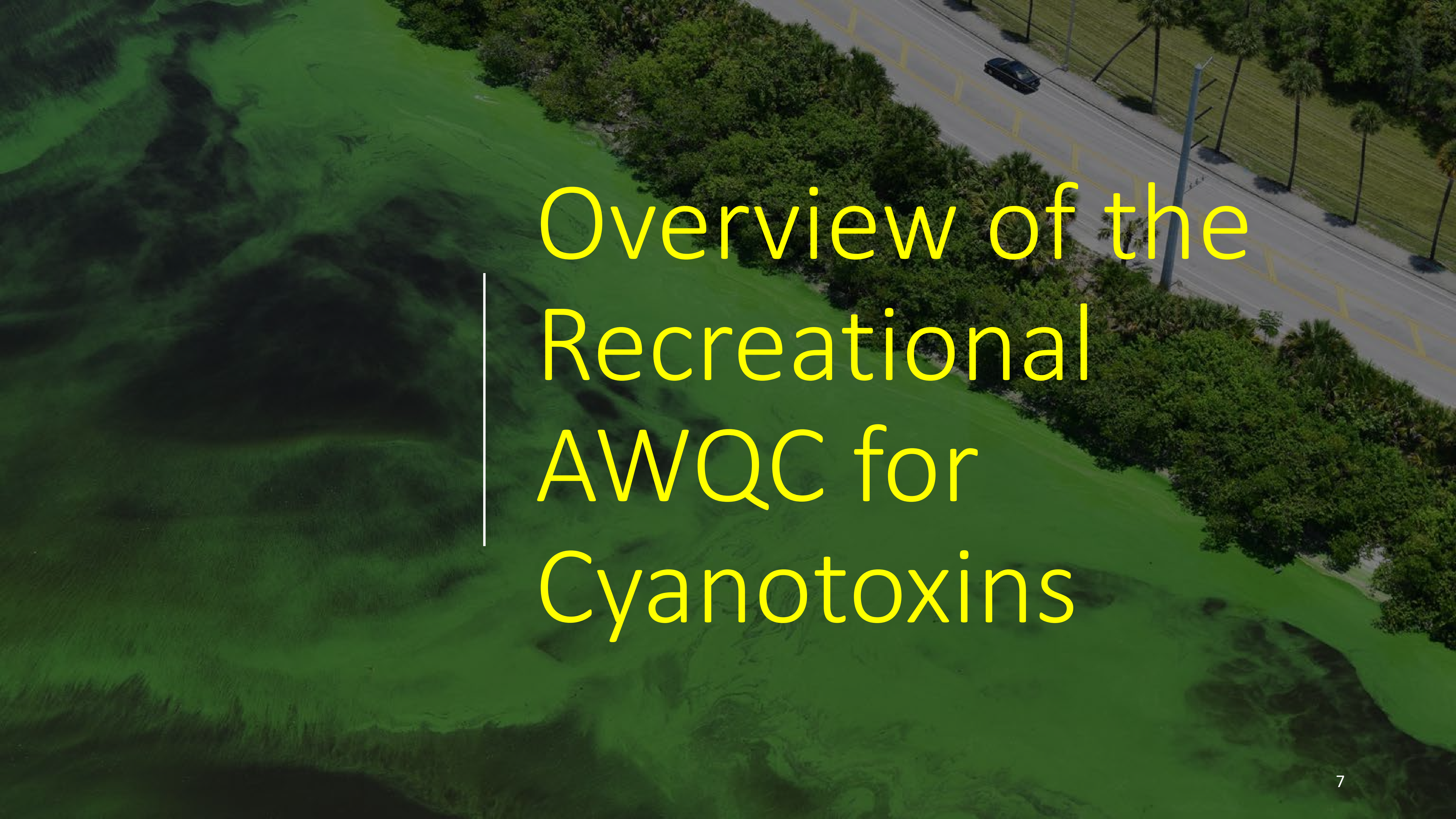

United States Environmental Protection Agency
Office of Water Mail Code 4304T
EPA 822-P-16-002 December 2016

Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin

Draft

Application	Draft Recreational Advisory Values	
	Microcystins	Cylindrospermopsin
	4 µg/L	8 µg/L
Swimming Advisory	Not to be exceeded on any day.	
Recreational Water Criteria	Not to be exceeded more than 10 percent of days per recreational season up to one calendar year.	

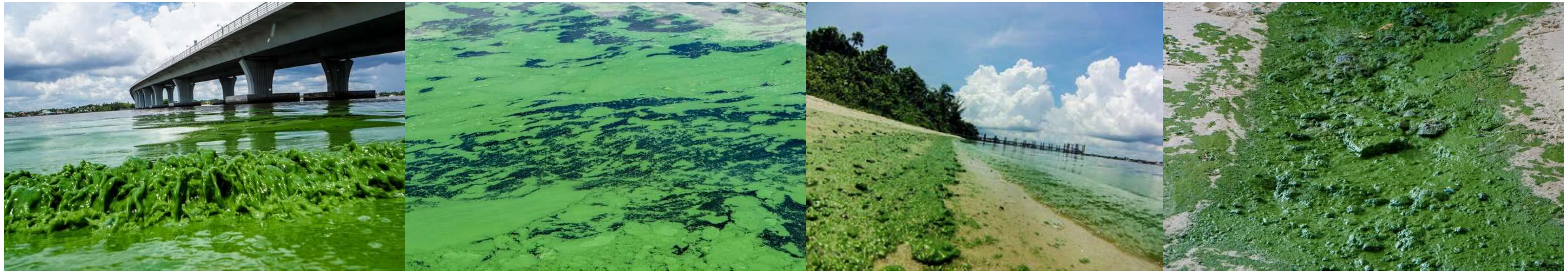
https://www.epa.gov/sites/production/files/2016-12/documents/draft-hh-rec-ambient-water-swimming-document.pdf



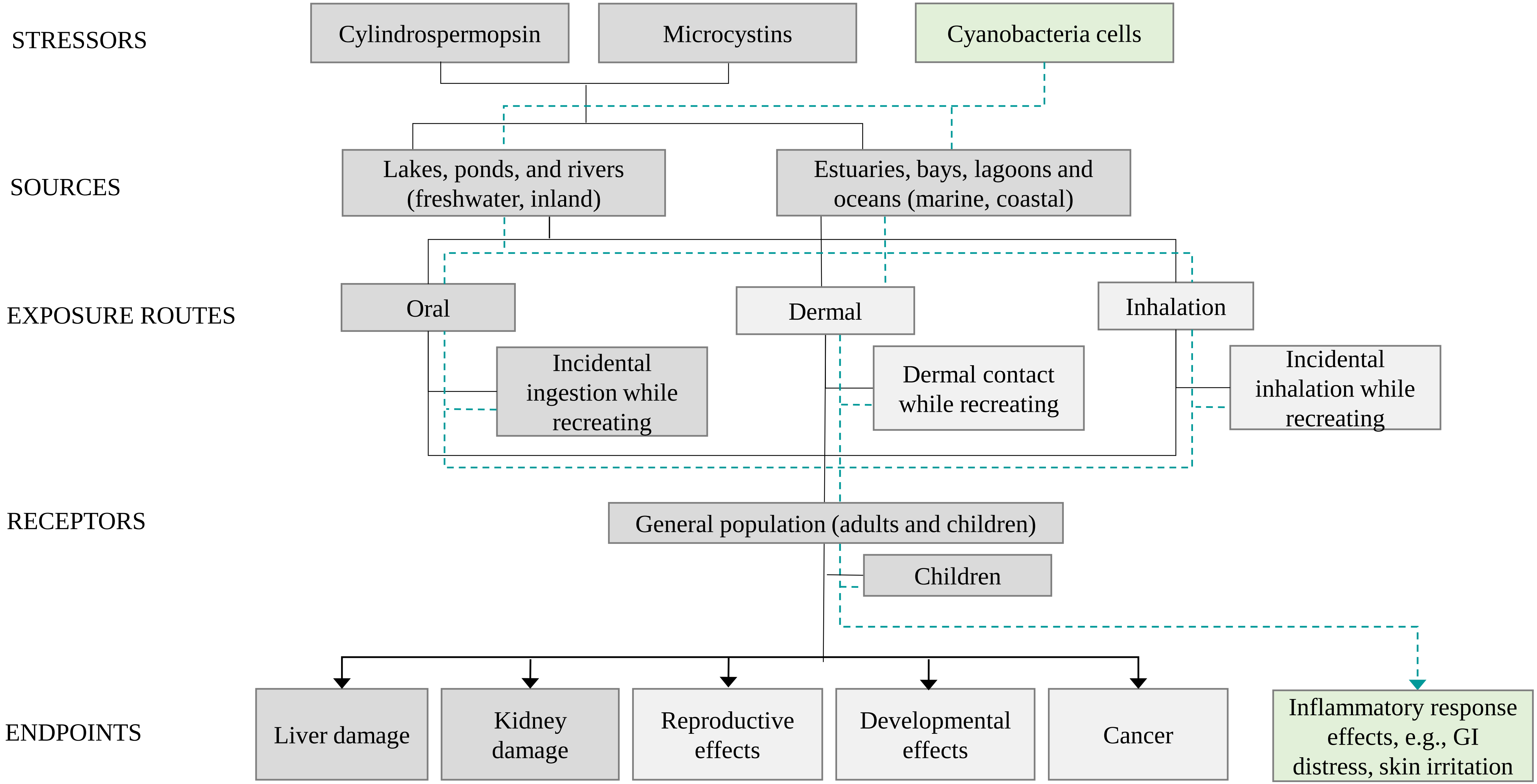
Overview of the Recreational AWQC for Cyanotoxins

Development Approach

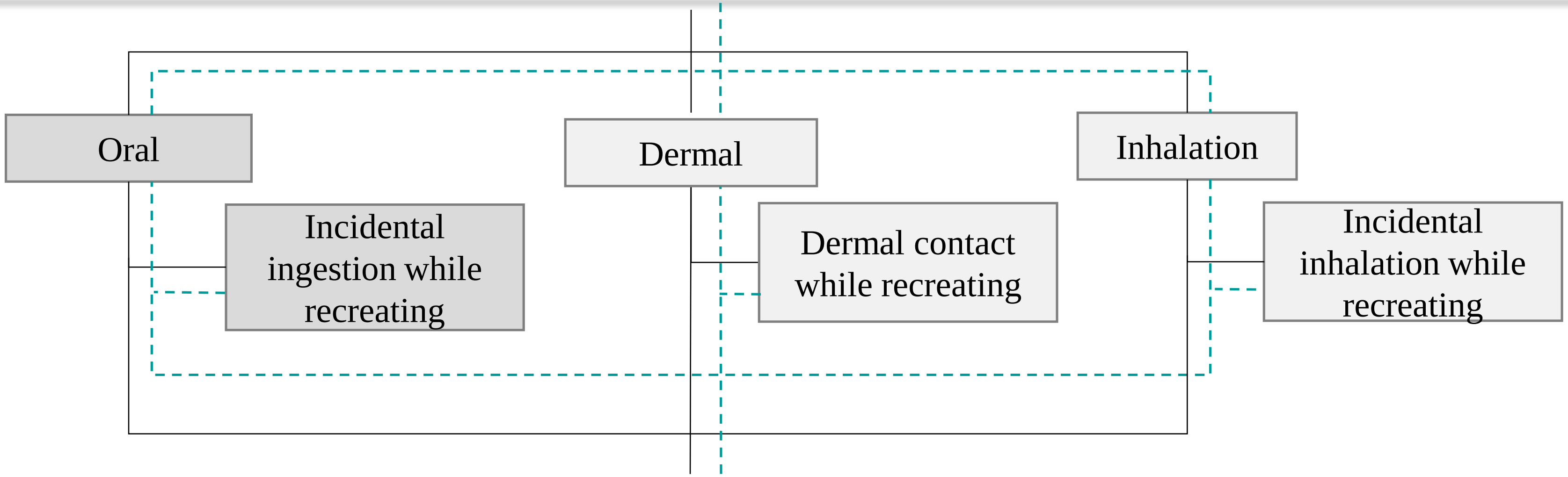
- Used peer-reviewed information to develop recommended values for microcystins and cylindrospermopsin.
- Used Agency-recommended recreational exposure values in a scenario which includes immersion and incidental ingestion of ambient water.
- Also evaluated science describing health effects from exposure to cyanobacteria cells.



Conceptual Model of Cyanotoxin and Cyanobacteria Exposure Pathways While Recreating



Exposure Routes: How are recreators exposed?



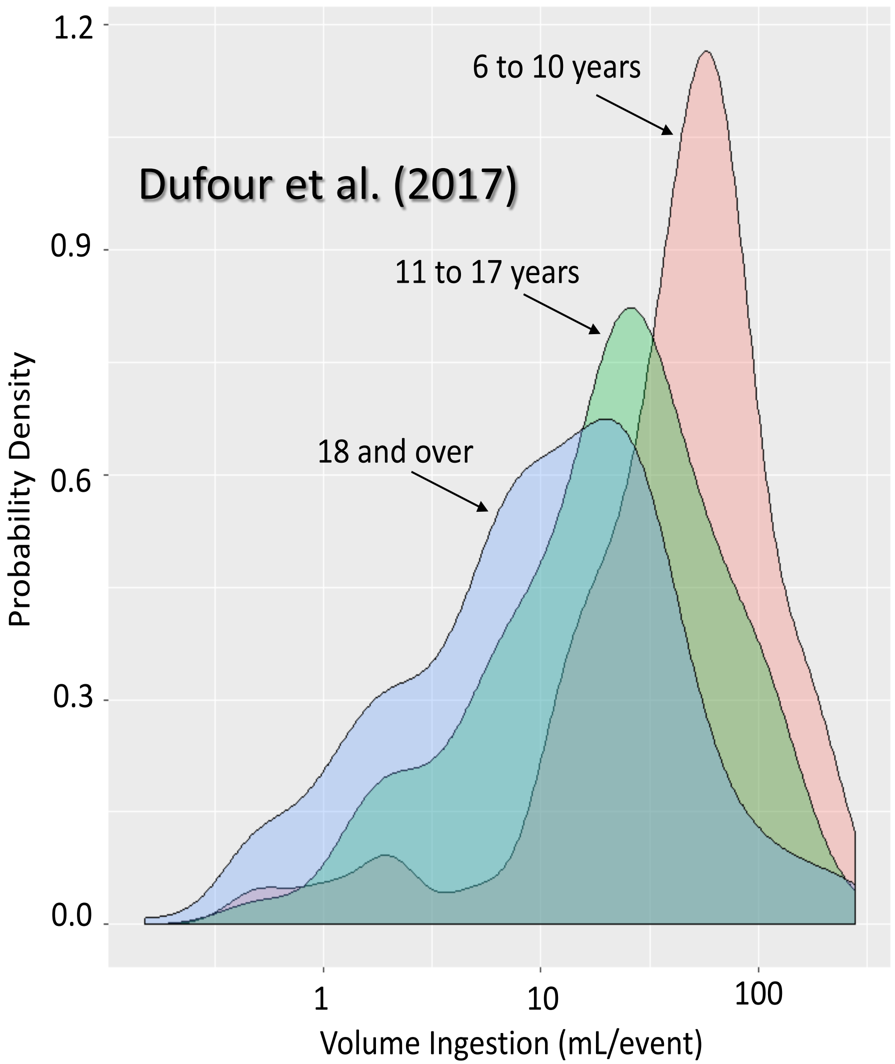
- Evaluated the scientific literature for information on three exposure routes.
- Incidental ingestion of water while swimming is a primary pathway for exposure compared to other recreational water activities.
- Although inhalation and dermal toxicity data were not available, analyses were conducted to compare exposure relative to ingestion.
- HAB-related illness outbreaks in recreational waters reported by CDC suggests dermal and inhalation pathways can be important to consider for recreational exposure to cyanobacterial cells. This is described in the effects characterization of the criteria.

Children: Exposure and Health

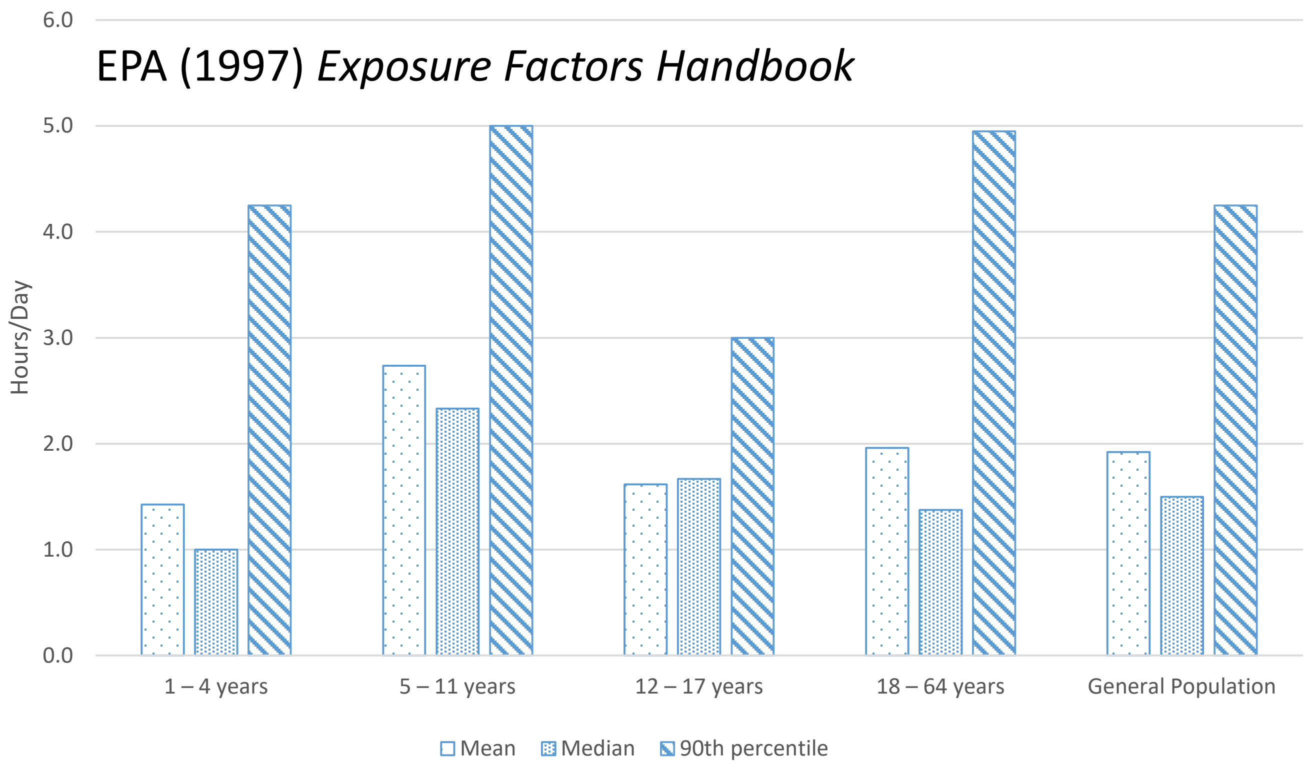
- Children share a disproportionate share of the incidents during HAB-associated outbreaks (Hilborn et al. 2014; Weirich and Miller 2014).
  - 66% of the outbreaks in 2009-2010 were <19 yr.
  - 35% were <9 yr
  - 80% of all confirmed illness reports due to fresh water cyanotoxin exposure involved children.
- Children have greater potential exposure compared to others when recreating.
  - Incidentally ingest a larger volume of water.
  - Spend more time in the water compared to other age groups.
- Evidence shows younger children can be more highly exposed (DeFlorio-Barker et al. 2017; Dufour et al. 2017; Schets et al. 2011).

Incidental Ingestion for Age Groups

- Reviewed seven incidental ingestion studies found in the scientific literature.
- Three studies reported information on children's ingestion.
- Younger children ingest more than older children or adults.



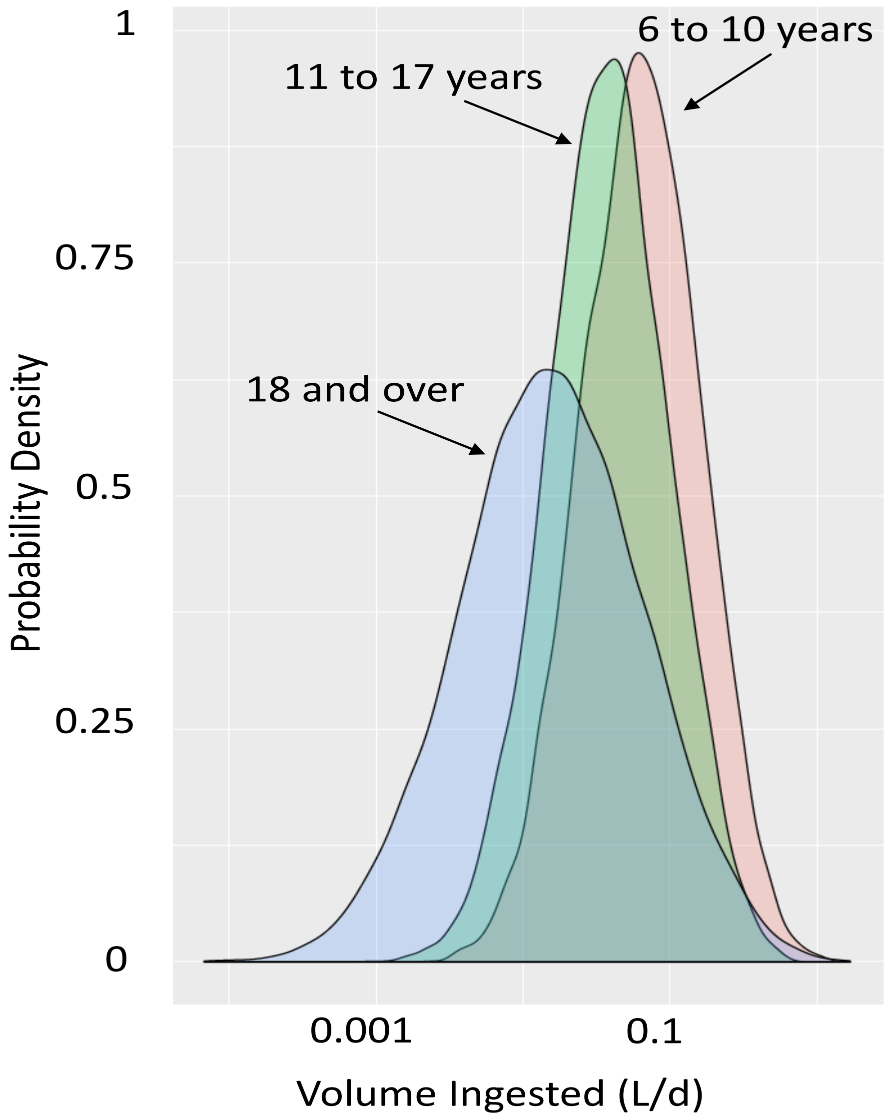
Direct Contact Recreational Exposure Duration by Age Group



- Exposure duration parameter included for calculating a daily exposure value.
- The 5-11yr cohort exhibited the longest exposure duration.

Daily Exposure by Age Group

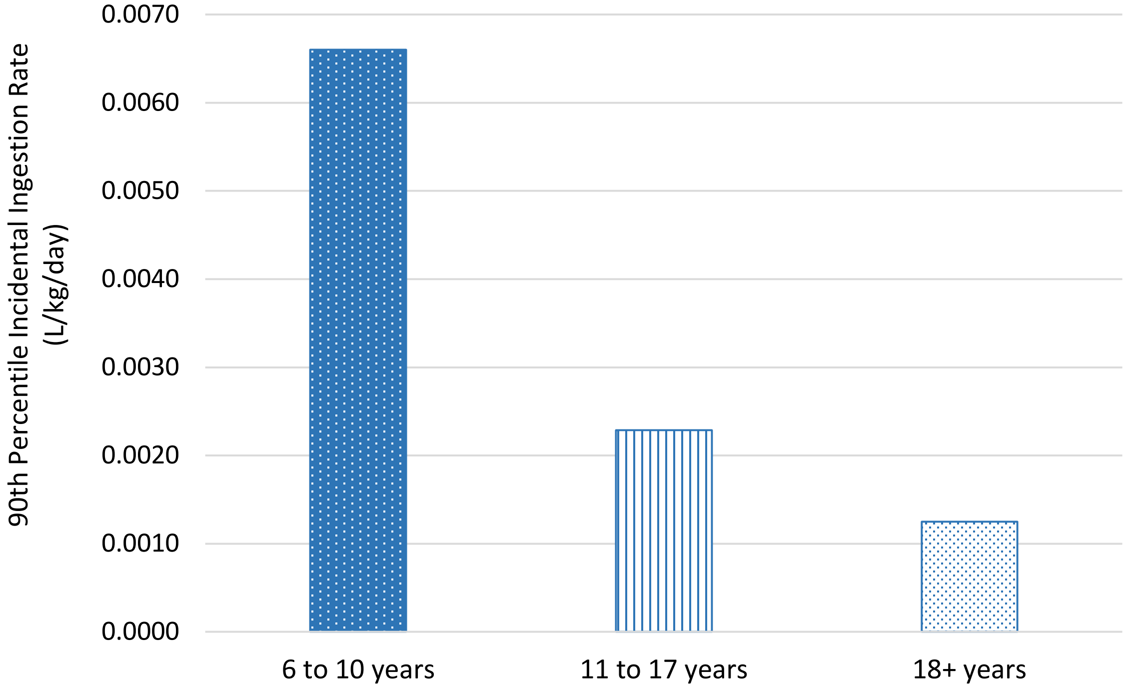
- The product of ingestion volume and recreation duration.
- Distributions were combined using a Monte Carlo simulation.



Body Weight

- Body weight statistics can be found in EPA's *Exposure Factors Handbook.*
- Used the mean body weight for children 6<11yr (31.8 kg).
- Aligned best with the age group associated with higher ingestion volumes and exposure duration.
- Body weight-adjusted exposure highest for younger children.

Figure: Comparison of Children and Adults Incidental Ingestion During Recreational Activity Adjusted for Body Weight



Cyanobacterial Cells Characterization

- Document describes available data on effects related to cell exposure.
- Elevated cell densities associated with inflammatory health endpoints
    - Health studies demonstrate a linkage between cell exposure and health effects
    - Available epidemiological data were insufficient to suggest a nationally-applicable value.
        - Significant density range: 5,000—100,000 cells/mL (freshwater)
        - Differences in health endpoints between studies.

Cyanobacterial Cells Characterization (2)

- Toxigenic Cyanobacteria
  - Increasing cell densities can be associated with increased potential for elevated toxin concentrations.
  - The toxigenic cyanobacterial population can be a better predictor of toxin levels than total cyanobacteria or chlorophyll *a*.
  - Discussed derivation of toxigenic cyanobacteria densities consistent with approaches taken by WHO, Australia and others.
  - EPA calculated a toxigenic cell density for microcystin-producing *Microcystis* sp. benchmarked to the recommended AWQC.

AWQC/Swimming Advisories Current Status and Next Steps

- Draft AWQC/Swimming Advisory posted for public comment in December 2016.
- Received comments from approximately 50 entities.
- Currently, revising AWQC/SA based on comments received with the goal of publishing a final document in summer 2018.

Revision Highlights

- Incorporating new children's ingestion data published in 2017.
  - Larger study
  - Specific data available for younger children
- Providing additional information and detail on the science underpinning the recommendations.
  - Toxicological studies
  - Cell quota information
  - Duration of recreation

Implementation Tools for Cyanotoxins in Recreational Waters

Implementation Tools - Phase 1

EPA posted suite of materials on July 7, 2017:

- *Help states and communities protect public health during harmful blooms*
- *Assist in developing cyanobacteria monitoring programs*
- *Communicate health risks to the public*
- *Address harmful bloom outbreaks*

Development Process

- *Cooperative EPA/State Effort*
  - *Workgroup with Association of Clean Water Administrators (ACWA) members*
    - *6 states (NC, WI, IN, UT, IA, CA)*
  - *Solicited implementation issues related to cyanotoxin criteria and/or numeric nutrient criteria for lakes*
  - *Used webinars and face-to-face meetings to discuss and work through implementation issues*
- *Also worked with: EPA -Drinking Water, Monitoring, Wastewater Permitting, ORD; ASTHO, CDC.*

Monitoring and Responding to Cyanobacteria and Cyanotoxins in Recreational Waters

A compilation of web materials, useful documents and links

- *Main Page:*
  - *Basic info on cyanotoxins and cyanobacteria*
  - *Many links to state/local government documents, NOAA, CDC, WHO sites*
- *Monitoring Document*
  - *Information on setting up a monitoring program and prioritizing waters, recommendations for notifying the public, considerations for methods*
- *Communication Toolbox*
  - *FAQs, social media template and press release templates, Cyanobacteria Bloom Response Contact List and notification signage examples*

Implementation Tools – Phase 2

- *In conjunction with finalization of the cyanotoxin criteria/advisory document, provide additional implementation support materials*
  - *FAQs for assessment/listing/TMDLs/NPDES permits in recreational waters*
  - *Adoption and implementation flexibilities for criteria*
- *Expected summer 2018*

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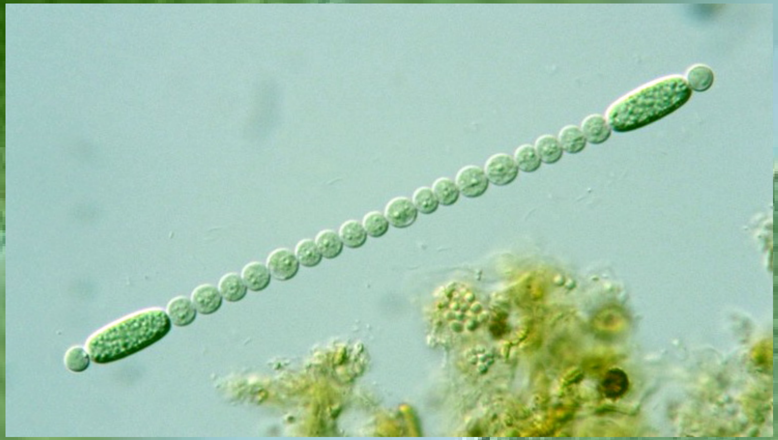

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EPA's CyanoHABs Website

www.epa.gov/cyanohabs

Progress in HAB Mitigation for Aquatic Systems?

Kevin Sellner
Hood College Center for Coastal & Watershed Studies

EPA Region IV HA Conference
May 15, 2018

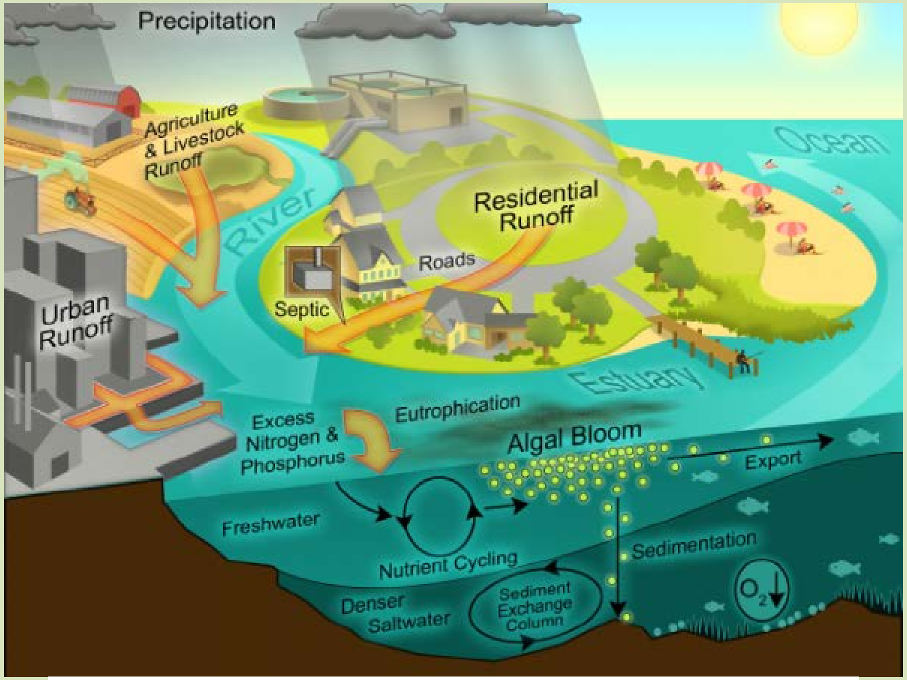
Issues

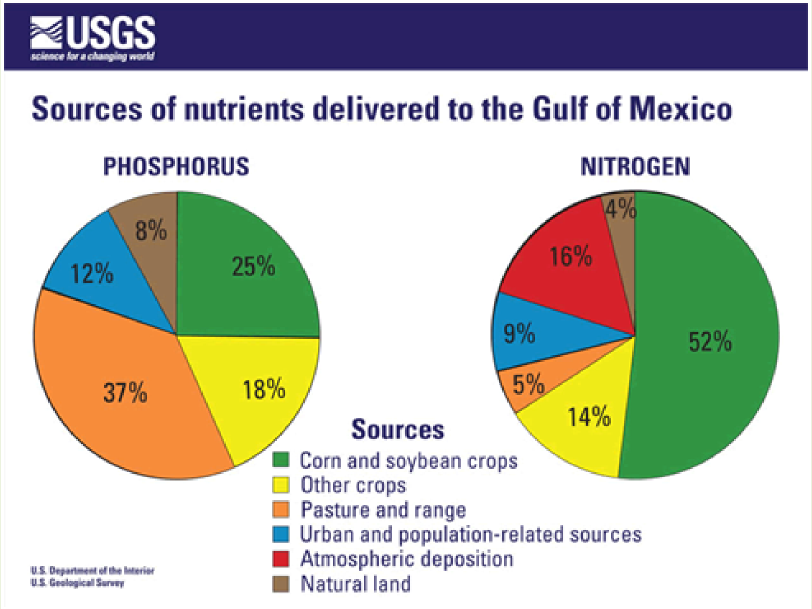
- Nutrient enrichment - increases in human populations & supporting food production
- Loads: decades-to-centuries of accumulation
- Funding for nutrient controls are rarely built into product costs
- Hence, mandated NUTRIENT REDUCTION POLICIES must occur

Nutrient Controls

H. Paerl, pers. comm.

- Land use is <u>THE</u> most effective mitigant for nutrient loads & hence, most HABs/CyanoBlooms
- Regulate stormwater & ag runoff
- Preserve natural wetlands, marshes, & forests
- Expand floodplain connectivity & limit floodplain development
- Require riparian buffers

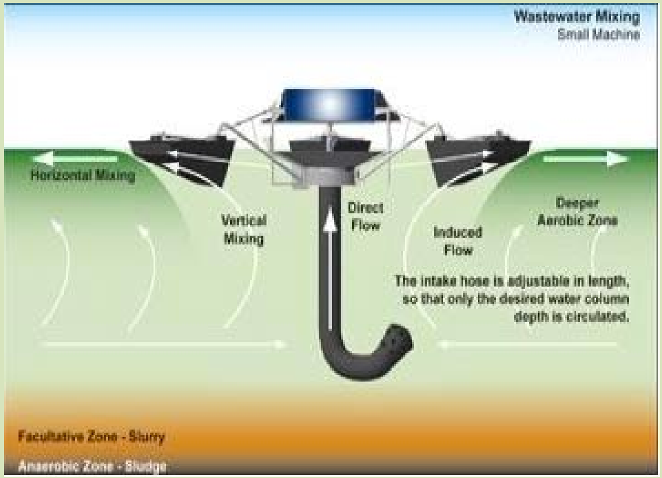




Mitigation (aka Band-aids)

Freshwater systems offer best opportunities for mitigating HABs/CyanoBlooms

- Closed systems
  - Mixing (K. Hudnell pleas)
  - Hydraulics
  - Ultrasound
  - Algicides
  - Flocculants & capping
  - Dredging
  - Nutrient-binders (alum, Phoslock®)



- Flowing waters
  - Flow (low flow = benthic cyano blooms, high flow = normal river phytoplankton)
  - Water depth (flow-controlled euphotic depth)

Mitigation (aka Band-aids)

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http://mediad.publicbroadcasting.net/p/wksu/files/201603/cuy_dredge_2.jpg

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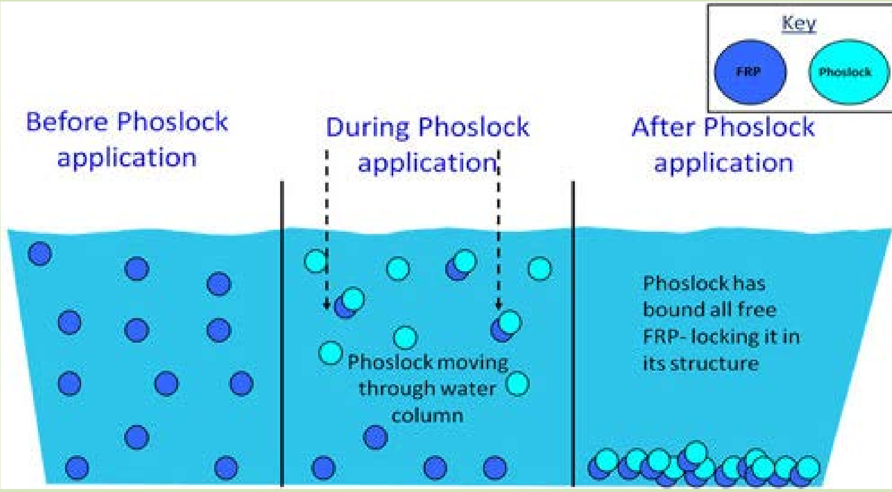

http://www.phoslock.eu/media/6784/how-phoslock-works-english.jpg

- Flowing waters
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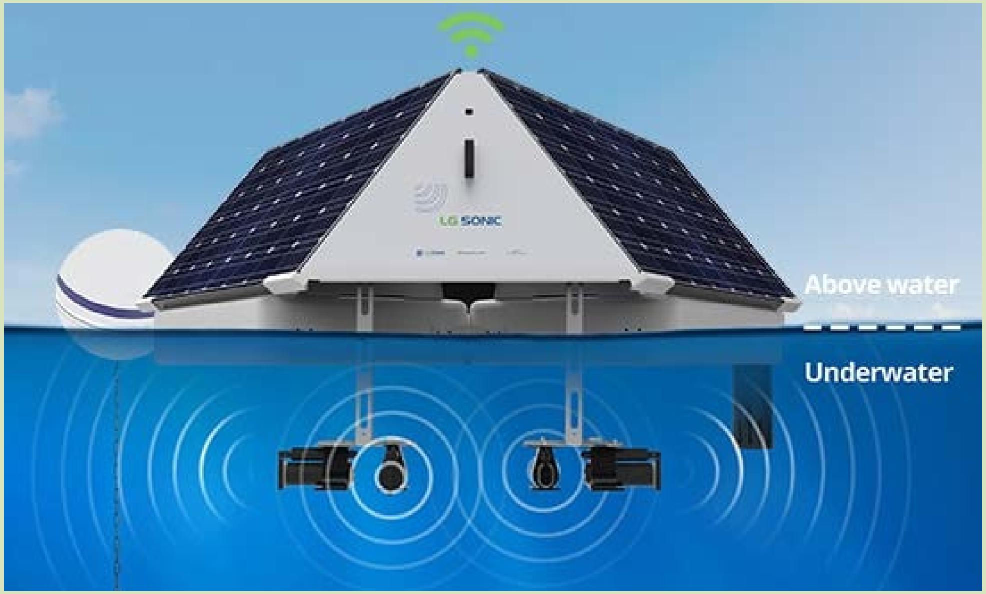
  - Water depth (flow-controlled euphotic depth)

‘New-er’ Freshwater Mitigants

- Ultrasound: Increased power & taxa-specific programming
- Hydraulics
- Algicides
  - Barley straw
  - Minimal ClO^-, H_2O_2, $CuSO_4$, MnO_4 additions
- Flocculants + capping
  - Nanosilica (26 nm)

G. Pan, Pers. Comm.



https://www.lgsonic.com/product/control-monitor-algae-mpc-buoy/

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https://www.modellbahnunion.com/dm-toys-en/prodpic/H0-Stauwehr-Busch-1483_b_0.JPG

‘New-er’ Freshwater Mitigants

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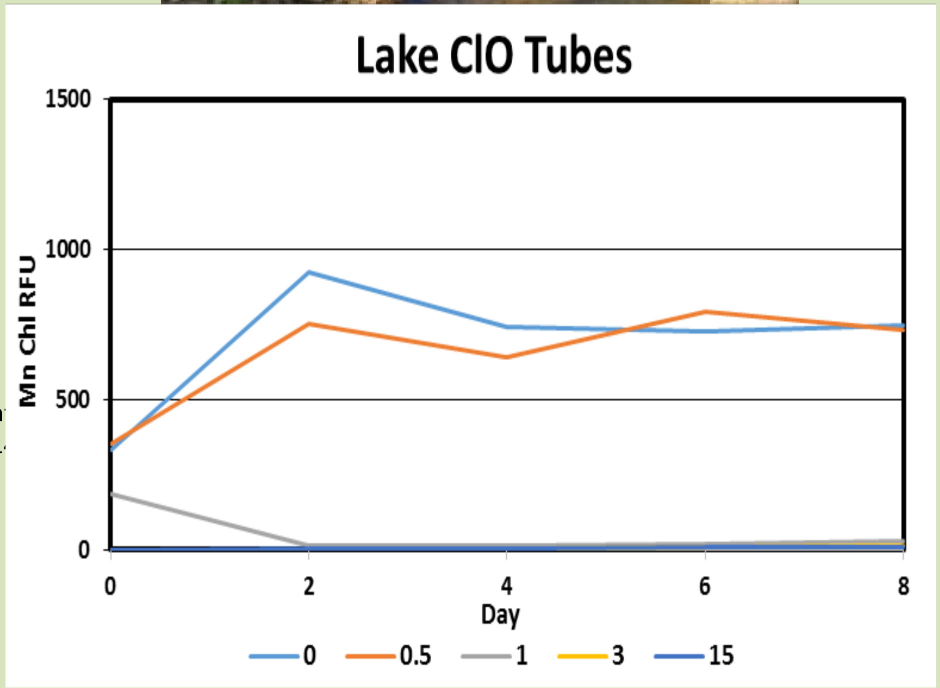
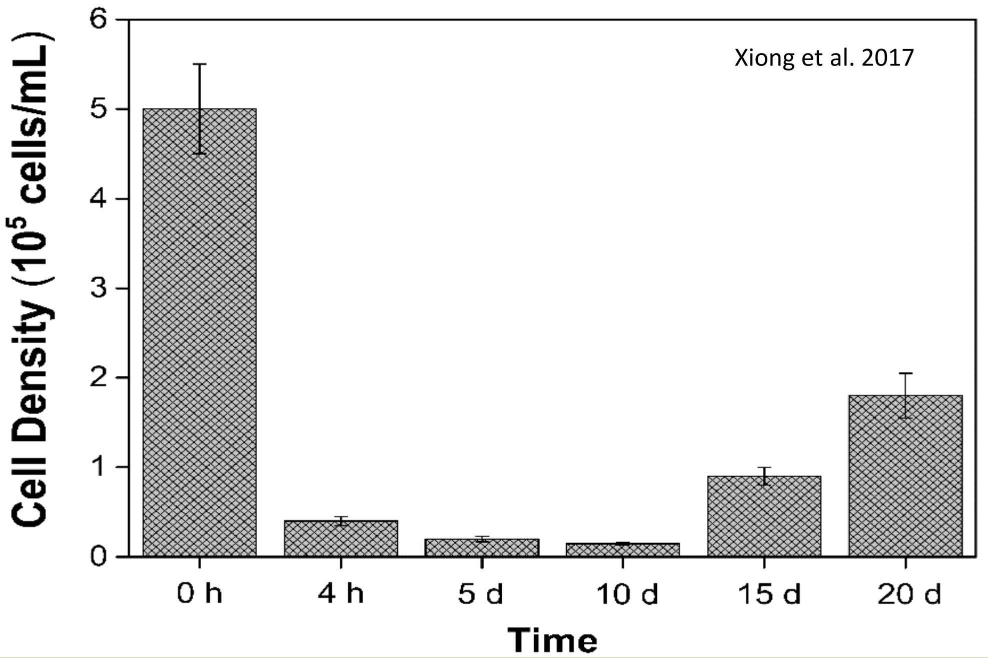


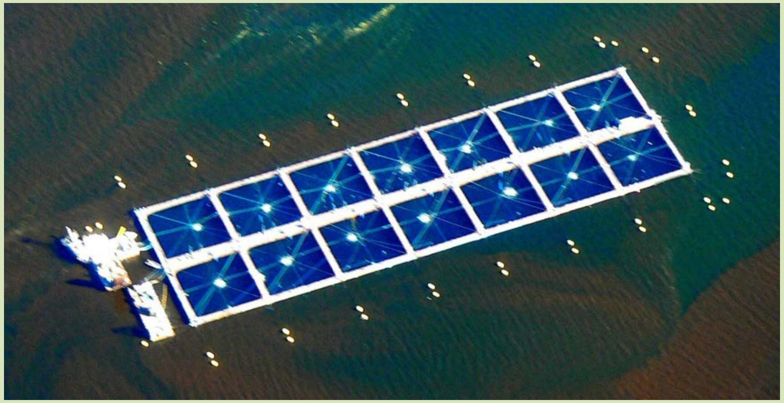
‘New-er’ Freshwater Mitigants

- Ultrasound: Increased power & taxa-specific programming
- Hydraulics
- Algicides
  - Barley straw
  - Minimal ClO^-, H_2O_2, $CuSO_4$, MnO_4 additions
- <u>Flocculants + capping</u>
  - Nanosilica (26 nm)

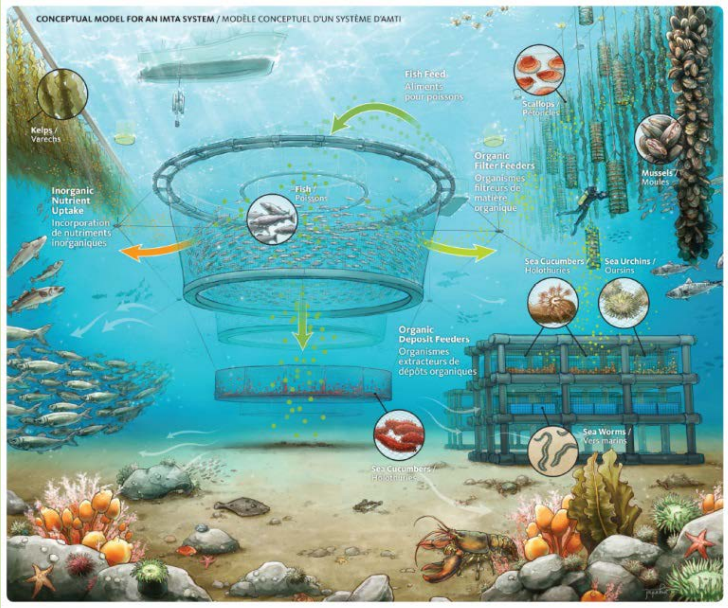


Brackish-Oceanic Systems

Courtesy of German Campos, General Manager of Operations, Cermaq Canada, Ltd.



- <u>Fish pen areas</u>: Aerators/screens/relocation & polyculture?
- Locally applied oxidants or flocculants
- Mixing of upper sediment cysts
- Resuspension of diatoms



http://www.dfo-mpo.gc.ca/aquaculture/sci-res/imta-amti/images/
imta-amti-007-large.jpg

Brackish-Oceanic Systems

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http://www.whoi.edu/cms/images/lstokey/2005/1/v43n1-sengco3en_5573.jpg

Brackish-Oceanic Systems

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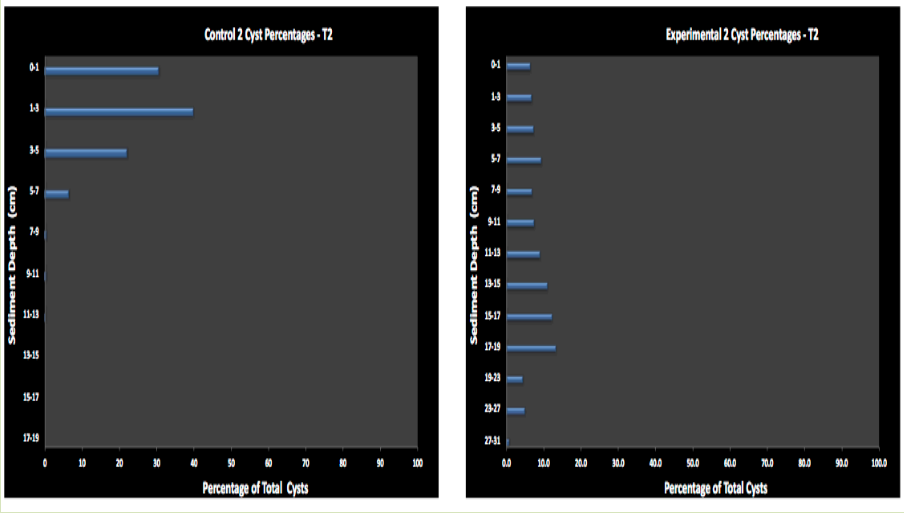

D. Anderson & D. Kulis, unpubl.

Brackish-Oceanic Systems

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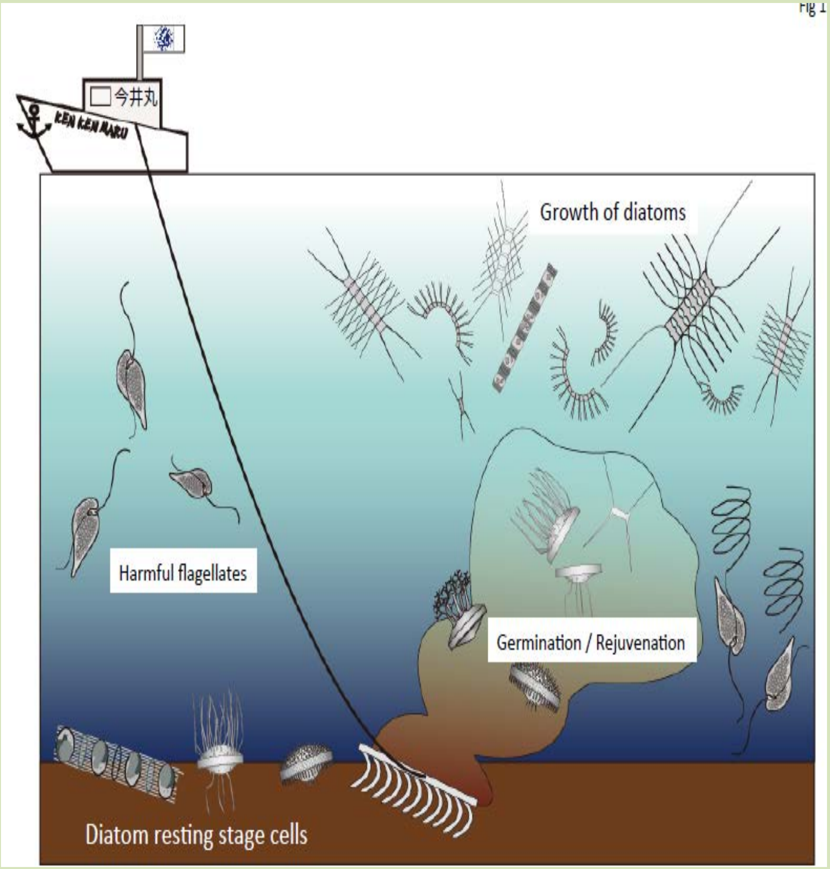


Imai et al. (in press). Bull. Fish. Sci. Hokkaido Univ. 67.

Has there really been Progress in Mitigation?

Questionable in most of the world, except Asia

- Yu Shiming et al. (in press) – max removal at sediment additions 10-25x lower than reported most effective clay flocculation in lakes
- Xiong et al. (2017) – nanosilica particles, $\geq$75 mg/L with coagulant (\$0.60/m^3)

Future Mitigation

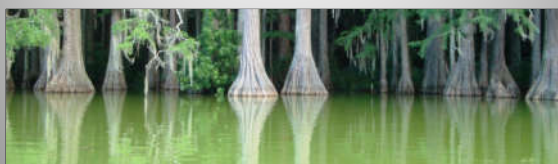
- OMG: Warming & ppt patterns will select for some HA & Cyano taxa
- Land use decisions (& hence, human behavior) that protect receiving waters must become a priority
- With increasing importance of aquaculture for fish protein, local implementation of mitigation technologies increasingly important
- In the U.S., permitting issues limit interventions

Plea for the Community

- Continue 'band-aid' development & application
- <u>Agencies should emphasize new 'multi-disciplinary training projects' to include land uses that lower nutrient loads to select for non-bloom taxa</u>
  - For established researchers, 1) collaborate with experts in land use & surface/groundwater flows & 2) broaden student education in these fields
  - Substantial project outreach to local-regional officials responsible for land use, zoning, and load reductions

Public Health Response to Freshwater Harmful Algal Blooms in Florida

Environmental Protection Agency Region 4 Harmful Algal Bloom Southeast Regional Workshop May 14- 16, 2018



Andrew Reich, MS, MSPH, RRT
Scientific Advisor
Bureau of Environmental Health

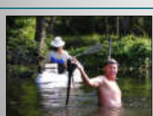
Division of Disease Control and Health Protection

2

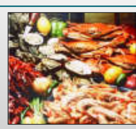
Exposures

3

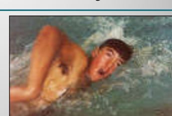
Potential Exposure Pathways



Direct Skin Contact



Ingestion of Food



Incidental Ingestion

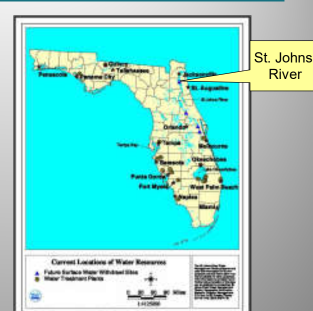
Drinking Water

Inhalation of Aerosols

4

Drinking Water Resources

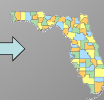
- 10-15% of Florida's population utilizes surface water supplies for drinking water
- Floridian Aquifer unable to meet projected demands for 2020
- Some surface supplies experience cyanobacteria blooms that produce toxins



5

Drinking Water Resources

Regulatory Responsibilities



6

Susceptible Populations

- Elderly
- Immuno-suppressed
- Underlying disease: Asthma
- Pregnant women, fetus
- Children
- People with extended exposure periods

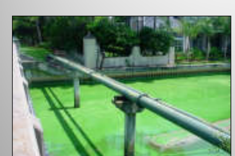
7

Freshwater: Cyanobacteria

- *Microcystis, Anabaena, Cylindrospermopsis Oscillatoria, Aphanizomenon*
- Cyanotoxins: microcystins, cylindrospermosins, anatoxins, etc.

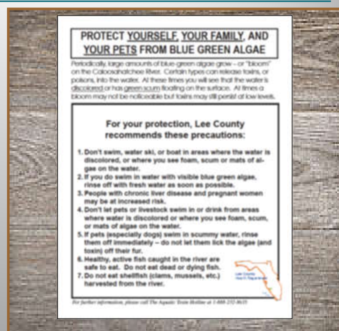
8

Cyanobacteria Blooms in Florida



9

Information to the Public



PROTECT YOURSELF, YOUR FAMILY, AND YOUR PETS FROM BLUE GREEN ALGAE

Periodically, large amounts of blue-green algae grow – or "bloom" on the Caloosahatchee River. Certain types can release toxins, or poisons, into the water. At these times you will see that the water is discolored or has green scum floating on the surface. At times a bloom may not be noticeable but toxins may still persist at low levels.

For your protection, Lee County recommends these precautions:

1. Don't swim, water ski, or boat in areas where the water is discolored, or where you see foam, scum or mats of algae on the water.
2. If you do swim in water with visible blue green algae, rinse off with fresh water as soon as possible.
3. People with chronic liver disease and pregnant women may be at increased risk.
4. Don't let pets or livestock swim in or drink from areas where water is discolored or where you see foam, scum, or mats of algae on the water.
5. If pets (especially dogs) swim in scummy water, rinse them off immediately – do not let them lick the algae (and toxin) off their fur.
6. Healthy, active fish caught in the river are safe to eat. Do not eat dead or dying fish.
7. Do not eat shellfish (clams, mussels, etc.) harvested from the river.

10

Information to the Public, cont.

Human Health Impacts – Target Audience: health care providers, residents, visitors, workers

11

Public Health Surveillance Tools

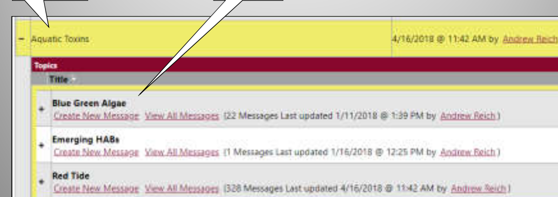
- EpiCom: Public Health Bulletin Board
- Florida Poison Information Centers
  - Tampa, Jacksonville, Miami
    Aquatic Toxins Hotline
- Florida Reportable Disease System
  - Merlin
- ESSENCE
  - Syndromic Surveillance
    Includes Florida Hospital ED and Acute Care Facility data

12

EpiCom
The Florida Department of Health

Aquatic Toxins "Forum"

Blue Green Algae



13

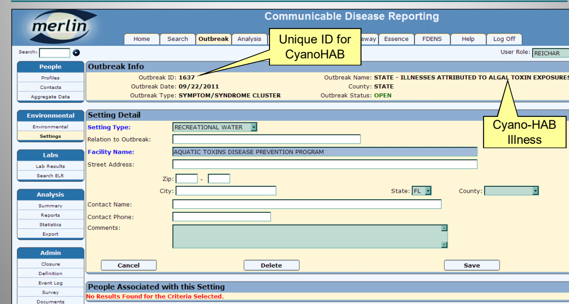
FLORIDA'S POISON CONTROL CENTERS
Jacksonville • Miami • Tampa

- Staffed by doctors, nurses and pharmacists
- Speak with a poison specialist
- Free, confidential service: 24/7, 365
- 3 Centers receive 550-600 total calls/ day
- > 25,000 calls since 1998 on Aquatic Toxins

POISON Help
1-800-222-1222

14

Merlin: CyanoHAB Outbreak Module



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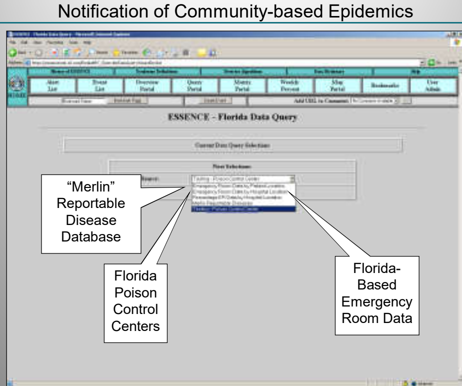
ESSENCE: Florida System

Electronic Surveillance System for Early Notification of Community-based Epidemics



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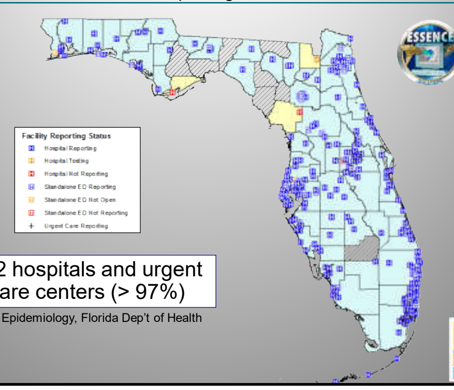
ESSENCE Participating Hospitals

Hospital Emergency Departments and Urgent Care Centers Reporting, March 2018



252 hospitals and urgent care centers (> 97%)

Bureau of Epidemiology, Florida Dep't of Health

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Cyanobacteria Tracking Module

caspio

- DOH online tracking module for coordinating statewide cyanobacteria bloom response.

Access a Searchable Database of Bloom Records
Access a Searchable Map of Bloom Records
Upload Files to the Document Library
View the Document Library
Upload Files to the FDEP GovDelivery Algal Bloom Reports
View the FDEP GovDelivery Algal Bloom Reports
Upload Document to the Satellite Health Bulletin Library
Search the Satellite Health Bulletin Library
Log Out of Caspio

Caspio User Login   Caspio Public Portal

Florida HEALTH

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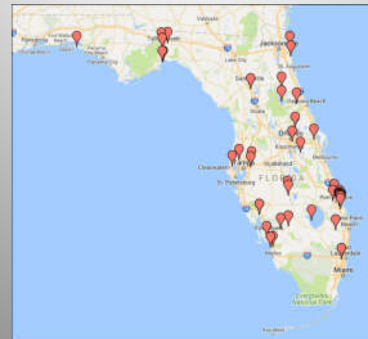
Cyanobacteria Tracking Module, cont.



Florida HEALTH

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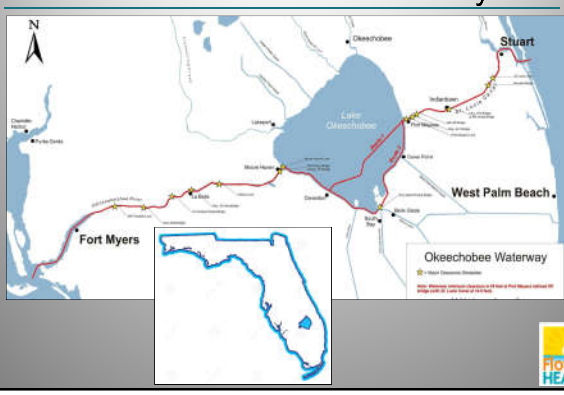
Lake Okeechobee Waterway



Florida HEALTH

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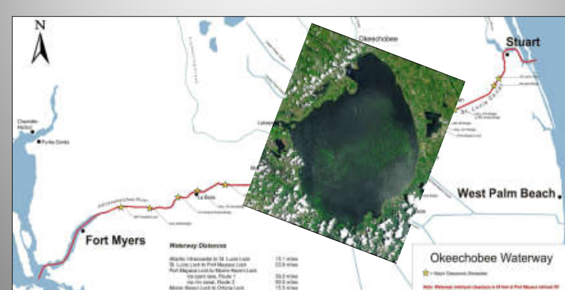
Lake Okeechobee Waterway, cont.



NASA Earth Observatory July 2, 2016

US Army Corps of Engineers

Florida HEALTH

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Caloosahatchee River

22

Lake Okeechobee Discharge

Red Fish Pass, Captiva Island, Lee County

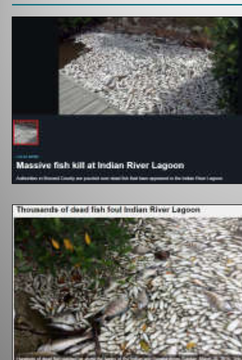
23

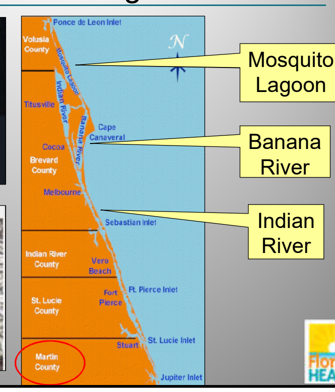
Lake Okeechobee Discharge, cont.

St. Lucie River, Martin County

24

Indian River Lagoon





25

Martin County

26

Martin County

27

Martin County, continued

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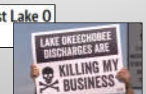
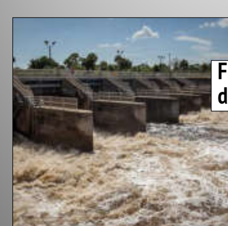
Media

Senator Bill Nelson calls Lake Okeechobee water releases 'idiotic'

Businesses, charter captains protest Lake O 'catastrophe'





Florida to assess Lake Okeechobee discharges' damage to businesses

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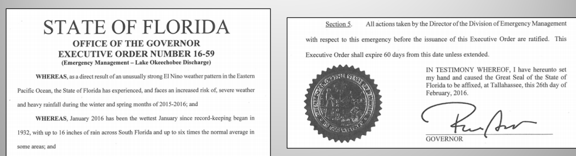
Emergency Management – Lake Okeechobee Discharge


STATE OF FLORIDA
OFFICE OF THE GOVERNOR
EXECUTIVE ORDER NUMBER 16-59
(Emergency Management – Lake Okeechobee Discharge)

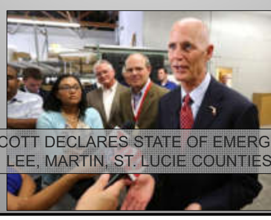
WHEREAS, as a direct result of an unusually strong El Nino weather pattern in the Eastern Pacific Ocean, the State of Florida has experienced, and faces an increased risk of, severe weather and heavy rainfall during the winter and spring months of 2015-2016; and

WHEREAS, January 2016 has been the wettest January since record-keeping began in 1932, with up to 16 inches of rain across South Florida and up to six times the normal average in some areas; and

Section 5. All actions taken by the Director of the Division of Emergency Management with respect to this emergency before the issuance of this Executive Order are ratified. This Executive Order shall expire 60 days from this date unless extended.

IN TESTIMONY WHEREOF, I have hereunto set my hand and caused the Great Seal of the State of Florida to be affixed, at Tallahassee, this 26th day of February, 2016.

GOVERNOR



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Emerging HAB Threats

- Diverse taxa of cyanobacteria
  - Beta-methylamino-L-alanine (BMAA)
  - Amyotrophic lateral sclerosis/ parkinsonism-dementia complex ??


Guam

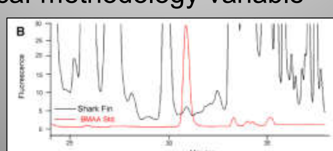

“Chamorro” people

31

Emerging HAB Threats

BMAA

- Little consensus of its ubiquitous occurrence
- Uncertainty on concentrations reported
- Problems with replication of study findings
- Analytical methodology variable



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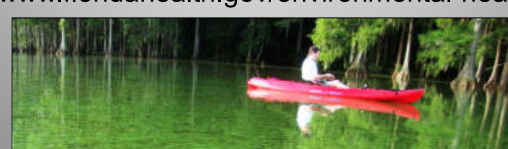
Contact Information

Andrew Reich MS, MSPH, RRT
andy.reich@flhealth.gov
(813) 307-8015 ext. 5961

www.floridahealth.gov/environmental-health/



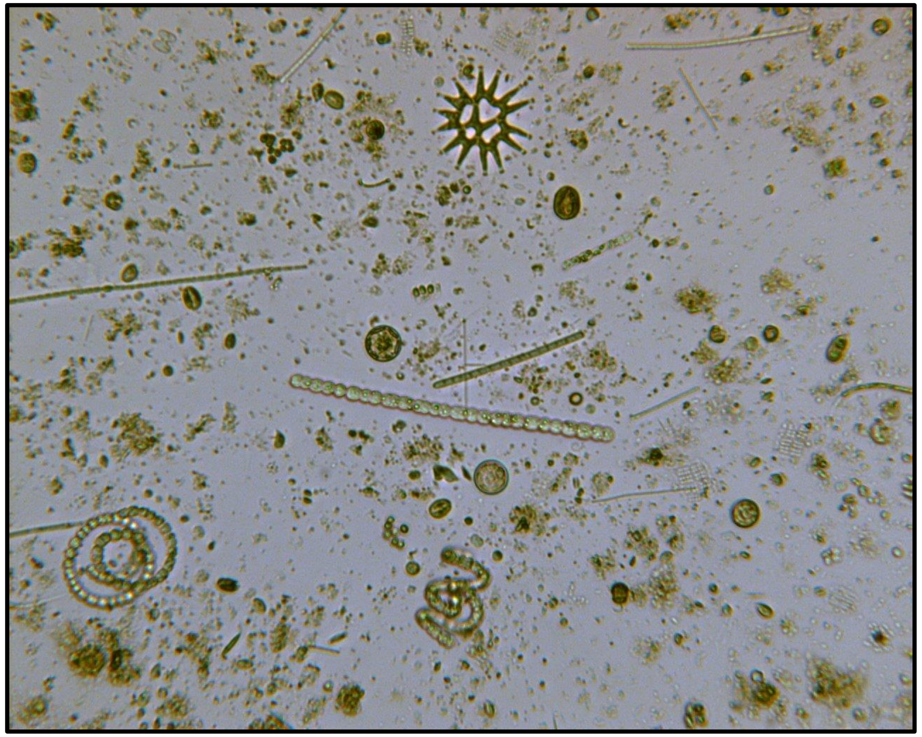
Division of Disease Control and Health Protection

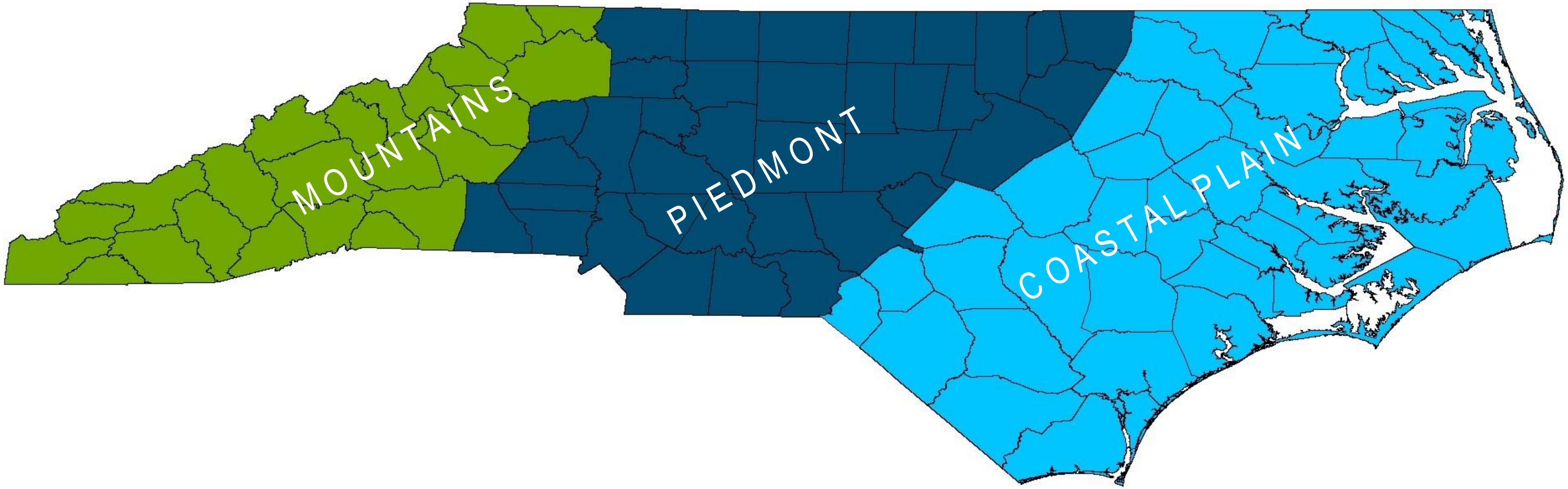
May 15, 2018

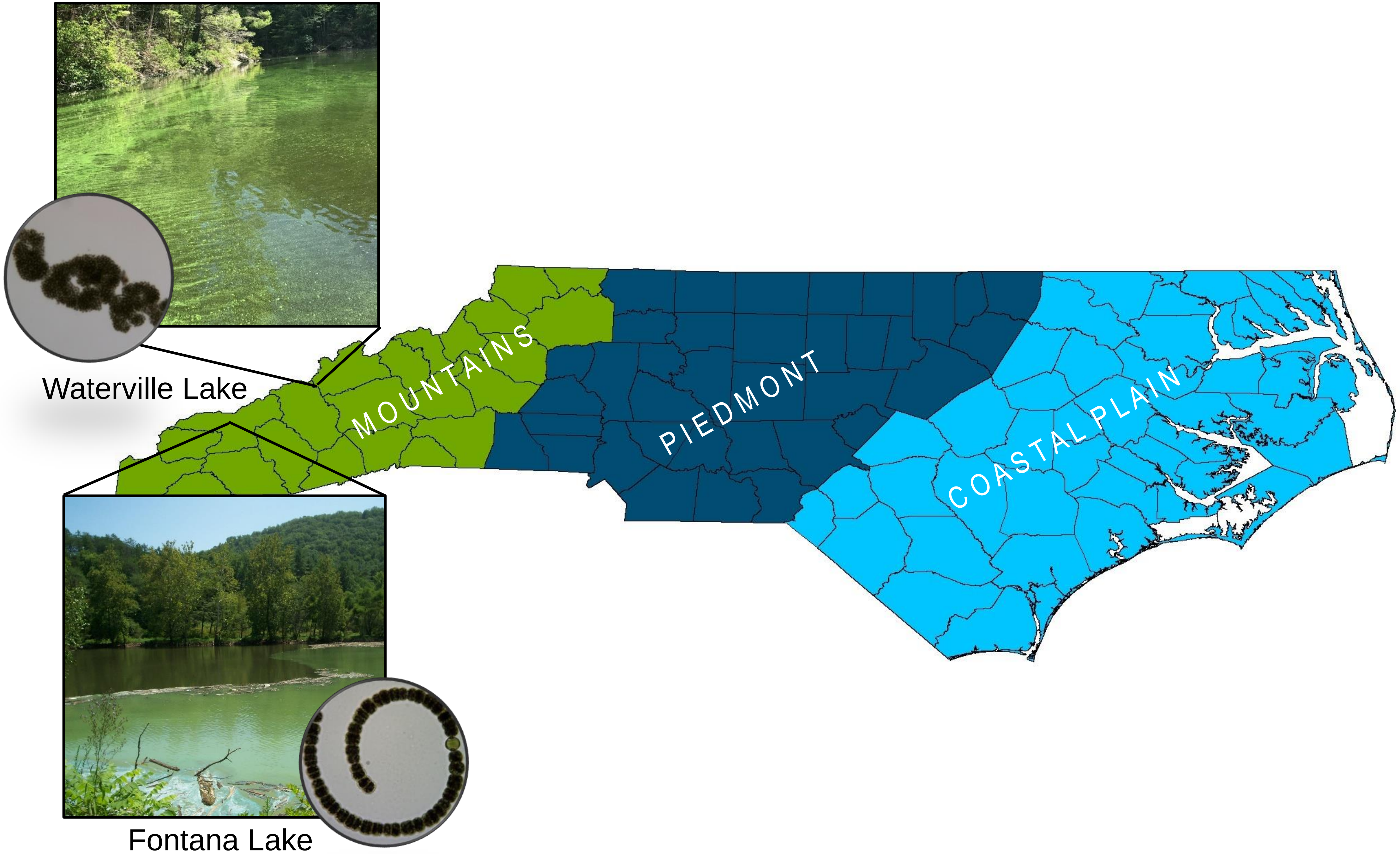
North Carolina Algal Bloom Assessment Program
Department of Environmental Quality
Division of Water Resources

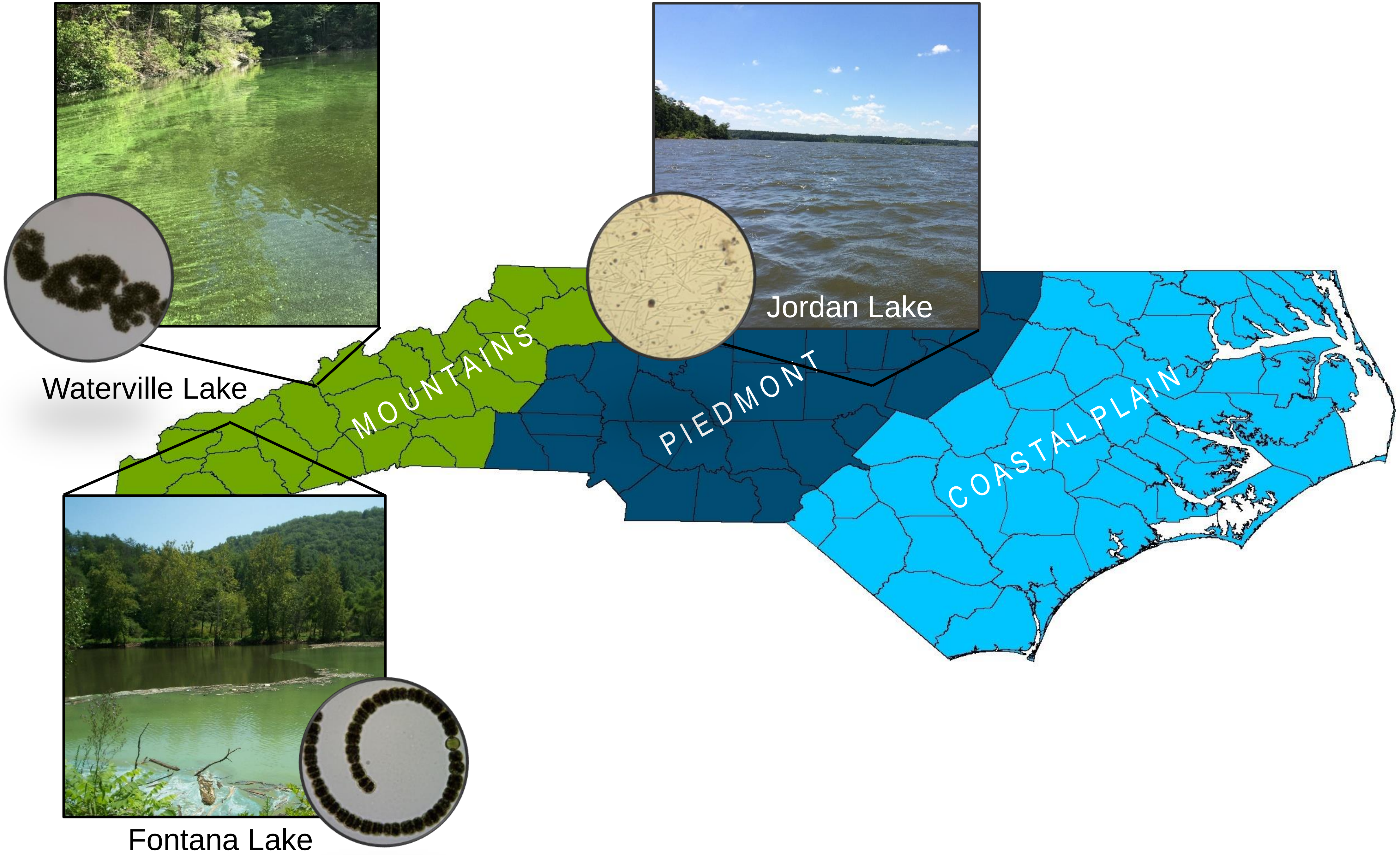
NC Algal and Aquatic Plant Assessment Program

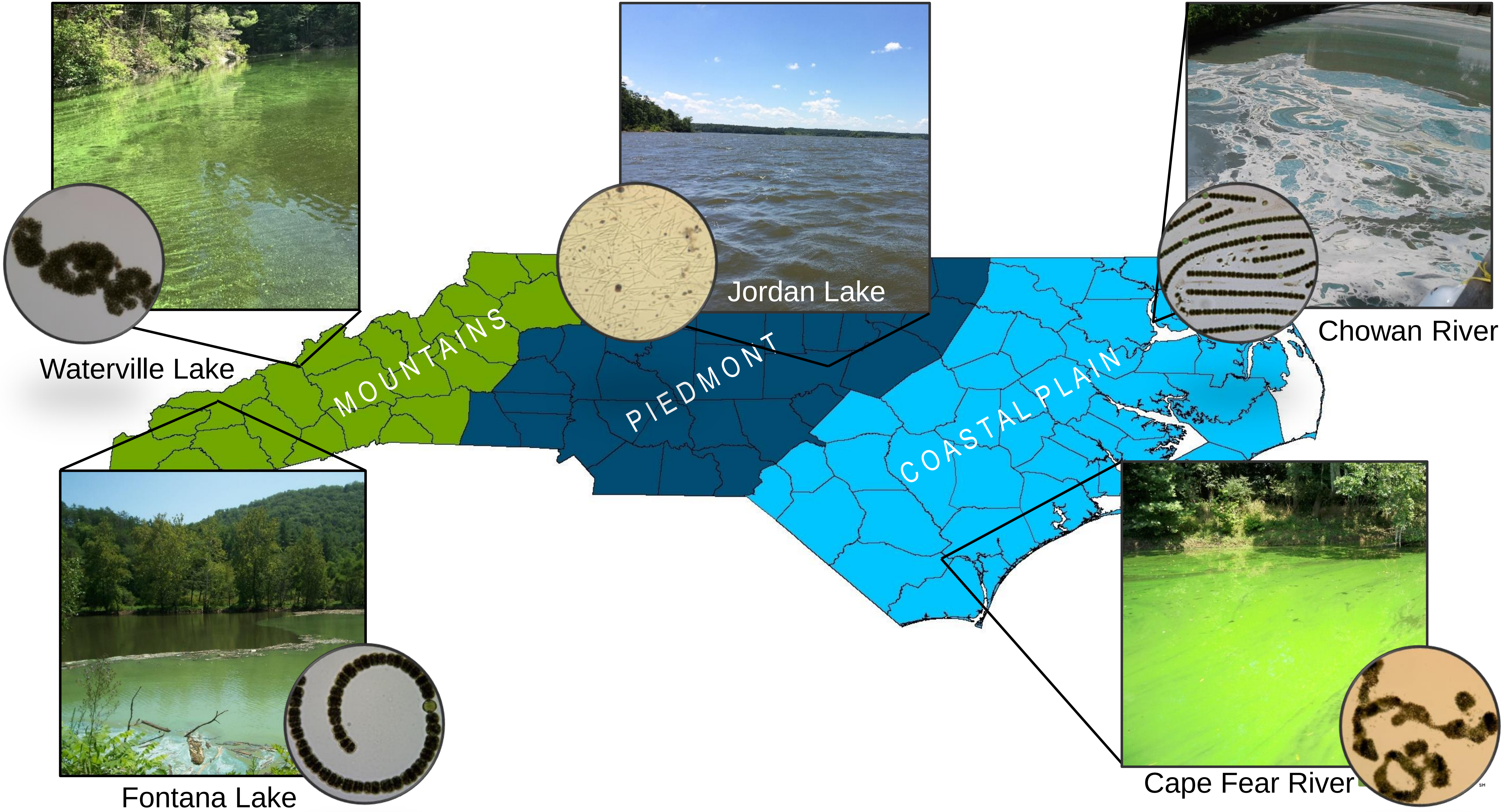
- Began in the 1980's
- **Objectives**
  - Monitor algal populations in North Carolina lakes, rivers, and estuaries
  - Coordinate algal bloom monitoring and response
  - Public Outreach and Communication




MOUNTAINS
PIEDMONT
COASTAL PLAIN

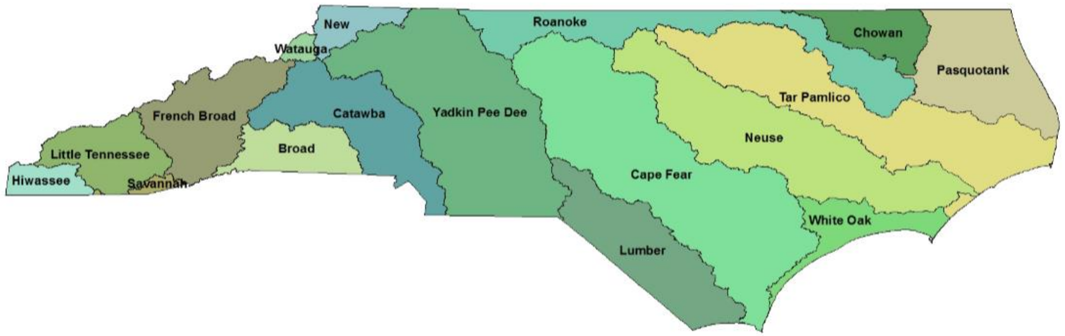

Waterville Lake
MOUNTAINS
PIEDMONT
COASTAL PLAIN
Fontana Lake


Waterville Lake
Jordan Lake
Fontana Lake
MOUNTAINS
PIEDMONT
COASTAL PLAIN


Waterville Lake
Jordan Lake
Chowan River
MOUNTAINS
PIEDMONT
COASTAL PLAIN
Fontana Lake
Cape Fear River

Algal Bloom Monitoring

- **Routine Monitoring**
  - Basinwide Lakes Assessments (5 year rotation)
  - Phytoplankton stations selected with emphasis on locations likely to experience excessive algal growth
- **Episodic Events**
  - Reported by private citizens, municipalities environmental groups, and Regional Office staff
  - Algal bloom site investigations, analysis, and reporting (2-3 days)
- **Special Studies**
  - Typically in systems where chronic algal blooms occur
  - White Lake, Waterville Lake, Jordan Lake



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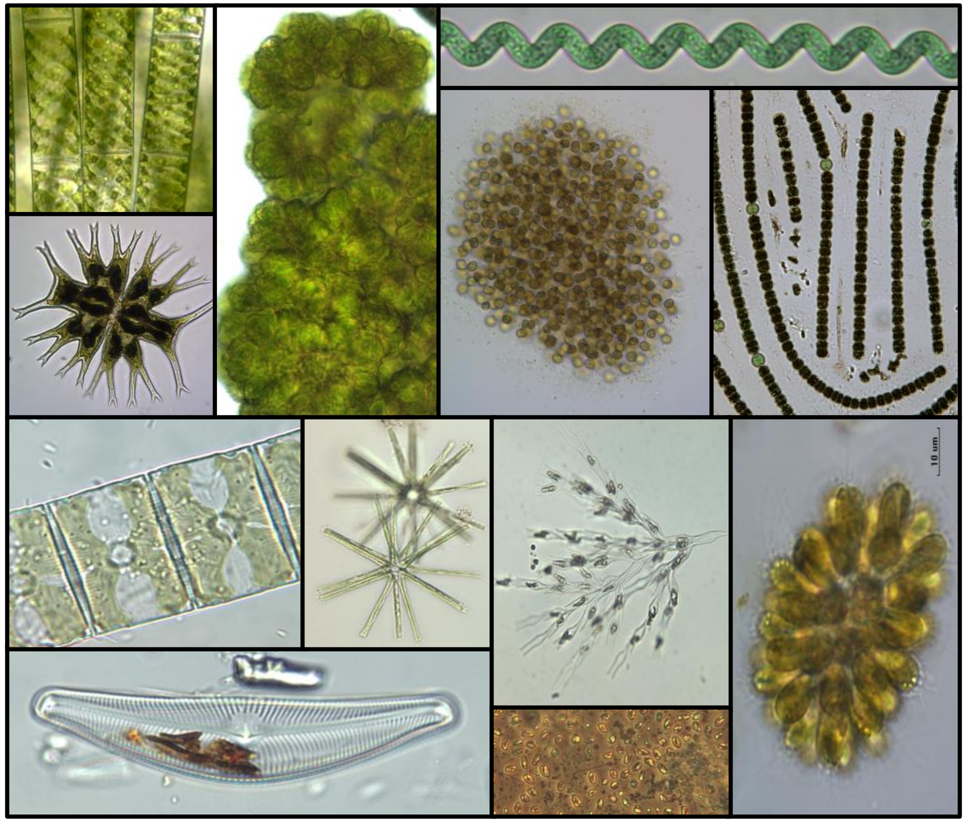
Waterville Lake, 2017

Algal Bloom Response – Site Investigation

- **Bloom Investigation** – DWR Regional Office Staff
  - Site Photos
  - Chemical/Physical Parameters
  - Phytoplankton samples
  - Cyanotoxin samples (if applicable)
  - Exposure Risks
- **ABRAXIS Test Strips**
  - Preliminary indicator for presence of cyanotoxins
  - Currently testing accuracy and reliability
  - Cost vs. Benefit

Algal Bloom Response - Microscopy

- Preliminary ID
  - Presence of Cyanobacteria
  - Preliminary Reporting (email)
- Algal Community Assessment
  - Identification (lowest level practical)
    - Taxa List
  - Enumeration
    - Cell Density (cells/mL)
    - Unit Density (units/mL)
    - Biovolume (mm^3/m^3)

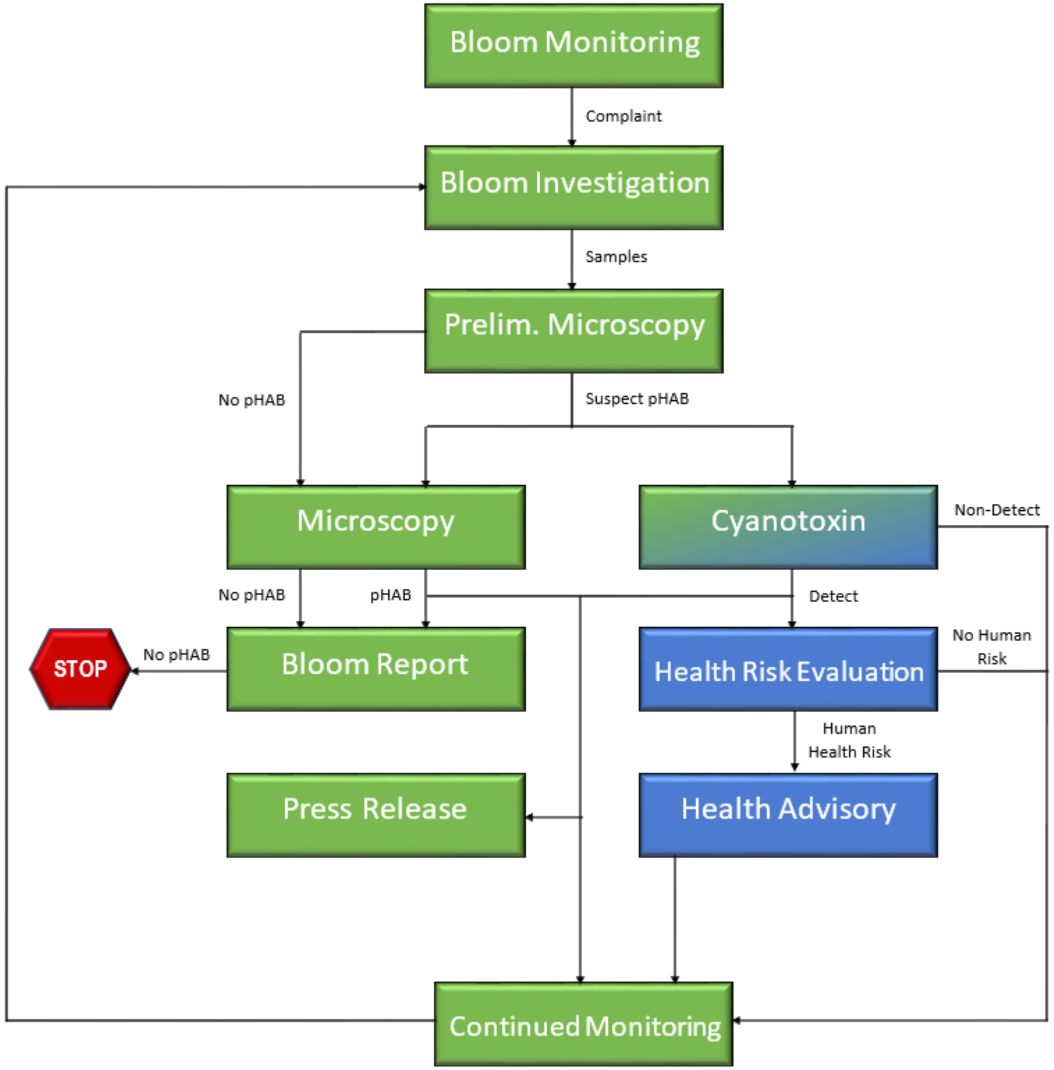


Algal Bloom Response - Cyanotoxin Analysis

- Total Microcystins
- ABRAXIS Cyanotoxin Automated Assay System (CAAS)
  - Housed in DWR Central Chemistry Lab
  - EPA method 546
- ENVIROLOGIX QuantiPlate Kit for Microcystins
  - Housed in NC Department of Health and Human Services

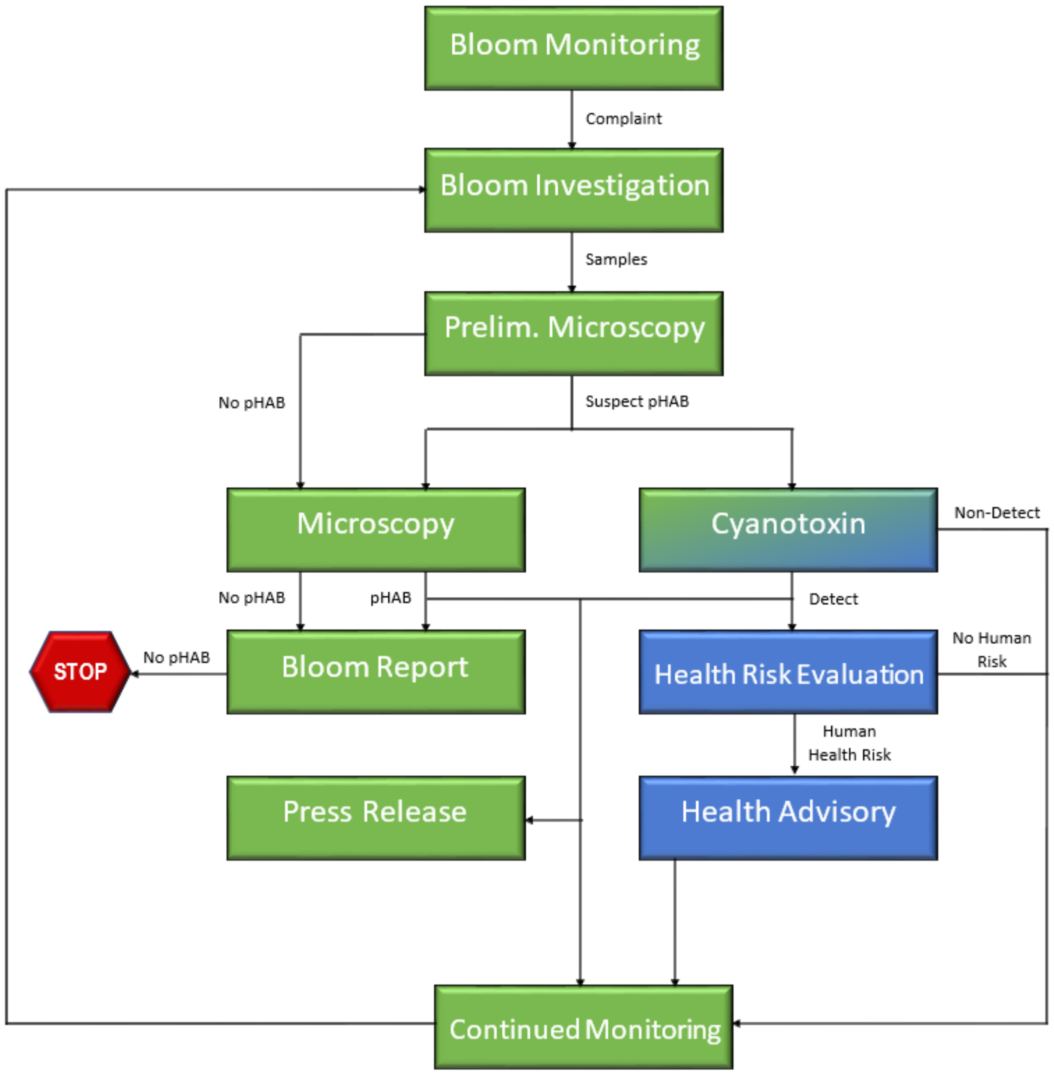
Photo Credit: Abraxis (https://www.abraxiskits.com/)

State Guidelines



- **State Water Quality Standards**
  - Chl-a (40 ug/L)
- **Bloom Criteria**
  - Unit Density ≥ 10,000 units/mL
  - Biovolume ≥ 5,000 mm^3/m^3
- **Potentially Harmful Algal Bloom (pHAB)**
  - Meets bloom criteria
  - Dominated by toxigenic algae
- **Dominance Criteria**
  - Cyanobacteria Relative Abundance ≥ 0.40
  - Individual Taxa Relative Abundance ≥ 0.30

State Guidelines



- **Department of Health and Human Services (DHHS)**
  - Health Risk Evaluations (HRE)
  - Communicates with Local Health Departments (LDH)
- **Microcystin Concentration Guidelines**
  - No state specific guidelines…yet
  - Rely on existing guidelines
- **Recreational**
  - WHO → 10 ug/L
  - EPA → 4 ug/L
- **Finished Drinking Water**
  - No monitoring by DWR
  - Several WTP analyze source and finished drinking water for cyanotoxins

Outreach and Public Communication

- **Bloom Communication**
  - DWR – Algal Report and Press Releases
  - DHHS – Health Risk Evaluation
  - LDH – Health Advisories/Closures
- **Education/Outreach**
  - Algal fact sheets
  - Presentations to stakeholders
  - Websites
    - www.algae.nc.gov
    - http://epi.publichealth.nc.gov/oee/algae/protect.html
  - Algal Bloom Web Map

IDENTIFICATION GUIDE: Blue-green Algae

fact sheet

Blue-green algae bloom

Blue-green algae bloom

Blue-green algae bloom decaying along shoreline

Algal group:
Cyanophyta (cyanobacteria, blue-greens)

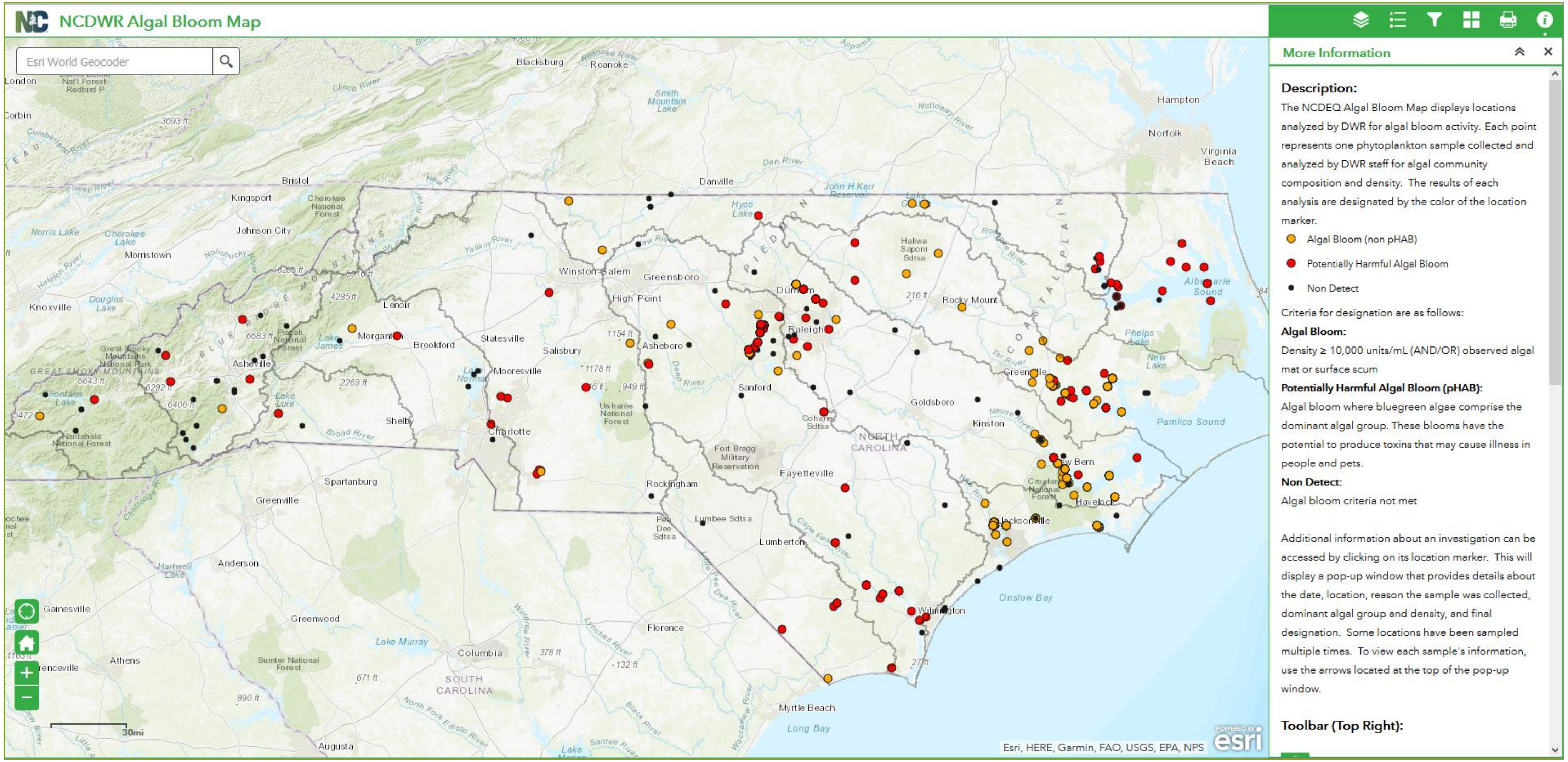
Scientific Name:
Some of the most common forms of blue-greens are *Anabaena, Aphanizomenon, Oscillatoria, Microcystis, Aphanocapsa*, and *Chroococcus*.

Description:
There are hundreds of species of blue-green algae. They are usually microscopic, but high concentrations can sometimes be seen with the naked eye. They can be individual spherical cells, colonial, or filamentous. Many blue-green algae species have special adaptations that give them a competitive advantage over other types of algae. For example, *Microcystis aeruginosa* can control its exposure to sunlight and nutrients using floatation devices called gas vesicles, that allow it to move up and down in the water column. Other species in this group have structures known as heterocysts that allow them to transform nitrogen from the air into a biologically usable form. This gives blue-greens a nutrient source unavailable to other types of algae.

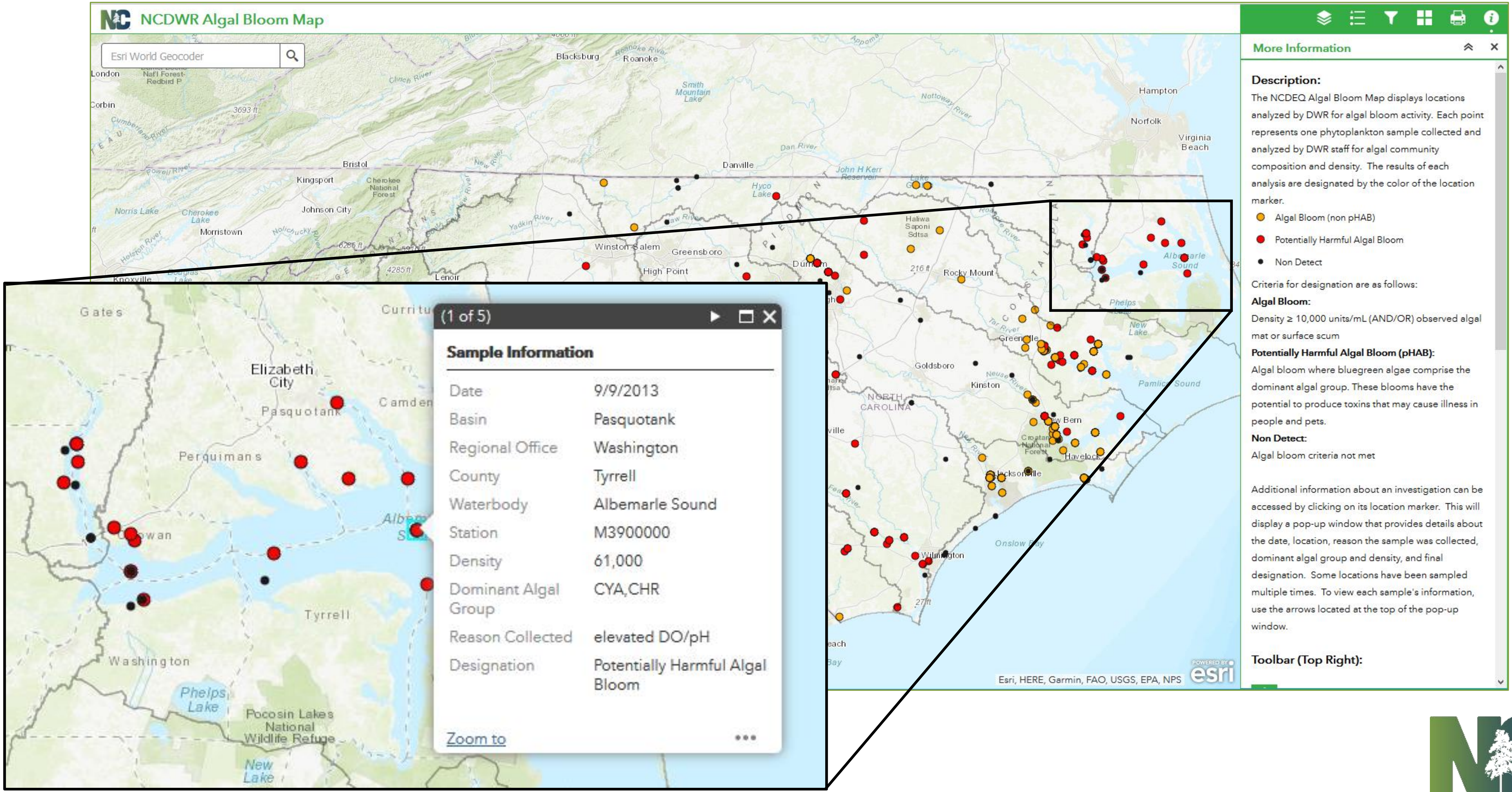
Habitat:
Blue-green algae can be found in all aquatic habitats, including wet walls and ditches. Most are found floating freely in nutrient-rich ponds, lakes and slow moving rivers. Some filamentous blue-greens grow within sediment and form thick, dense mats that break apart and float to the water's surface.

Significance:
Blue-greens are notorious bloom formers. These blooms can cause unsightly water discoloration, surface films, flecks, mats, and taste and odor problems. Some are even known to produce toxins. However, there have been no documented cases of health problems caused by blue-green algae in North Carolina.

North Carolina Division of Water Resources
Learn more: www.algae.nc.gov



Interactive Algal Bloom Map

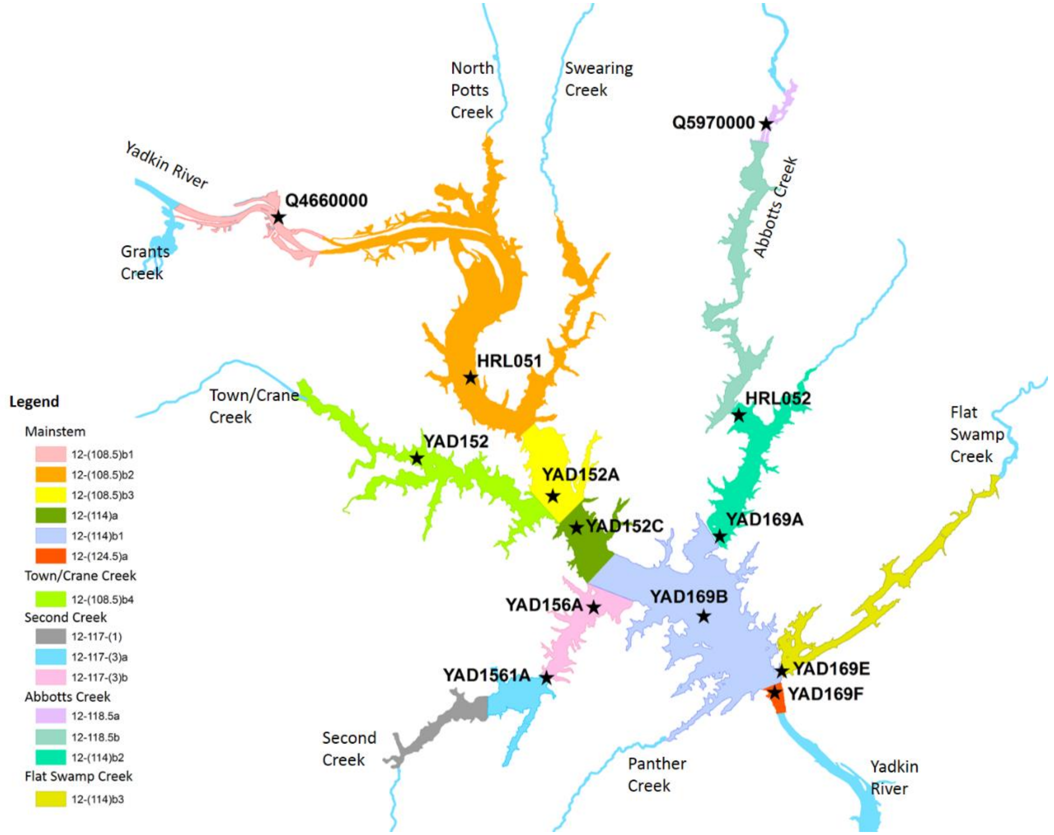


NCDWR Algal Bloom Map
Esri World Geocoder
More Information
Description:
The NCDEQ Algal Bloom Map displays locations analyzed by DWR for algal bloom activity. Each point represents one phytoplankton sample collected and analyzed by DWR staff for algal community composition and density. The results of each analysis are designated by the color of the location marker.
Algal Bloom (non pHAB)
Potentially Harmful Algal Bloom
Non Detect
Criteria for designation are as follows:
Algal Bloom:
Density ≥ 10,000 units/mL (AND/OR) observed algal mat or surface scum
Potentially Harmful Algal Bloom (pHAB):
Algal bloom where bluegreen algae comprise the dominant algal group. These blooms have the potential to produce toxins that may cause illness in people and pets.
Non Detect:
Algal bloom criteria not met
Additional information about an investigation can be accessed by clicking on its location marker. This will display a pop-up window that provides details about the date, location, reason the sample was collected, dominant algal group and density, and final designation. Some locations have been sampled multiple times. To view each sample's information, use the arrows located at the top of the pop-up window.
Toolbar (Top Right):
(1 of 5)
Sample Information
Date 9/9/2013
Basin Pasquotank
Regional Office Washington
County Tyrrell
Waterbody Albemarle Sound
Station M3900000
Density 61,000
Dominant Algal Group CYA,CHR
Reason Collected elevated DO/pH
Designation Potentially Harmful Algal Bloom
Zoom to
Gates
Elizabeth City
Pasquotank
Camden
Perquimans
Tyrrell
Washington
Phelps Lake
Pocosin Lakes National Wildlife Refuge
New Lake
Blacksburg
Roanoke
Danville
Winston-Salem
Greensboro
High Point
Durham
Rocky Mount
Goldsboro
Kinston
Greenville
New Bern
Havelock
Jacksonville
Wilmington
Hampton
Norfolk
Virginia Beach
Albemarle Sound
Pamlico Sound
Onslow Bay
Bristol
Kingsport
Johnson City
Morristown
Knoxville
NORTH CAROLINA
Esri, HERE, Garmin, FAO, USGS, EPA, NPS

Nutrient Criteria Development

- NCDWR developing numeric nutrient criteria for 3 specific water bodies
- Evaluate causal (nutrients) and response (chl-a, DO, pH etc.) variables

1. **Scientific Advisory Council (SAC)** - Developing scientifically defensible criteria to protect <u>designated uses</u>
2. **Criteria Implementation Committee (CIC) -** Provides feedback on social and fiscal impacts of draft criteria
3. **Rule Making Process**



High Rock Lake

Moving Forward

- Expand cyanotoxin testing capabilities and monitoring program
  - More toxin types
  - Finished drinking water
  - Marine toxins (shellfish)
- Improve Collaboration
  - State Agencies (DHHS, PWS, Marine Fisheries)
  - Federal Agencies (EPA, USGS, NOAA)
  - Academic Institutions (NCSU, UNCW, etc)
  - Local Citizen Groups

Questions?

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Healthy People. Healthy Communities.

South Carolina Department of Health and Environmental Control

Status of HABs and Cyanotoxins Monitoring and Response in South Carolina

Presented by David Chestnut

History

- SCDHEC freshwater species I*Ds 70s? – 2000s?*
- *Pfiesteria* Workgroup
  - CDC Grant
- Coastal Carolina University & SCDNR Long Bay sample during fish kill
- Stormwater Ponds Testing
  - Coastal Carolina University IDs and microcystins by ELISA in 2012 & 2013 for Horry County Stormwater
    - Never found any measurable microcystin
  - SCDNR participating in water quality sampling at Kiawah since 2001 including phytoplankton assemblages including HABs
    - Since 2010, 258 blooms, 65 fish kills

State Guidelines and Response Strategies

- Drinking Water
  - follow EPA guidelines/recommendations and work closely with the impacted water system as cyanotoxins are currently **unregulated** in drinking water
- Recreational Waters
  - Current algal bloom response guidance cannot be followed, needs update

Drinking Water
Unregulated Contaminant Monitoring Rule 4
UCMR4

- **Contaminants not currently regulated** but known to exist and could potentially be found in potable waters of public water systems (PWSs)
- **Assessment Monitoring 3** tier includes 9 cyanotoxins

Assessment Monitoring 3 (Cyanotoxins)

UCMR4 Monitoring Plan	
Type of Water System (population)	Assessment Monitoring 3 (Cyanotoxins) AM3
Small Systems (25-10,000)	Selected SW or GWUDI [SC = 17 PWSs]
Large Systems (>10,000)	All SW or GWUDI (including systems that purchase surface water) [SC = 75 PWSs]

- Total microcystins
- Microcystin-LA
- Microcystin-LF
- Microcystin-LY
- Microcystin-RR
- Microcystin-YR
- Nodularin
- Anatoxin-a
- Cylindrospermopsin

Where are UCMR AM3 Cyanotoxin sampling locations?

- AM3 Cyanotoxins – Entry Point To Distribution System (EPTDS) [finished water] and applies to surface water systems and surface water purchasing systems, EPTDS S, if more than one connection, then highest volume connection; does not apply to groundwater EPTDS

Sampling Frequency

Monitoring Plan/Method(s)
AM3-Cyanotoxin "total microcystins"/EPA 546 Adda ELISA
AM3-Cyanotoxin "specific microcystins"/EPA 544
AM3-Cylindrospermopsin and anatoxin-a/EPA 545

AM3 (collected by the water system):

- Surface water systems – 8 sampling events, every other week, 4 consecutive months (excluding December-February)

Ambient Surface Water Monitoring

- Presently no ongoing statewide ambient surveillance monitoring
- SCDHEC reservoir study planned for this summer
  - Species IDs and ELISA microcystin & cylindrospermopsin
  - Selected sites, primarily with long-term chlorophyll *a* data
  - A few statistical survey sites in additional minor lakes
  - A few inactive sites located in problem areas of interest
- After this study SCDHEC will look at the data and decide where to go in the future

Prevention/Control & Mitigation

- Only as addressed by nutrient TMDLs where lake nutrient & chlorophyll *a* standards exceedances indicate impairment (§303(d) listed)

Source Water Protection, etc.

- Algal toxins not a priority
  - Unregulated for drinking water
  - Priorities more for industrial toxins, pesticides, etc.
- Not a focus of any current SWP activities

Coordination, Outreach, Public Communication

- Within South Carolina a group of entities are coming together to develop a plan and collaborate
  - Realignment of the old *Pfiesteria* workgroup
- The group will be discussing updates to the algal bloom response guidance
- Working on a State-of-the-State white paper to promote interest in developing consistent long term programs

Collaboration and Coordination Initiative

COASTAL CAROLINA UNIVERSITY

Sea Grant
S.C. Sea Grant Consortium

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

dhec
S.C. Department of Health and Environmental Control

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

BARUCH INSTITUTE
FOR MARINE AND COASTAL SCIENCES
SCHOOL OF THE EARTH, OCEAN, AND ENVIRONMENT
UNIVERSITY OF SOUTH CAROLINA

1801
UNIVERSITY OF SOUTH CAROLINA
Arnold School of Public Health

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

Areas of Need

- ELISA Training for any partners interested
- HPLC-MS/MS instrumentation for use by all partners
- HABs identification training any partners interested

SCDHEC Contacts

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Overview of Mississippi Harmful Algal Blooms

Atlanta, GA

May 2018

Pete Howard

MDEQ, Field Services Division

State History of blooms and cyanotoxins

- Bloom/Cyanotoxins detected in freshwater systems
- Very few documented cases
- Rely on Citizen Reporting

- Freshwater – Cyano/HABs
  - Bluegreen – Microcystis aeruginosa
  - Golden Algae – Prymnesium parvum

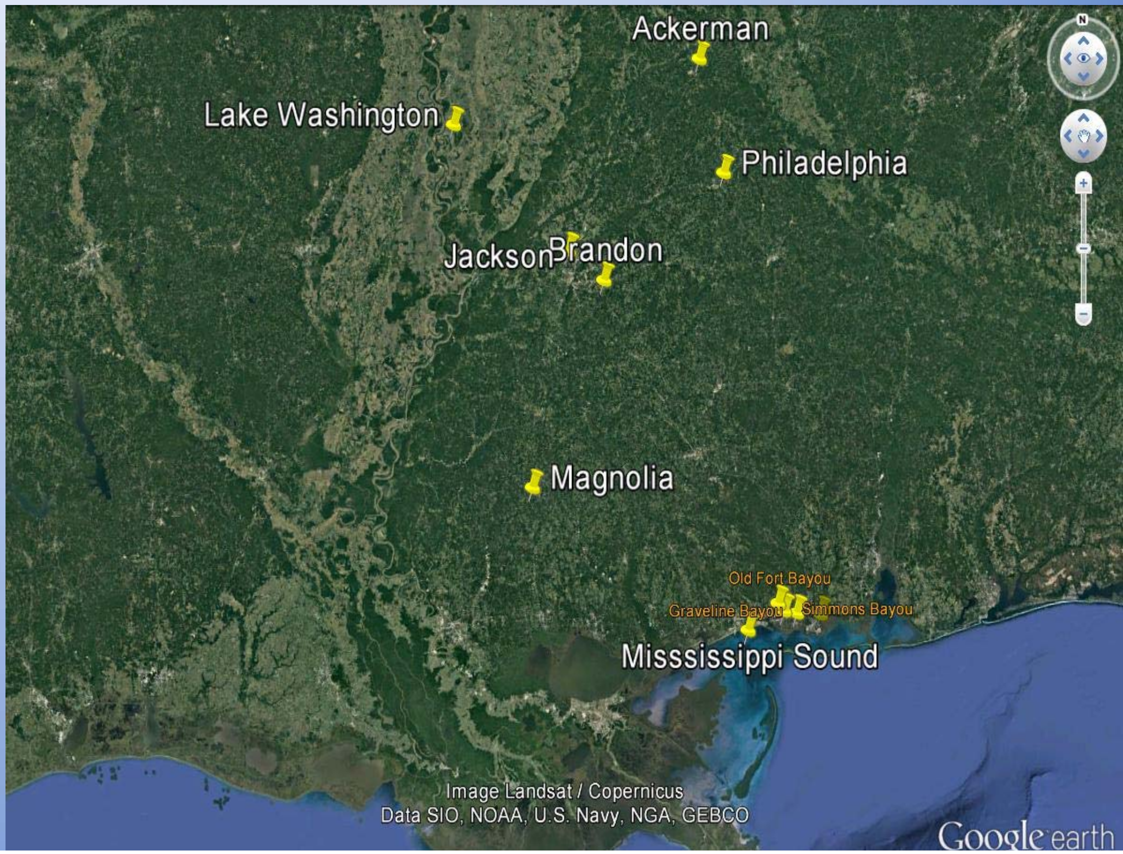
State History of blooms and cyanotoxins

- Bloom detected in marine systems
  - Karenia brevis
  - Chattonella subsalsa

  - Pfiesteria piscicida (detected)
  - Prorocentrum micans – (detected)

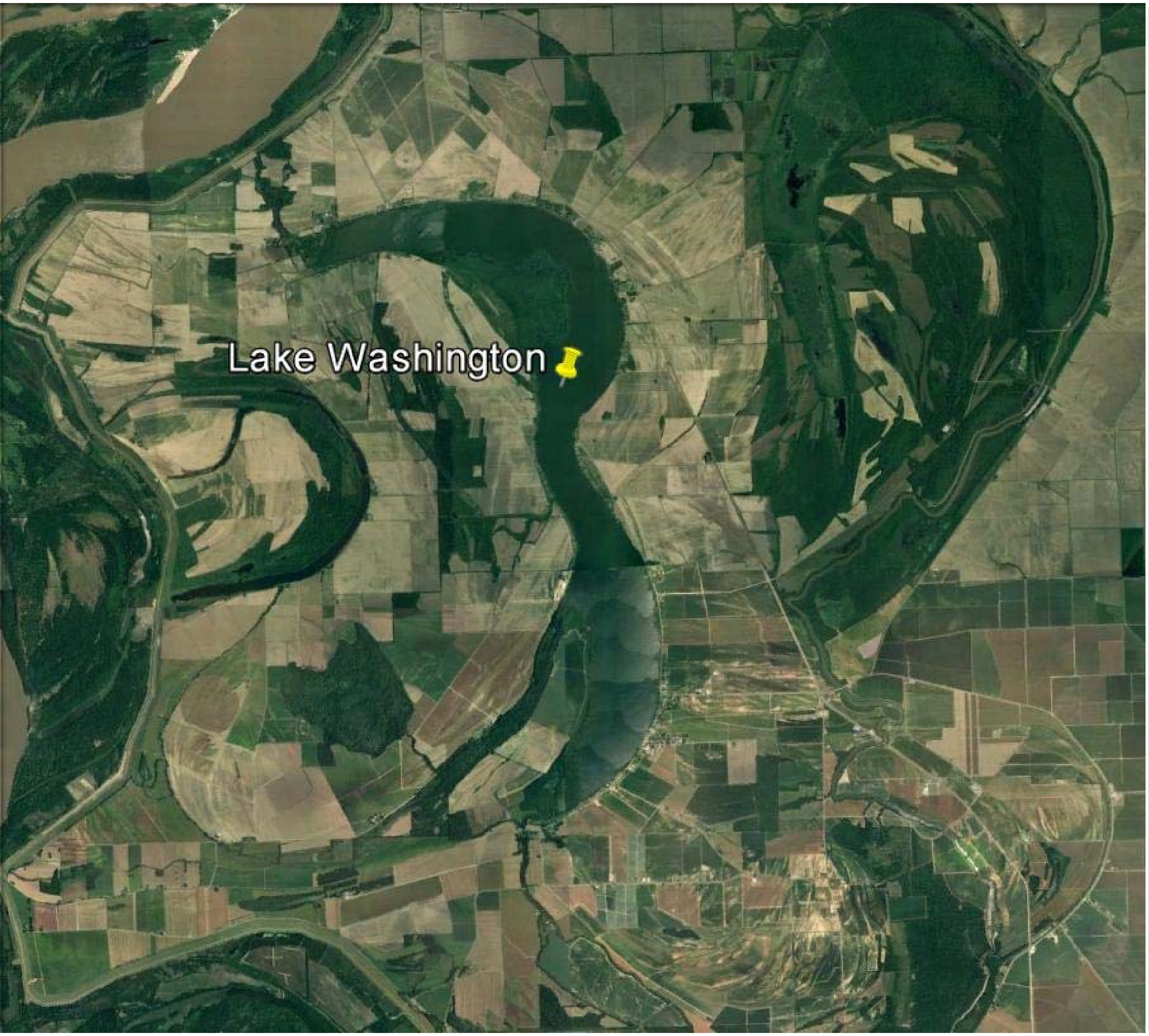
State History of blooms and cyanotoxins

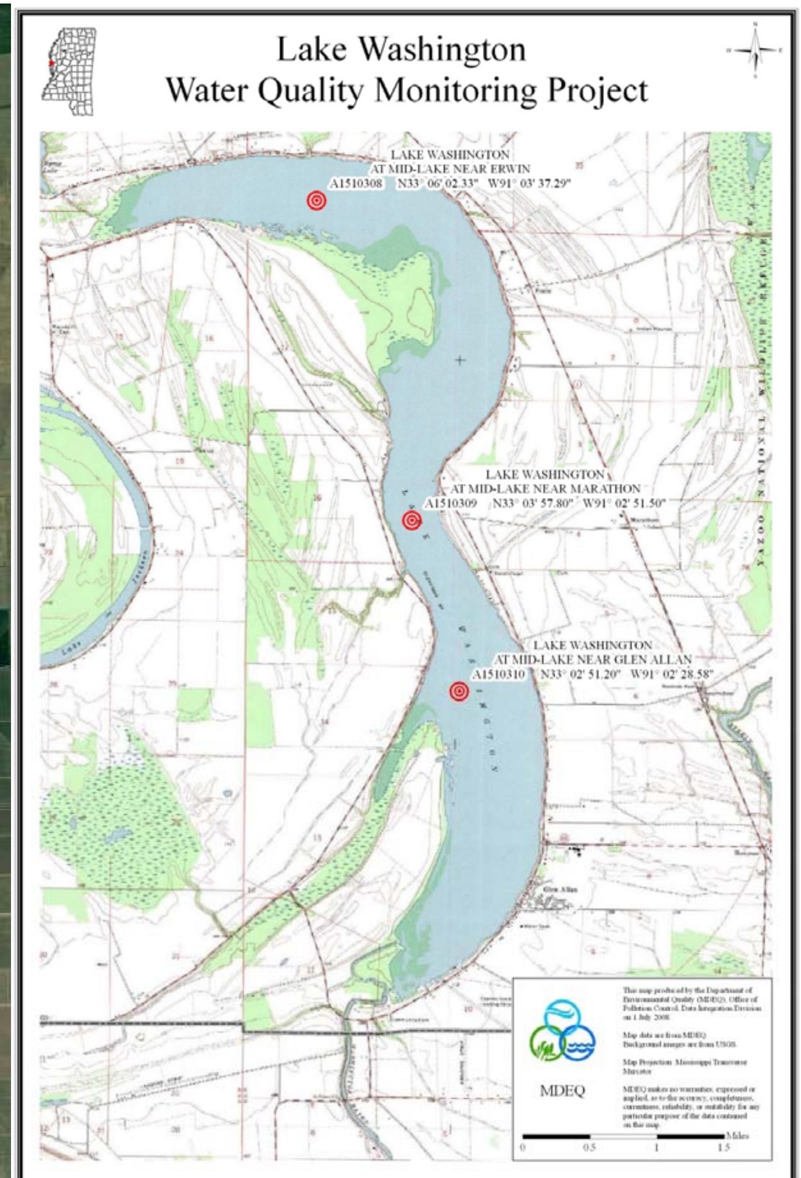
- **Lake Washington 1990**
- Coastal Pfiesteria Study 2004
- Brandon 2004
- Jackson 2008
- Philadelphia 2011
- MS Sound 2011
- **MS Sound 2015,2016**
- Ackerman 2017
- Magnolia 2017



State History of blooms and cyanotoxins

- 2 Major Blooms in 28 years
- Lake Washington is located in a highly developed agricultural watershed and then unsewered town of Glen Allen.
- MS Sound is the receiving point of major watersheds of Pearl River, Pascagoula River, Lake Bourne and the Coastal watersheds with their Non-Point Source enrichments.


Lake Washington


Lake Washington
Water Quality Monitoring Project
LAKE WASHINGTON
AT MID-LAKE NEAR ERWIN
A1510308 N33° 06' 02.33" W91° 03' 37.29"
LAKE WASHINGTON
AT MID-LAKE NEAR MARATHON
A1510309 N33° 03' 57.80" W91° 02' 51.50"
LAKE WASHINGTON
AT MID-LAKE NEAR GLEN ALLAN
A1510310 N33° 02' 51.20" W91° 02' 28.58"
Glen Allan
This map produced by the Department of Environmental Quality (MDEQ), Office of Pollution Control, Data Integration Division on 1 July 2008.
Map data are from MDEQ
Background images are from USGS.
Map Projection: Mississippi Transverse Mercator
MDEQ makes no warranties, expressed or implied, as to the accuracy, completeness, currentness, reliability, or suitability for any particular purpose of the data contained on this map.
MDEQ
Miles
0
0.5
1
1.5

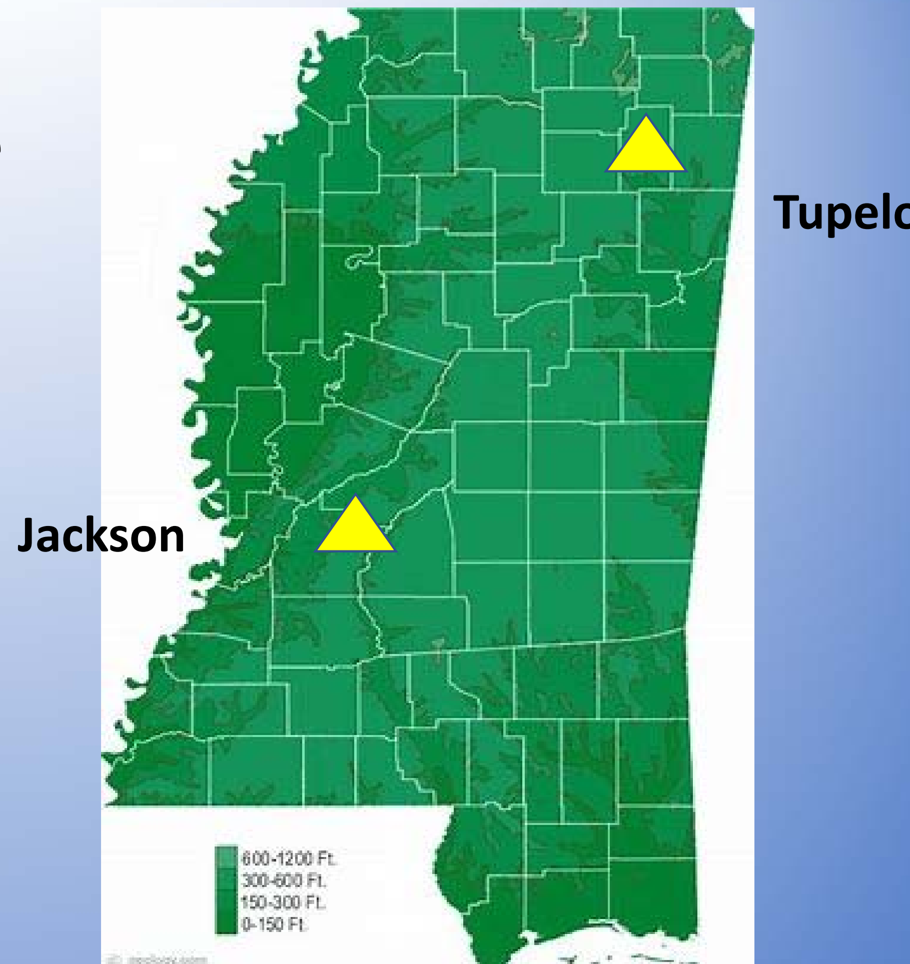
State History of blooms and cyanotoxins

- Advisory Postings
- Beach Closure — 11 Dec 2015- 4 Jan 2016
  - Karenia brevis
- Lake Washington — August 1990
  - Microcystis aeruginosa
  - Closed to fishing, contact recreation
  - Warning for pets and livestock

State Guidelines and Response Strategies

Drinking Water – only 2 areas in Mississippi have surface water sources, Jackson and Tupelo.

Drinking Water contamination from HABs is not an issue with the current conditions and controls.



State Guidelines and Response Strategies

- Recreational Waters
- Closures of Waterbody as in the case of Lake Washington
- Closures of Beaches as in the Karenia brevis and E. coli
- Closures of Oyster Reef harvesting

State guidelines and Response Strategies

- Lake Washington CLOSED to ALL
  - fishing, recreational and commercial
  - Pets and Livestock
- Farm Ponds
  - Advise Landowners,
  - Fishing, Pets and Livestock

- Oyster Reef Harvesting CLOSED to ALL

Monitoring

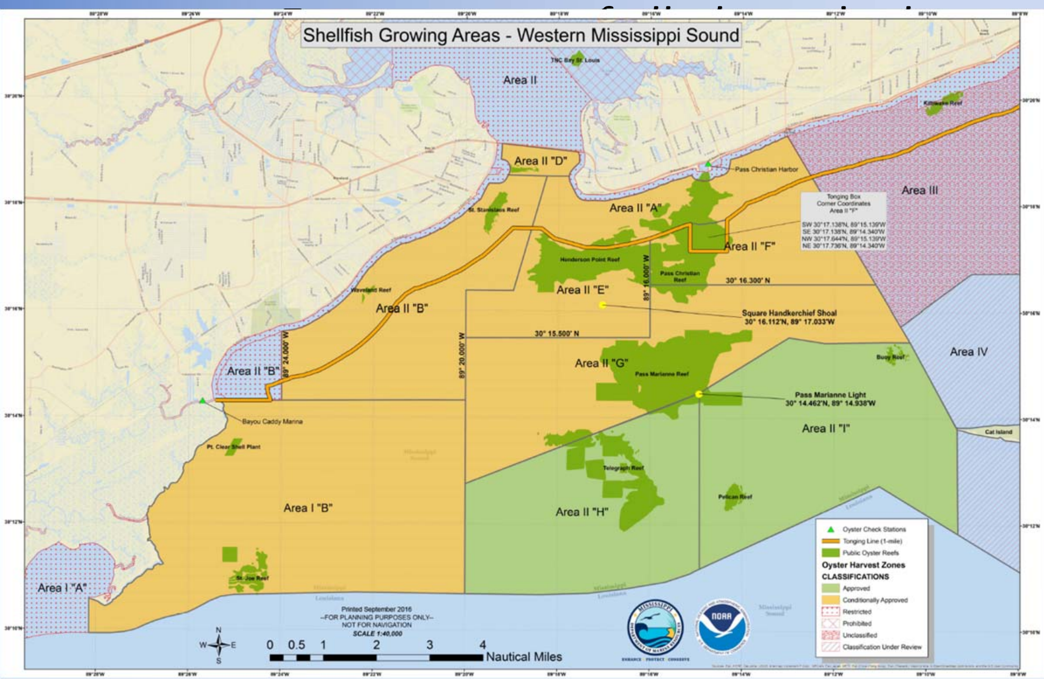
- No Routine Monitoring Statewide for HABs
- Monitor Major incidents on as needed basis
- Laboratory Analysis
- No Molecular capabilities
- Microscopy to verify ID and cell counts (in-house)

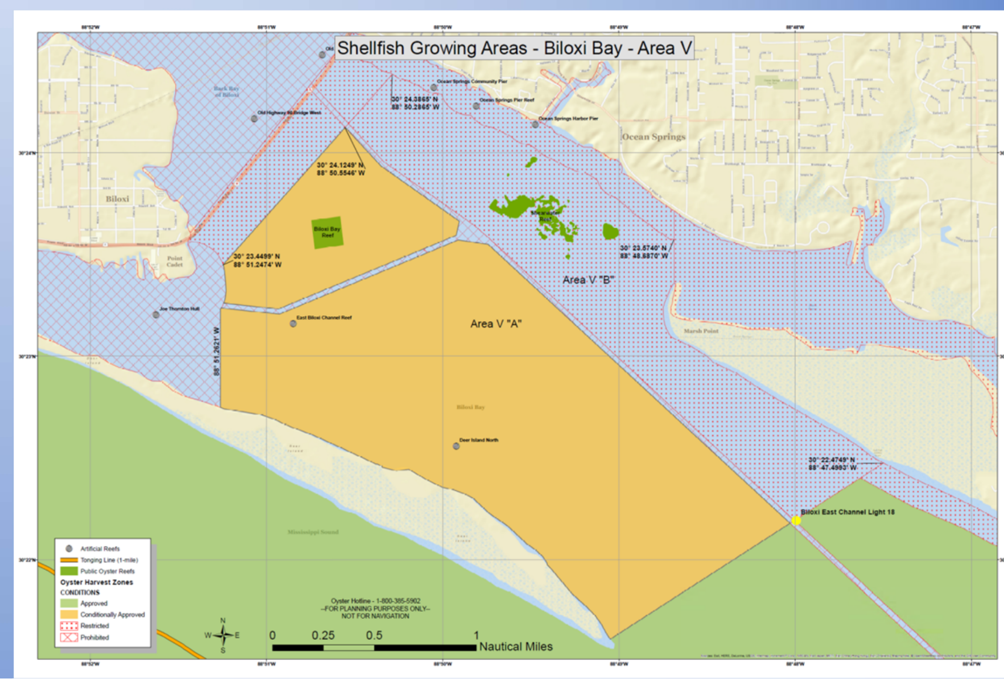
Collaborate with multiple partners,

- GCRL, Dauphin Island, MS State University
  - Methods and Analysis
  - Laboratory capacity

Monitoring

- **MS DMR, Shellfish Bureau**
- Conducts bimonthly phytoplankton samples at 2 sites





Monitoring

- **MDEQ, Coastal Monitoring**
- Conducts weekly sampling
- 21 sites

- **MDEQ, Monitoring Section**
- Ambient Lakes -28 sites monthly
- Ambient Streams 48 sites monthly
- Ambient Fixed Bacteria 48 sites
  6x/contact season for E. coli

Water Protection

- Nutrient Management initiatives

- NPS Projects – Lake Washington area BMPs
- Clean Lakes - Lake Washington
- Glen Allen – WWTP Assistance
- Deepwater Horizon Water Quality Projects Nutrient Reduction for MS Sound and Estuaries
- *Note: None of this is done specifically to prevent HABs

Coordination, Outreach and Public Communication

- Surface Water Quality and Recreation (CWA) coordination with PWSS(SDWA) Programs

- Gulf States Marine Fisheries Commission
- Deepwater Horizon Trustee Council (Gulf wide)
- Lake Washington

- Not specific to HABs

Coordination, Outreach and Public Communication

- Public Relations Officers issues Press Releases
  to local TV, Radio ,Print media and Websites.
  www.mdeq.ms.gov ***www.dmr.ms.gov***

- Incident specific notices issued.

- Beaches also have postings noting if a beach is Open or Closed.

Coordination, Outreach and Public Communication

Beaches are tested weekly

Bacteria Level
Is Acceptable

Coordination, Outreach and Public Communication

Or Not.

Coordination, Outreach and Public Communication

- MDEQ, MSDH , MDWFP and MDMR would be involved in closures.

- Governor has appointed MDEQ as the Lead Agency in incidents.

Successful Initiatives

- Clean Lakes Program and
- improvements with BMPs,
- Glen Allen WWTP

- Can't directly attribute to improvements, but we have not had another HAB event…..yet.

Areas in Needs

- Technical assistance
- Resources
- Training
- Collaborations
- Education

- **YES to all the above**.
- Dr Paula C Furey’s, workshop on **Algal Taxonomy Freshwater Flora**
- Included a section on HAB causing Taxa,
- DEQ funded this workshop to train biologists and inspectors.

State Points of Contact

- **Doug Upton, Field Services Dir.**

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Emily Cotton, Coastal Monitoring Chief

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Pete Howard, Environmental Scientist

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Joe Jewell, Marine Fisheries Dir

MS Dept. of Marine Resources

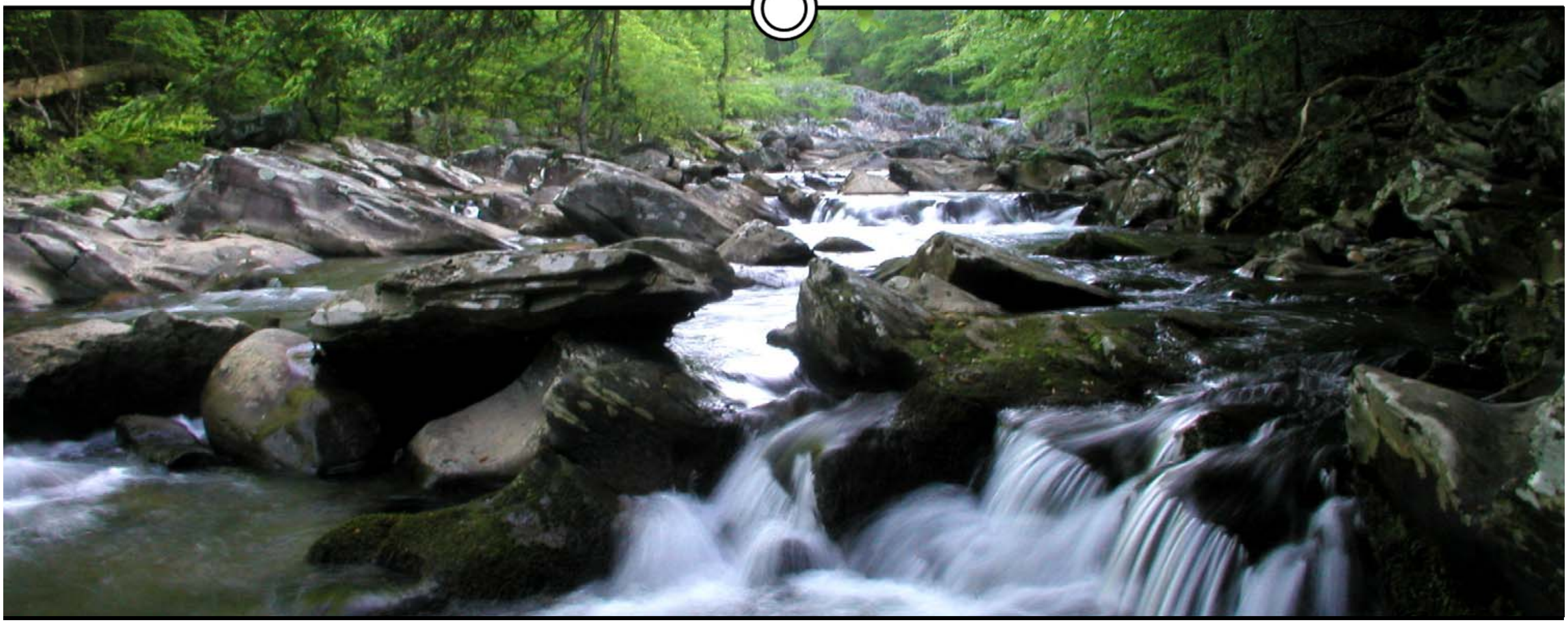
Joe.Jewell@dmr.ms.gov

Kristina Broussard, Marine Scientist

kristina.broussard@dmr.ms.gov

GEORGIA
DEPARTMENT OF NATURAL RESOURCES

HABs & Toxins in Georgia



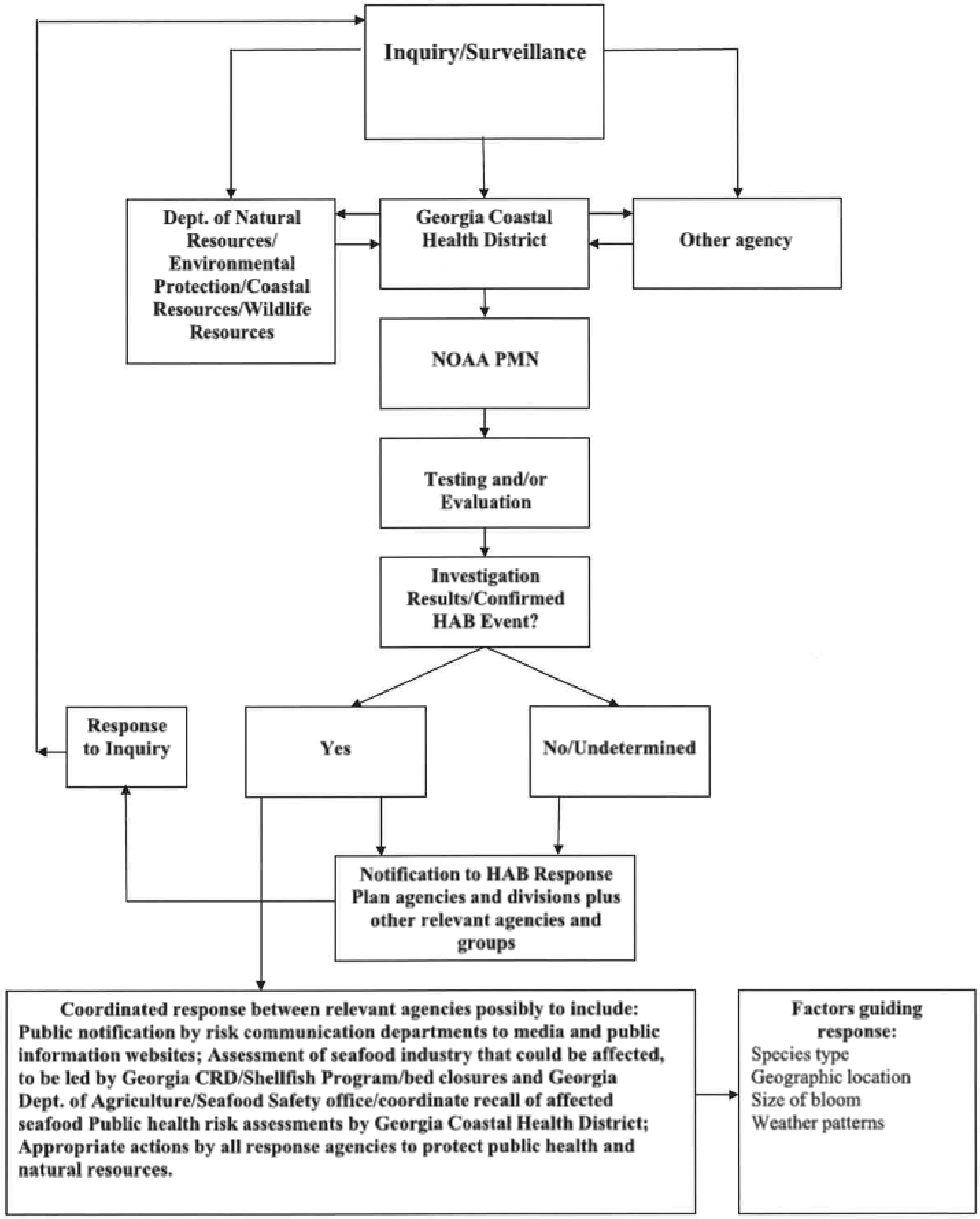
May 15, 2018

GA EPD & Blooms

EPD's Ambient Monitoring Unit handles the collection for algal bloom testing, unless the owner of the water body has already tested (GA Power, USACE, etc.)

All of EPD's samples (and many samples taken by others) are sent to Dr. Kalina Manoylov of Georgia College for analysis

Should it be deemed necessary, a Swimming Advisory is issued by the manager of that water body


Inquiry/Surveillance
Dept. of Natural Resources/ Environmental Protection/Coastal Resources/Wildlife Resources
Georgia Coastal Health District
Other agency
NOAA PMN
Testing and/or Evaluation
Investigation Results/Confirmed HAB Event?
Response to Inquiry
Yes
No/Undetermined
Notification to HAB Response Plan agencies and divisions plus other relevant agencies and groups
Coordinated response between relevant agencies possibly to include: Public notification by risk communication departments to media and public information websites; Assessment of seafood industry that could be affected, to be led by Georgia CRD/Shellfish Program/bed closures and Georgia Dept. of Agriculture/Seafood Safety office/coordinate recall of affected seafood Public health risk assessments by Georgia Coastal Health District; Appropriate actions by all response agencies to protect public health and natural resources.
Factors guiding response:
Species type
Geographic location
Size of bloom
Weather patterns

EPA Recommends...

In 2017 EPA published a document recommending numerical cyanobacteria standards:

Microcystins	Cylindrospermopsin
4 µg/L [a,b]	8 µg/L [a,b]

a) Swimming Advisory: not to be exceeded on any day

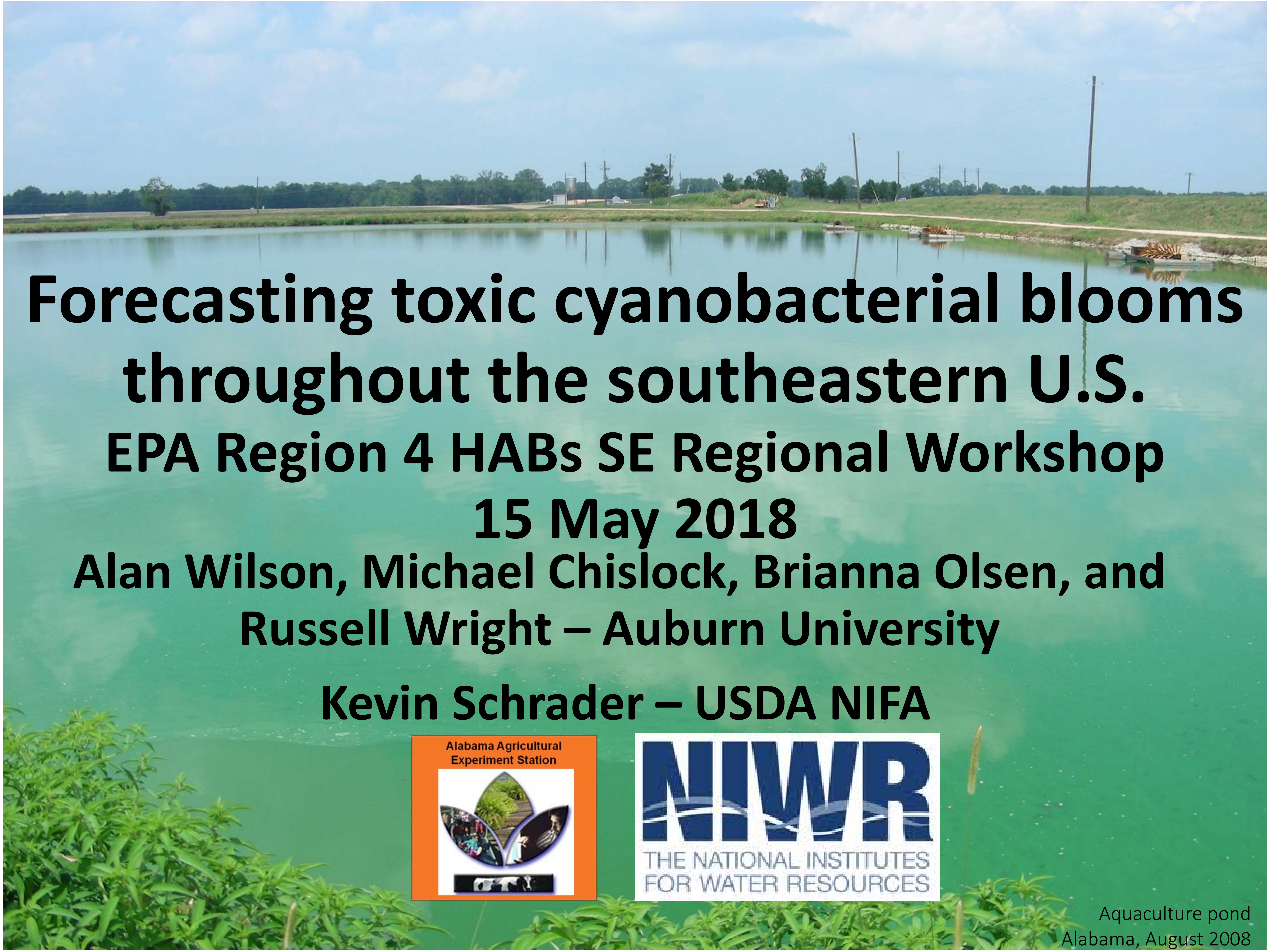
b) Recreational Criteria for Waterbody Impairment: not exceeded more than 10 percent of days per recreational season up to one calendar year.

GA EPD & Blooms

Algal blooms should decrease as nutrient control measures are increased (i.e. the execution of Georgia's Numeric Nutrient Development Plan)

Georgia EPD plans to continue using Swimming Advisories as the tool to protect the health of those who choose to recreate in our waters

Questions?



Forecasting toxic cyanobacterial blooms throughout the southeastern U.S.

EPA Region 4 HABs SE Regional Workshop
15 May 2018

Alan Wilson, Michael Chislock, Brianna Olsen, and Russell Wright – Auburn University

Kevin Schrader – USDA NIFA

Alabama Agricultural Experiment Station

NIWR
THE NATIONAL INSTITUTES FOR WATER RESOURCES

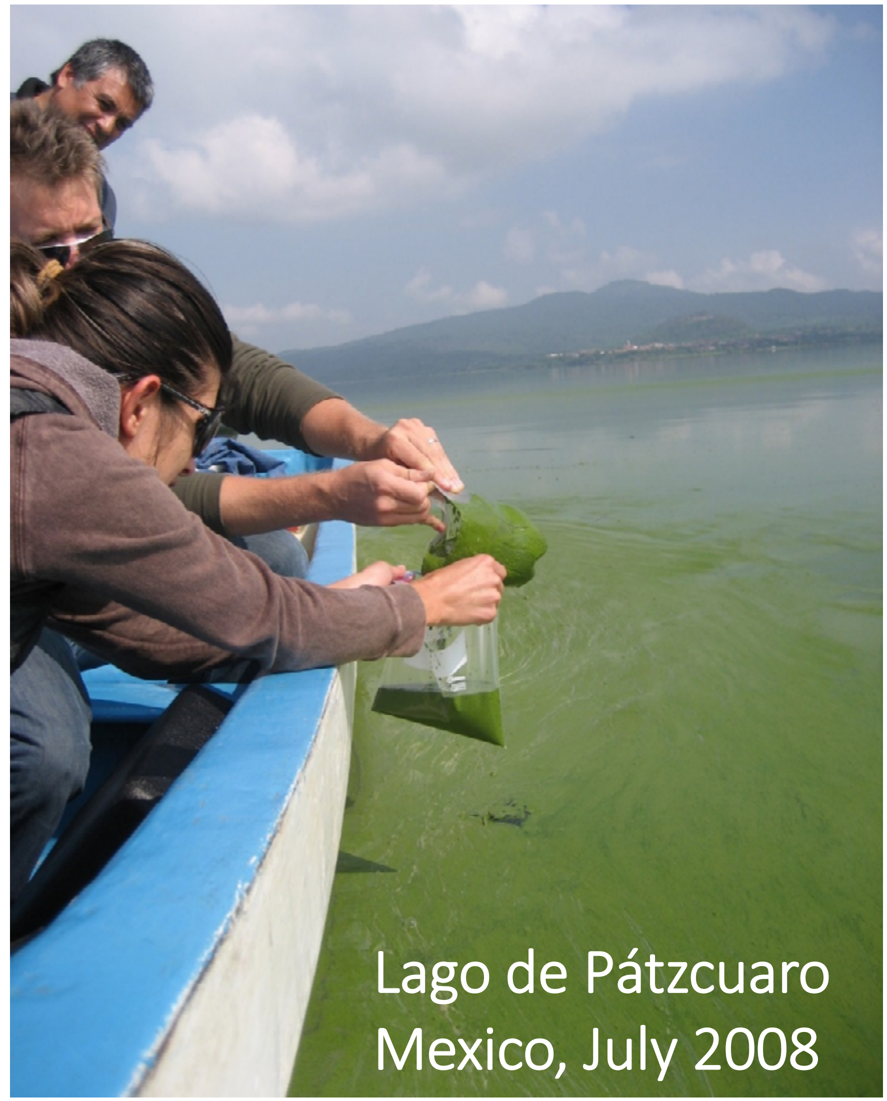
Aquaculture pond
Alabama, August 2008

Lake Erie (photo: summer 2011)
http://ngm.nationalgeographic.com/2013/05/fertilized-world/essick-photography


Lake Fox
16 January 2016
0.3 m Secchi depth

Two approaches to forecast HABs

- Remote sensing
- Large-scale lake monitoring projects



Remote sensing-based forecasting

- Remote sensing

Satellite Comparison for cyano applications

Satellite	Spatial	Temporal	Key Spectral
MERIS (2002-12) OLCI Sentinel-3 2015	300 m *OK*	2 day *good*	10 (5 on red edge) *good*
MODIS high res Terra 1999; Aqua 2002	250/500 m *OK* *poor*	1-2 day *good* *good*	4 (1 red, 1 NIR) *marginal* *OK*
MODIS low res & SeaWiFS	1 km *good*	1-2 day *poor*	7-8 (2 in red edge) *marginal*
Landsat	30 m *good*	8 or 16 day *Potential with 2*	4 (1 red, 1 NIR) *potential*
Sentinel-2 (2015)	20 m	10 day (5 day with 2nd satellite in 2017)	5 (1 red; 2 NIR, 1 in red edge)

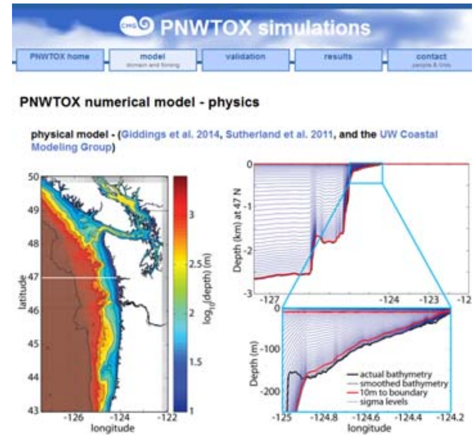
Minimum resolution, 3 pixels across (2 mixed land/water)

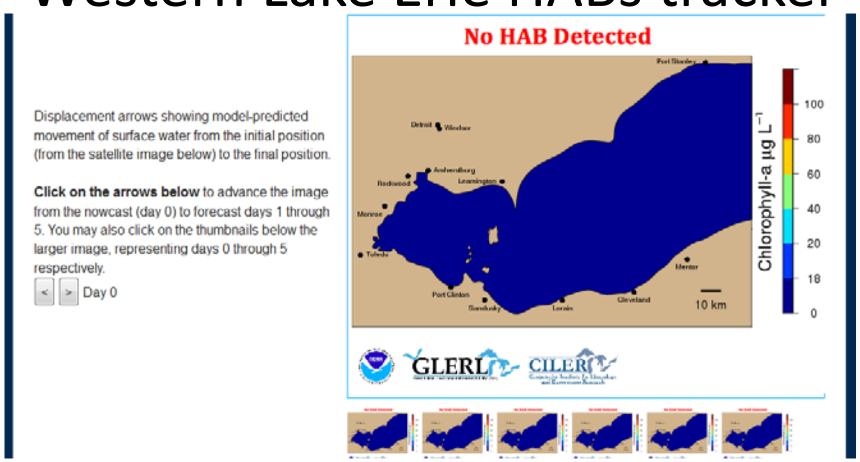
COASTALOCEANSCIENCE.NOAA.GOV Cyanos, May 2015 #‹#›

Stumpf et al. 2015 talk

Remote sensing-based forecasting

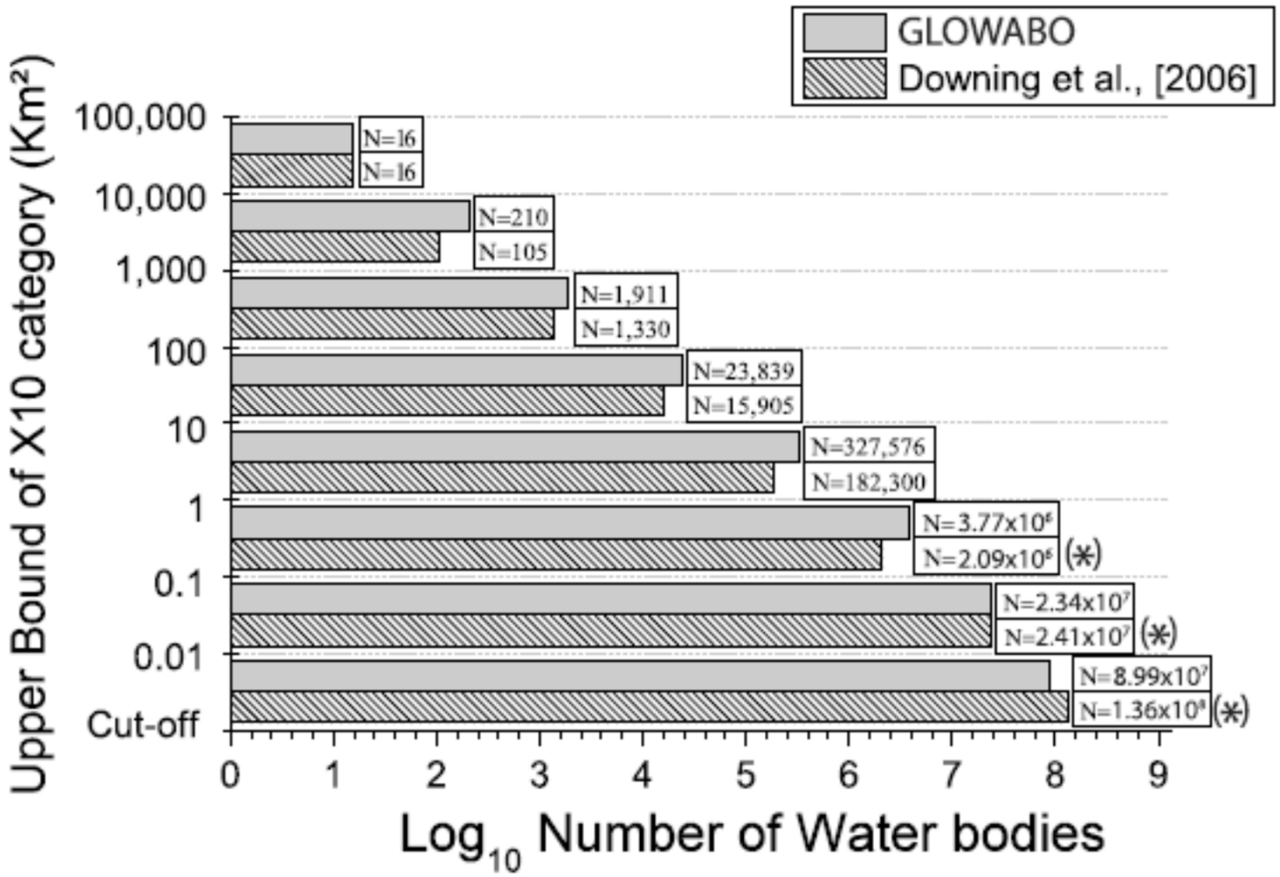
- Large marine systems
  - Pacific Northwest - *Pseudo-nitzscha*
  - Puget Sound - *Alexandrium*
  - Southern California - *Pseudo-nitzschia*
  - Gulf of Maine - *Alexandrium*
  - Gulf of Mexico – *Karenia brevis*
- Large freshwater systems
  - Western Lake Erie HABs tracker





Remote sensing-based forecasting

- **What about the <u>~117 million</u> inland lakes on earth?**



Verpoorter et al. 2014

Remote sensing-based forecasting

- **What about the <u>~117 million</u> inland lakes on earth?**



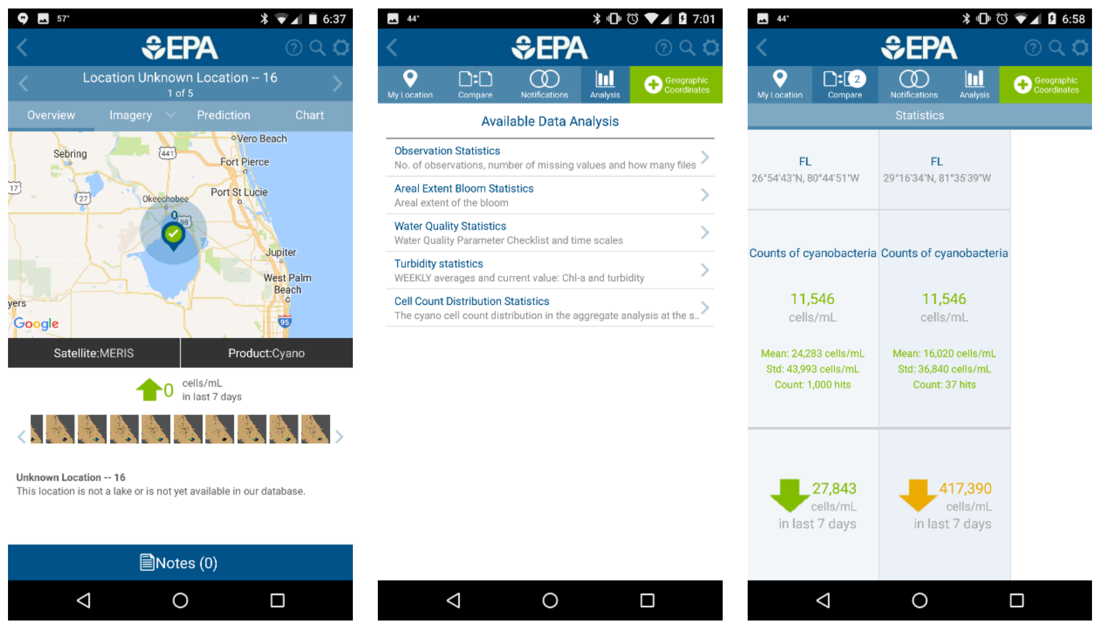

Remote sensing-based forecasting

- California Surface Water Ambient Monitoring Program (SWAMP)
  - Uses remote sensing surface water color satellite data to estimate and forecast HABs in fresh waterbodies

SWAMP
Surface Water Ambient Monitoring Program

Remote sensing-based forecasting

- USEPA, NOAA, USGS, and NASA working together to develop an android HABs app for inland systems
  - Cyanobacteria Assessment Network (CyAN) mobile app
  - Uses MODIS surface water color satellite data to estimate and forecast HABs



Remote sensing-based forecasting

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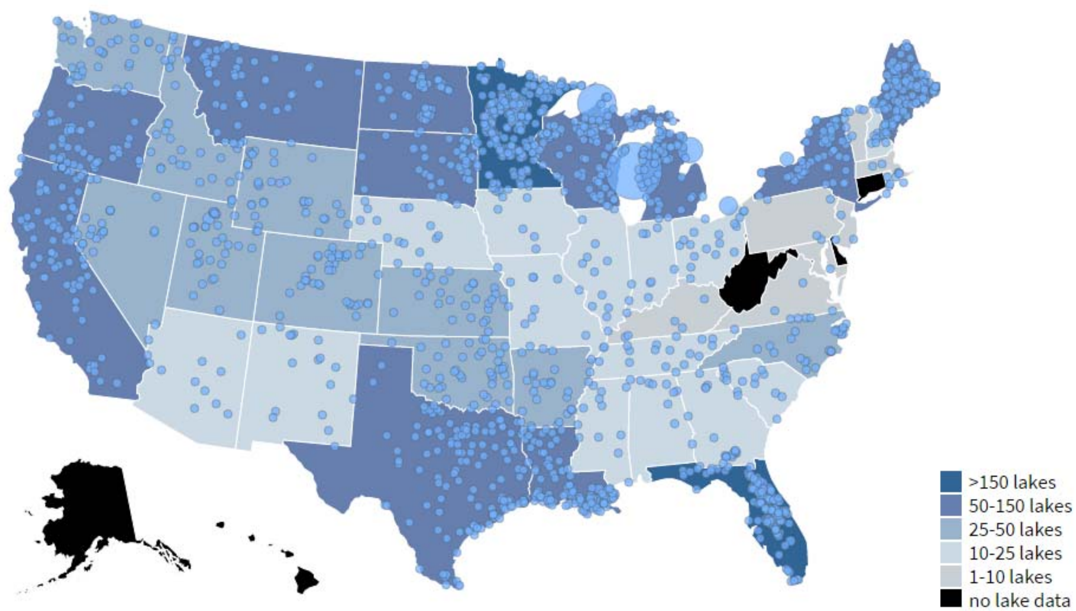

Two approaches to forecast HABs

- Remote sensing
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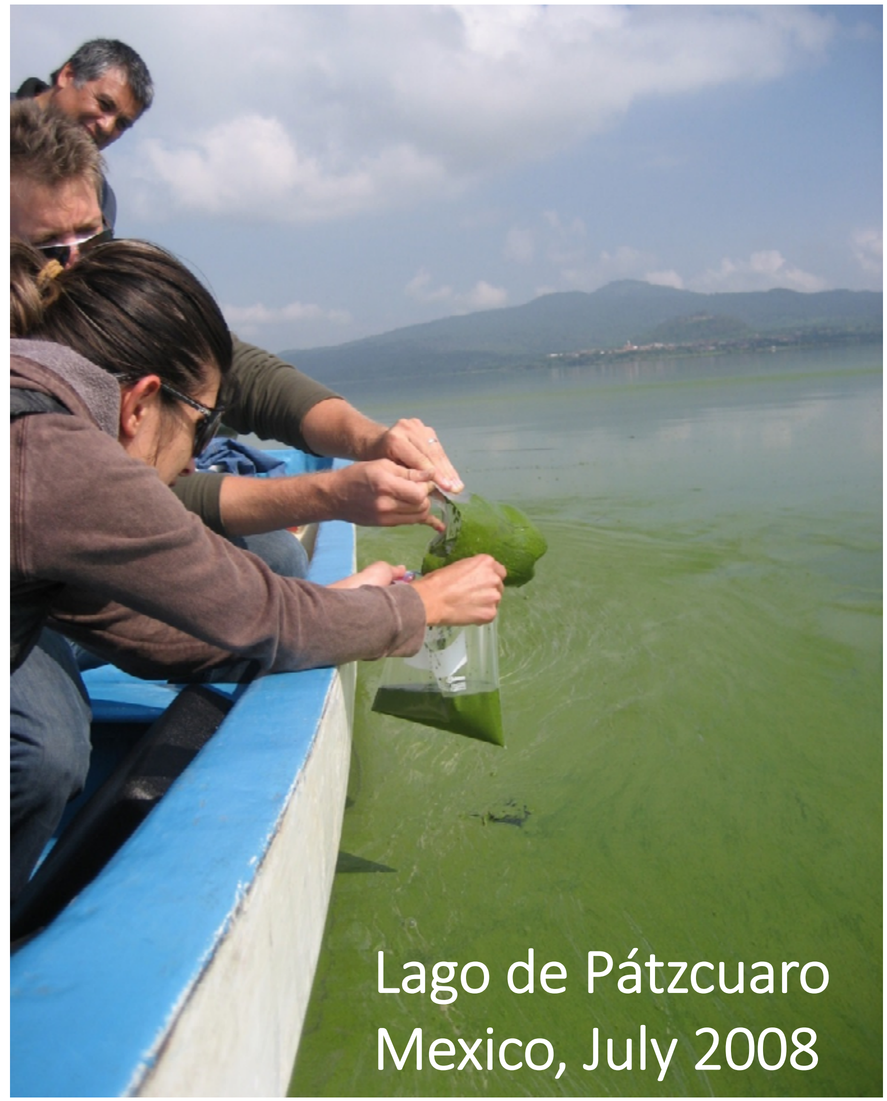


HABs lake surveys

Predicting Cyanobacteria dominance in lakes

John A. Downing, Susan B. Watson, and Edward McCauley

Low Nitrogen to Phosphorus Ratios Favor Dominance by Blue-Green Algae in Lake Phytoplankton **Global**

Environ Sci Pollut Res (2014) 21:8006–8015
DOI 10.1007/s11356-014-2699-9

Harmful Algae 10 (2011) 207–215

Contents lists available at ScienceDirect

Harmful Algae

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

The relationships between nutrients, cyanobacterial toxins and the microbial community in Taihu (Lake Tai), China

Steven W. Wilhelm [a,*], Sarah E. Farnsley [a], Gary R. LeCleir [a], Alice C. Layton [b], Michael F. Satchwell [c], Jennifer M. DeBruyn [d], Gregory L. Boyer [c], Guangwei Zhu [e], Hans W. Paerl [f]

Freshwater Biology (2006) **51**, 2309–2319 doi:10.1111/j.1365-2427.2006.01652.x

Relationships between microcystins and environmental parameters in 30 subtropical shallow lakes along the Yangtze River, China

China

S. K. WU, P. XIE, G. D. LIANG, S. B. WANG AND X. M. LIANG

1987–2000: Occurrence, Toxicity, and Impacts in the Mediterranean Region

Elisabeth Vardaka[b],
Tom Lanaras[c]

[a] National Agricultural Research

Environ Sci Pollut Res (2014) 21:8006–8015
DOI 10.1007/s11356-014-2699-9

Harmful Algae 10 (2011) 207–215

Limnol. Oceanogr., 42(3), 1997, 487–495

Patterns in phytoplankton taxonomic composition across temperate lakes of differing nutrient status

North America Canada

Susan B. Watson, Edward McCauley, and John A. Downing[1]

J. Phycol. **31,** 248–263 (1995)

VARIABILITY OF THE HEPATOTOXIN MICROCYSTIN-LR IN HYPEREUTROPHIC DRINKING WATER LAKES[1]

Brian G. Kotak,[2] *Angeline K-Y. Lam, Ellie E. Prepas*

Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E9

Sandra L. Kenefick and Steve E. Hrudey

Environmental Health Program, Faculty of Medicine, University of Alberta, Edmonton, Alberta, Canada T6G 2G3

S. K. WU, P. XIE, G. D. LIANG, S. B. WANG AND X. M. LIANG

Toxic Cyanobacteria in Greek Freshwaters, 1987–2000: Occurrence, Toxicity, and Impacts in the Mediterranean Region

Harmful Algae 56 (2016) 77–90

Contents lists available at ScienceDirect

Harmful Algae

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

Cyanotoxins in inland lakes of the United States: Occurrence and potential recreational health risks in the EPA National Lakes Assessment 2007

Keith A. Loftin[a,*], Jennifer L. Graham[b], Elizabeth D. Hilborn[c], Sarah C. Lehmann[d], Michael T. Meyer[a], Julie E. Dietze[a], Christopher B. Griffith[a]

Freshwater Biology (2014) **59**, 1970–1981 doi:10.1111/fwb.12400

Managing microcystin: identifying national-scale thresholds for total nitrogen and chlorophyll *a*

LESTER L. YUAN*, AMINA I. POLLARD†, SANTHISKA PATHER*, JACQUES L. OLIVER* AND LESLEY D'ANGLADA*

Freshwater Biology (2015) 60, 1901–1916 doi:10.1111/fwb.12620

Deriving nutrient targets to prevent excessive cyanobacterial densities in U.S. lakes and reservoirs

LESTER L. YUAN AND AMINA I. POLLARD

North America USA

F1000Research F1000Research 2016, 5:151 Last updated: 25 DEC 2016

Check for updates

RESEARCH ARTICLE

Associations between chlorophyll *a* and various microcystin-LR health advisory concentrations [version 1; referees: 1 approved, 2 approved with reservations]

Jeffrey W. Hollister, Betty J. Kreakie

Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, US Environmental Protection Agency, Narragansett, RI, USA

Limnol. Oceanogr., 49(2), 2004, 482–487

Dominance of the noxious cyanobacterium *Microcystis aeruginosa* in low-nutrient lakes is associated with exotic zebra mussels

David F. Raikow[1]
Kellogg Biological Station and Department of Zoology, Michigan State University, 3700 East Gull Lake Drive, Hickory Corners, Michigan 49060

Orlando Sarnelle and Alan E. Wilson[2]
Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan 48824

Stephen K. Hamilton[3]
Kellogg Biological Station and Department of Zoology, Michigan State University, 3700 East Gull Lake Drive, Hickory Corners, Michigan 49060

WATER RESEARCH 44 (2010) 141–150

Available at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/watres

Citizen monitoring: Testing hypotheses about the interactive influences of eutrophication and mussel invasion on a cyanobacterial toxin in lakes

Orlando Sarnelle[a,*], *Jamie Morrison*[a], *Rajreni Kaul*[a], *Geoffrey Horst*[a], *Howard Wandell*[a], *Ralph Bednarz*[b]

Invasive zebra mussels (*Dreissena polymorpha*) increase cyanobacterial toxin concentrations in low-nutrient lakes

Lesley B. Knoll, Orlando Sarnelle, Stephen K. Hamilton, Carrie E.H. Kissman, Alan E. Wilson, Joan B. Rose, and Mechelle R. Morgan

Cyanotoxin Mixtures and Taste-and-Odor Compounds in Cyanobacterial Blooms from the Midwestern United States

JENNIFER L. GRAHAM,* KEITH A. LOFTIN, MICHAEL T. MEYER, AND ANDREW C. ZIEGLER

Lake and Reservoir Management, 30:268–272, 2014

ISSN: 1040-2381 print / 2151-5530 online
DOI: 10.1080/10402381.2014.917347

NOTE

Midwestern US

Summary of microcystin concentrations in Minnesota lakes

Lake and Reservoir Management, 25:253–263, 2009

ISSN: 0743-8141 print / 1040-2381 online
DOI: 10.1080/07438140903143239

Microcystin in Missouri reservoirs

Jennifer L. Graham* and John R. Jones

...phyll a and various microcystin-LR health advisory concentrations [version 1; referees: 1 approved, 2 approved with reservations]

Jeffrey W. Hollister, Betty J. Kreakie
Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, US Environmental Protection Agency, Narragansett, RI, USA

Limnol. Oceanogr., 49(2), 2004, 482–487

Dominance of the noxious cyanobacterium *Microcystis aeruginosa* in low-nutrient lakes is associated with exotic zebra mussels

David F. Raikow[1]

WATER RESEARCH 44 (2010) 141–150

Available at www.sciencedirect.com

ScienceDirect

WATER RESEARCH

Lake and Reservoir Management, 28:46–58, 2012

ISSN: 0743-8141 print / 1040-2381 online
DOI: 10.1080/07438141.2011.650835

Florida

Phosphorus, nitrogen, and the designated uses of Florida lakes

Roger W. Bachmann,* Dana L. Bigham, Mark V. Hoyer, and Daniel E. Canfield Jr.

Midwestern United States

Lesley B. Knoll, Orlando Sarnelle, Stephen K. Hamilton, Carrie E.H. Kissman, Ala

Factors Influencing the Abundance of Blue-Green Algae in Florida Lakes[1]

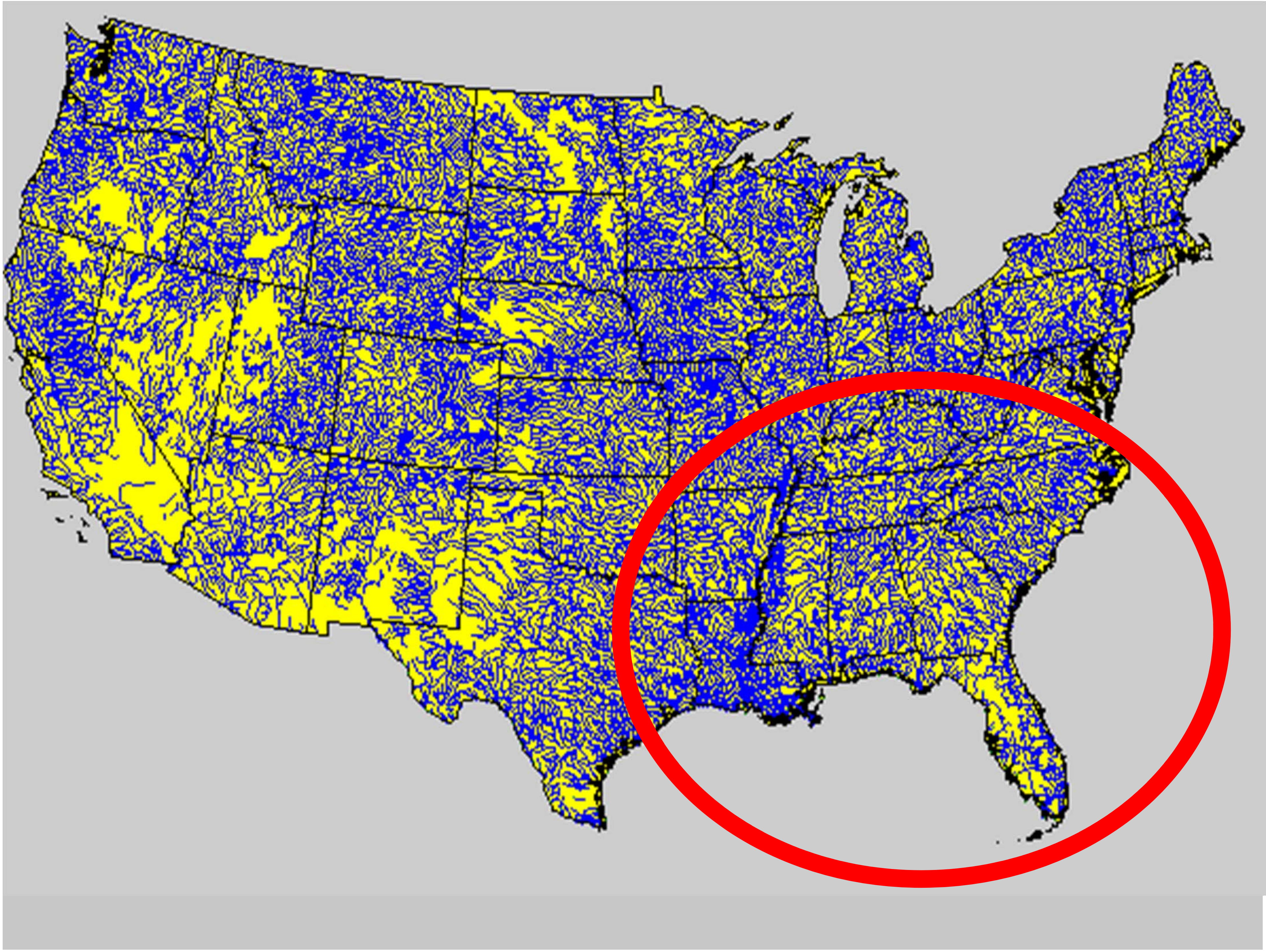
Daniel E. Canfield, Jr.[2], Edward Phlips, and Carlos M. Duarte[3]

Jennifer L. Graham* and John R. Jones

Summary of microcystin concentrations in Minnesota lakes

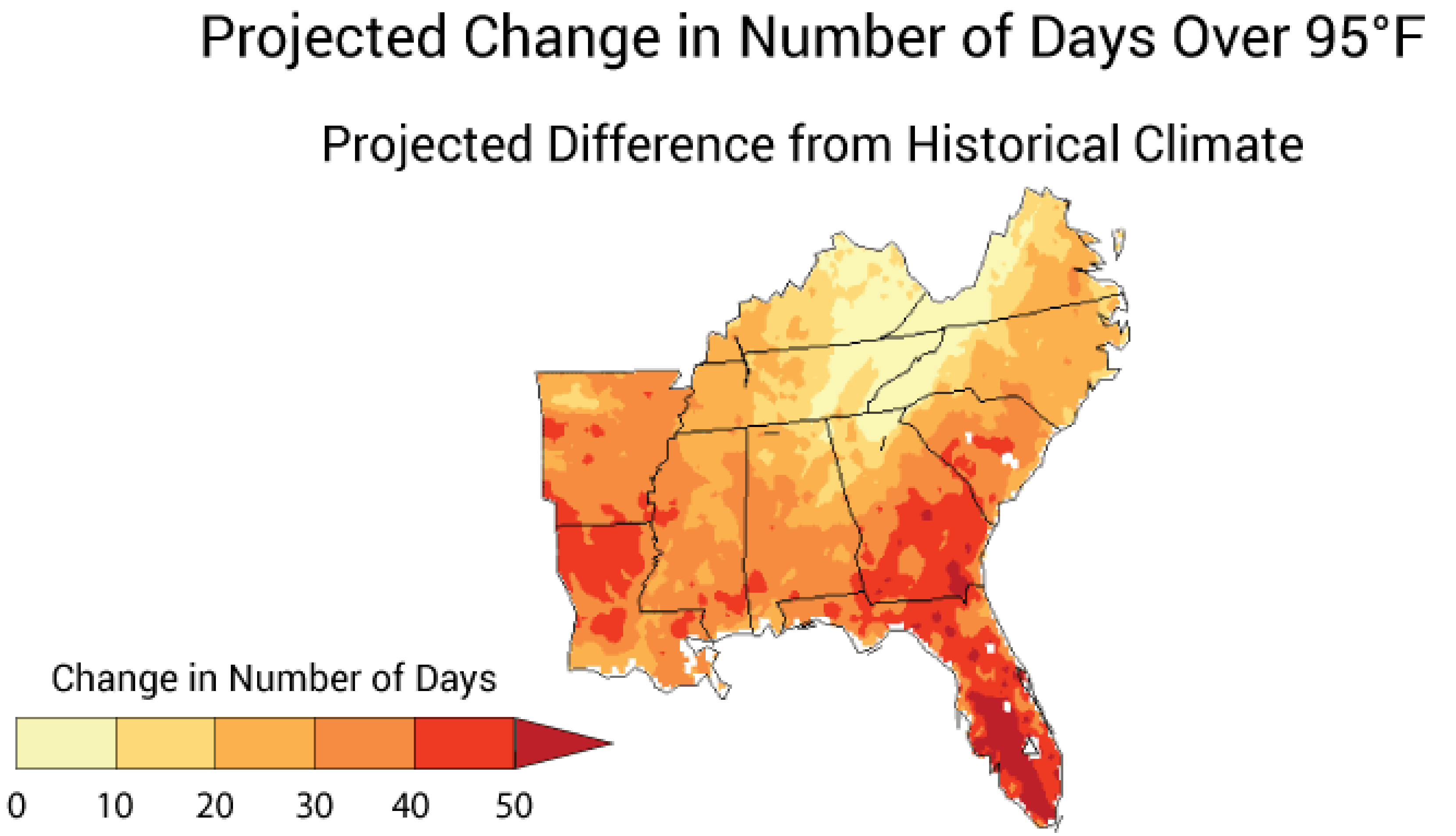
microcystin-LR health advisory concentrations [version 1; referees: 1 approved, 2 approved with reservations]

Jeffrey W. Hollister, Betty J. Kreakie
Environmental Protection Agency, Narragansett, RI, USA



US surface waters

https://archive.epa.gov/emap/archive-emap/web/html/index-43.html



<u>Projection</u>

More very hot days = more blooms

http://apr.org/post/new-climate-report-details-harms-southeast-us#stream/0

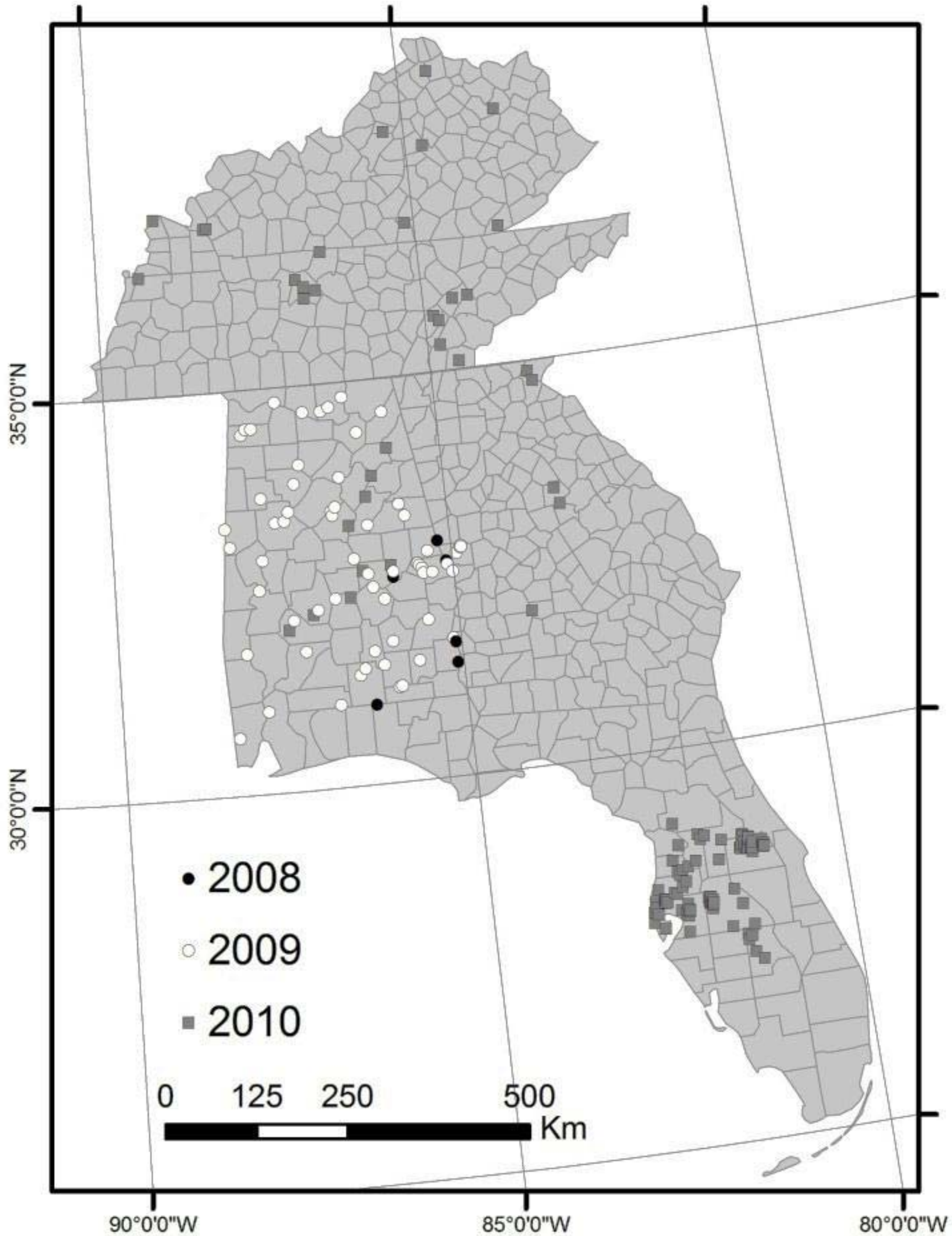
Project goal

- To develop models to help water resource managers forecast blooms of cyanobacteria throughout the southeastern U.S.

Model targets

Target	**Water quality parameters**
phytoplankton *(algal blooms)*	chlorophyll (µg/L) - integrated (filtered)
cyanobacteria *(HABs)*	phycocyanin (µg/L) - integrated (filtered)
toxic cyanobacteria *(toxic HABs)*	microcystin (µg/L), cylindrospermopsin (µg/L), saxitoxin (µg/L) - integrated (filtered) - surface (whole water)

WilsonLab survey



SAMPLING EFFORTS

2008 - WilsonLab

2009 - WilsonLab + ADEM

2010 - many collaborators

Alabama

AL Dept of Environmental Management

Auburn University

Florida

FL Dept of Environmental Protection

Lakeland Lakes and Stormwater Division

Pinellas County Dept of Environ Management

Seminole County Public Works

Seminole County Water Quality Section

SW FL Water Management District

Georgia

Centers for Disease Control

Georgia Power, Southern Company

Georgia Southwestern State Univ

New Echota Rivers Alliance

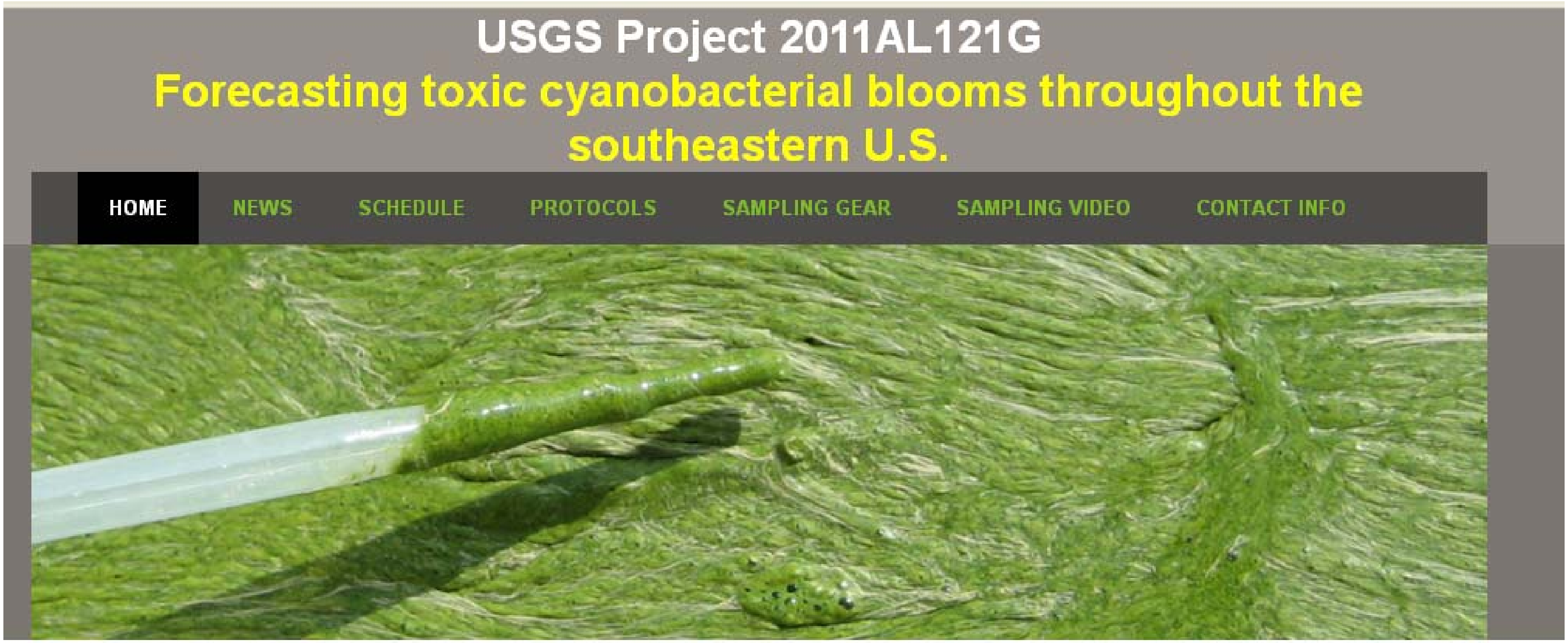
Kentucky

KY Division of Water

Tennessee

TN Dept of Environment and Conservation

TN Division of Water Pollution Control



Project Investigators

Alan Wilson (AU) – project management, sample analyses (toxins, phycocyanin, phytoplankton)

Russell Wright (AU) – outreach, connecting with public

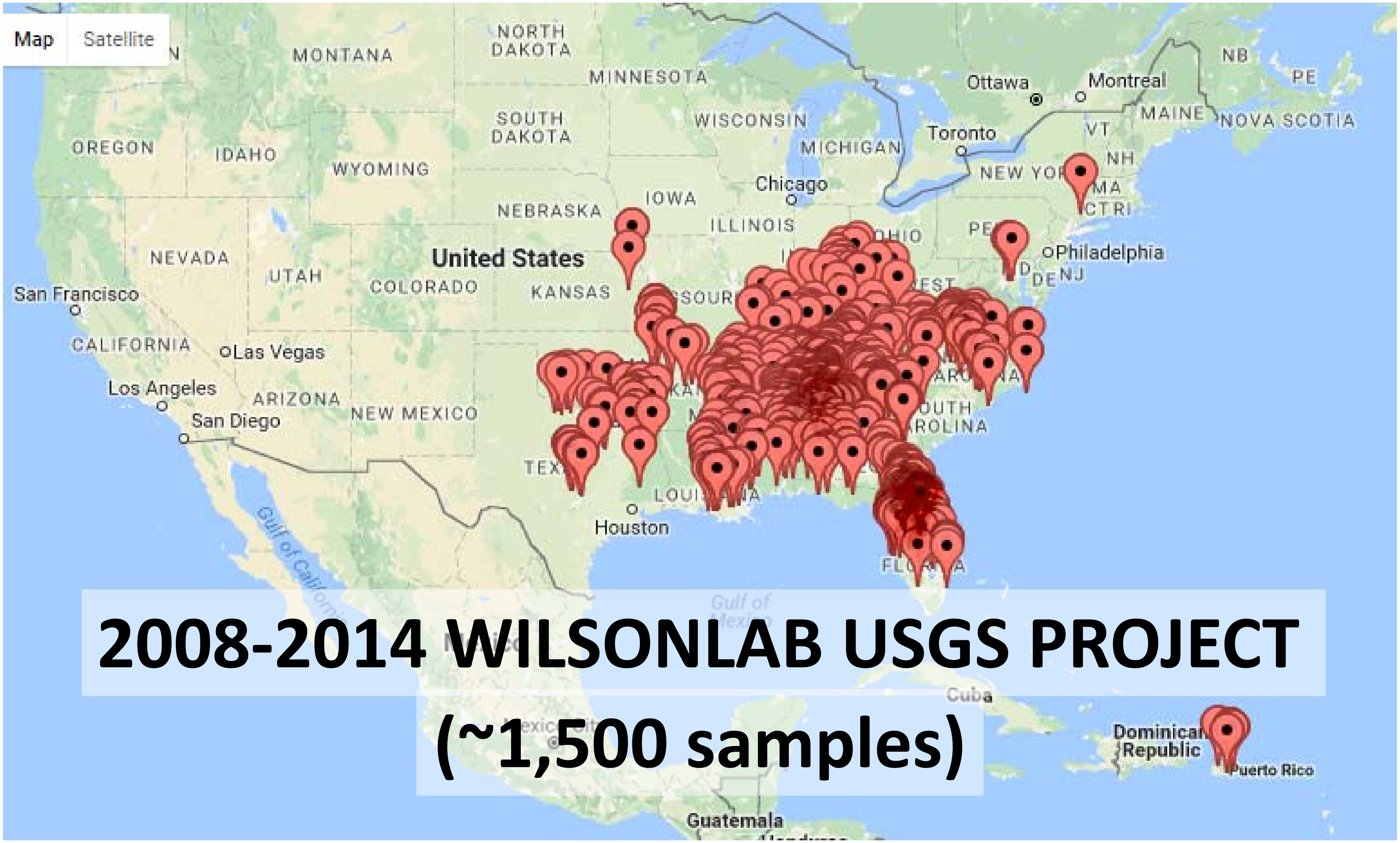
Kevin Schrader (USDA) – off-flavor analyses

Barry Rosen (USGS) – outreach, phytoplankton training workshops

Sampling period – 2012-2014 summers

Project website: http://wilsonlab.com/bloom_network/

2008-2014 WILSONLAB USGS PROJECT (~1,500 samples)

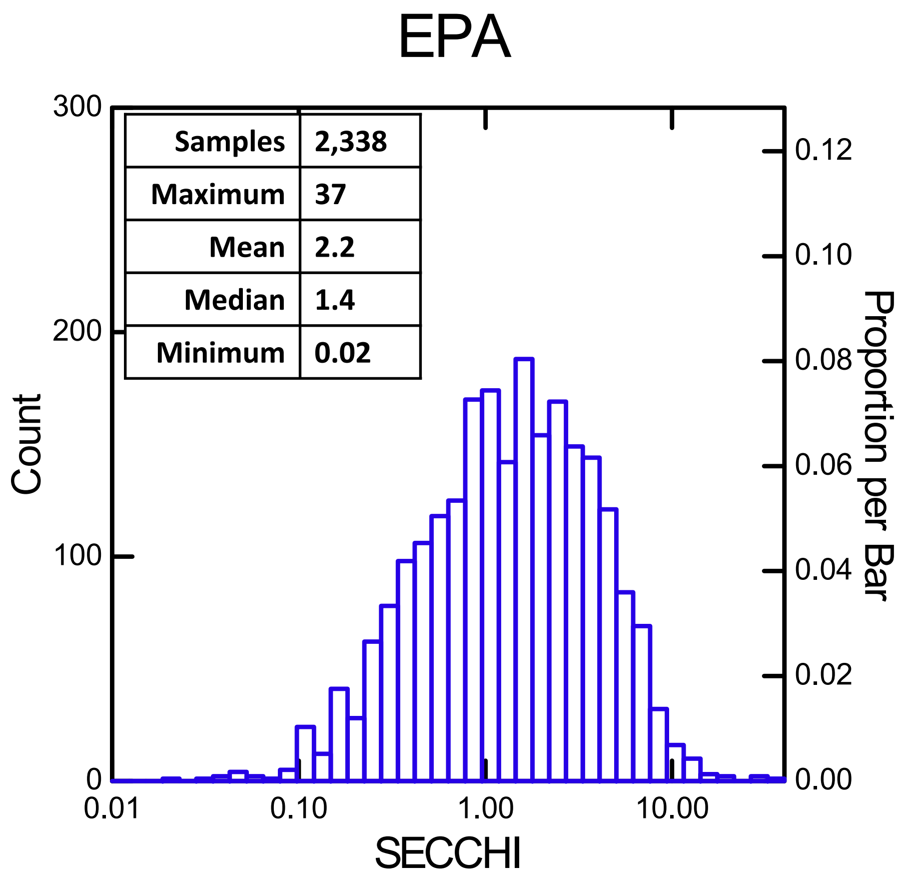


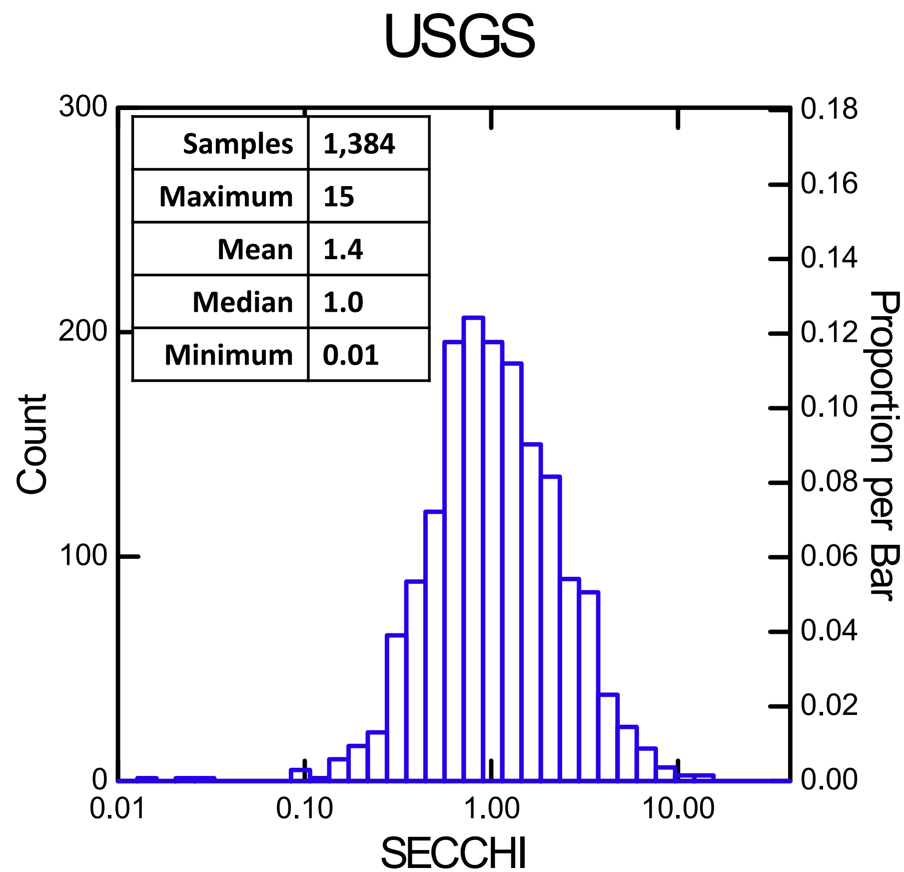
EPA NATIONAL LAKES ASSESSMENTS

(2007 ~1,200 samples)

(2012 ~1,200 samples)

Secchi depth (m)

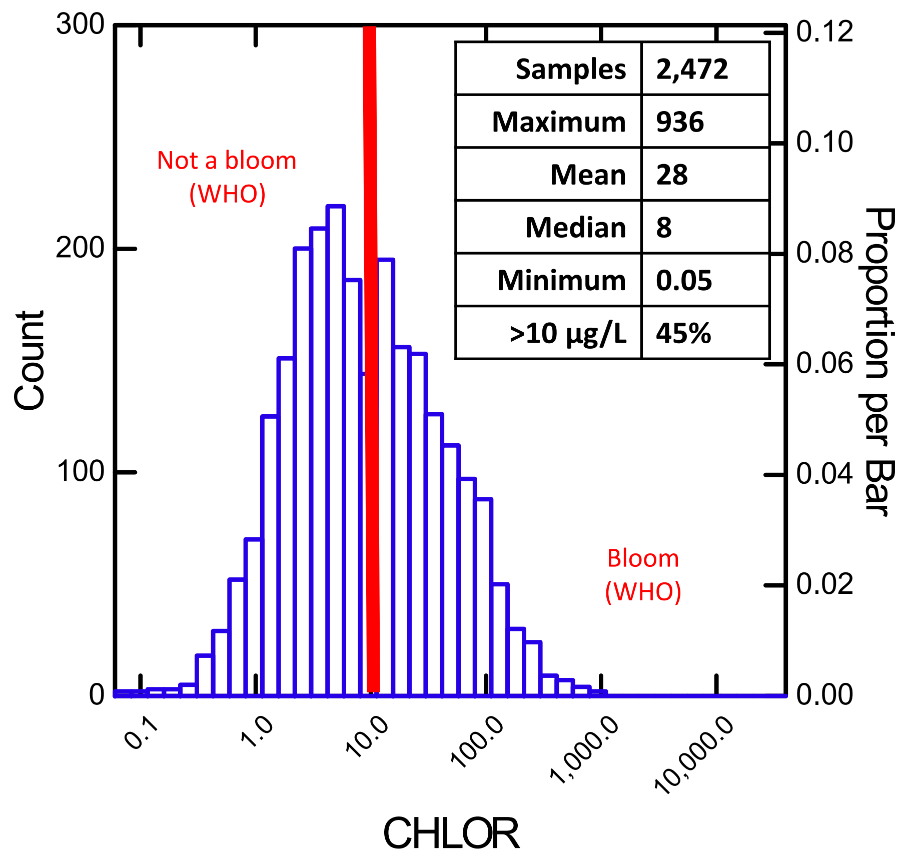




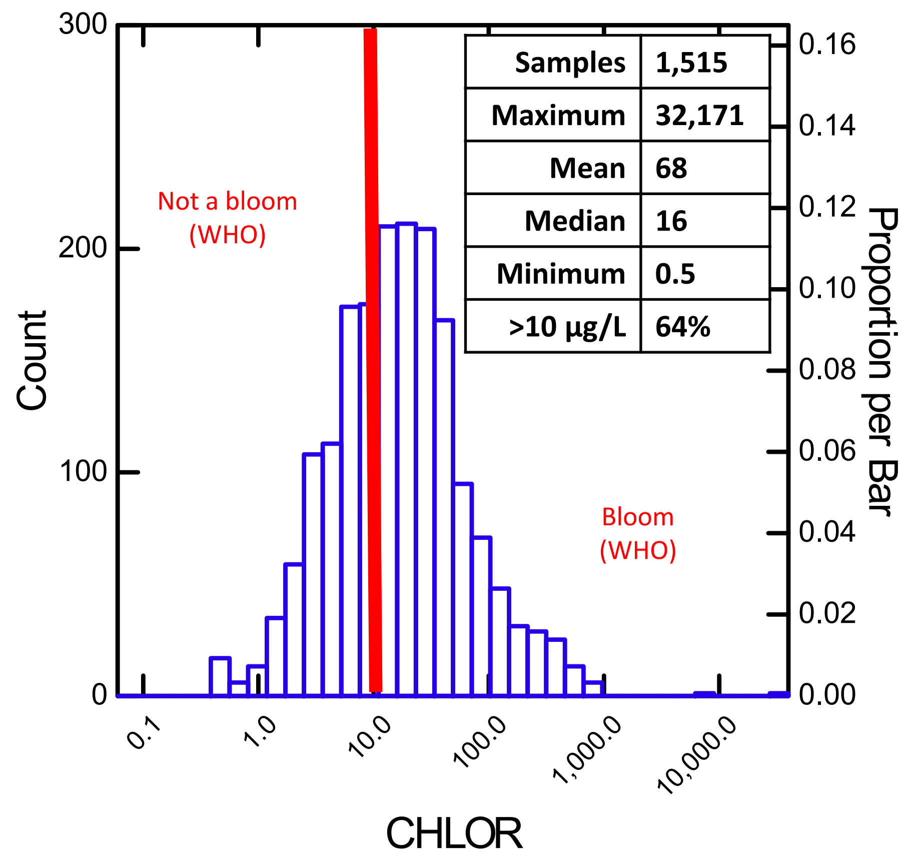
Note log transformed x-axis

Chlorophyll (µg/L)

EPA



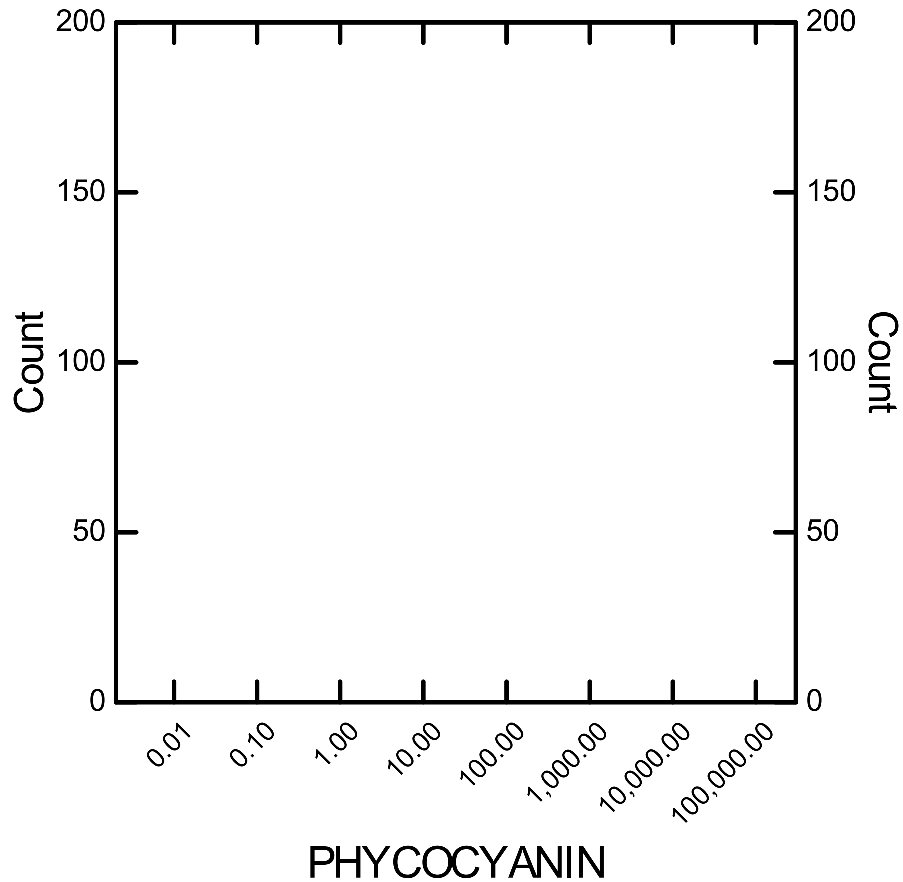
USGS



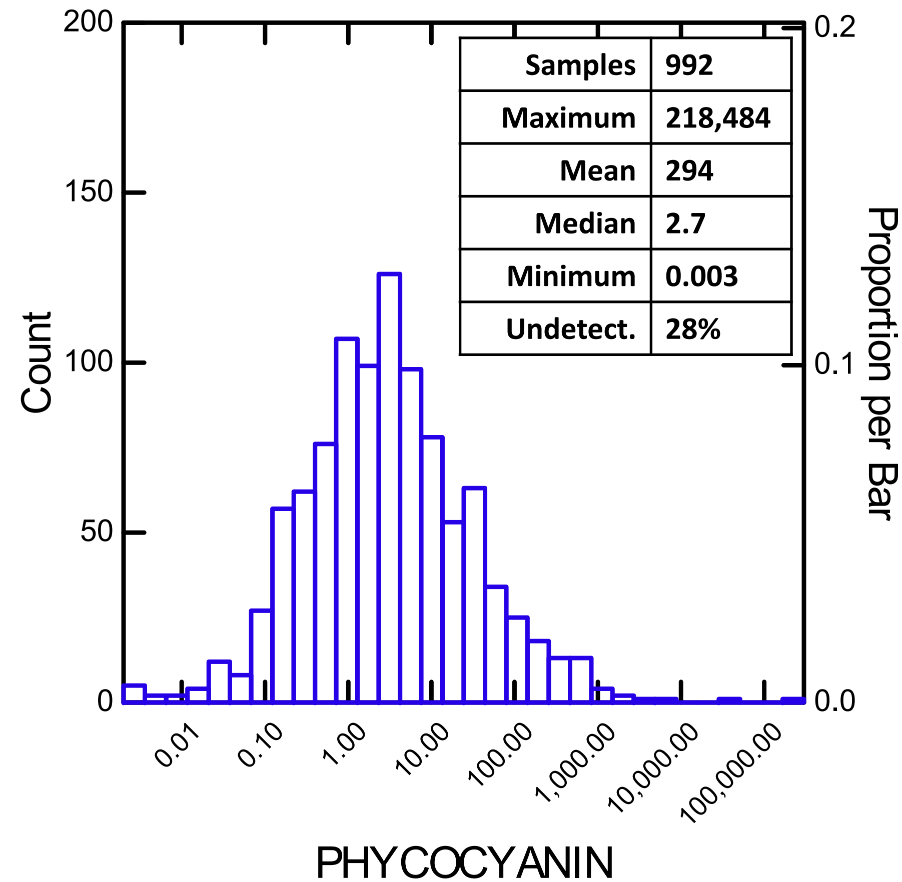
Note log transformed x-axis

Phycocyanin (µg/L)

EPA



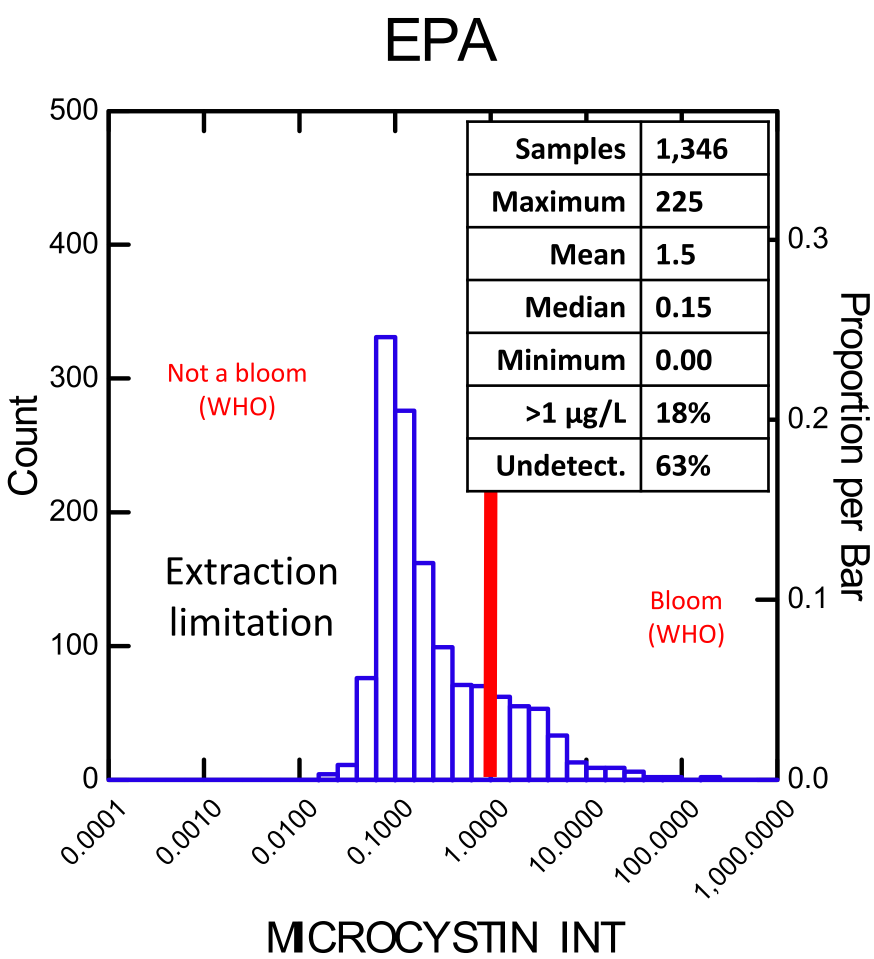
USGS

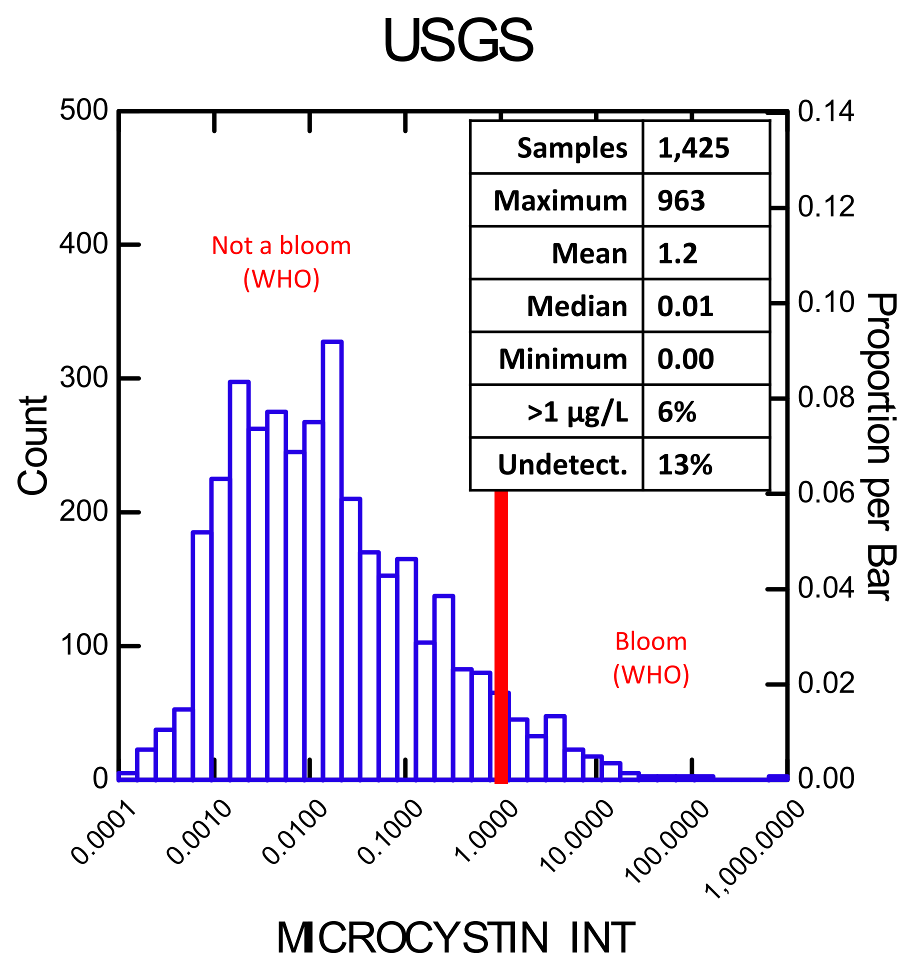


Kasinak et al. 2015 J. Plankton Research

Note log transformed x-axis

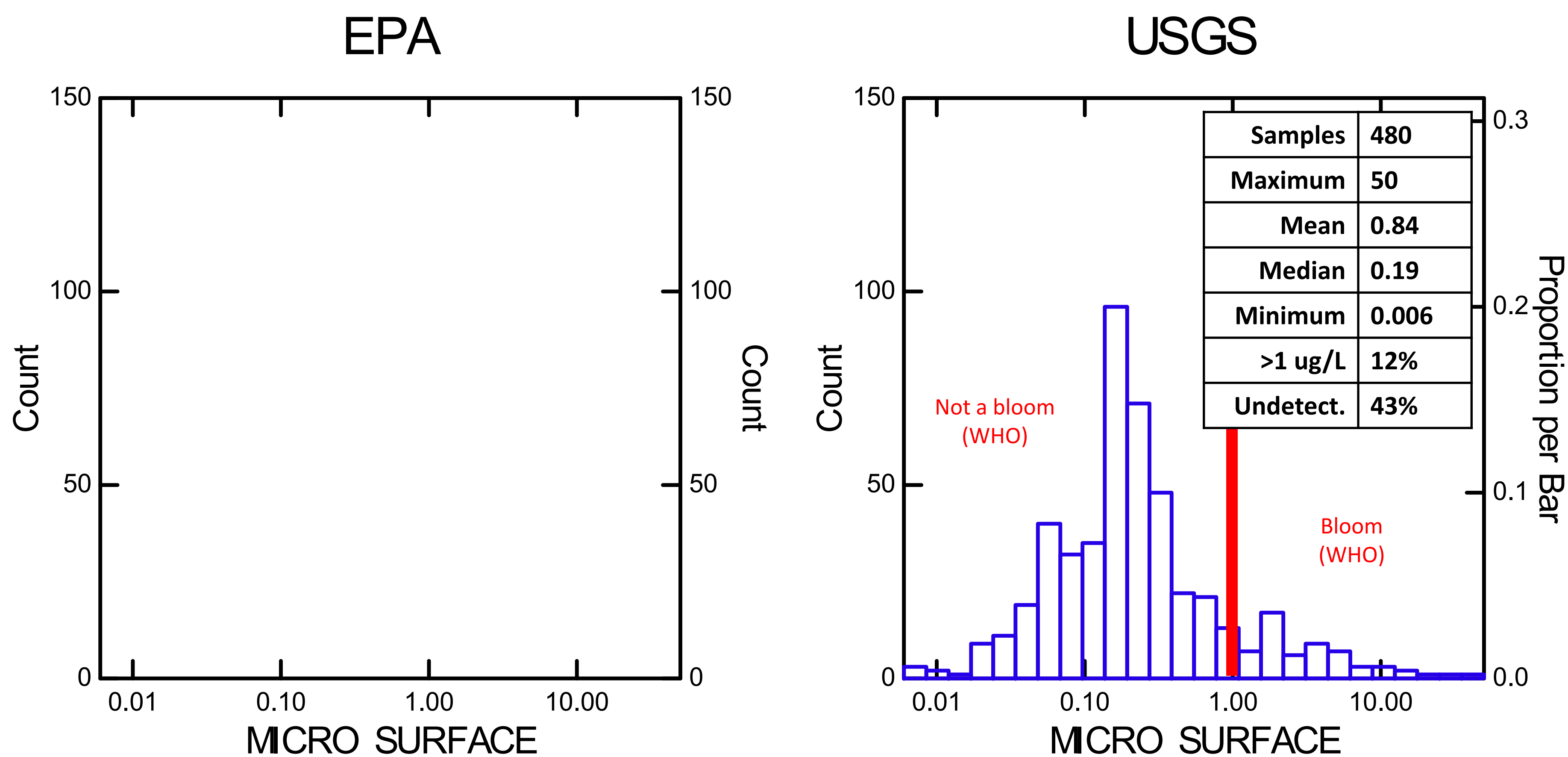
Integrated Microcystin (µg/L)





Note log transformed x-axis
Samples with no detectable microcystin were removed prior to analysis
New EPA advisories: 0.3 ug/L children (0-6 yrs) and 1.6 ug/L (>6 yrs)

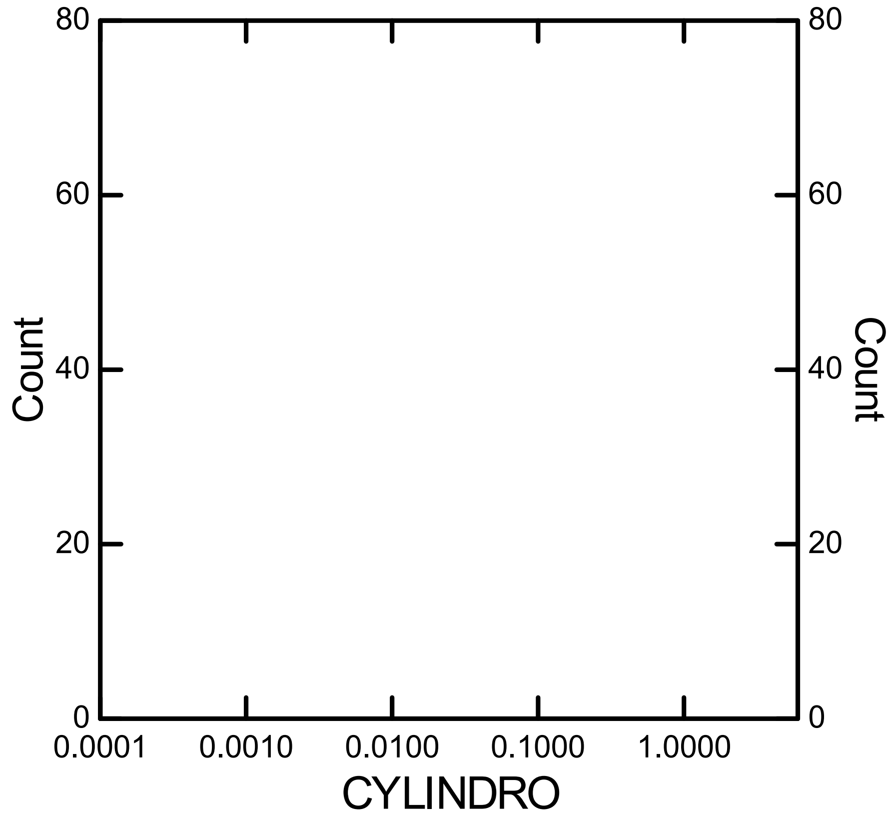
Surface Microcystin (µg/L)



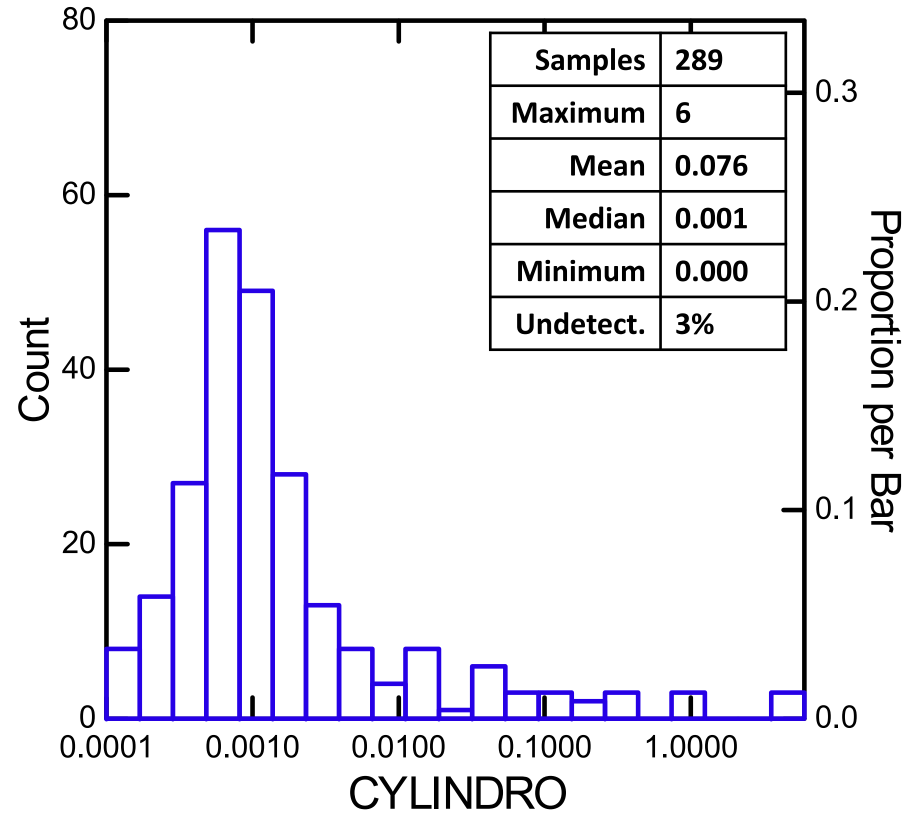
Note log transformed x-axis
Samples with no detectable microcystin were removed prior to analysis
New EPA advisories: 0.3 ug/L children (0-6 yrs) and 1.6 ug/L (>6 yrs)

Integrated Cylindrospermopsin (µg/L)

EPA



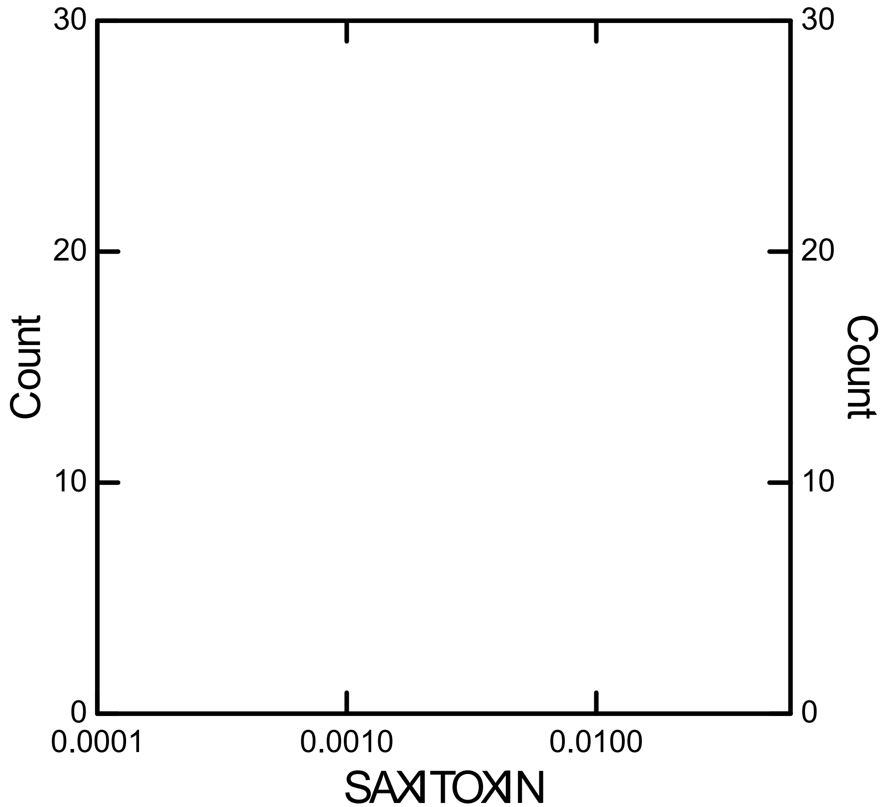
USGS



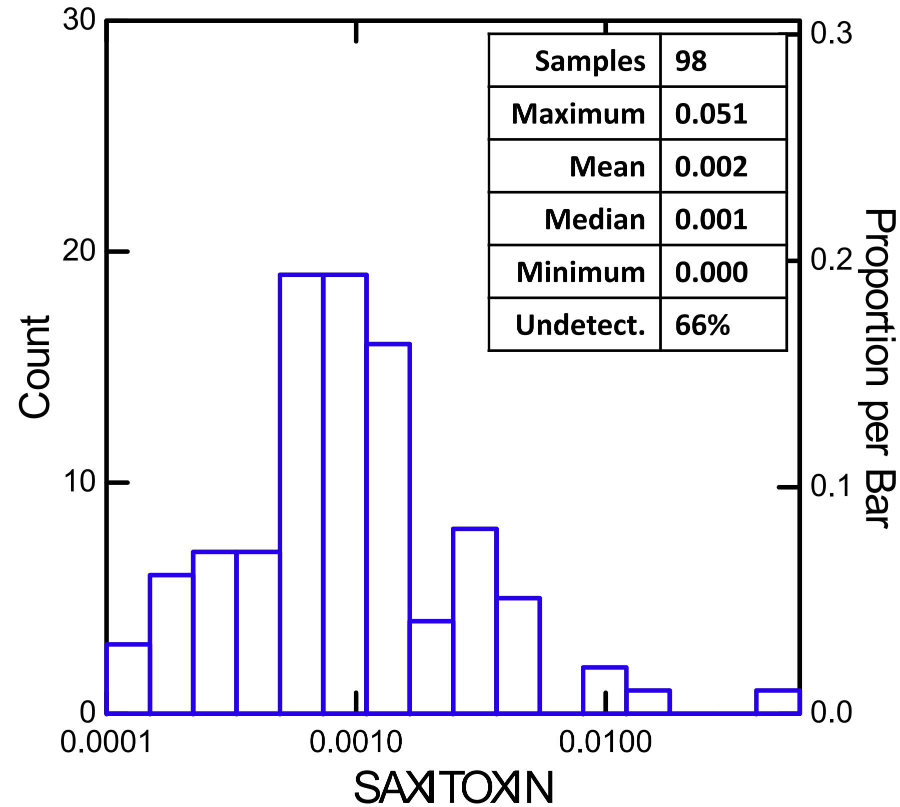
Note log transformed x-axis
Samples with no detectable microcystin were removed prior to analysis
Focused on highest ~100 integrated microcystin samples
New EPA advisories: 0.7 ug/L children (0-6 yrs) and 3 ug/L (>6 yrs)

Integrated Saxitoxin (µg/L)

EPA

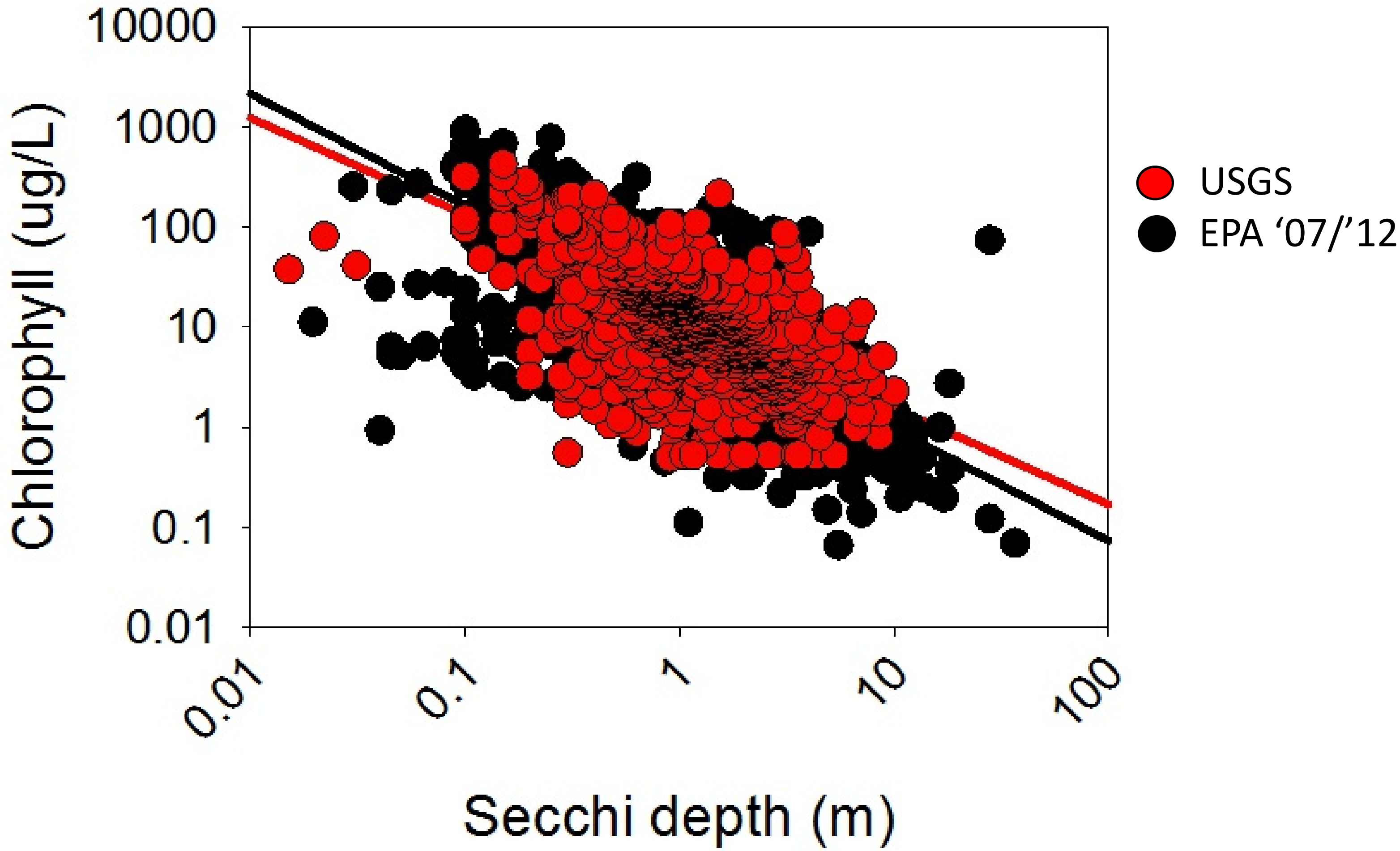


USGS



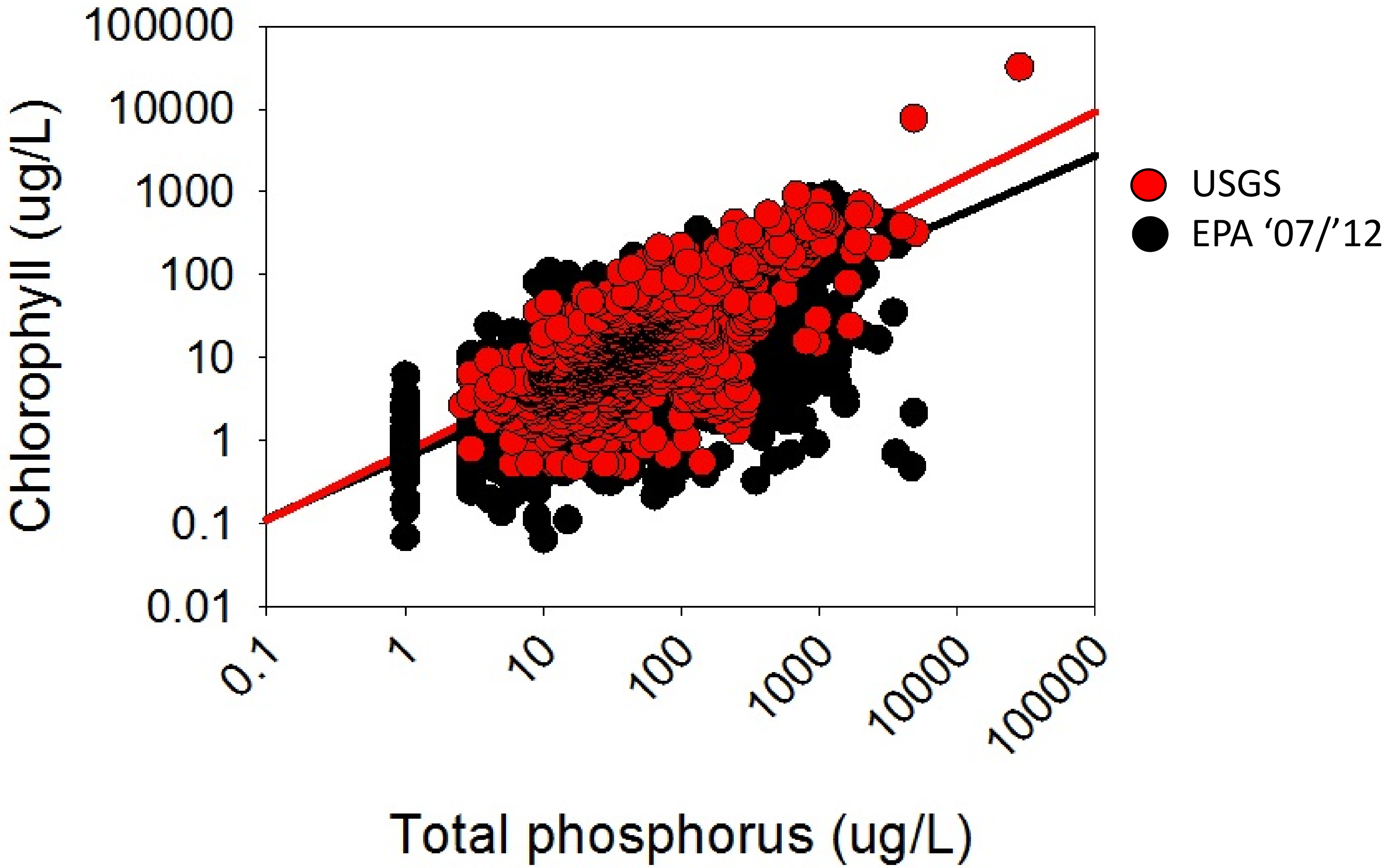
Note log transformed x-axis
Samples with no detectable microcystin were removed prior to analysis
Focused on highest ~100 integrated microcystin samples
No current threshold guidelines

Secchi depth (m) vs. Chlorophyll (µg/L)



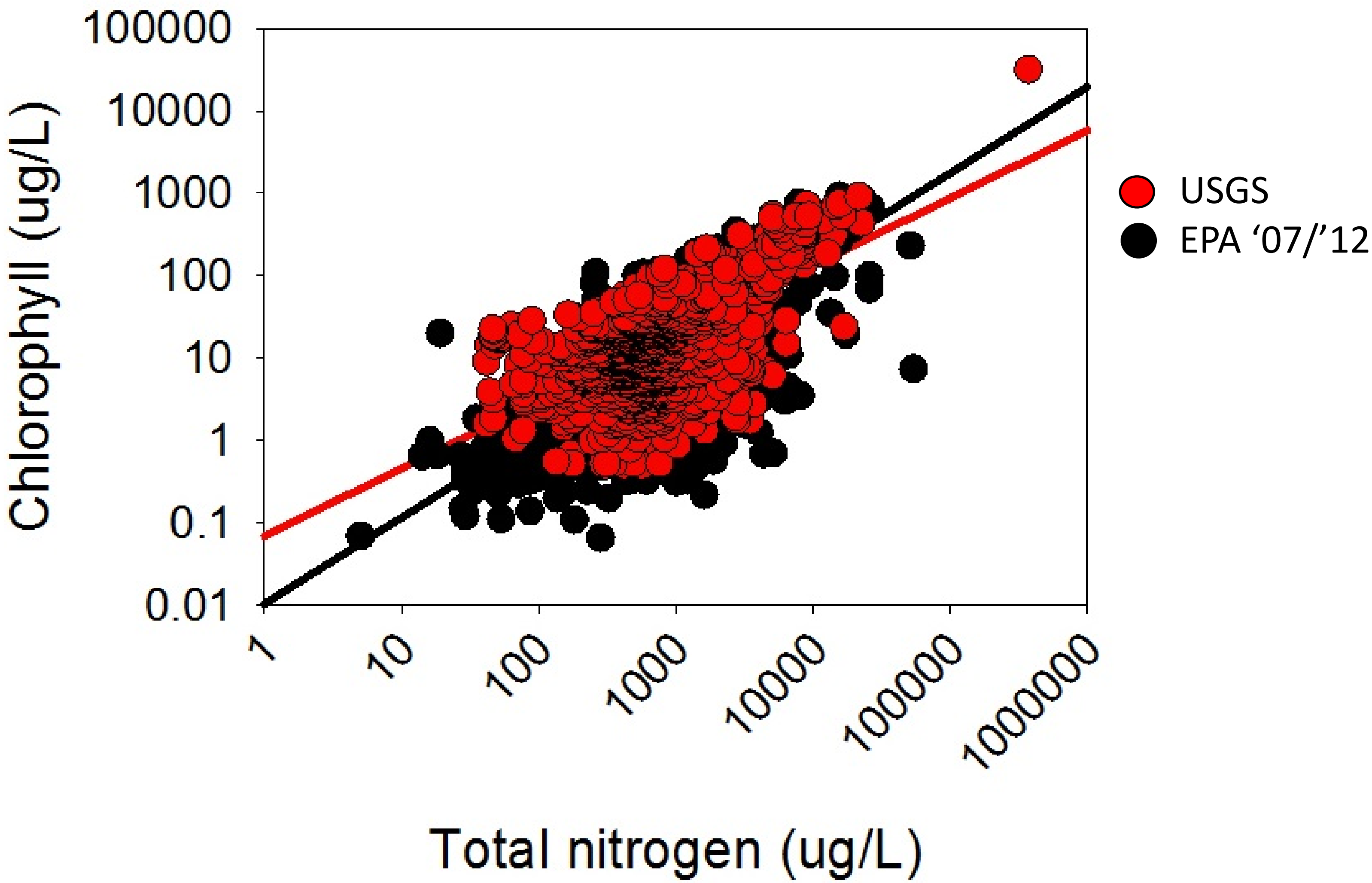
Note log transformed axes

Total phosphorus (µg/L) vs. Chlorophyll (µg/L)



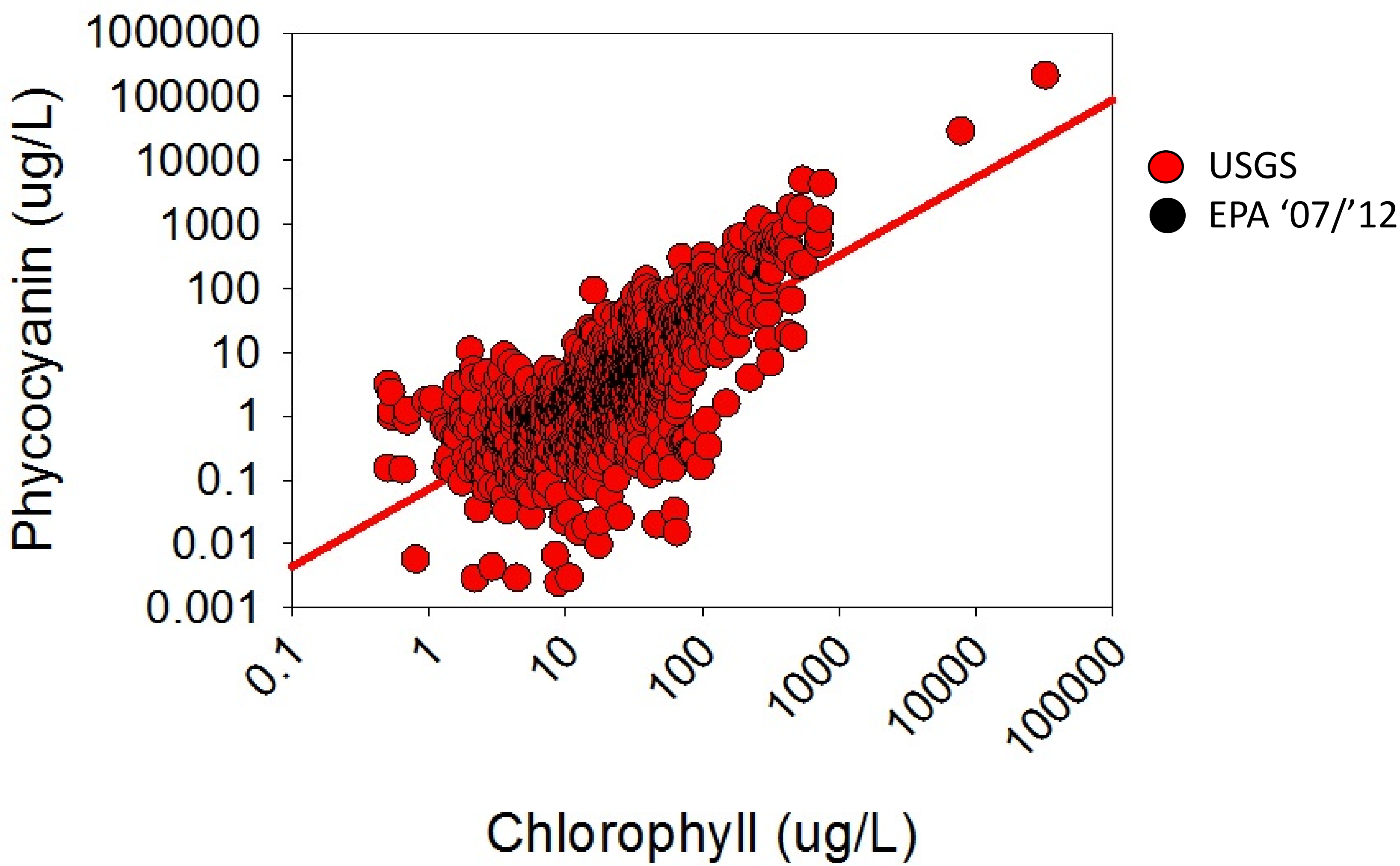
Note log transformed axes

Total Nitrogen (µg/L) vs. Chlorophyll (µg/L)



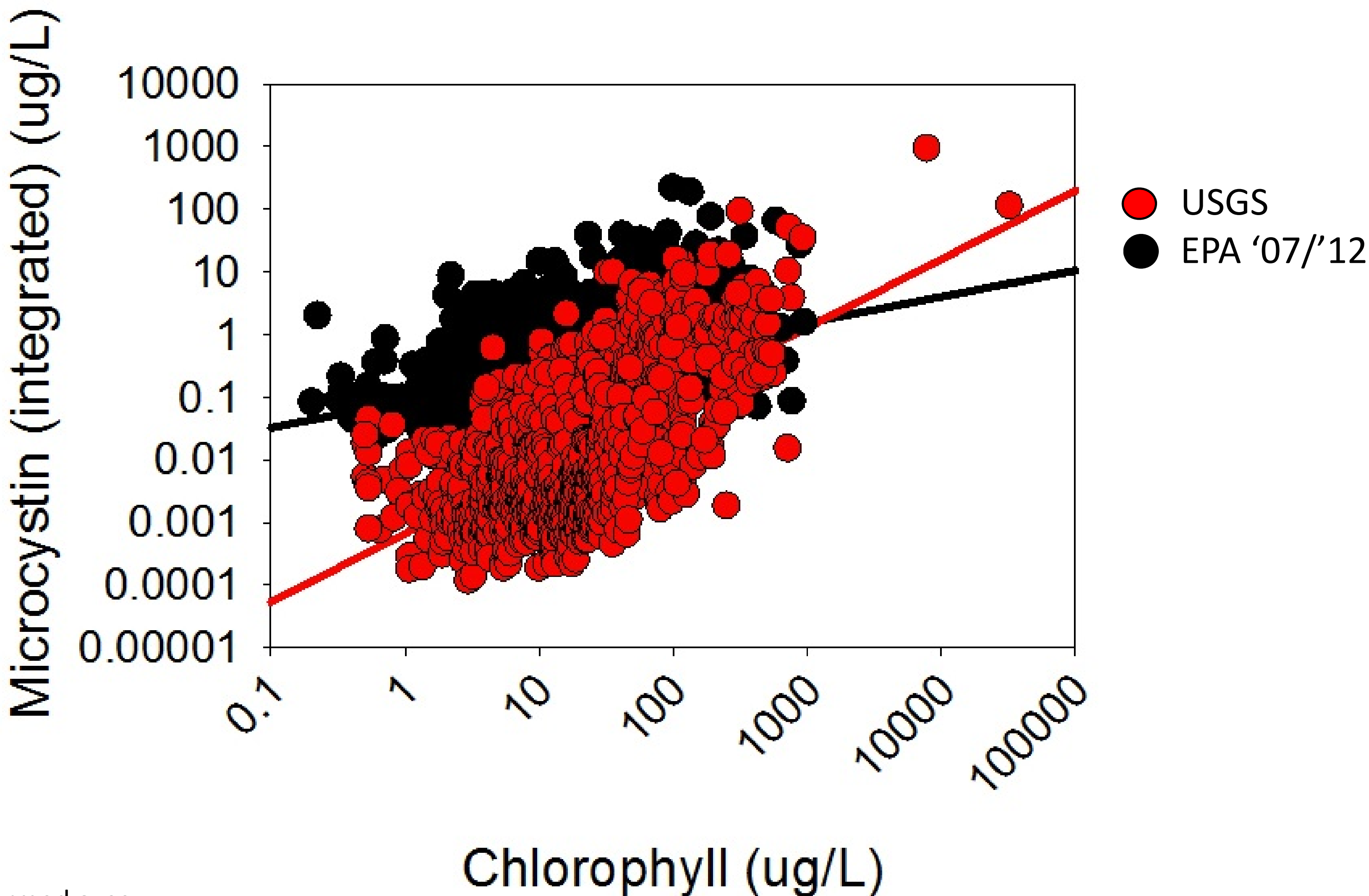
Note log transformed axes

Chlorophyll (µg/L) vs. Phycocyanin (µg/L)



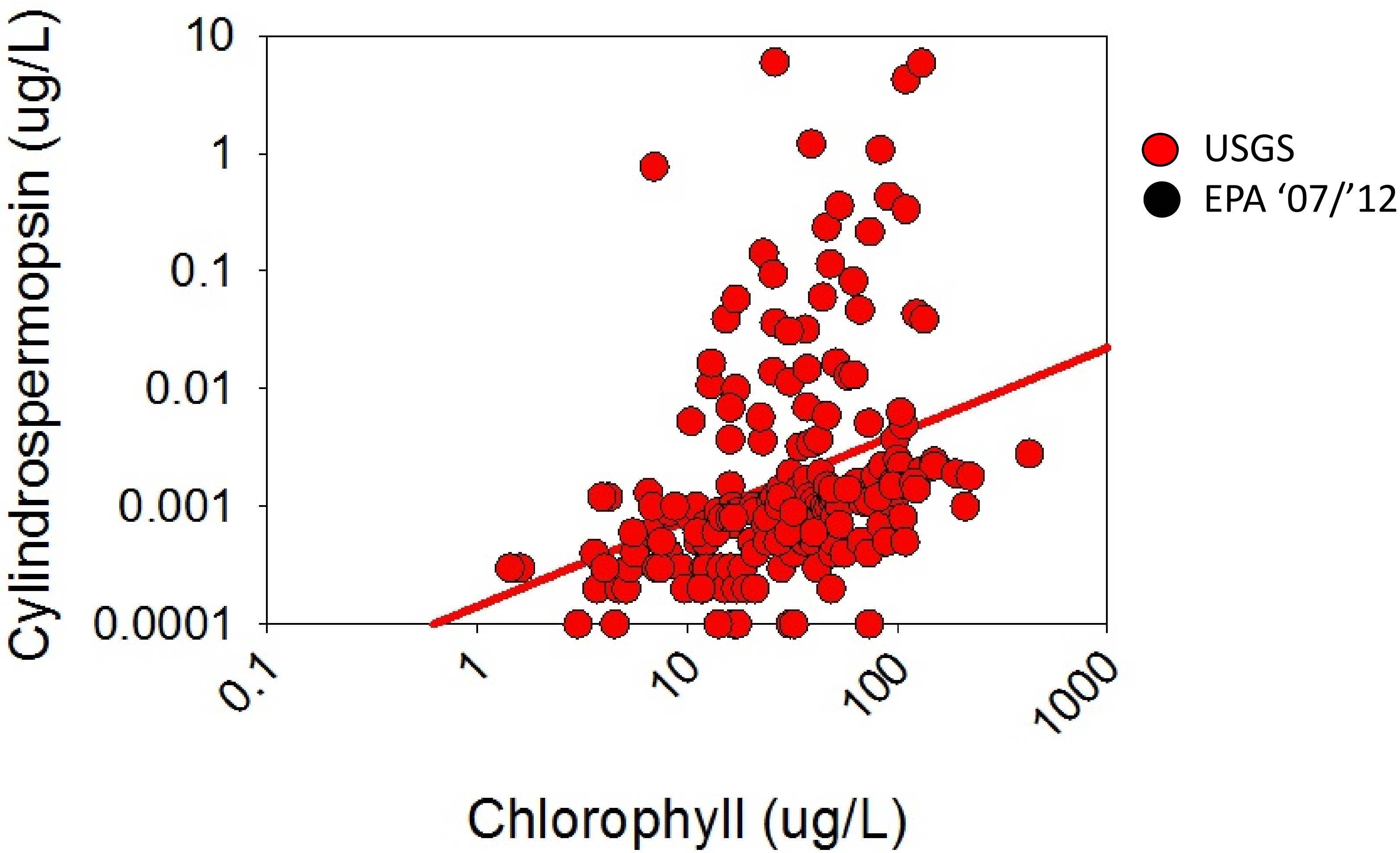
Note log transformed axes

Chlorophyll (µg/L) vs. Integrated Microcystin (µg/L)



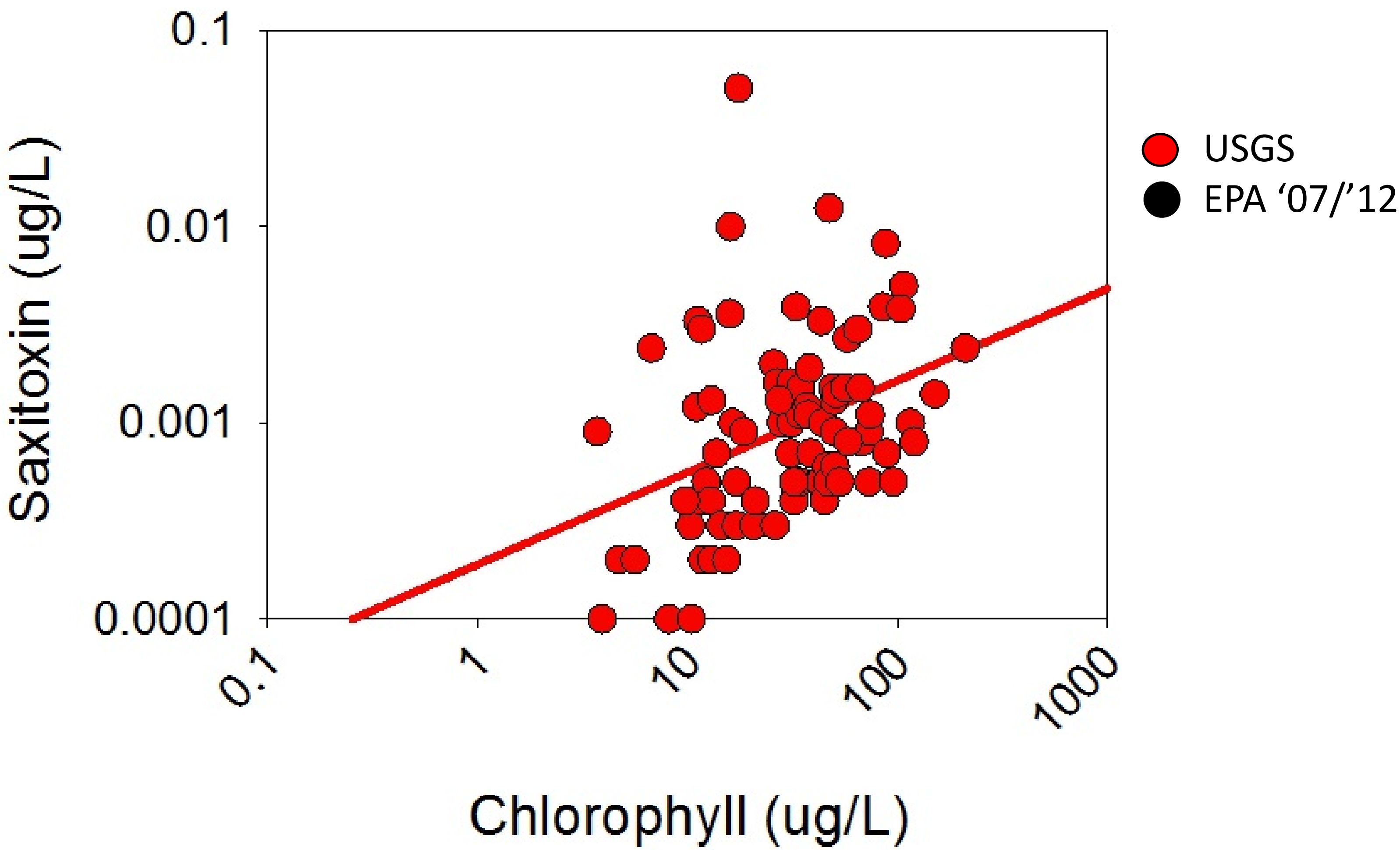
Note log transformed axes

Chlorophyll (µg/L) vs. Integrated Cylindrospermopsin (µg/L)



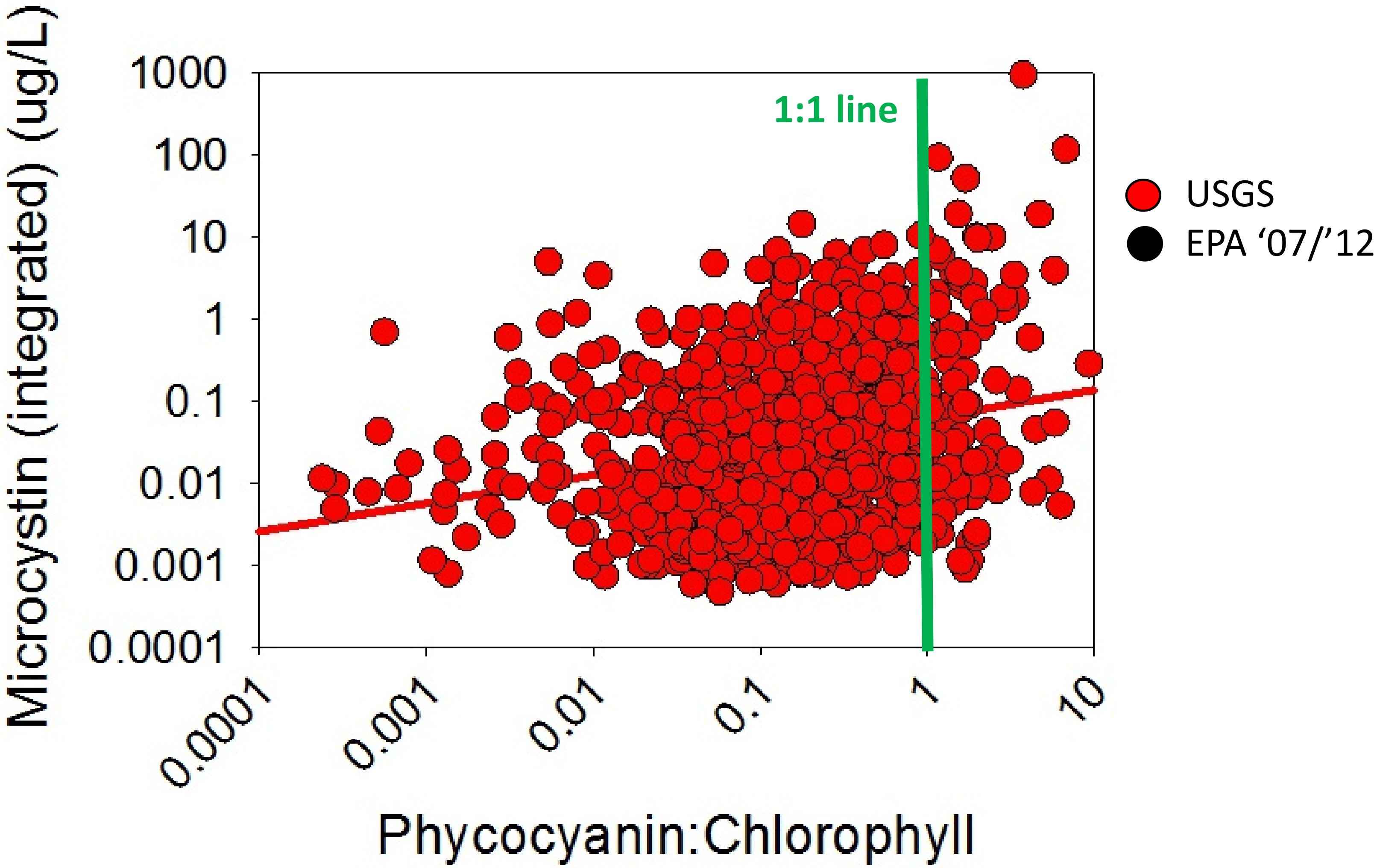
Note log transformed axes

Chlorophyll (µg/L) vs. Integrated Saxitoxin (µg/L)



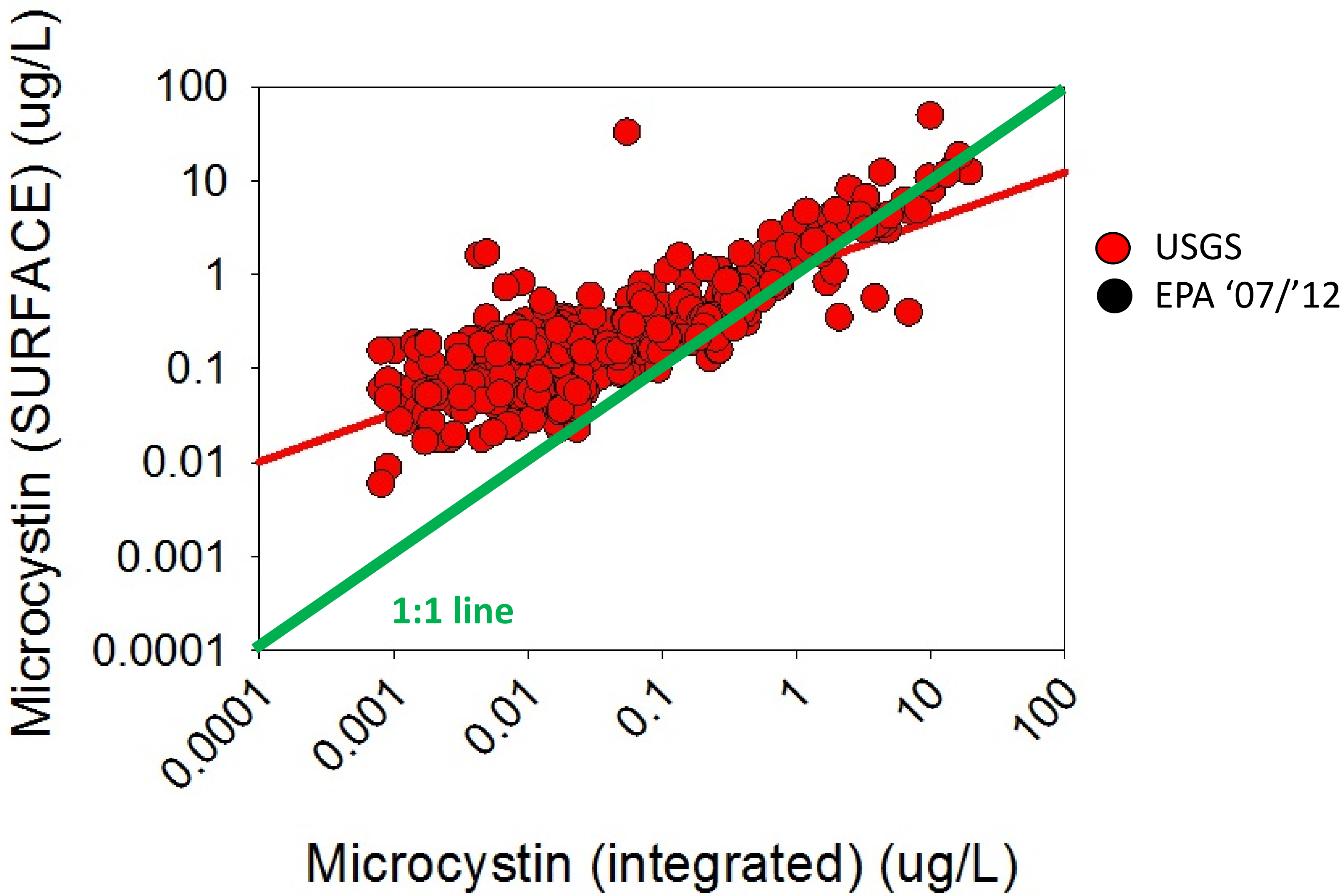
Note log transformed axes

Phycocyanin:Chlorophyll vs. Integrated Microcystin (µg/L)



Note log transformed axes

Integrated Microcystin (µg/L) vs. Surface Microcystin (µg/L)



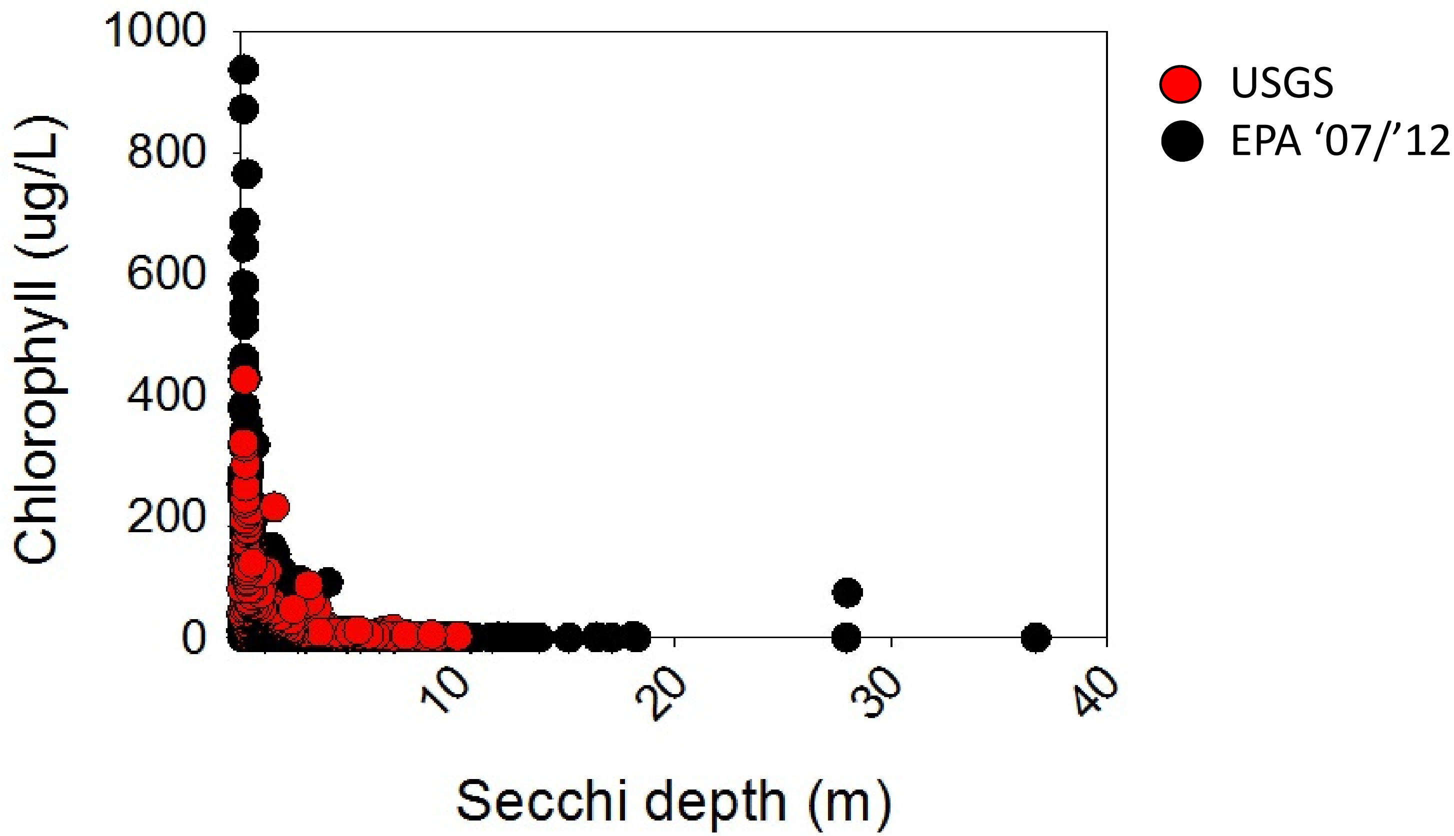
Note log transformed axes

Model targets

Target	**Water quality parameters**
phytoplankton *(algal blooms)*	chlorophyll (µg/L) - integrated (filtered)
cyanobacteria *(HABs)*	phycocyanin (µg/L) - integrated (filtered)
toxic cyanobacteria *(toxic HABs)*	microcystin (µg/L), cylindropsermopsin (µg/L), saxitoxin (µg/L) - integrated (filtered) - surface (whole water)

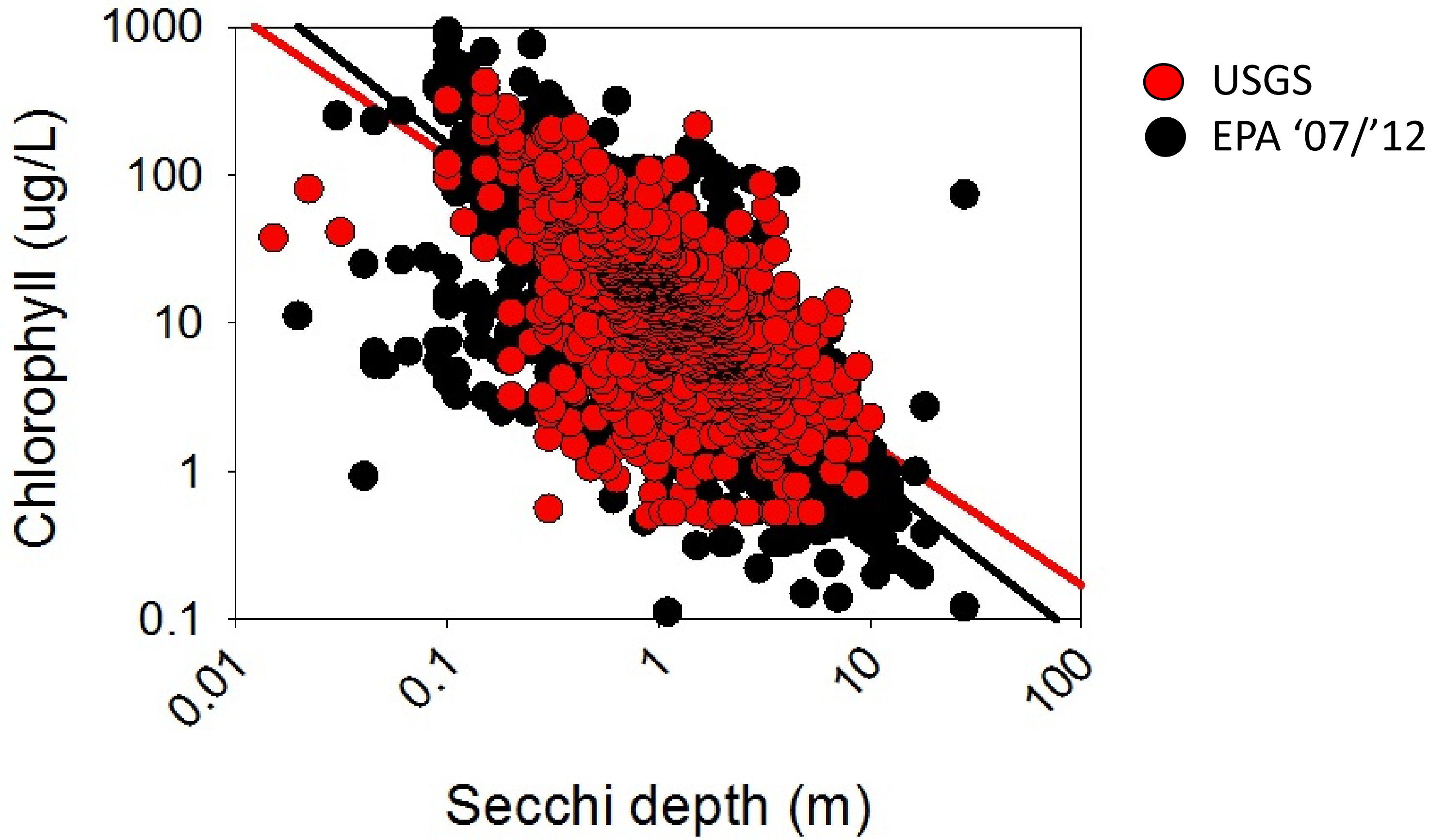
Modelling approaches

1. Linear regression



Modelling approaches

1. Linear regression w/ log transformed data



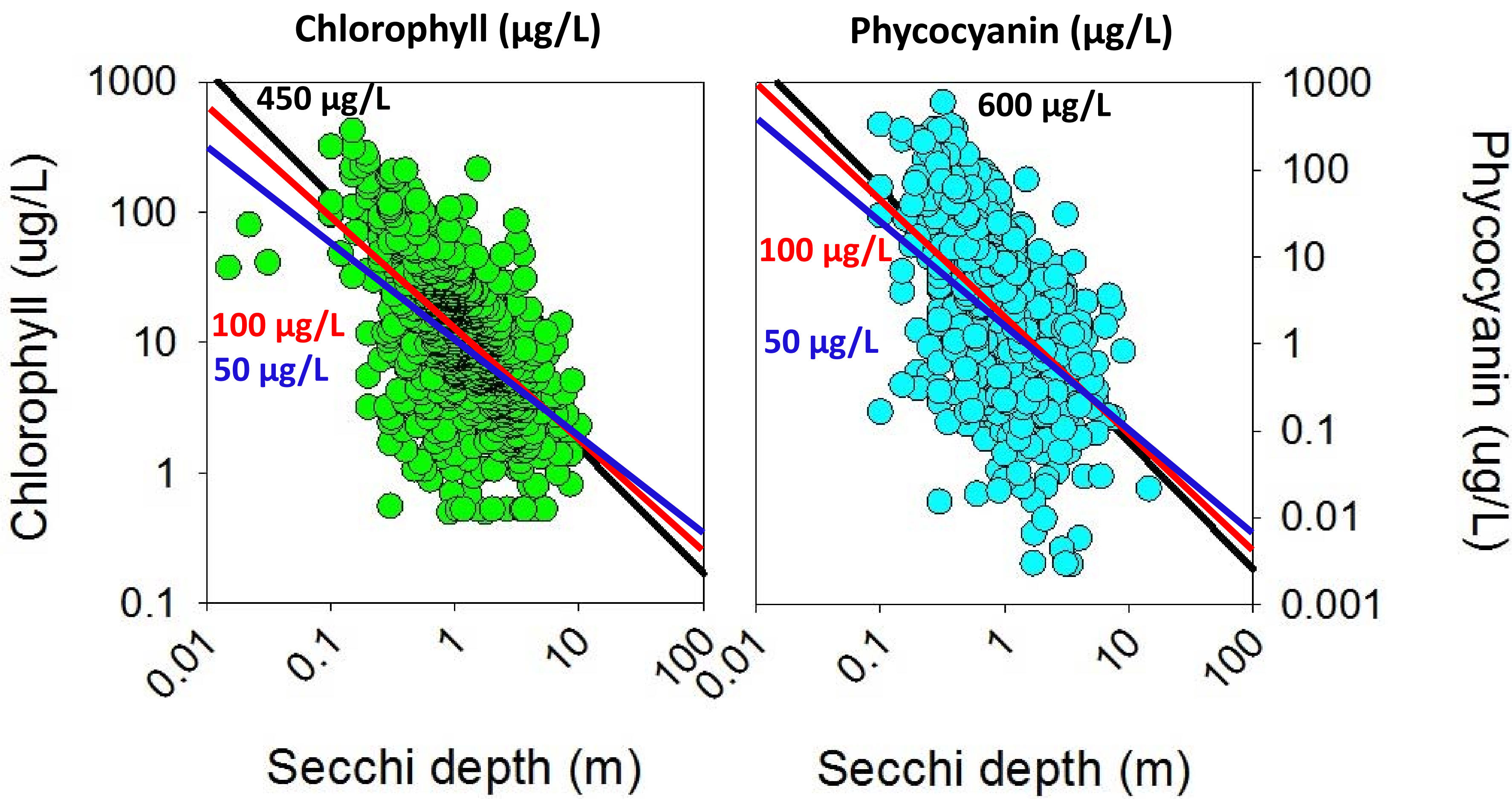
Note log transformed axes

Linear regression w/ Secchi only

- Parameter used: Secchi
- General equation: Y = ((slope)*X) + y-intercept
  - Log(target) = (log(Secchi slope)*log(Secchi depth)) + log(y-intercept)

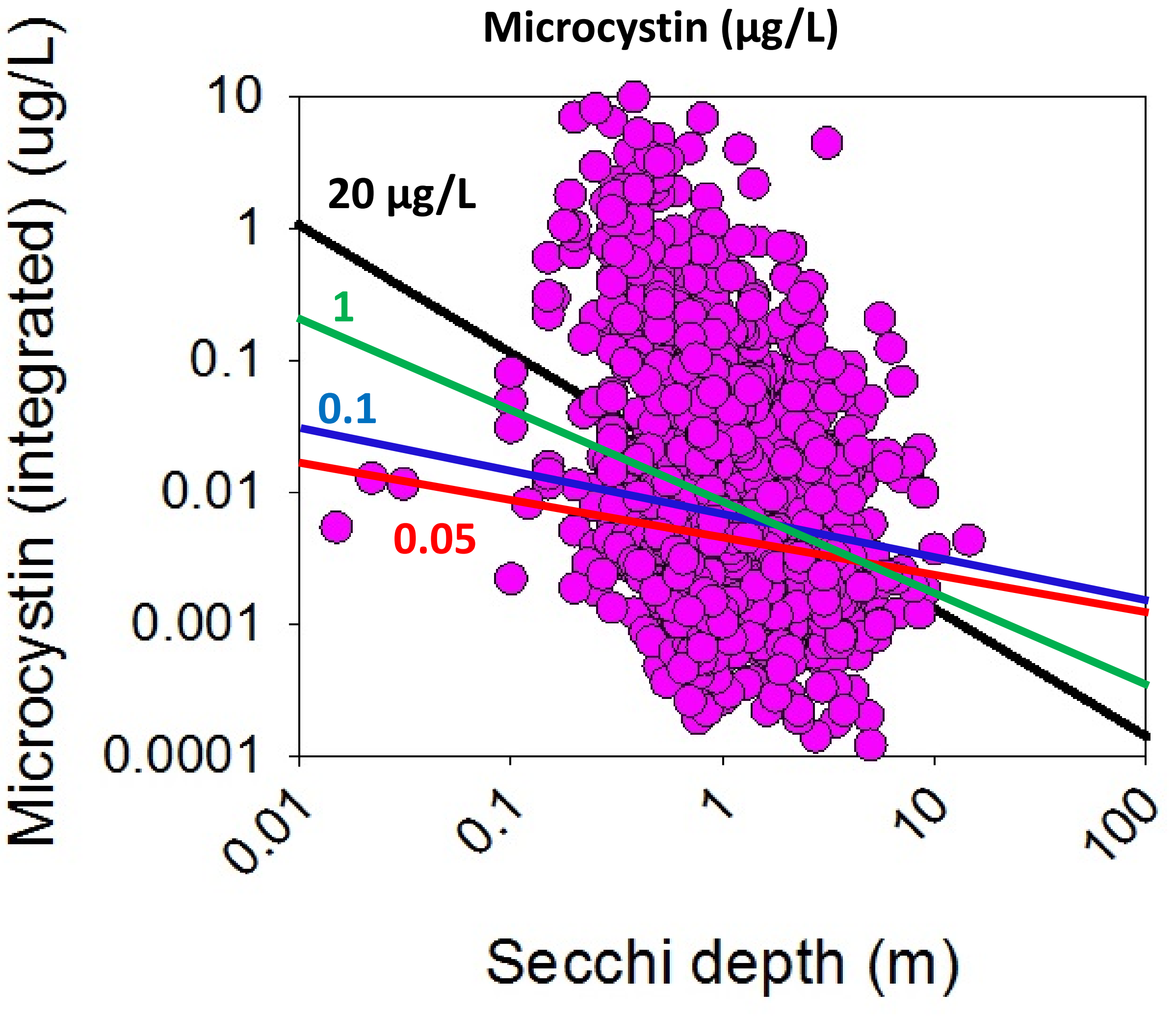
Model Variables	Chlorophyll (µg/L)	Phycocyanin (µg/L)	Microcystin (µg/L)	Cylindrospermopsin (µg/L)
Secchi (m) slope	-0.964	-1.462	-0.970	-0.747
Y-intercept	2.668	0.770	-4.409	-6.602
Sample size	*1,267*	*774*	*1,125*	*173*
NOTE THAT ALL PARAMETERS ARE LOG-TRANSFORMED				

Linear regression w/ Secchi only for different target thresholds



Note log transformed axes

Linear regression w/ Secchi only for different target thresholds



Multiple linear regression

- Backward stepwise regression analysis
- Keep significant parameters ($p < 0.05$)
- Parameters used: Chlorophyll, Secchi, TP, and TN
- Equation: $Y = ((slope_a)*X_a) + ((slope_b)*X_b) + \ldots + \text{y-intercept}$

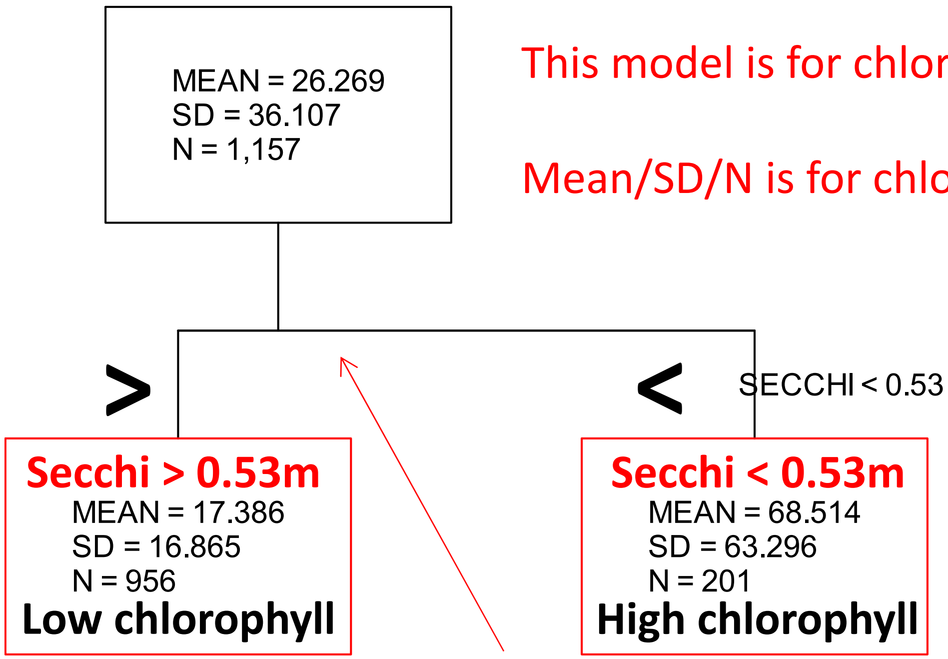
Model Variables	Chlorophyll (µg/L)	Phycocyanin (µg/L)	Microcystin (µg/L)	Cylindrospermopsin (µg/L)
Chlorophyll (µg/L) slope	Not used	0.792	0.791	0.732
Total phosphorus (µg/L) slope	0.335	-----	-0.306	-----
Total nitrogen (µg/L) slope	0.272	0.225	1.020	-----
Secchi (m) slope	-0.513	-0.480	-----	-----
Y-intercept	-0.326	-3.001	-12.191	-8.860
Sample size	*1,157*	*651*	*1,120*	*202*
NOTE THAT ALL PARAMETERS ARE LOG-TRANSFORMED				

Modelling approaches

1. Linear regression
2. Categorical and Regression Tree (CART) analysis
   - Aims to find the best way to split the data into two groups that minimizes variation within each group but maximizes variation between the groups
   - Each independent variable is tested against the target response variable
   - Results are sensitive to forced minimum terminal node size
   - Linearity is not required, thus transformations are not needed
   - Excellent tool for developing nutrient criteria for lakes

Modelling approaches

1. Linear regression
2. Categorical and Regression Tree (CART) analysis



This model is for chlorophyll (µg/L)

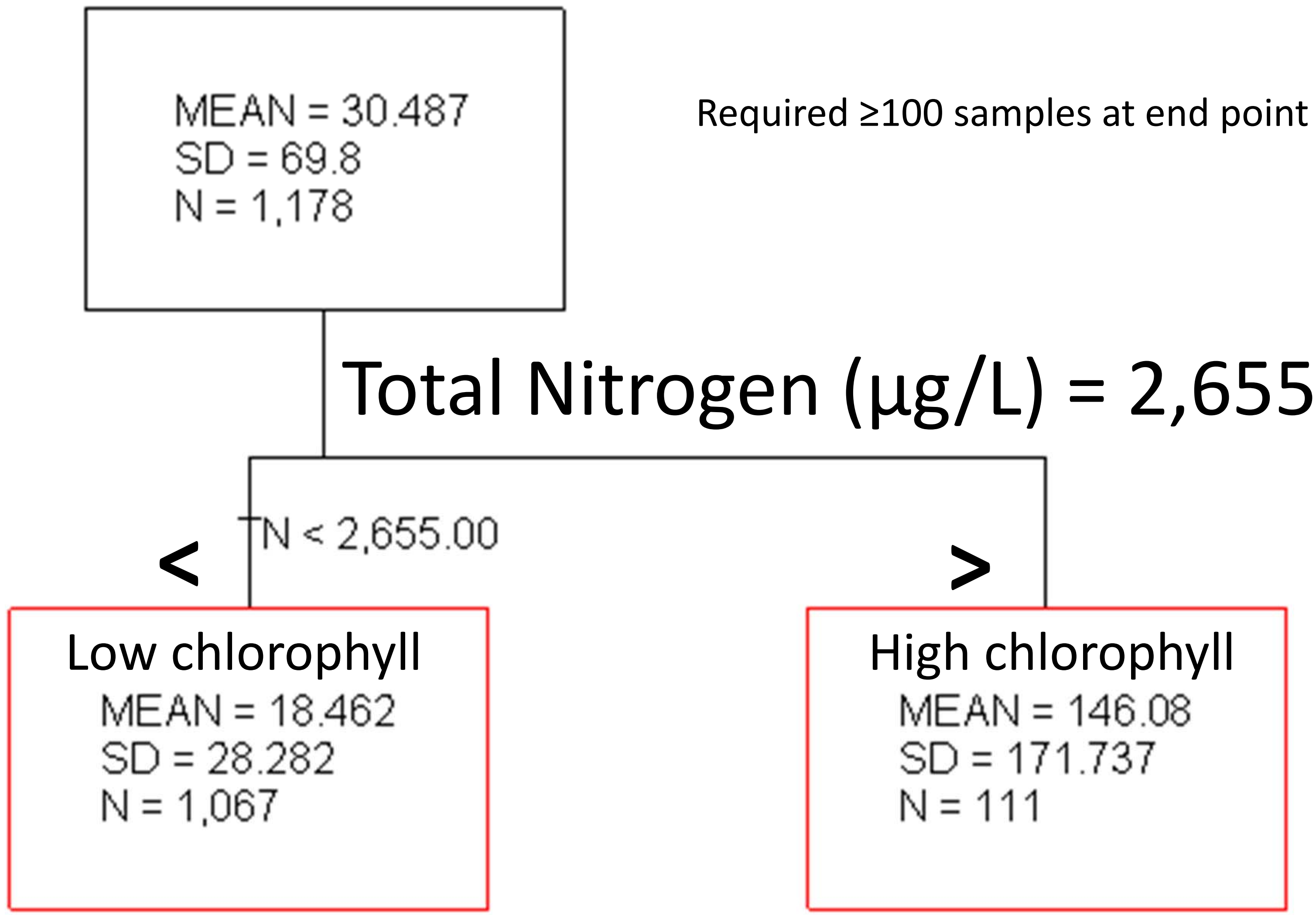
Mean/SD/N is for chlorophyll (µg/L)

Separations closer to top are more important than later divisions

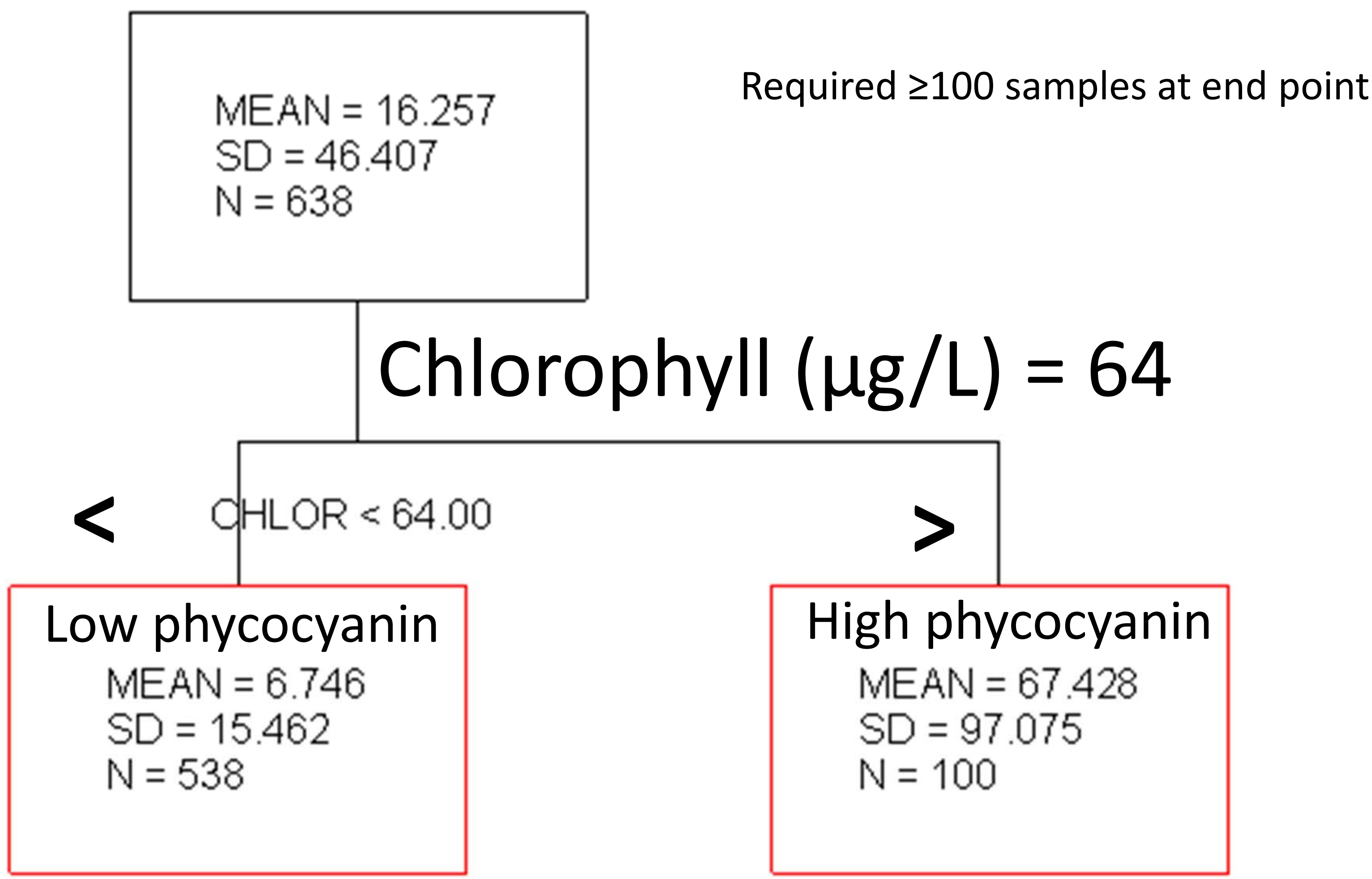
Separation at node relates to Secchi depth with break at 0.53m

So, deeper Secchi (>0.53m) is related to lower chlorophyll (µg/L)

CART for Chlorophyll (µg/L)

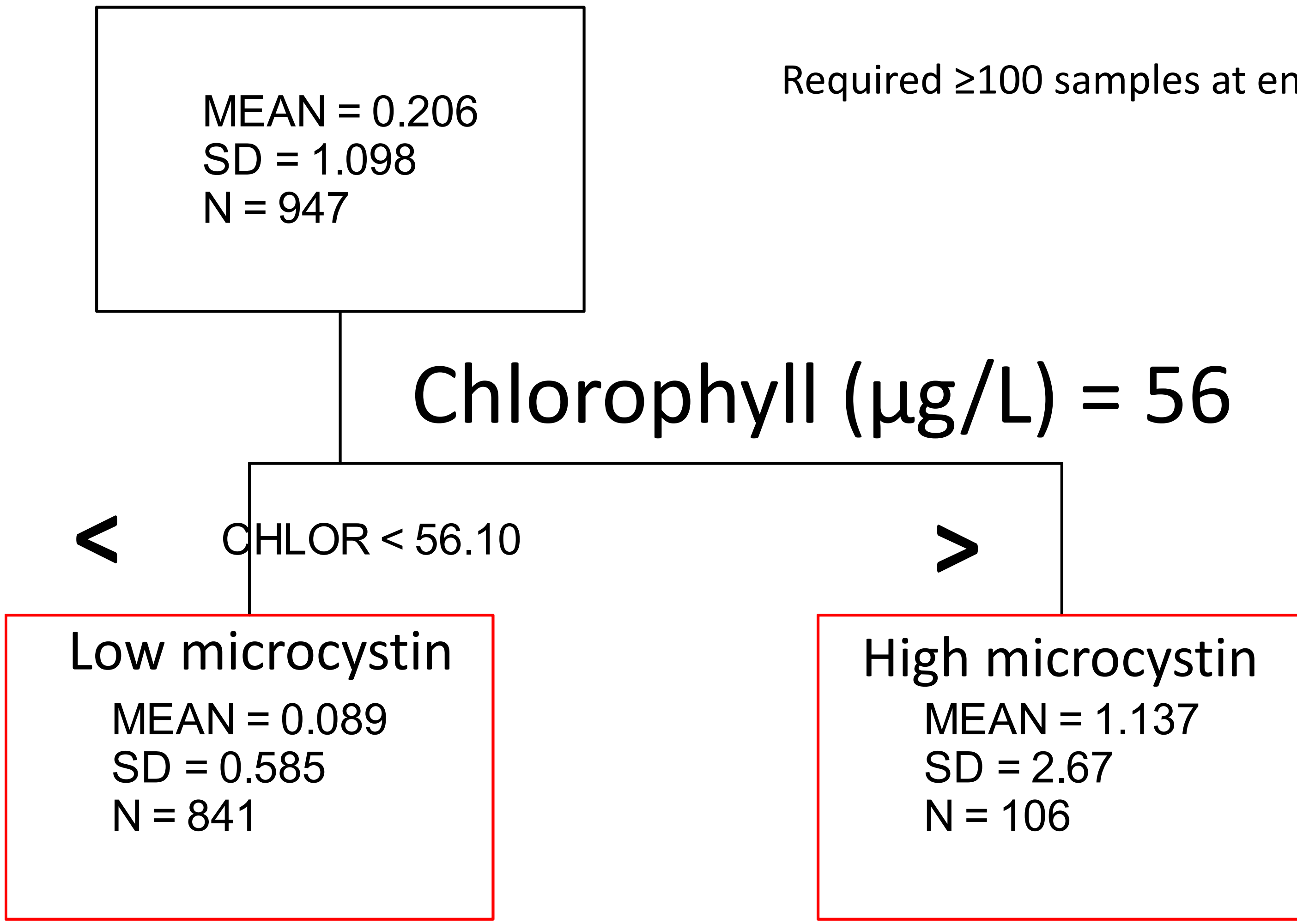


CART for Phycocyanin (µg/L)

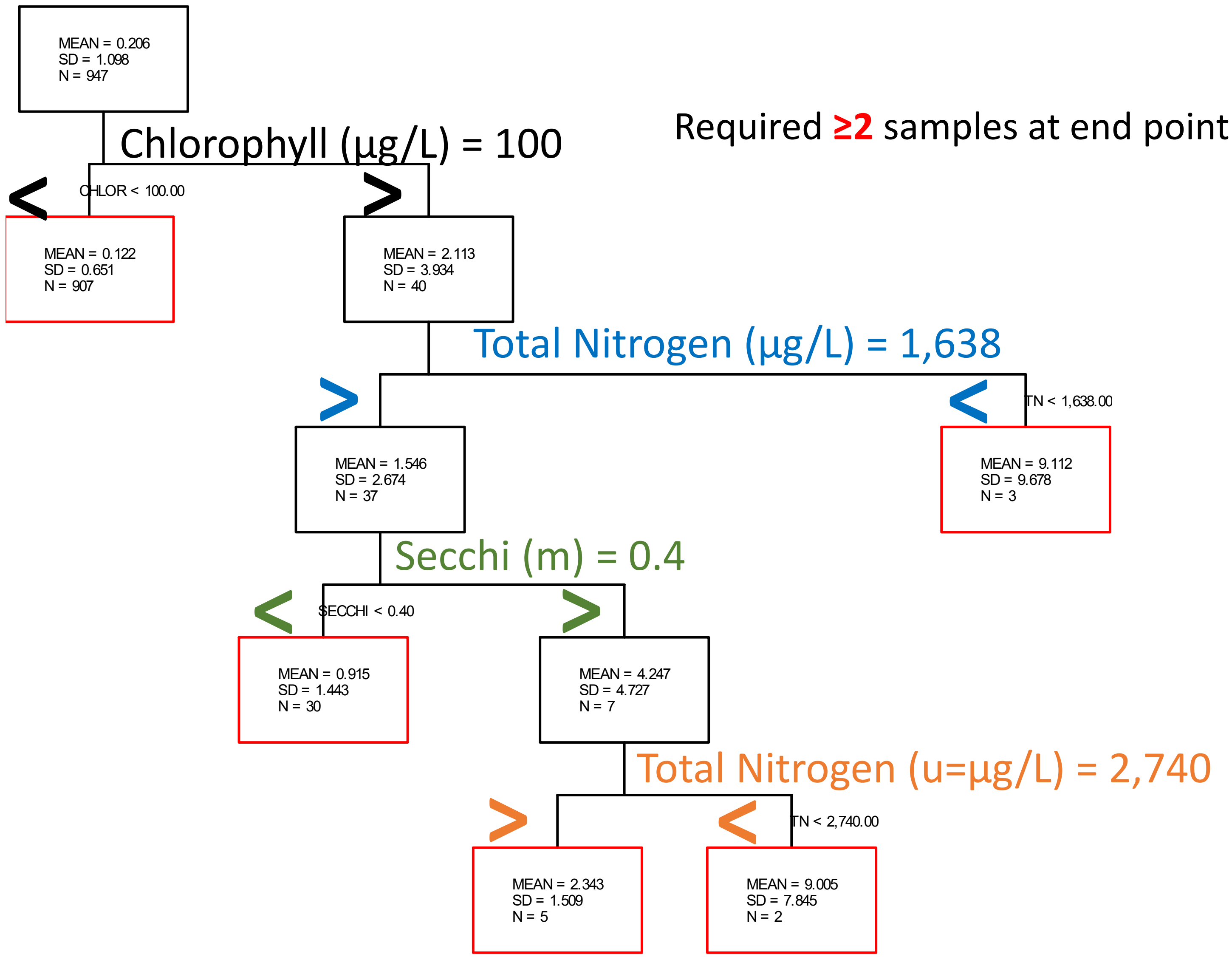


CART for Microcystin (µg/L)

Required ≥100 samples at end point



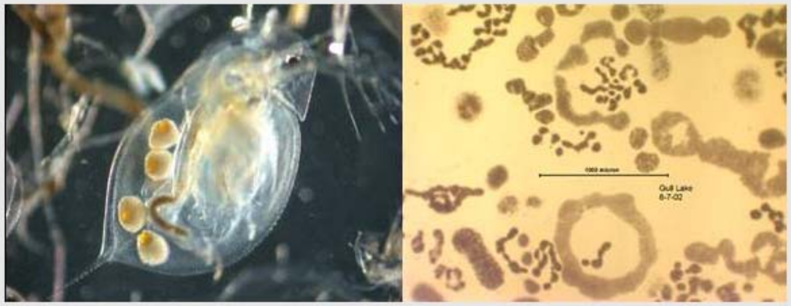
CART for Microcystin (µg/L)



Algal bloom forecasting website

WilsonLab at Auburn University

- **Home**
- **Lab members**
- **Research interests**
- **Projects**
- **Publications**
- **CV**
- **Courses**
- **Photos**
- **Contact information**



Models to forecast freshwater algal and cyanobacterial blooms

The following spreadsheet contains two models useful for water resource managers, lake owners, and researchers to forecast algal, cyanobacterial (blue-green algal), and toxic cyanobacterial blooms in lakes, ponds, and reservoirs. The models incorporate either Secchi depth (measured in meters) or commonly measured water quality parameters, such as chlorophyll *a* or total phosphorus concentrations, to predict algal blooms and their associated water quality risks. The current spreadsheet incorporates data from 103 waterbodies across Alabama that vary widely in morphology, mixing regime, flow, and nutrient concentrations sampled during the summers of 2008-2009. We are currently evaluating the utility of these models for sites throughout the Southeast. We will update the models, as well as provide alternative models specific for certain types of waterbodies, in the future. Please use the models and let us know if they are useful for you and/or if you have any questions, comments, or concerns about the models.

Available forecasting models

1. General use Secchi depth model (ideal for homeowners and general public)
2. Complex water quality model (ideal for water quality managers, state agency scientists, and academics)

Website development and coding - Mark Bransby

http://wilsonlab.com/forecasting.html

School of Fisheries, 203 Swingle Hall, Auburn University, Auburn, AL 36849

Home | **Lab** | **Research** | **Projects** | **Pubs** | **CV** | **Courses** | **Photos** | **Contact**

Web designer - Sarkis

CANADA
WASHINGTON
MONTANA
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MINNESOTA
SOUTH DAKOTA
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UTAH
COLORADO
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ILLINOIS
OHIO
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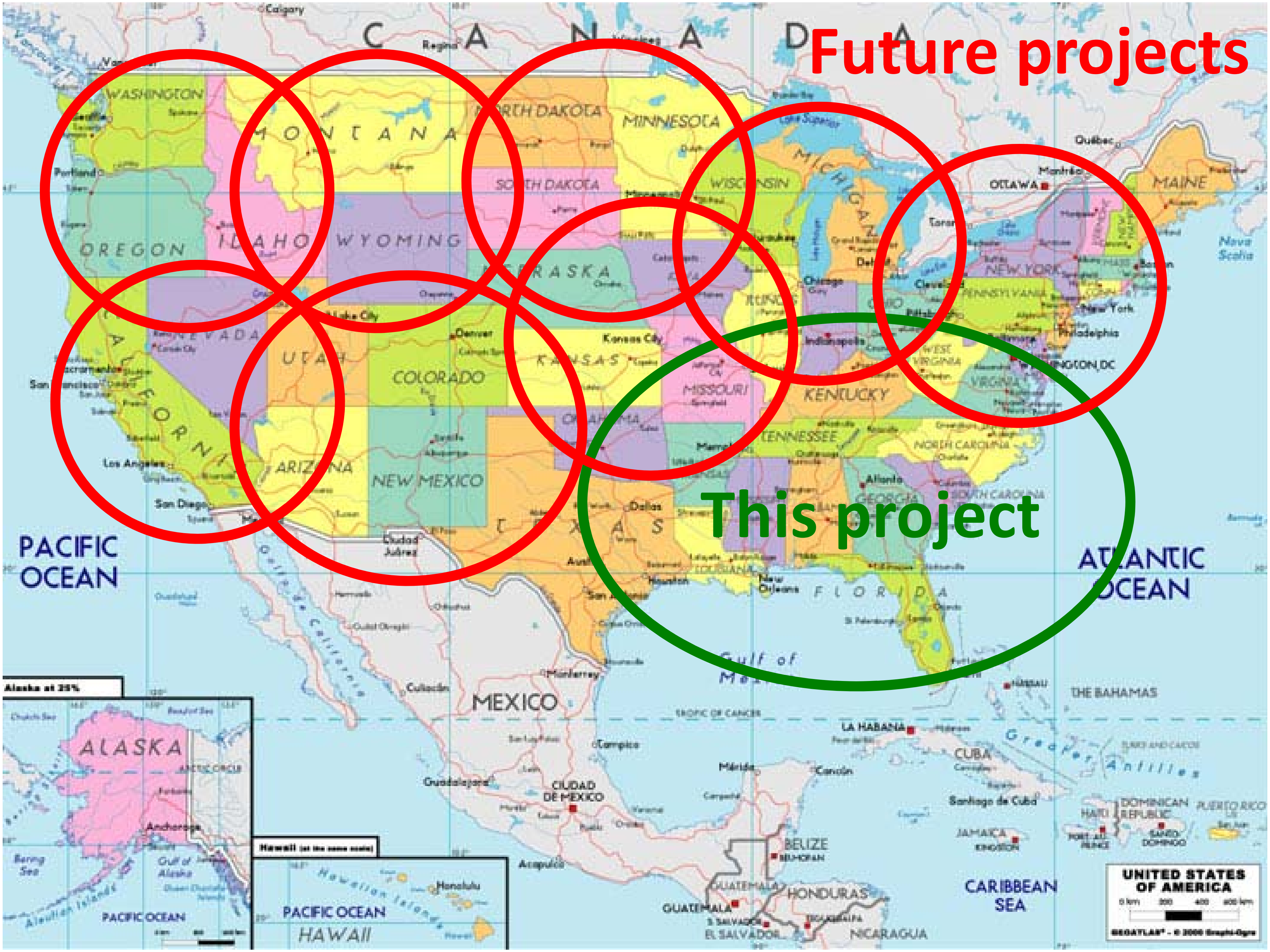
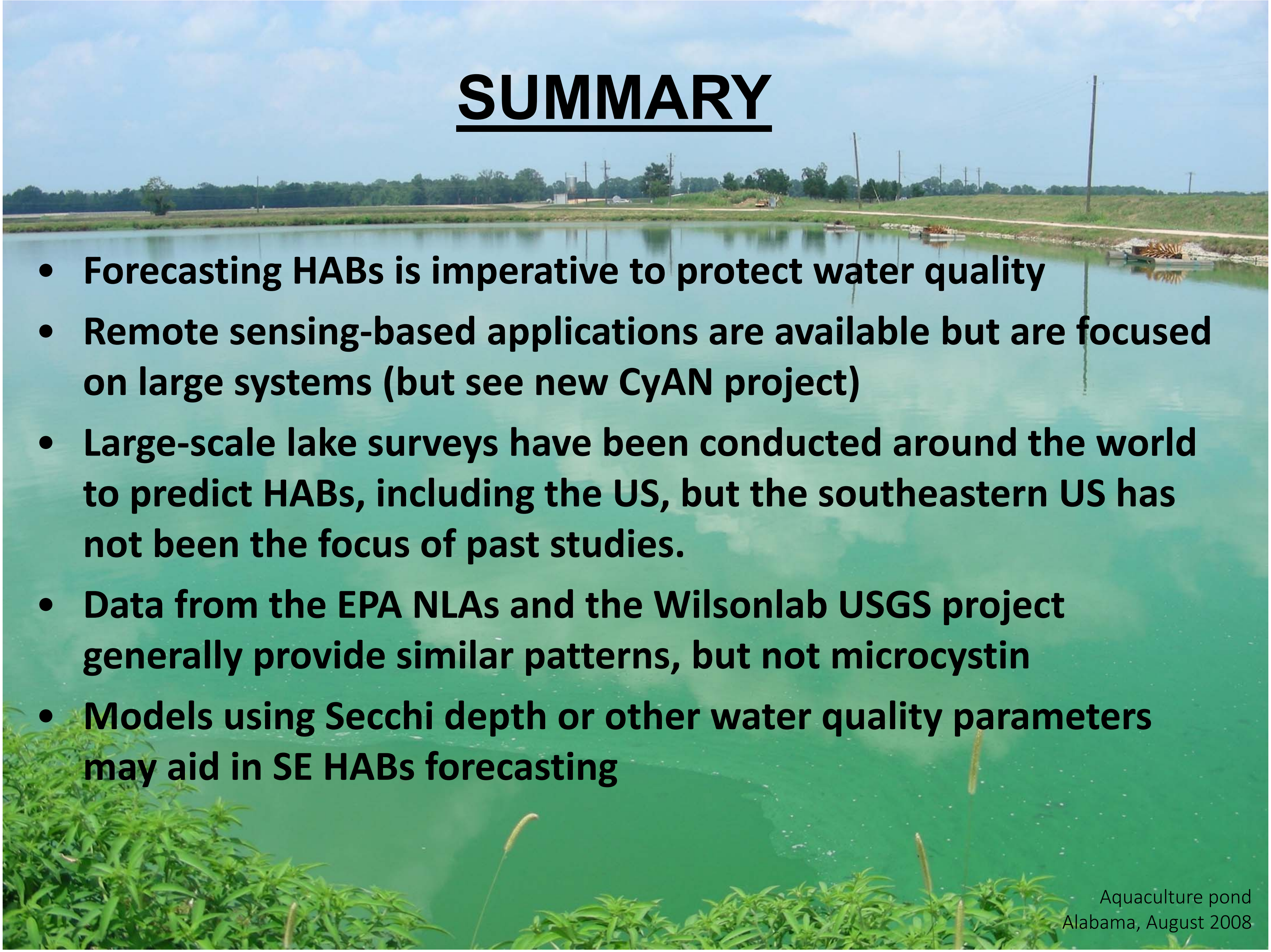
CALIFORNIA
MISSOURI
KENTUCKY
WEST VIRGINIA
VIRGINIA
OKLAHOMA
TENNESSEE
NORTH CAROLINA
ARIZONA
NEW MEXICO
ARKANSAS
SOUTH CAROLINA
GEORGIA
TEXAS
LOUISIANA
FLORIDA
This project
PACIFIC OCEAN
ATLANTIC OCEAN
Gulf of Mexico
MEXICO
THE BAHAMAS
CUBA
CARIBBEAN SEA
BELIZE
GUATEMALA
HONDURAS
EL SALVADOR
NICARAGUA
JAMAICA
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
ALASKA
Alaska at 35%
HAWAII
PACIFIC OCEAN
UNITED STATES OF AMERICA



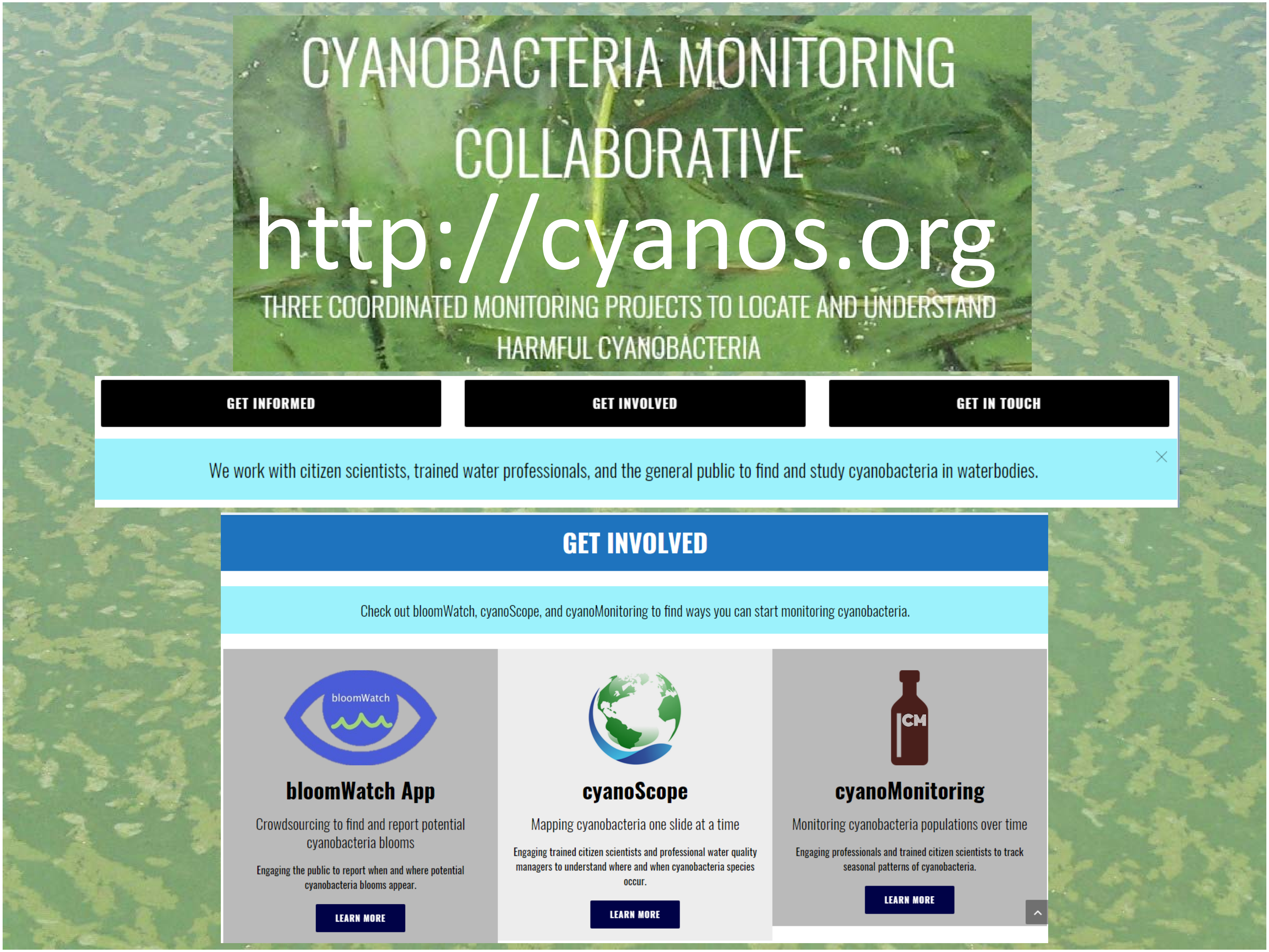
Future projects
This project
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
UNITED STATES OF AMERICA

SUMMARY

- **Forecasting HABs is imperative to protect water quality**
- **Remote sensing-based applications are available but are focused on large systems (but see new CyAN project)**
- **Large-scale lake surveys have been conducted around the world to predict HABs, including the US, but the southeastern US has not been the focus of past studies.**
- **Data from the EPA NLAs and the Wilsonlab USGS project generally provide similar patterns, but not microcystin**
- **Models using Secchi depth or other water quality parameters may aid in SE HABs forecasting**



Aquaculture pond
Alabama, August 2008


CYANOBACTERIA MONITORING COLLABORATIVE
http://cyanos.org
THREE COORDINATED MONITORING PROJECTS TO LOCATE AND UNDERSTAND HARMFUL CYANOBACTERIA
GET INFORMED
GET INVOLVED
GET IN TOUCH
We work with citizen scientists, trained water professionals, and the general public to find and study cyanobacteria in waterbodies.
GET INVOLVED
Check out bloomWatch, cyanoScope, and cyanoMonitoring to find ways you can start monitoring cyanobacteria.
bloomWatch
bloomWatch App
Crowdsourcing to find and report potential cyanobacteria blooms
Engaging the public to report when and where potential cyanobacteria blooms appear.
LEARN MORE
cyanoScope
Mapping cyanobacteria one slide at a time
Engaging trained citizen scientists and professional water quality managers to understand where and when cyanobacteria species occur.
LEARN MORE
CM
cyanoMonitoring
Monitoring cyanobacteria populations over time
Engaging professionals and trained citizen scientists to track seasonal patterns of cyanobacteria.
LEARN MORE

Contact information

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203 Swingle Hall, Auburn, AL 36849

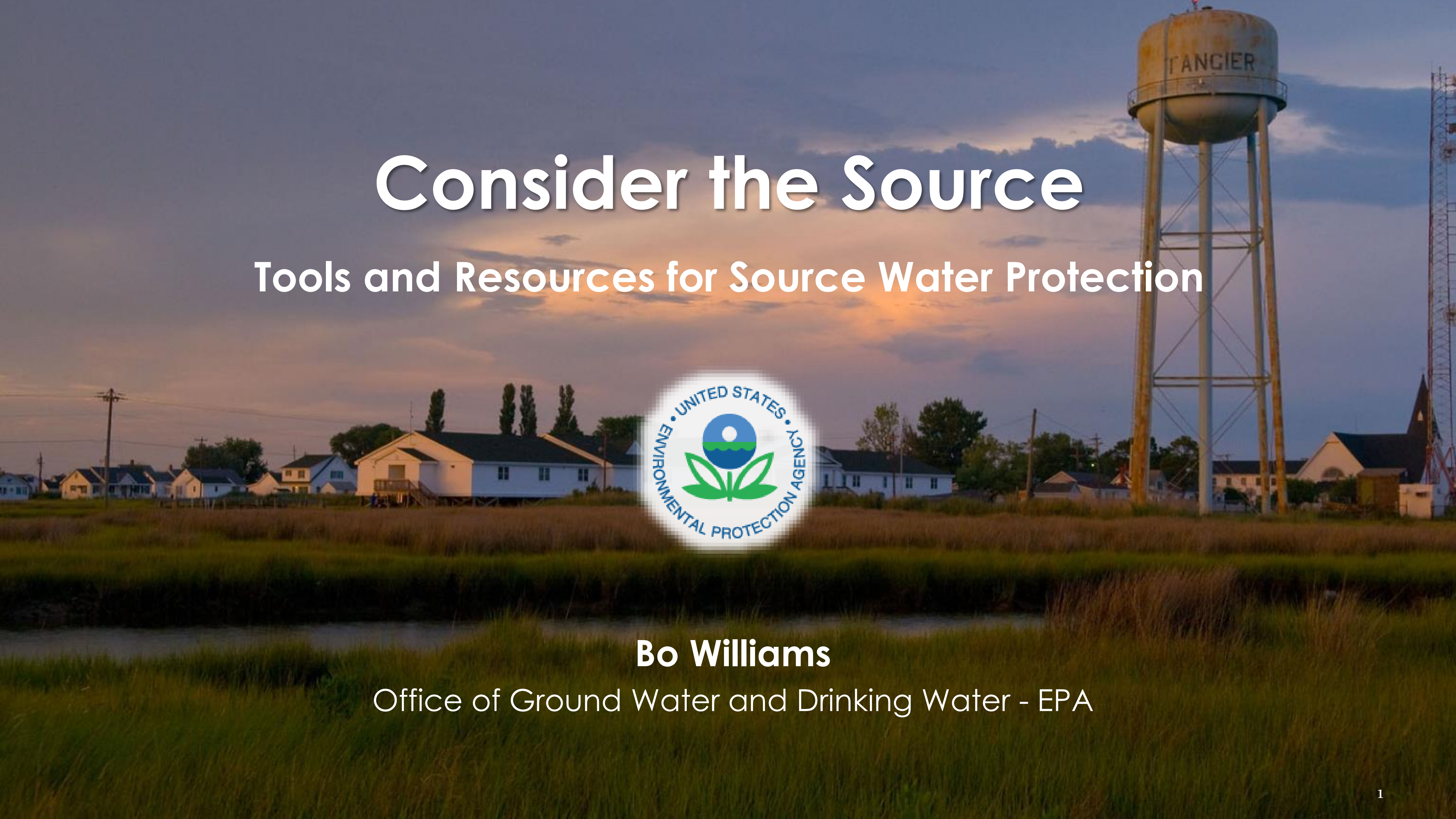
wilson@auburn.edu, 334-246-1120

http://wilsonlab.com/

Aquaculture pond
Alabama, August 2008

Consider the Source

Tools and Resources for Source Water Protection



Bo Williams

Office of Ground Water and Drinking Water - EPA

Watershed Management: Mitigation and Prevention

Control and Removal

Physical

- *Mechanical mixing*
- *Aeration*

Biological

- *Floating treatments*
- *Shade*

Chemical

- *Algaecides*
- *Flocculation*

Prevention

Drivers:

- Nutrient pollution
- Hydrologic alteration
- Temperature pollution

Sources:

- Agricultural and Urban runoff
- Atmospheric Deposition
- Point sources

Solutions & Practices

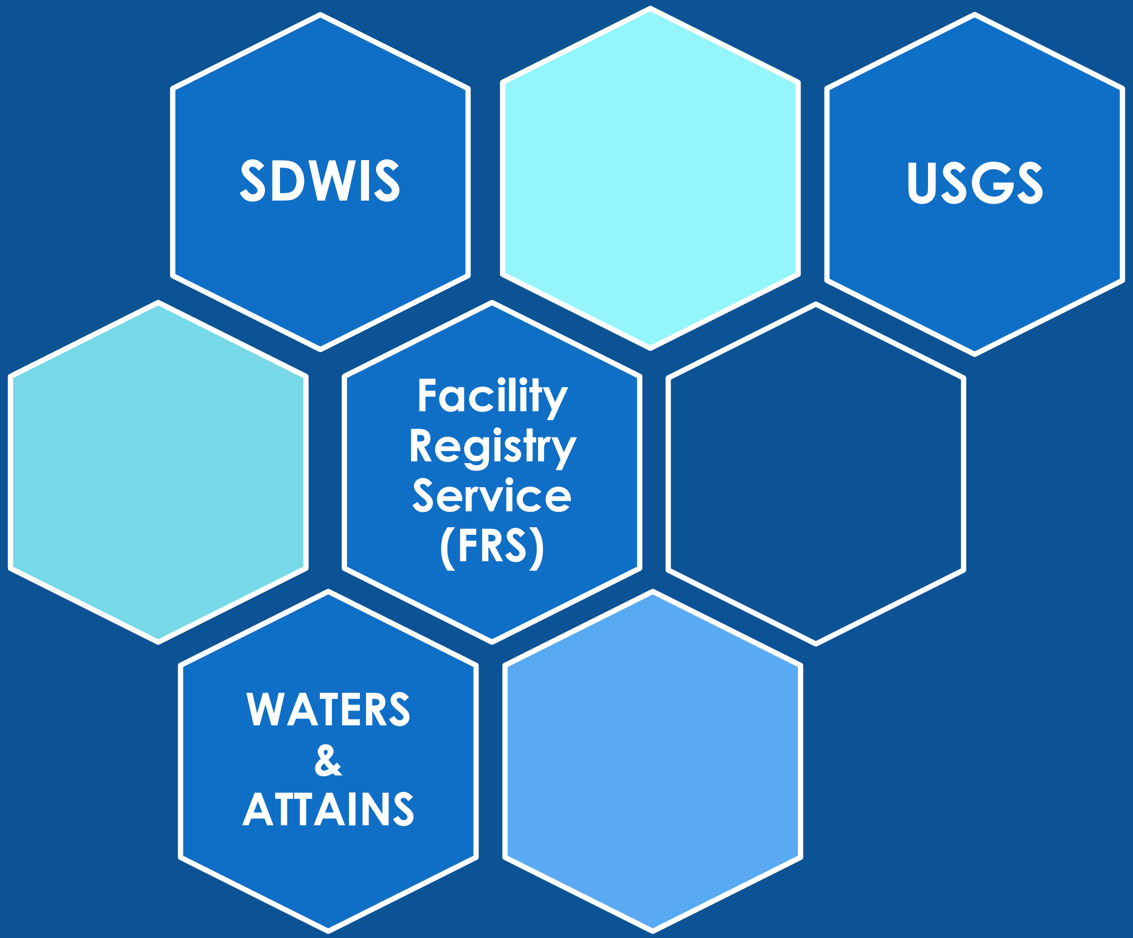
- Conservation measures
- Stream and wetland restoration
- Forest Management
- Land preservation

DWMAPS 2.0

Project Goal: Provide a nationwide online mapping tool for data critical to drinking water source protection.

- Public information (no intakes)
- Search tools for exploration
- Esri ArcGIS Online

Key Data Sources



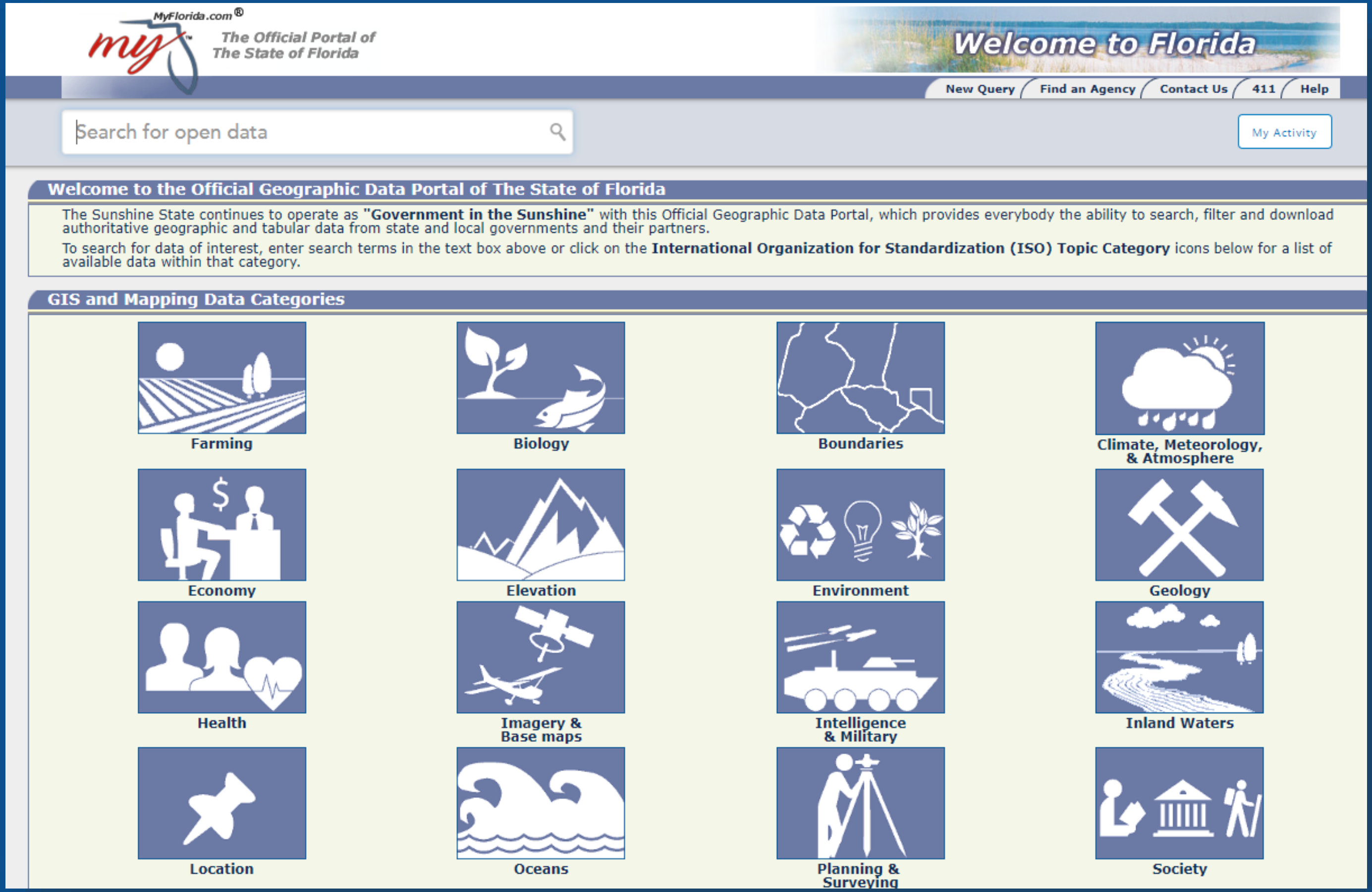
DWMAPS & Esri ArcGIS Platform

DWMAPS:

- Up-to-date data
- Add data layers from across the internet (web services)

Esri ArcGIS online:

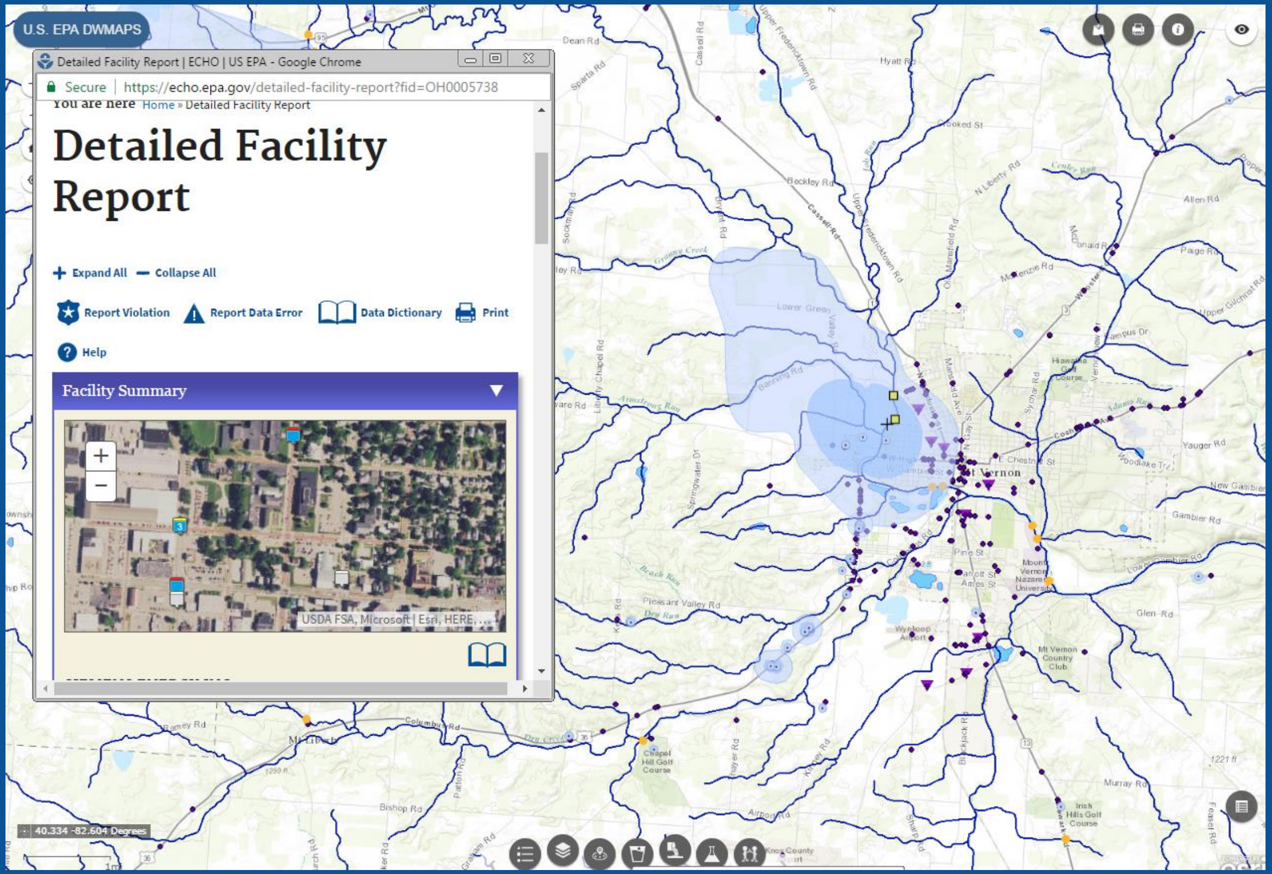
- Make and share maps, data, applications
- Manage and upload your own data to DWMAPS



Florida Geographic Data Portal

DWMAPS Uses

- ✓ View drinking water and watershed data to support source vulnerability assessments
- ✓ Identify HAB risk factors, including point and non-point pollution
- ✓ Prioritize protection strategies
  - ✓ Promote program integration (CWA-SDWA)



Points sources near Mount Vernon, OH

Locate Contaminant Sources

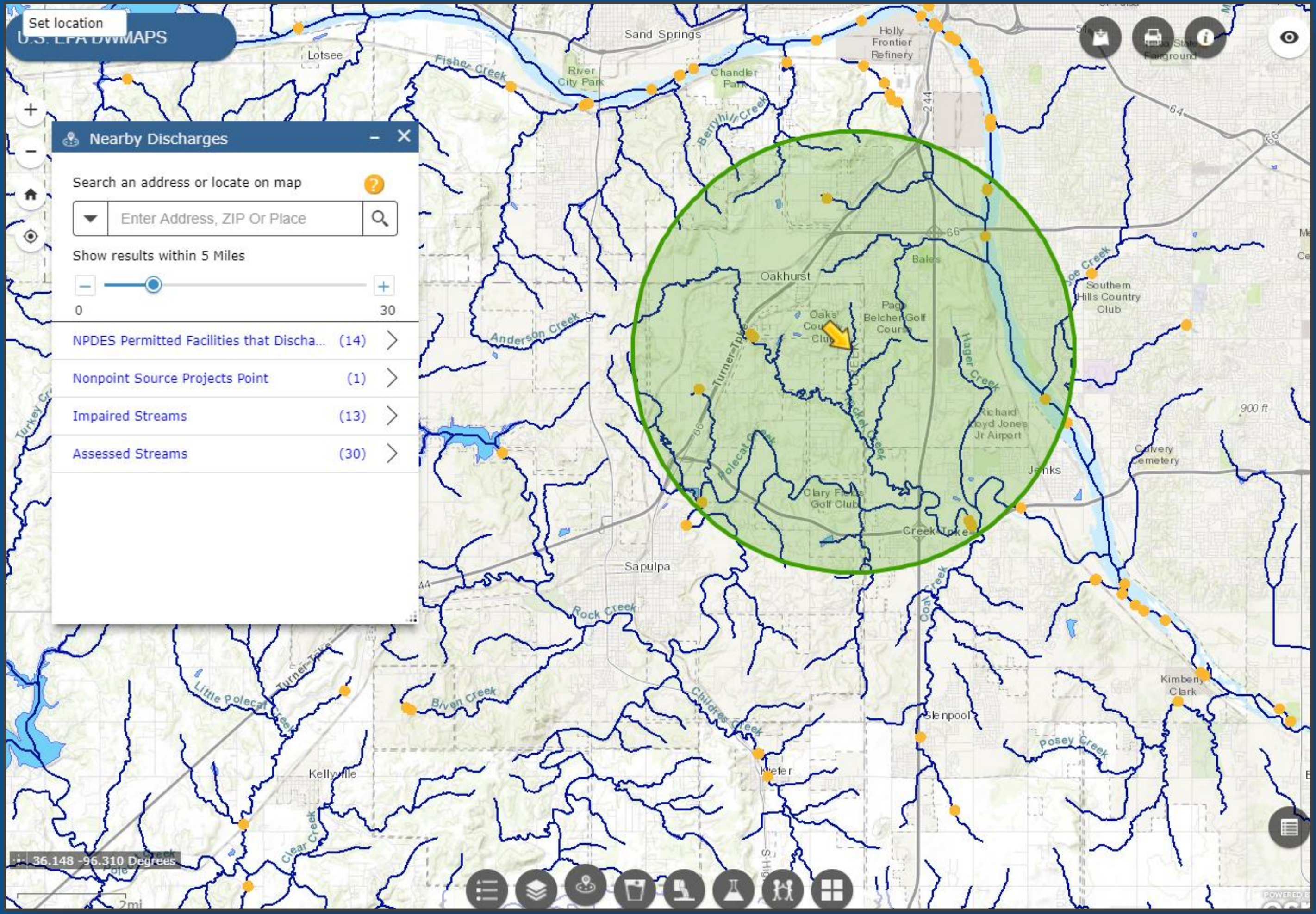
DWMAPS Query Tools:

1. Nearby Discharges

- 1-30 miles radius

2. Potential sources of contamination

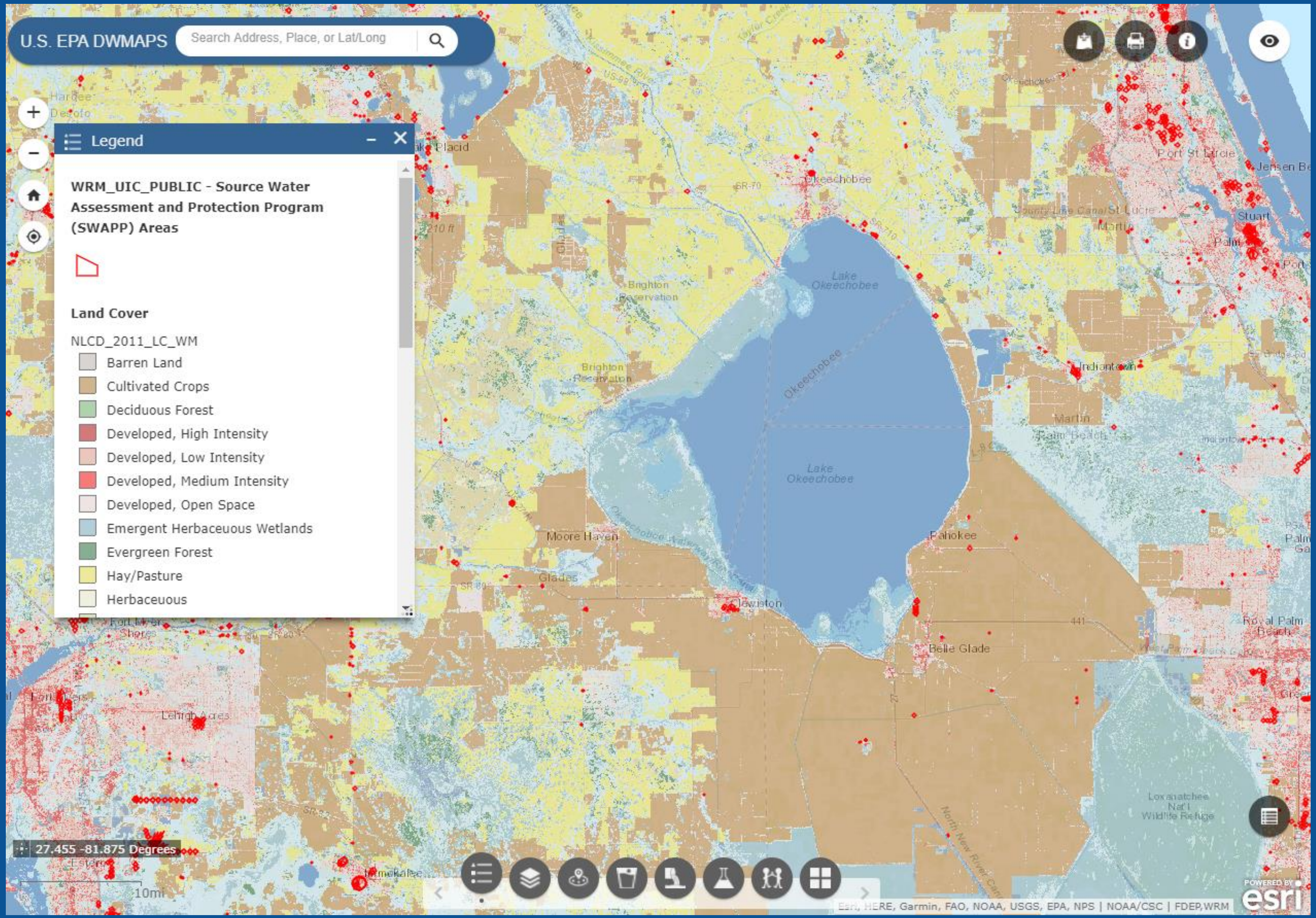
- Look upstream 1-10 miles



Potential Contaminants Sources within 5 mile radius

Potential Sources of Contamination

Lake Okeechobee



Source Assessment Areas & Land Cover

DWMAPS contaminant source data.

Non-point source:

- Land Use (NLCD)
- Impervious surfaces
- Natural Land Cover
- Protected areas

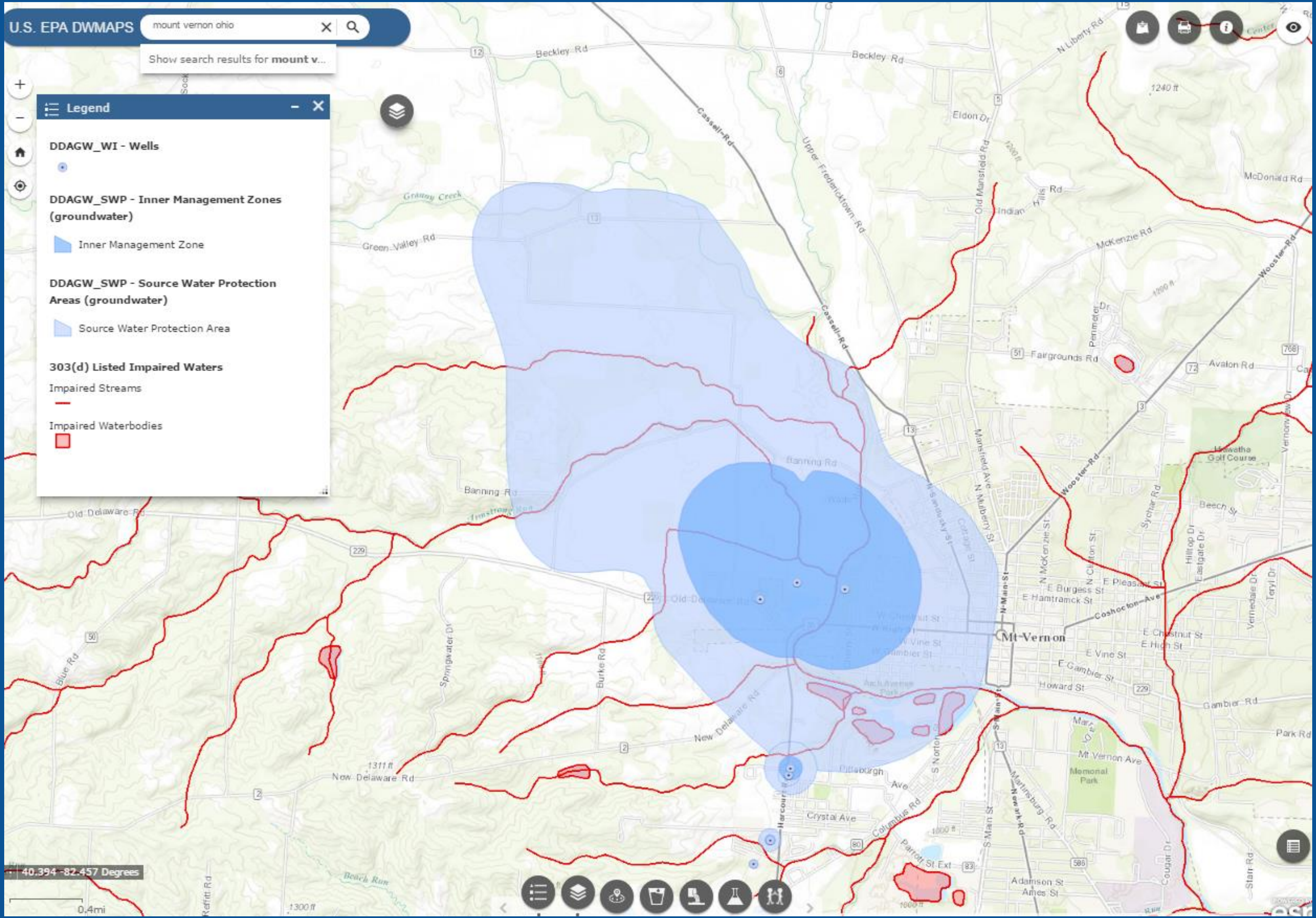
Leveraging the Clean Water Act

Are source waters prioritized for TMDL development?

- View impaired waters information, Waterbody Quality Assessment Reports, and TMDL Reports.

Are 319 projects targeting source waters?

- View 319 project locations and grant reports (GRTS)

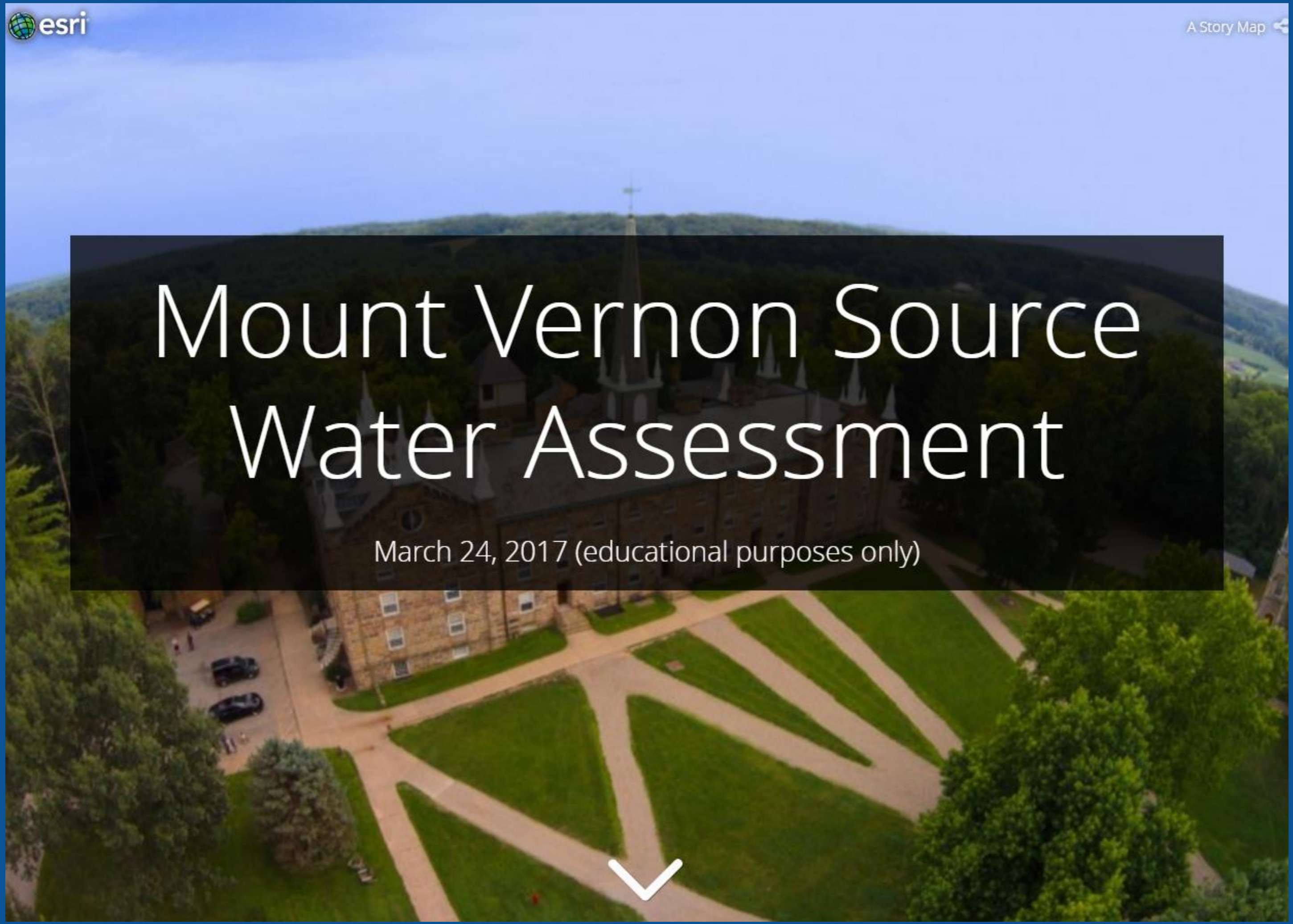


Waters Impaired for Nutrients & Organic Matter

Prioritizing & Implementing Protection Strategies

Present your findings & build partnerships:

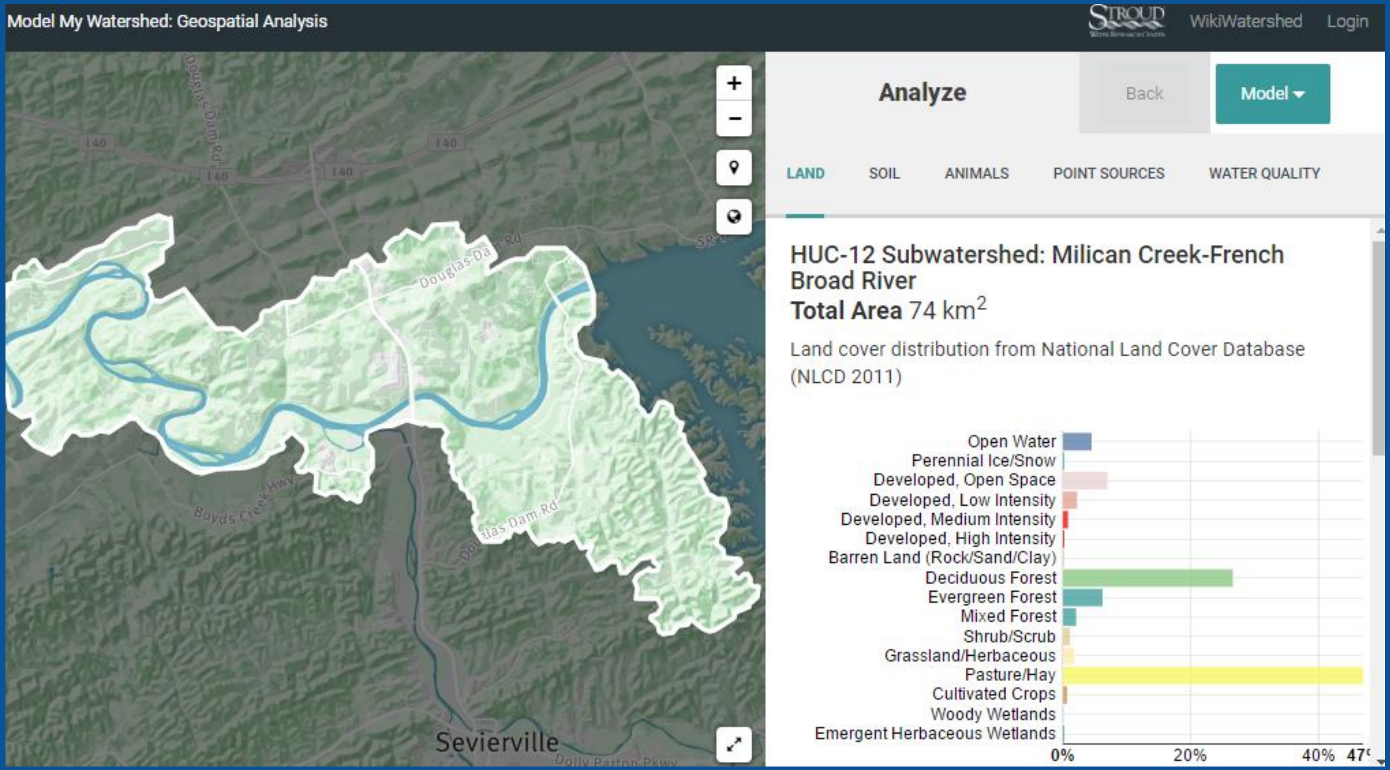
- Mapping applications and story maps



Fictitious SW Assessment Story Map

Mapping Tools: Wiki Watershed

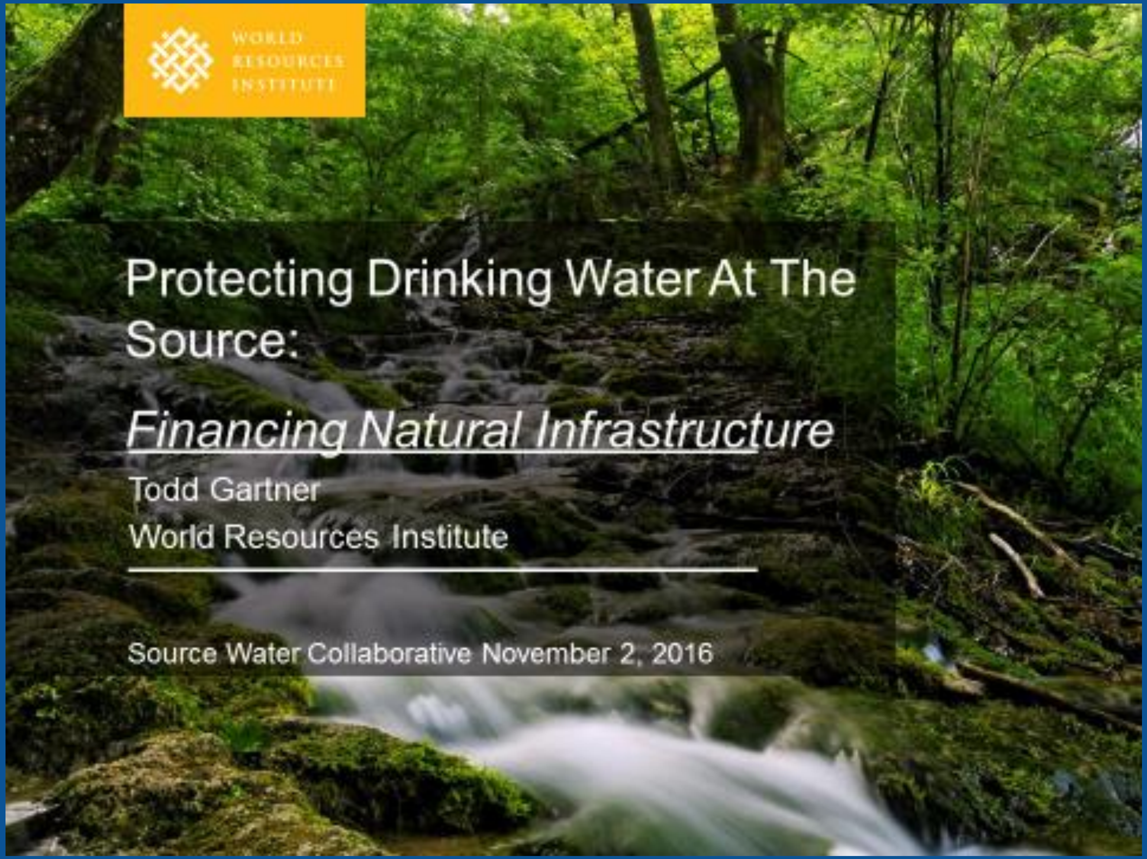
- ✓ View N & P sources by watershed scales
- ✓ View water quality data
- ✓ Model N& P runoff and water quality impacts with professional models
- ✓ Compare conservation and management scenarios



Project of STROUD Water Research Center

Partnership Building Tools

SWC How to Collaborate Toolkit



WRI: Protecting Drinking Water at the Source

WRI: Lessons from U.S. Watershed Investment Programs

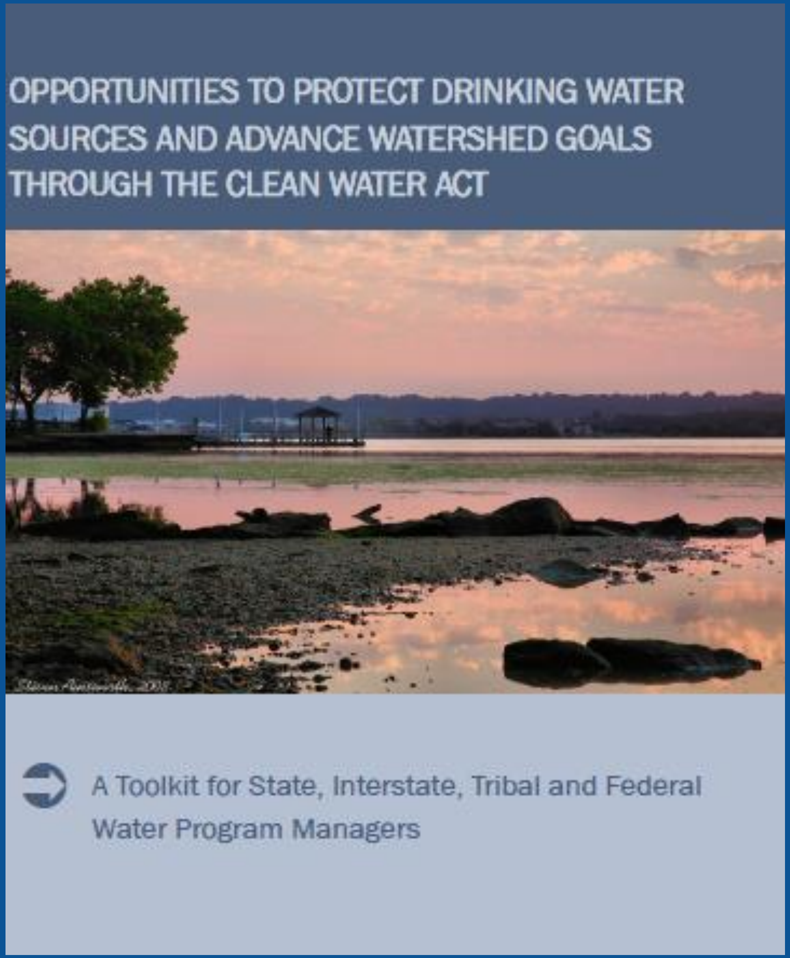
PHASE OF PROGRAM DEVELOPMENT	DESCRIPTION	LESSONS
Building momentum	Identifying a clear need and purpose for a watershed investment program; securing commitment from key stakeholders	1. Identify risks (wildfire, drought, etc.) and seize opportunities to rally support 2. Build partnerships to fill essential roles and responsibilities 3. Articulate a clear vision of success 4. Cultivate champions and advocates to build support (from water utilities, local government, NGOs, landowners, etc.)
Designing the program	Assessing the scientific and economic underpinnings of the program; creating a strategy to achieve program goals	5. Develop a scientifically informed watershed plan 6. Evaluate the business case for investment 7. Identify investors (water utilities, companies, foundations, etc.) and financing mechanisms for initial and long-term funding
Implementing the action plan	Actively and adaptively managing the program to make investments; tracking the results of those investments	8. Engage landowners and public managers to conserve, restore, and sustainably manage natural infrastructure 9. Define roles and plans for program administration 10. Monitor and evaluate performance (acres of forestland protected, acres treated for fire risk reduction, pounds of sediment avoided from filling waterways, etc.)

World Resources Institute, 2016

CWA-SDWA Integration

CWA-SDWA Toolkit:

- Water Quality Standards
  - Designated Uses
  - Water Quality Criteria
- Monitoring and Assessments
- TMDL priority setting
- **Section 319 program**



CWA-SDWA Integration Toolkit

Source to Tap Infographic

Links

- EPA Source Water Protection: https://www.epa.gov/sourcewaterprotection
- DWMAPS: https://www.epa.gov/sourcewaterprotection/dwmaps
- WikiWatershed: https://wikiwatershed.org/
- HAWQS: https://www.epa.gov/waterdata/hawqs-hydrologic-and-water-quality-system
- Esri ArcGIS online: http://www.arcgis.com/home/index.html
- Source Water Collaborative: http://sourcewatercollaborative.org/
    - Source to Tap: http://sourcewatercollaborative.org/infographic/
- CWA-SDWA Coordination Toolkit: http://www.gwpc.org/cwa-sdwa-coordination-toolkit

Thank you!

Williams.james@epa.gov

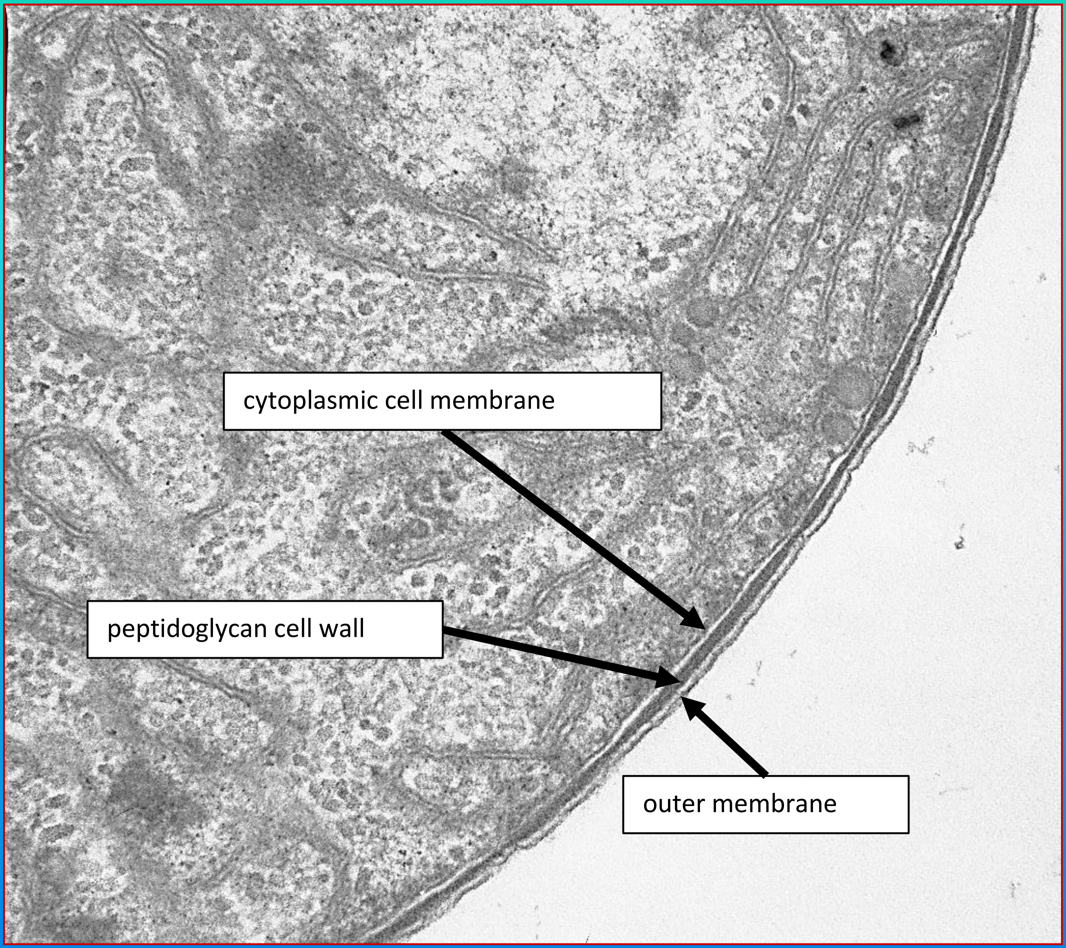
Cyanobacterial Ecological Strategies and how these Impact Monitoring Techniques

Barry H. Rosen, Ph. D.
Biologist & SE Region Tribal Liaison
US Geological Survey/Office of the SE Regional Director

brosen@usgs.gov
407-738-0669

Cyanobacteria (aka blue-green algae)

- gram-negative bacteria
- pigments in thylakoids
- exopolymeric substances



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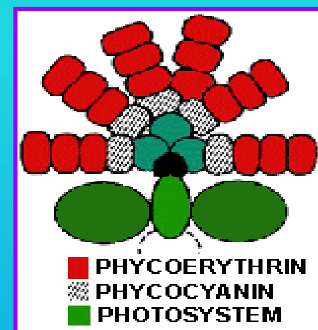
Ecological strategies for cyanobacteria: a sample

Morphology

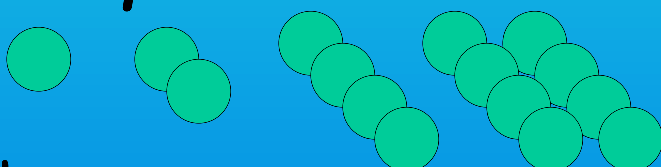
grazing, floating

Pigments



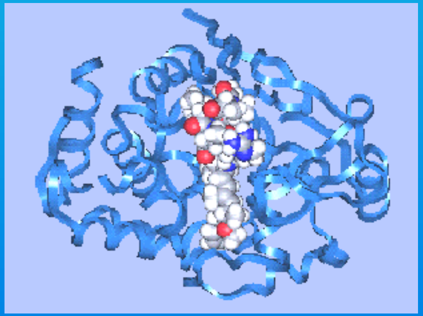
Buoyancy Regulation

Rapid Growth



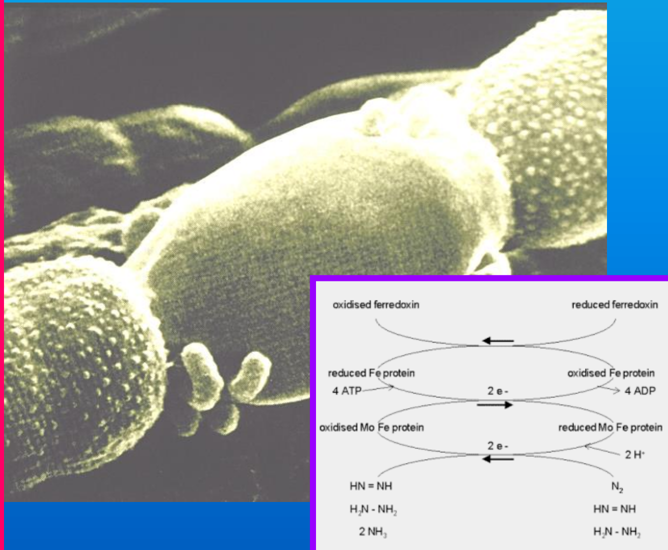
temp

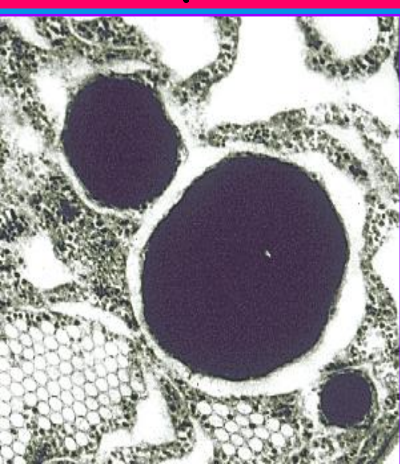
Toxicity



microcystin LR complex

Nitrogen Fixation





trace, P, C, N,

Nutrient Storage

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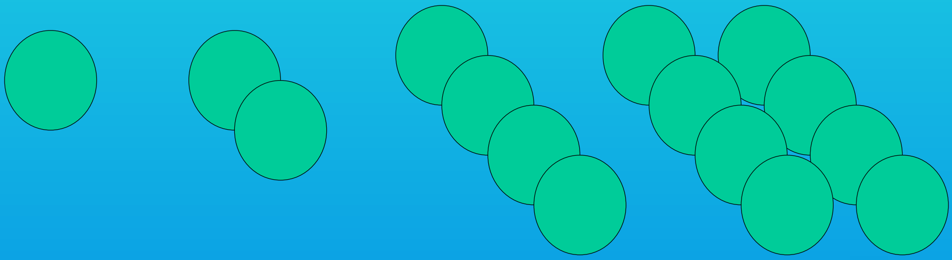
Ecological Strategies: thermophiles grow fast and will be worse as the climate warms



3 "doublings" or divisions every day

Ecological Strategies: internal structures for optimizing placement in the water column

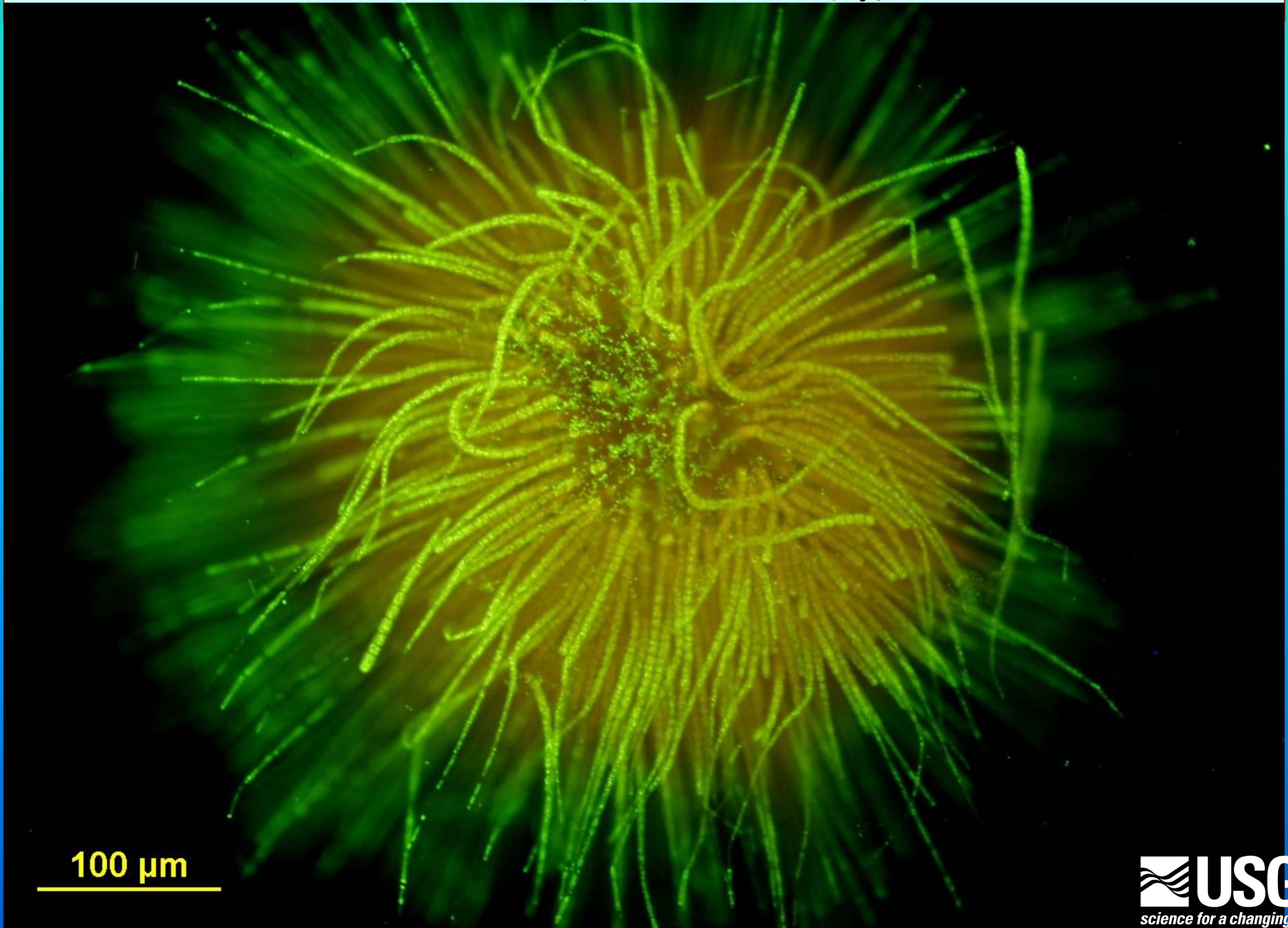
Gas Vesicles: *Buoyancy regulation and vertical migration*

Low light ↑

$(C_6H_{12}O_6)n$ ↓

Nutrients scavenged whilst near lake sediments or thermocline

Ecological Strategies: morphology for staying in the water column



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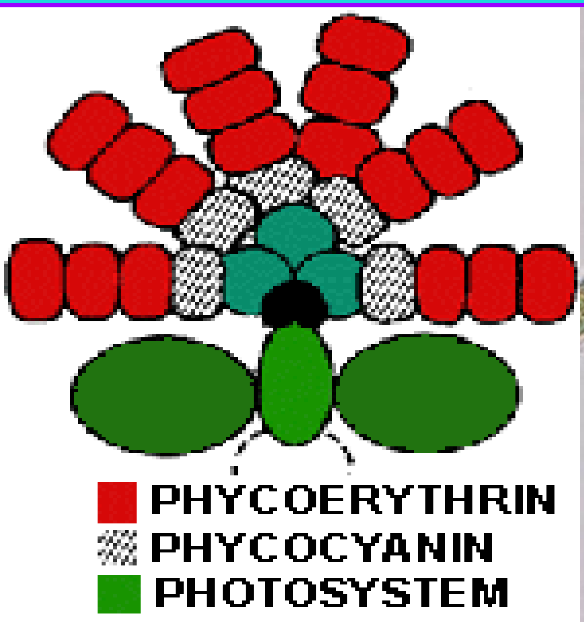
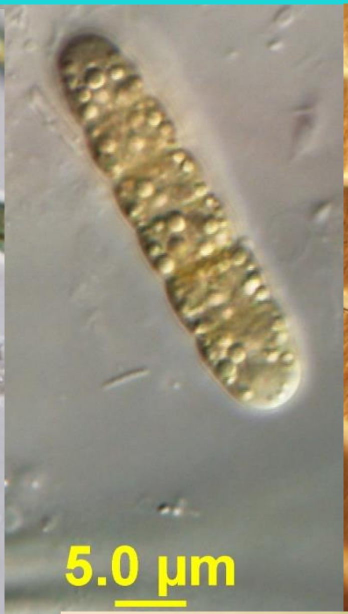
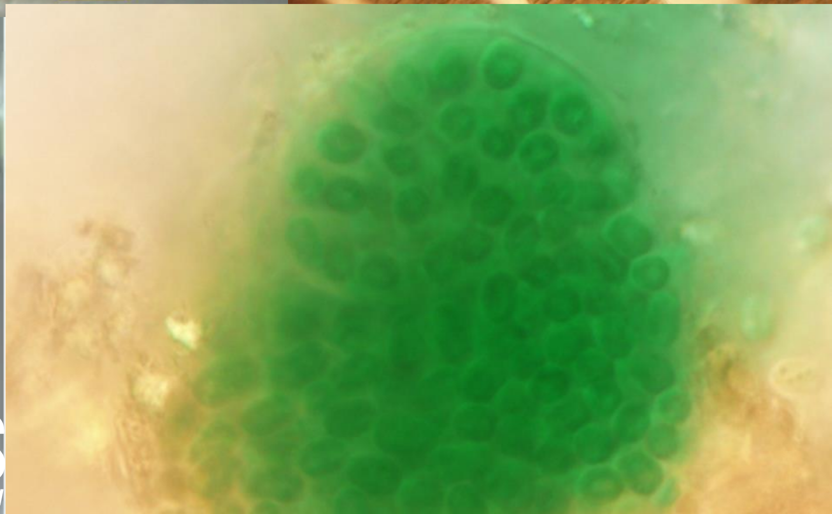
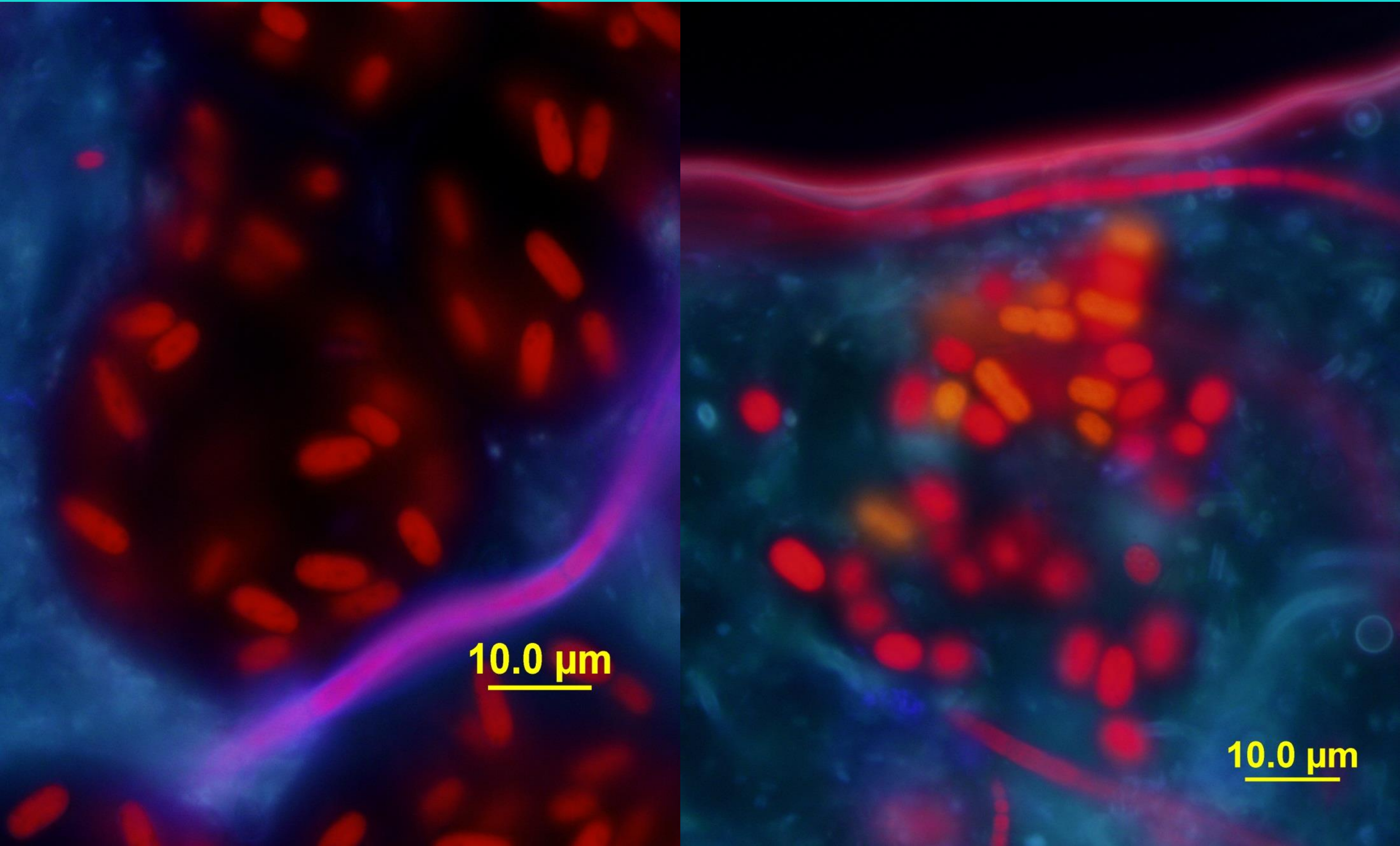
Ecological Strategies: complimentary pigments for maximizing photosynthesis



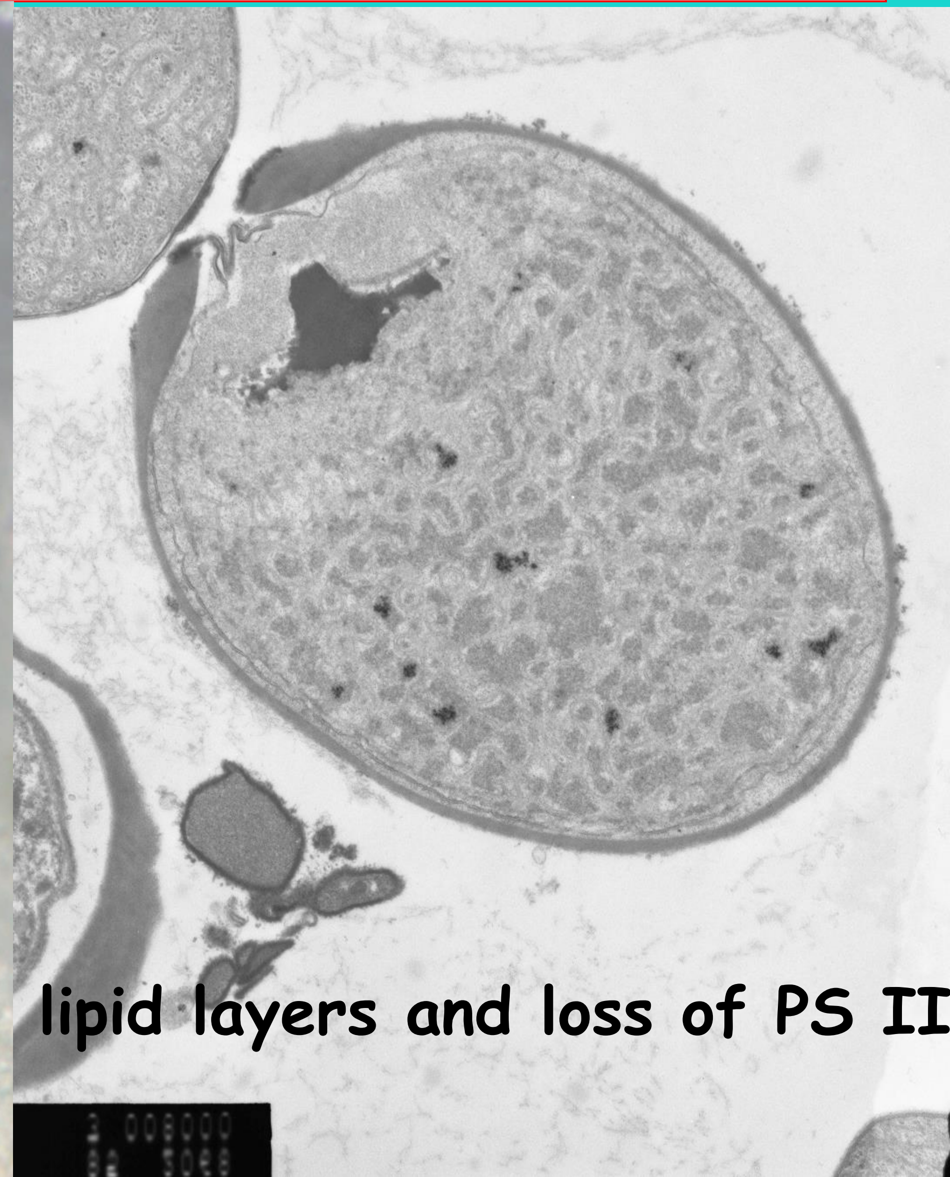




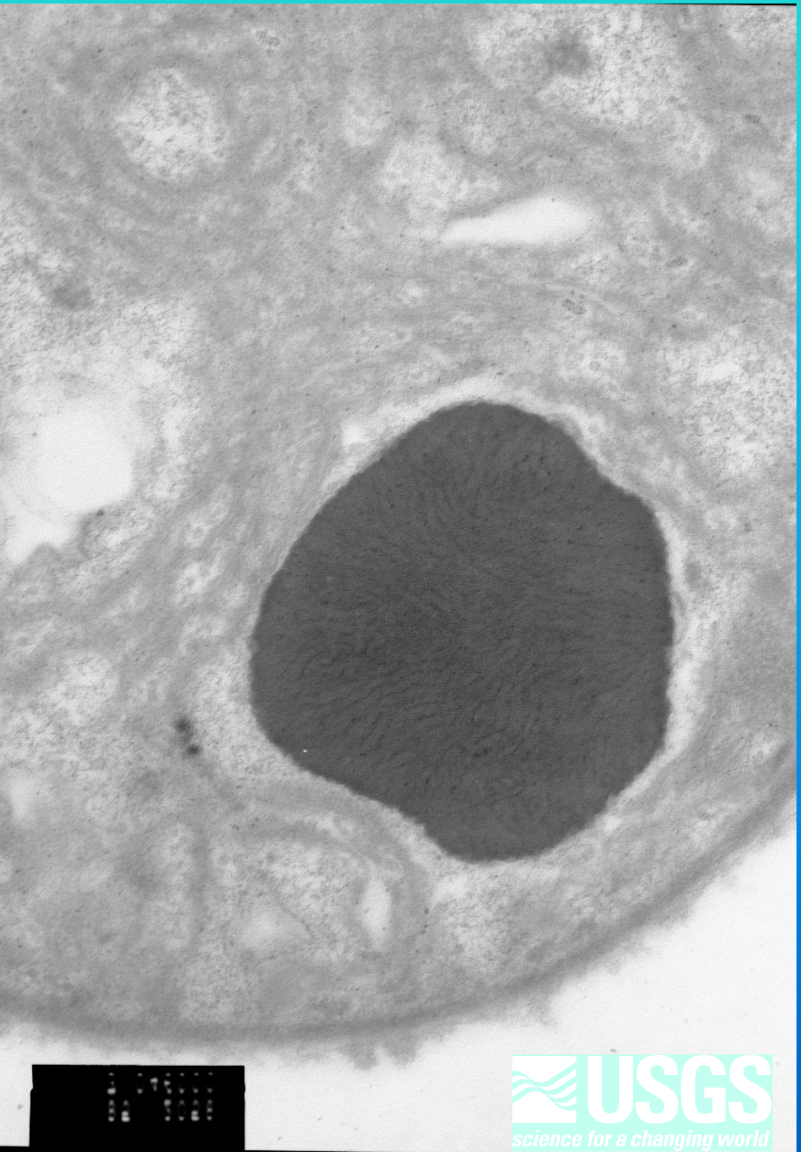
Ecological Strategies: complimentary pigments for maximizing photosynthesis



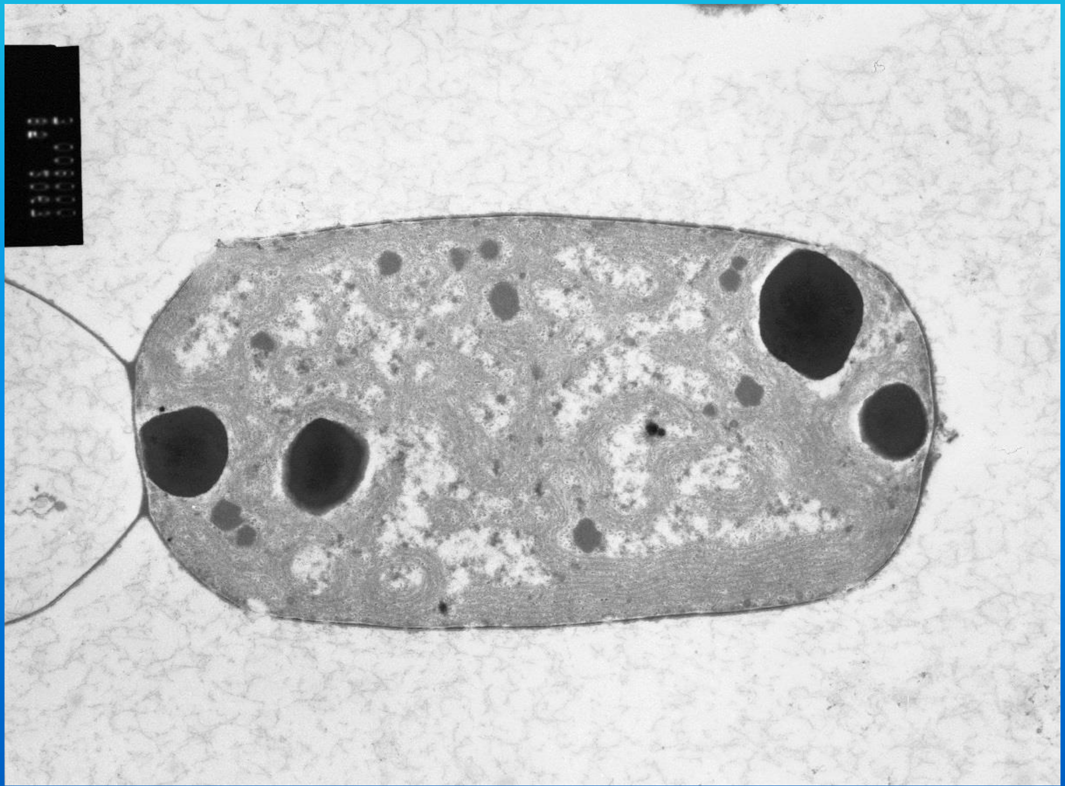
Ecological Strategies: make your own nitrogen from the atmosphere



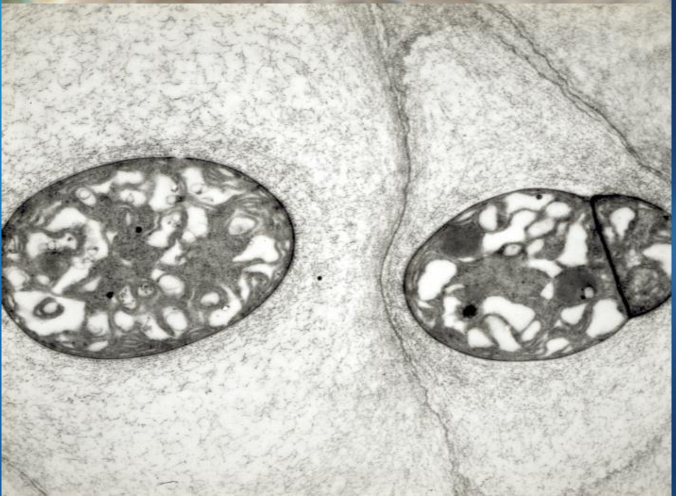
Ecological Strategies: luxuriant nutrient uptake and storage & metal sequestration

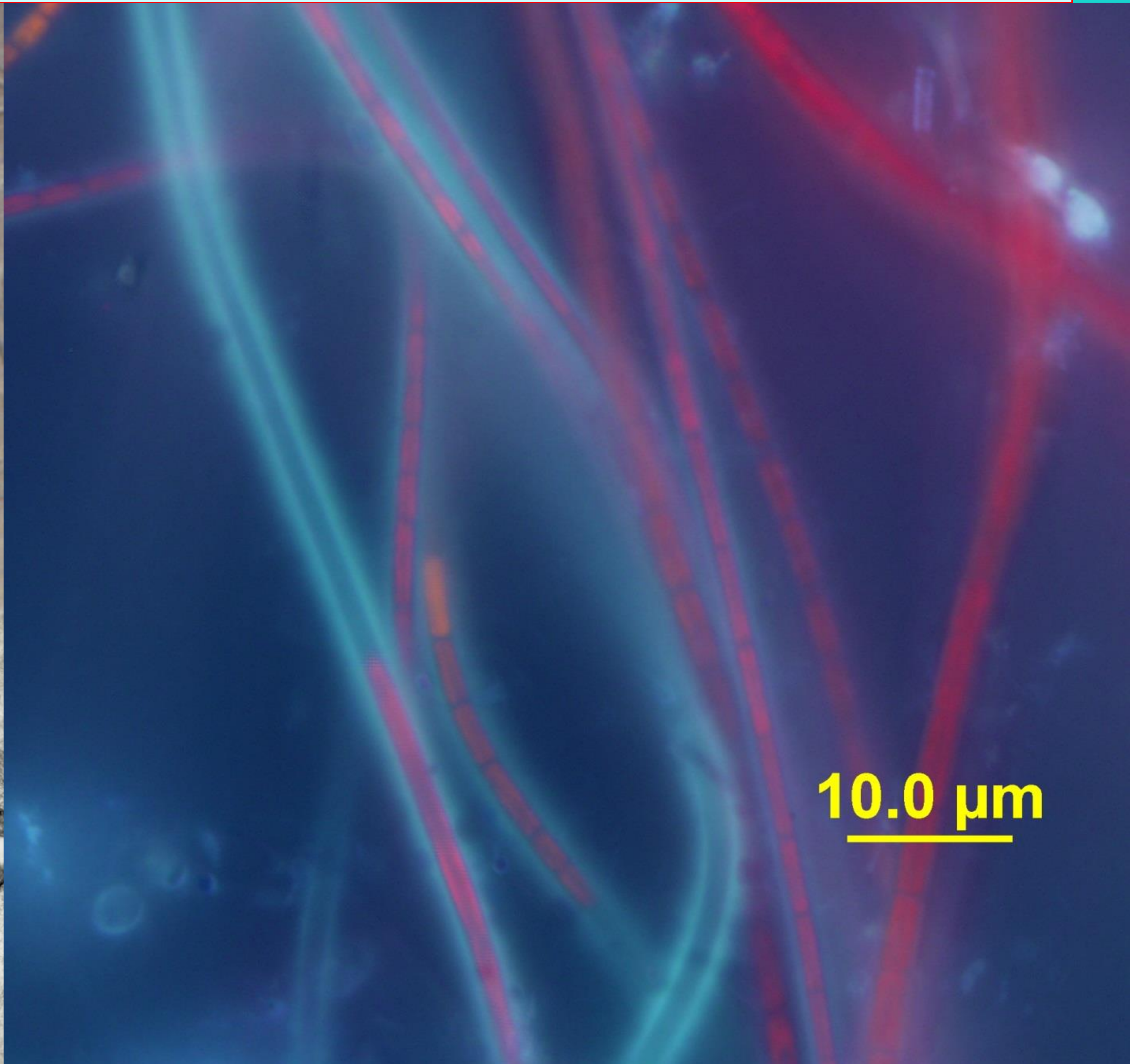


- Contain protein, lipids, polyP
- Na, Mg, Ca, K, Mn, Fe, Cu

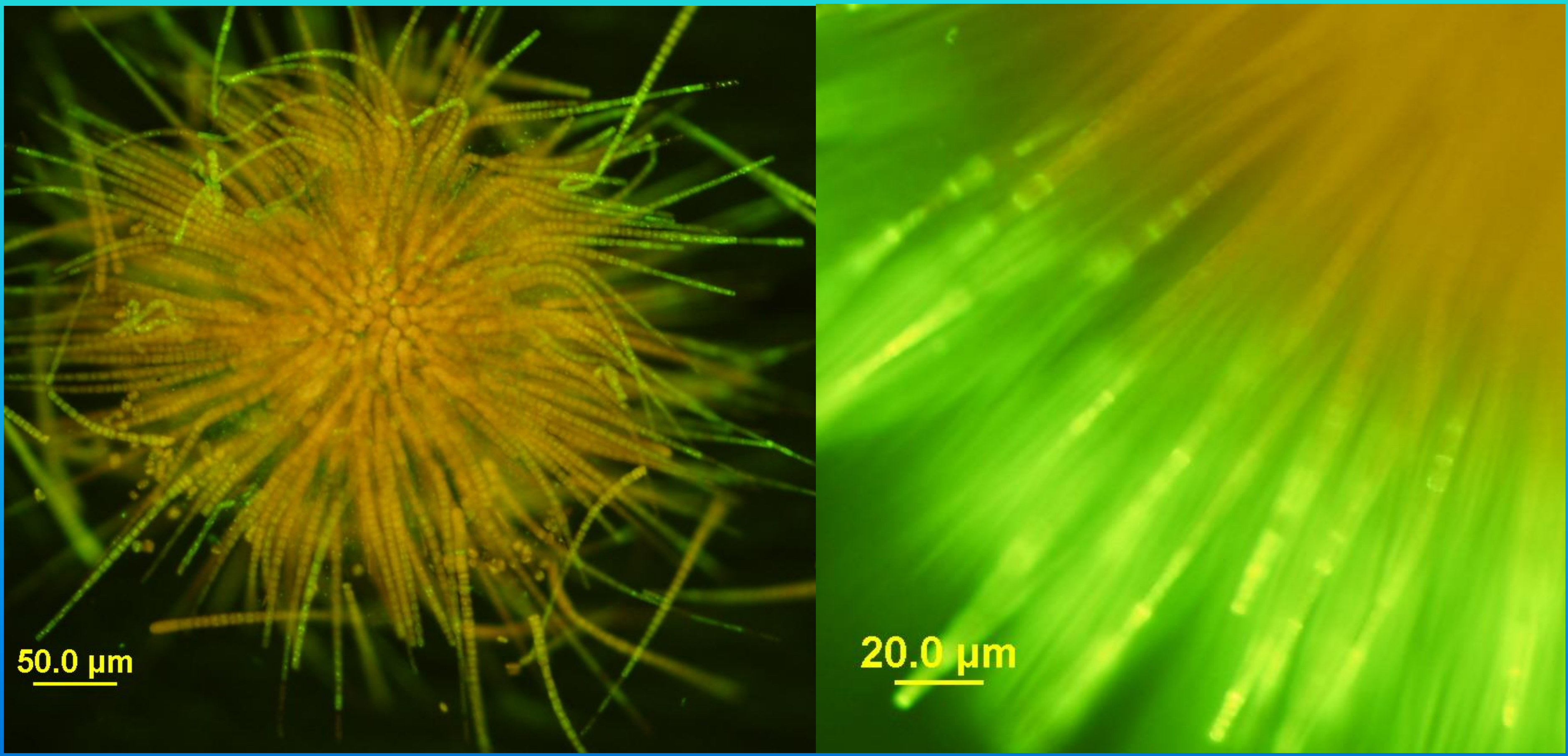


Ecological Strategies: desiccation tolerant (exopolymeric substances-often pigmented)

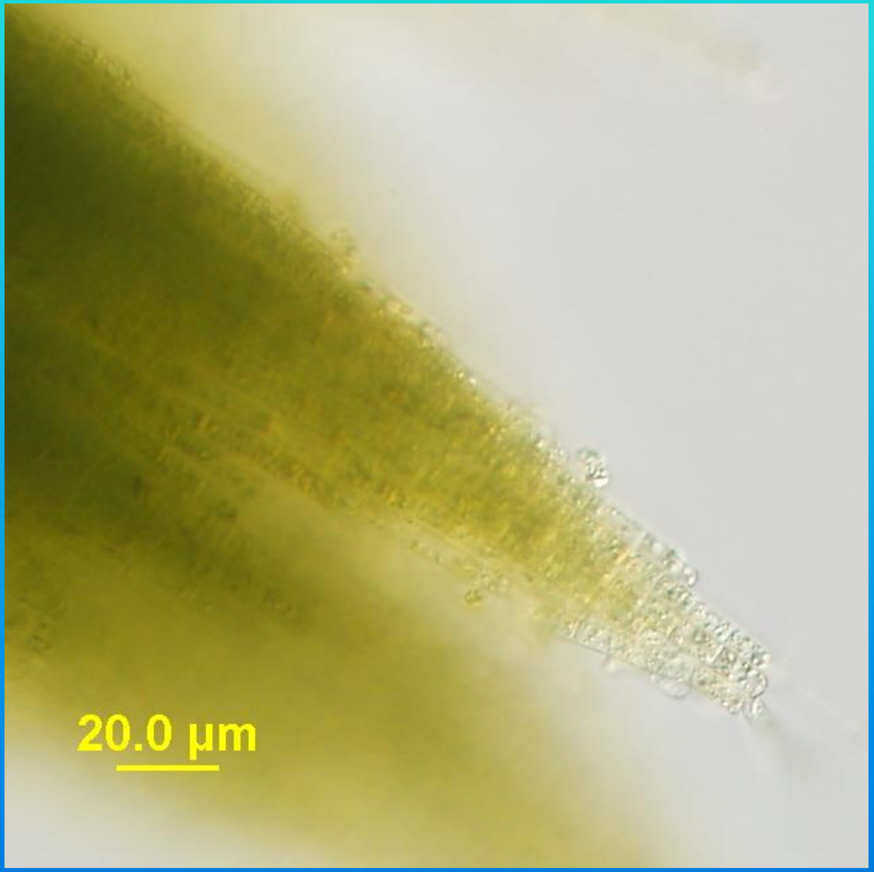




Ecological Strategies: morphology to prevent grazing

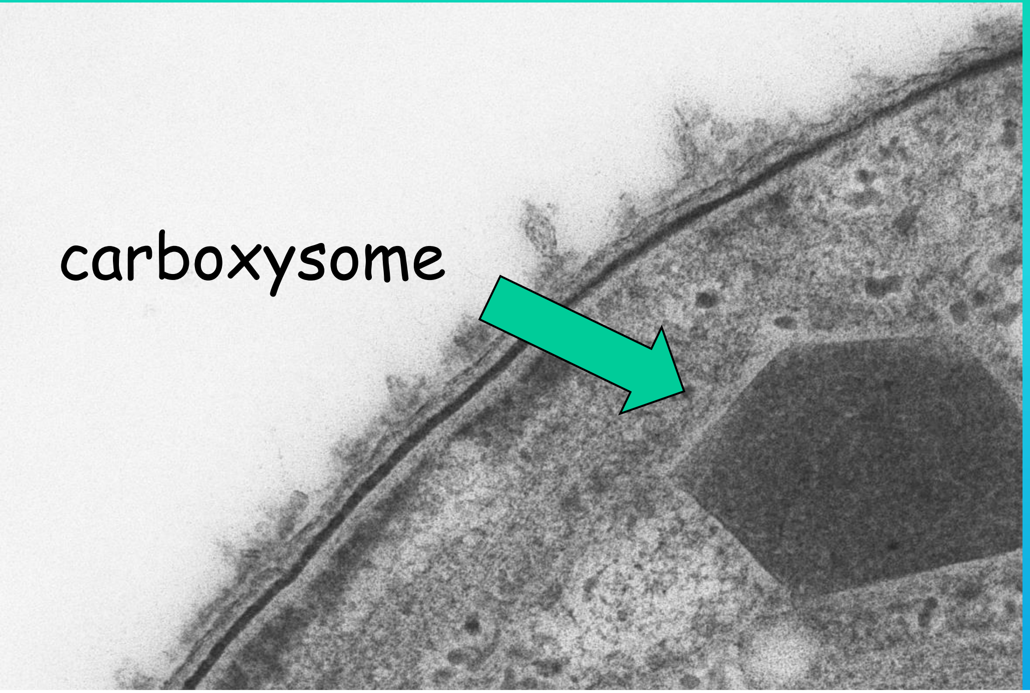


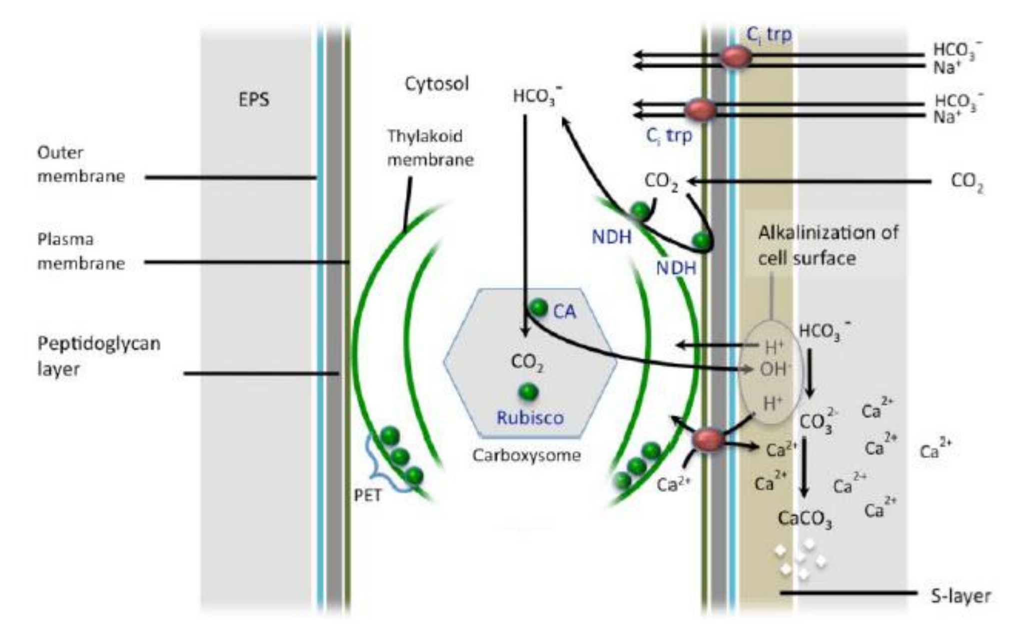
Ecological Strategies: morphology to prevent grazing



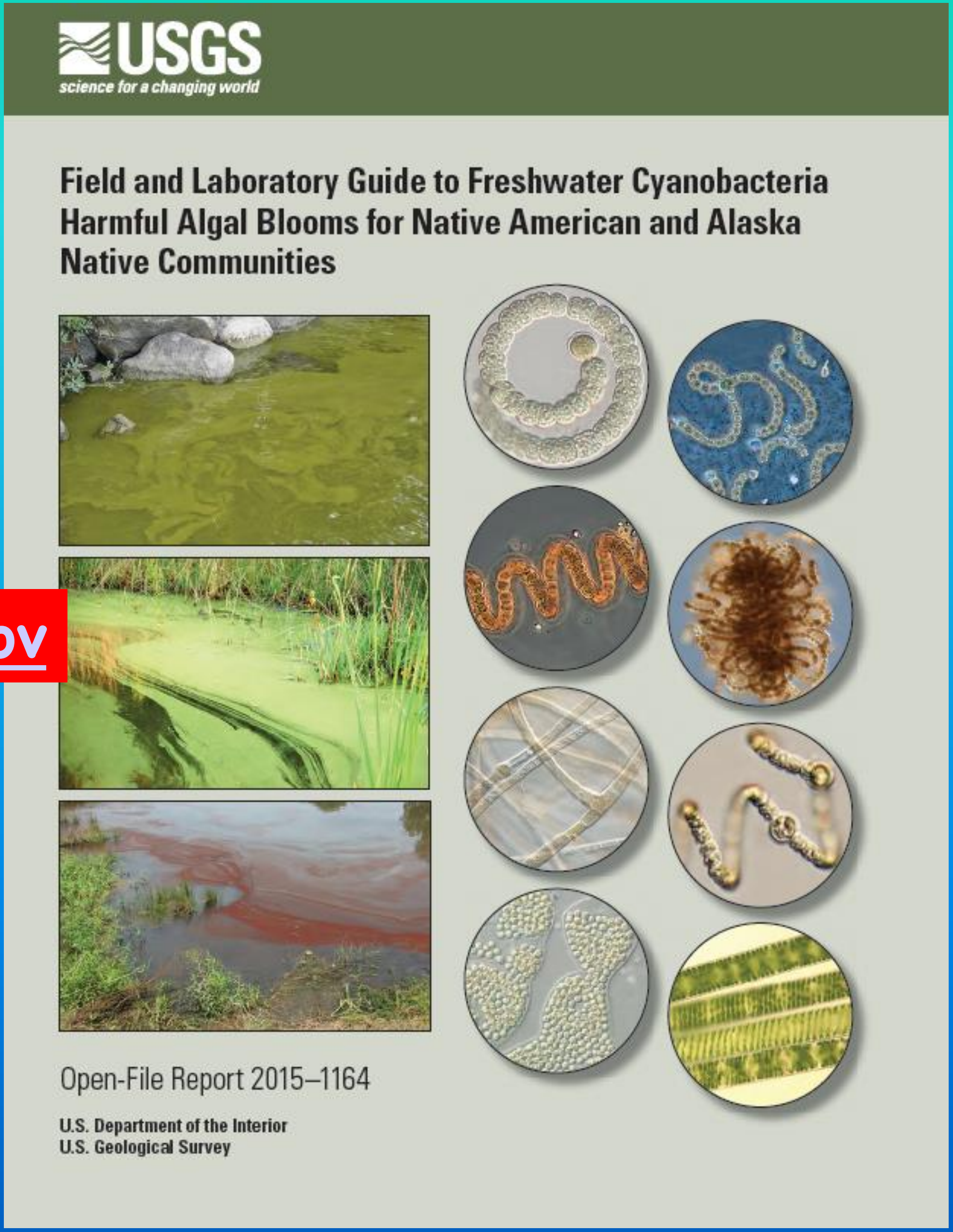
Ecological Strategies: carbon dioxide concentrating mechanism

When bicarboante is limiting, raises the CO_2 using a bio-chemical system that allows the cells to raise the concen-tration at the site of the Rubisco up to **1000-fold** over that in the surrounding medium.





Taxonomy: Initial ID and some of the major players



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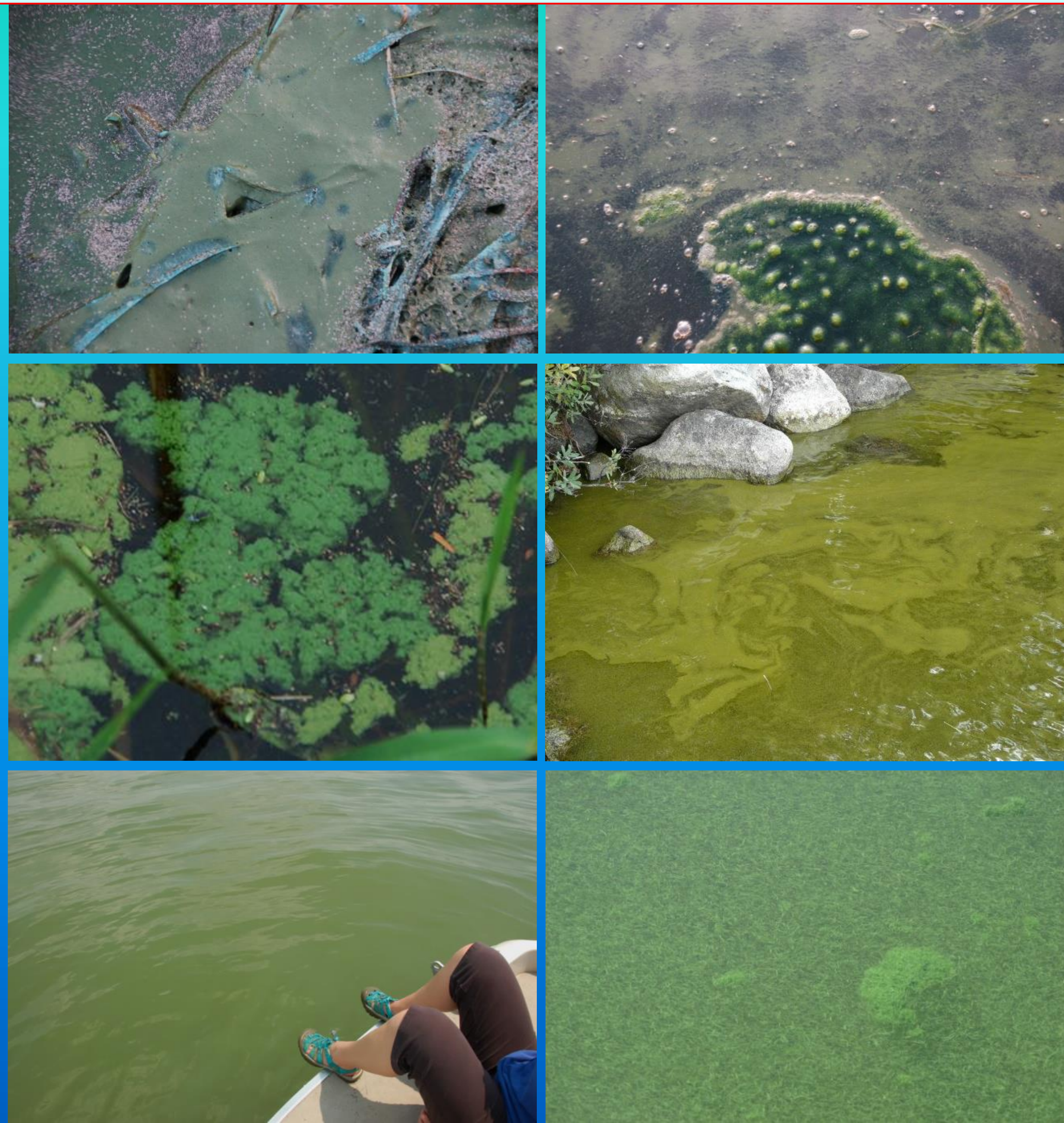
Recognizing a cyanobacteria bloom: field images (blue-green to greenish in color)



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Getting a Sample qualitative

Dense: use a glove!

Not dense: use a plankton net!

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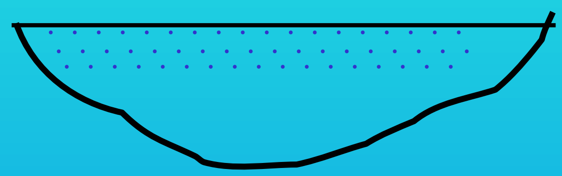
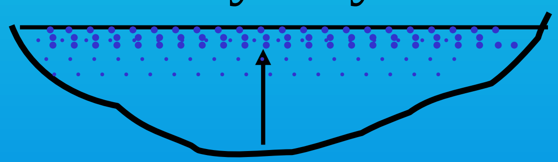
Beware of this phenomenon

initial distribution



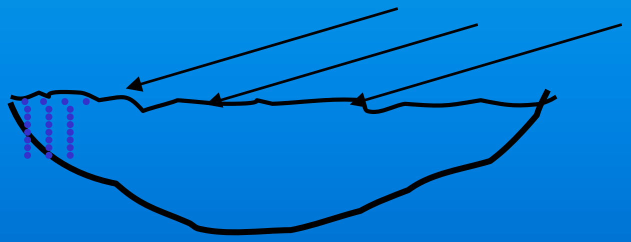
100,000 cells/L;
20 µg/L toxin

buoyancy



10,000,000 cells/L;
2000 µg/L toxin

wind

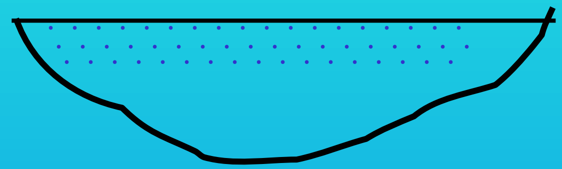


100,000,000 cells/L;
20,000 µg/L toxin

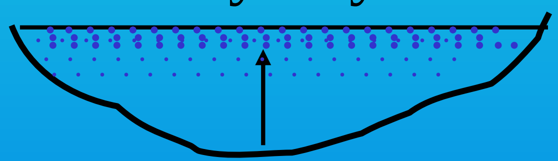
5,000-11,600 µg/kg bw causes liver damage = 2 mg in 10 kg child

Where do I sample?

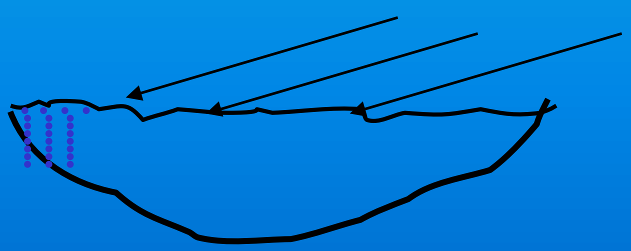
initial distribution

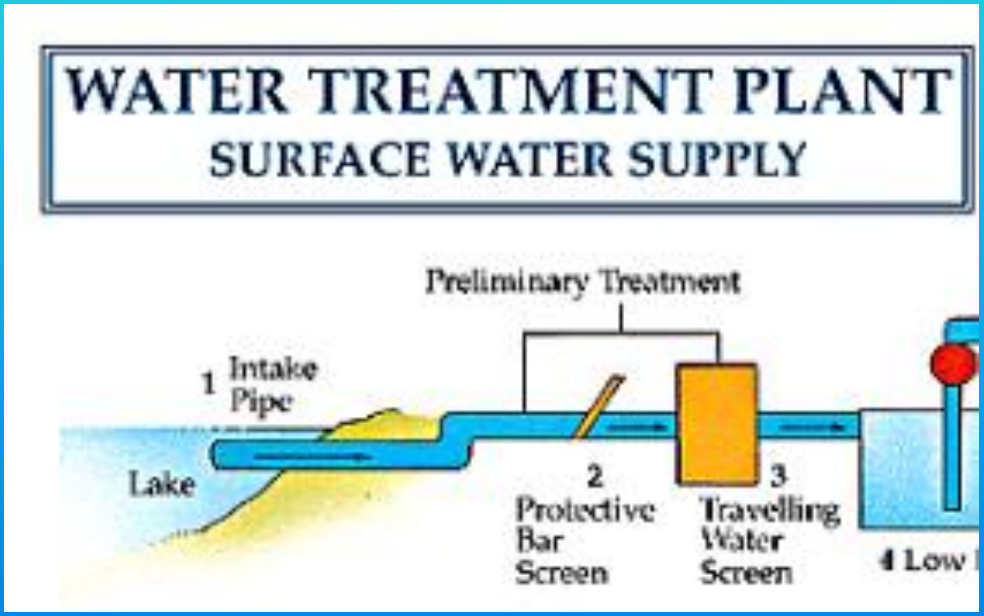


buoyancy



wind





Getting a Sample quantitative

Van Dorn

Depth Integrated Sampling

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How much of a sample and how should I "save" it

1. **Collect 100 mL sample of a bloom <u>live</u>**

   Possible Methods:

   a) A whole water sample by simple immersing a 500 mL bottle (glass or plastic) into a waterbody. The small volume in a large bottle allows for ample gas exchange during shipping.

   b) A plankton tow of a bloom, which concentrates a sample, and a liquid volume of 10 mL in a 100 mL bottle.

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How much of a sample and how should I "save" it

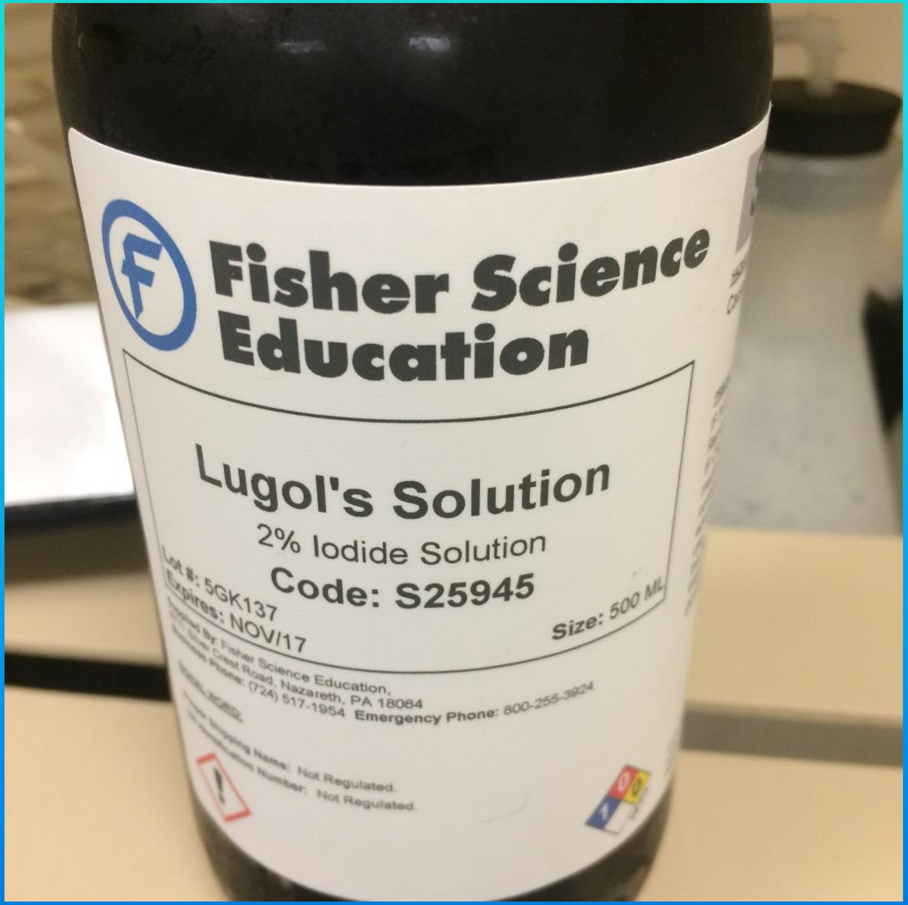
2) Collect 100 mL sample of a bloom, preserved with Lugol's iodine

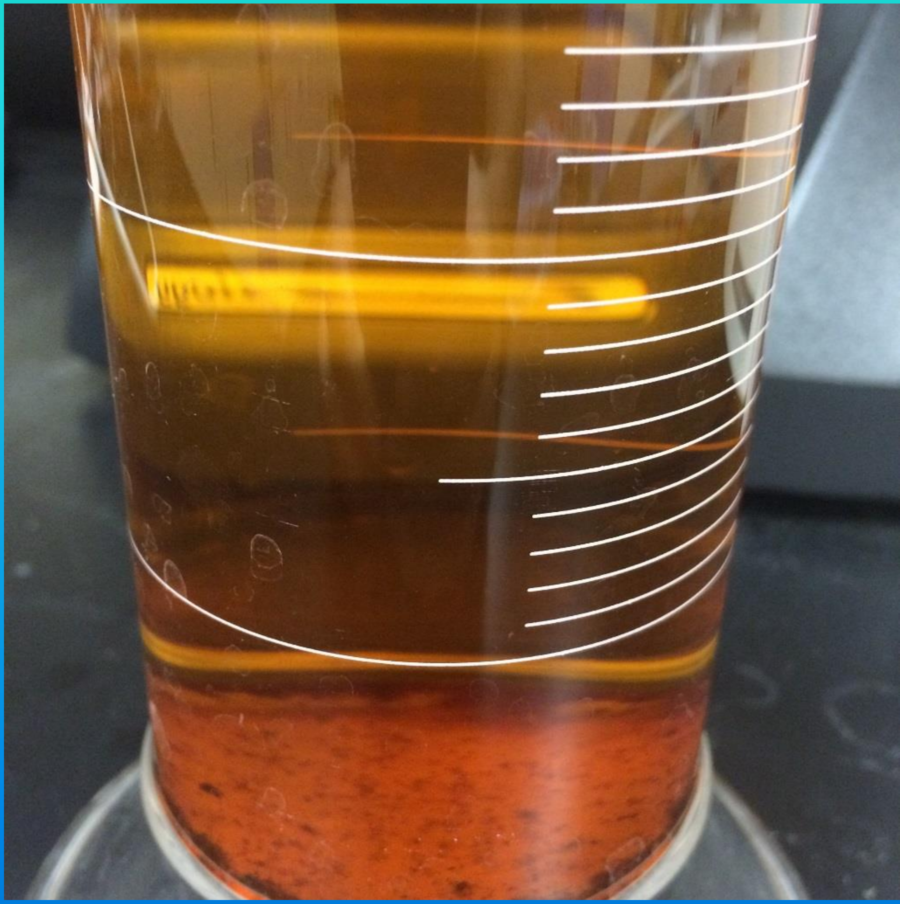
a) same procedures as step 1 to collect the samples

b) add 5% solution of Lugol's to turn the sample the color of tea. (5% (wt/v) iodine (I_2) and 10% (wt/v) potassium iodide (KI) mixed in distilled water and has a total iodine content of 126.5 mg/mL).

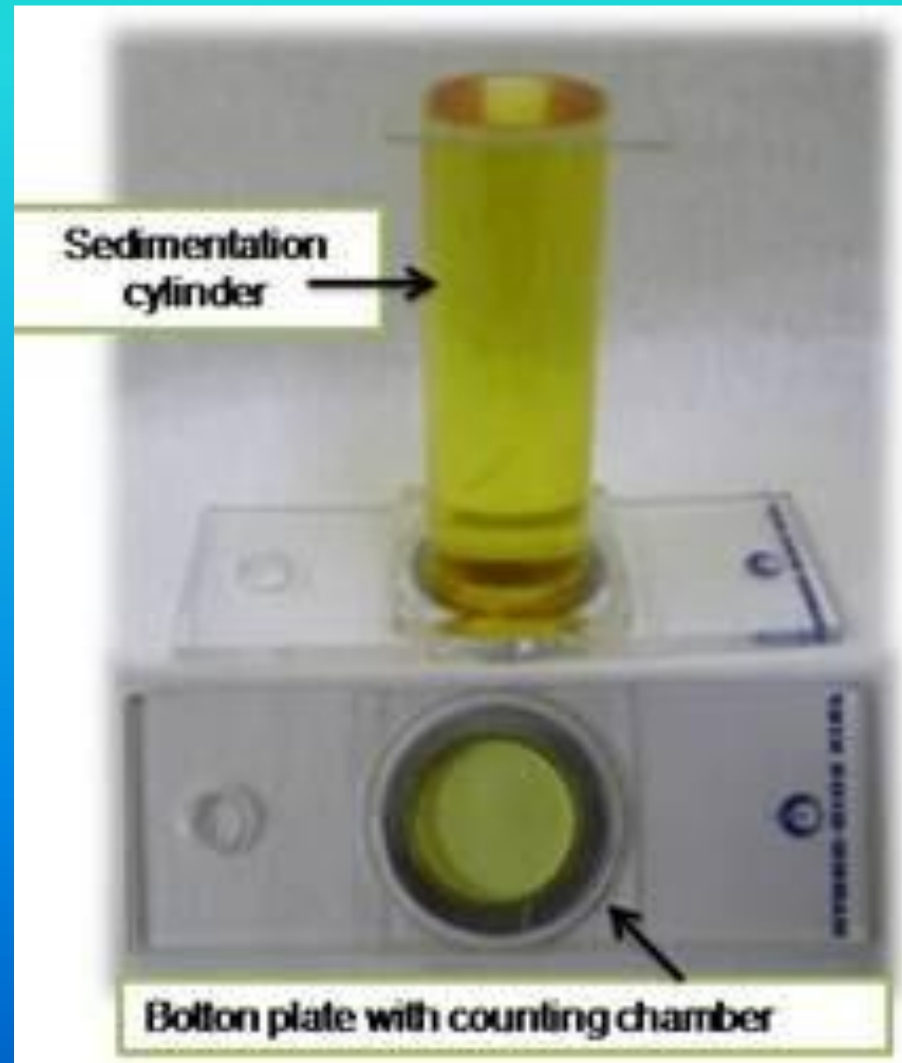
-alternatively, Povidone-iodine can be used.

Lugol's and Settling

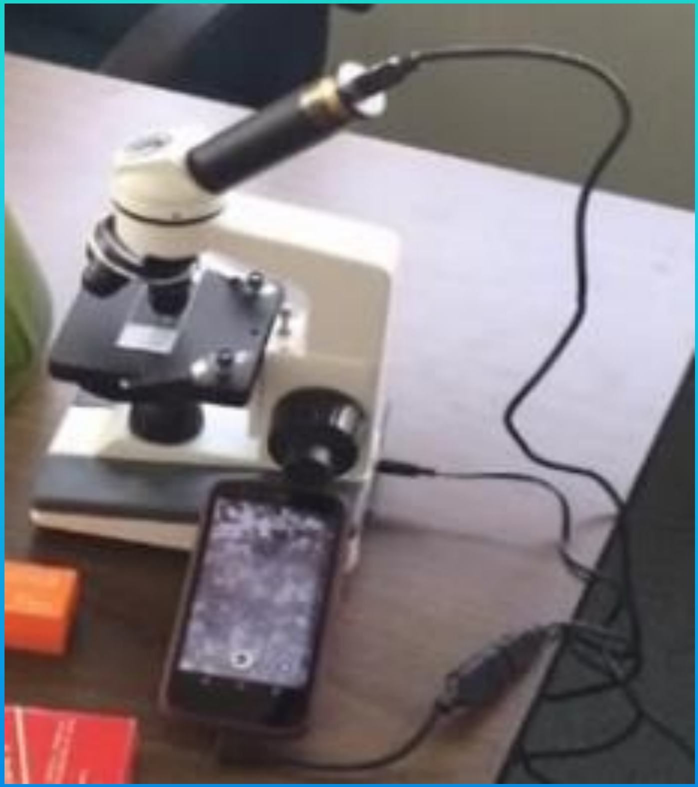




Quantitative Counting

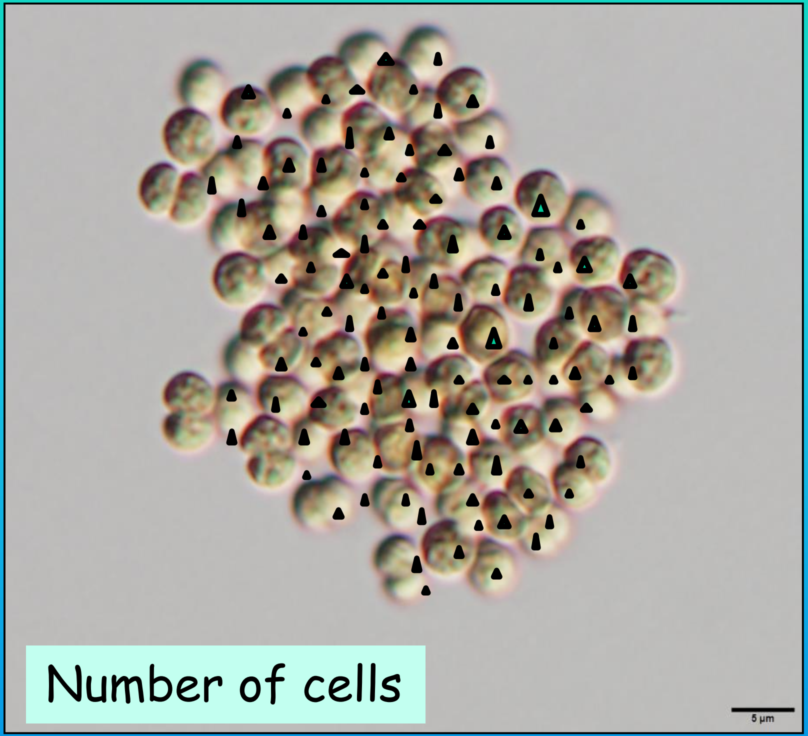


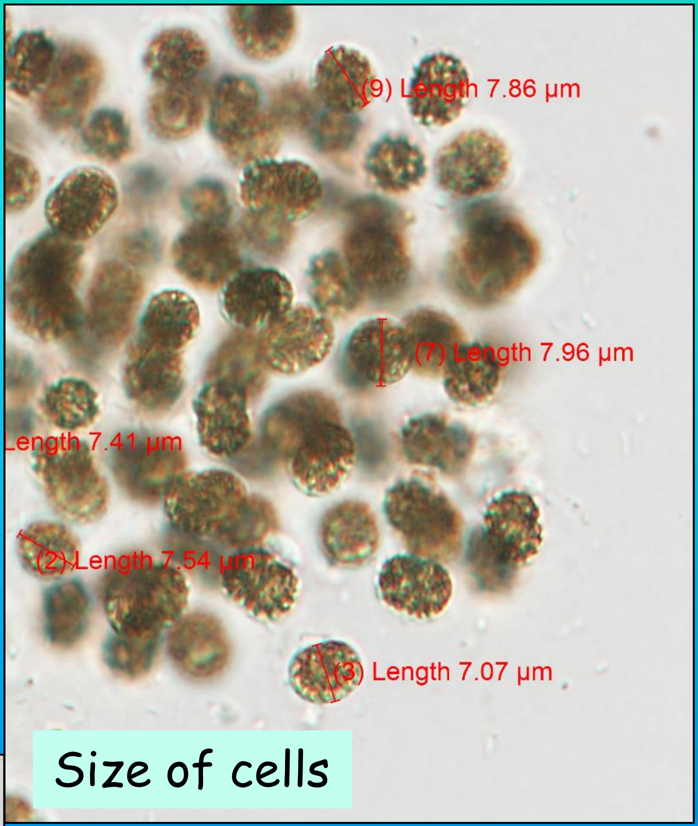
Lab Instruments



USGS
science for a changing world

Biovolume per mL



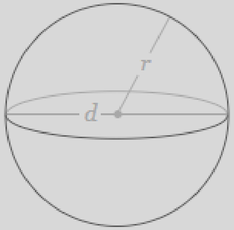


Sphere

Solve for volume

$$V = \frac{4}{3}\pi r^3$$

r Radius Enter value



USGS science for a changing world

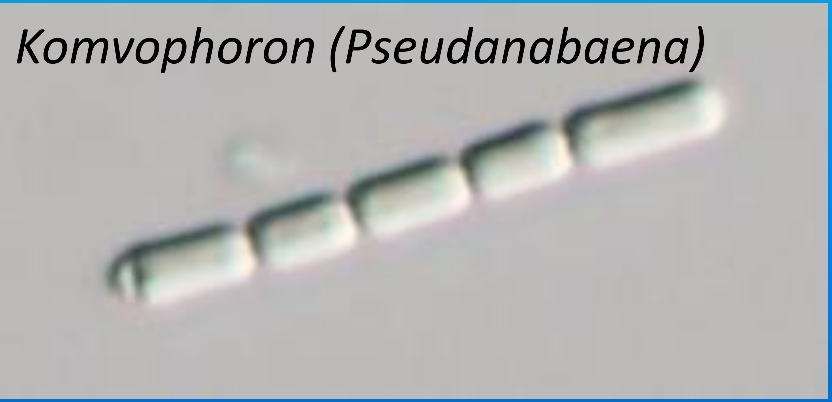
Common Filamentous Cyanobacteria

Lake Mattamuskeet, NC (East and West)

July 22, 2015

Cylindrospermopsis raciborskii **(CYN)**

Chrysosporum ovalisporum **(CYN)**



Komvophoron (Pseudanabaena)

Planktolyngbya contorta **(MYC)**

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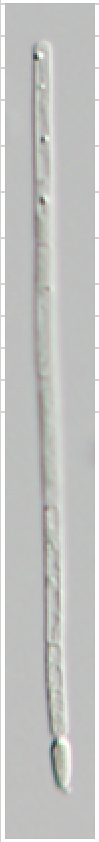
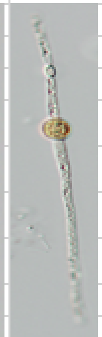
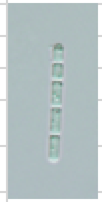
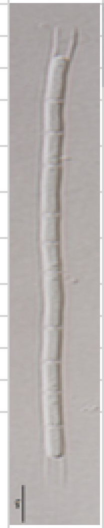
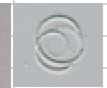
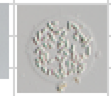
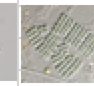
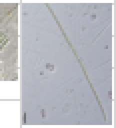









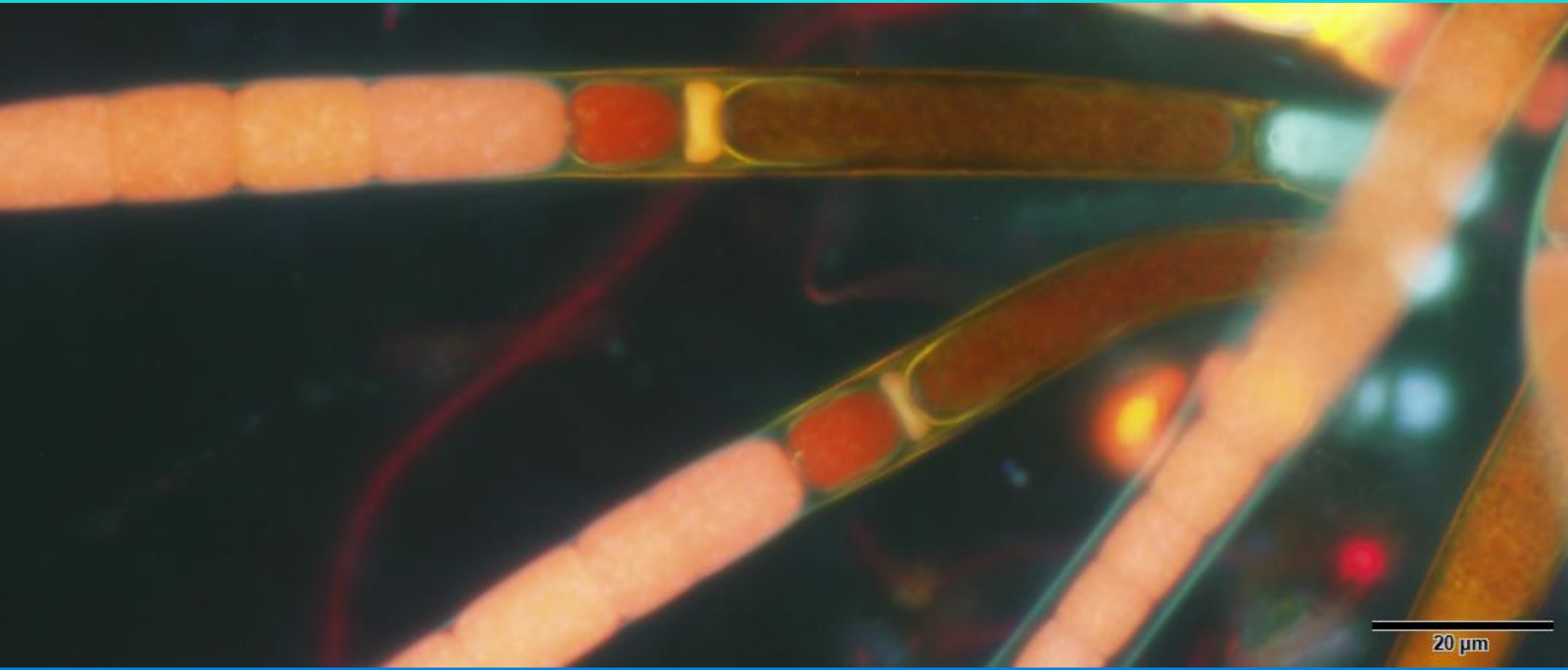



analysis of a sample quantitatively

plankton/ peri	Concentration factor	number of fields	cell count	Cylindrospermopsis raciborskii	Chrysosporum ovalis	Cylindrospermopsis cf. *catemaco*	Komvophoron sp.	Planktothrix limnetica	Planktolyngbya contorta	Romeria sp.	Aphanothece stagnina	Microcystis aeruginosa	Aphanocapsa nibilum	Aphanocapsa sp.	Chroococcus sp.	Snowella sp.	Merismopedia sp.	Sphaerospermopsis aphanizomenoides
plankton	10x	6	311	0	0	4	3	44	127	0	3	1	3	69	0	2	28	0
plankton	10x	6	318	0	0	3	23	32	117	0	3	0	0	71	6	20	14	1
plankton	10x	7	307	9	5	33	17	67	53	1	1	0	0	59	6	14	8	0
plankton	10x	6	343	19	1	41	72	81	38	2	14	1	0	40	0	11	6	0


WARNING
LIFEGUARD,
BACTERIOLOGIST,
MICROBIOLOGIST,
& TOXICOLOGIST
NOT ON DUTY
SWIM AT YOUR
OWN RISK

Thank You!



USGS
science for a changing world

Phytoplankton Monitoring Network (PMN)

Promoting a better understanding of Cyano Harmful Algal Blooms by way of volunteer monitoring.

PMN and Basic Cyanobacteria ID Practice

NOAA Marine Biotoxins Program
Jen Maucher Fuquay, PMN Coordinator

PHYTOPLANKTON MONITORING NETWORK

NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Science Serving Coastal Communities

To educate the public on harmful algal blooms (HABs) while expanding the knowledge of phytoplankton that exist in coastal waters through research based monitoring.

PMN is a national volunteer organization that monitors for potential Harmful Algal Blooms

Train citizen scientists to:

- *Collect samples from coastal or freshwater environments*
- *Identify potentially harmful algal/cyanobacterial species*
- *Enter information into NOAA database*

NOAA scientists can then:

- *Analyze water samples for HAB toxins*
- *Alert state/local agencies to presence of bloom*
- *Identify temporal and geographic HAB trends*

PHYTOPLANKTON MONITORING NETWORK

NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Science Serving Coastal Communities

EPA United States Environmental Protection Agency
Office of Water

- **CyanoHAB monitoring started in 2015 as part of an EPA Office of Water grant**
- **55 sites in 13 states**
- **EPA Regions 4, 5, 7, 8 & 9 currently represented**

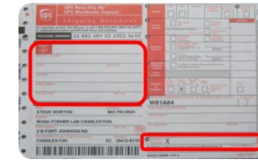
Cherry Creek Reservoir, Denver, CO June 2016
Dolichospermum bloom

Monitoring Benefits

- **Allows for an 'early warning system'**
  - e.g. Can close shellfish beds/recreational waters and help prevent or reduce exposure and potential illness
- Monitor and maintain an extended survey area along coastal & fresh water bodies throughout the year
- Create a comprehensive list of harmful algal/cyano species inhabiting marine and fresh waters (establish baseline)
- Identify general trends where HABs are more likely to occur
- Promote an increased awareness and education to the public on HABs
- Create a working relationship between volunteers and researchers

Volunteer Equipment

Volunteers are loaned all sampling equipment



- Thermometer
- 5 gridded slides
- Cover slips
- 1L & 125 mL bottles
- 30 mL of Lugol's solution for sample preservation
- Pre-paid overnight shipping label and shipping envelopes

*Identification sheets for target species

Volunteer Equipment (freshwater)

SWIFT M10 T digital microscope

- **Provided to Pilot Program participants**
- **Volunteers take digital pictures of suspected target species and send to PMN**
- **Allows for rapid confirmation of tentative ID**
- **Build virtual archive of organisms observed**
- **WiFi capable- Great for public demonstrations**

Training

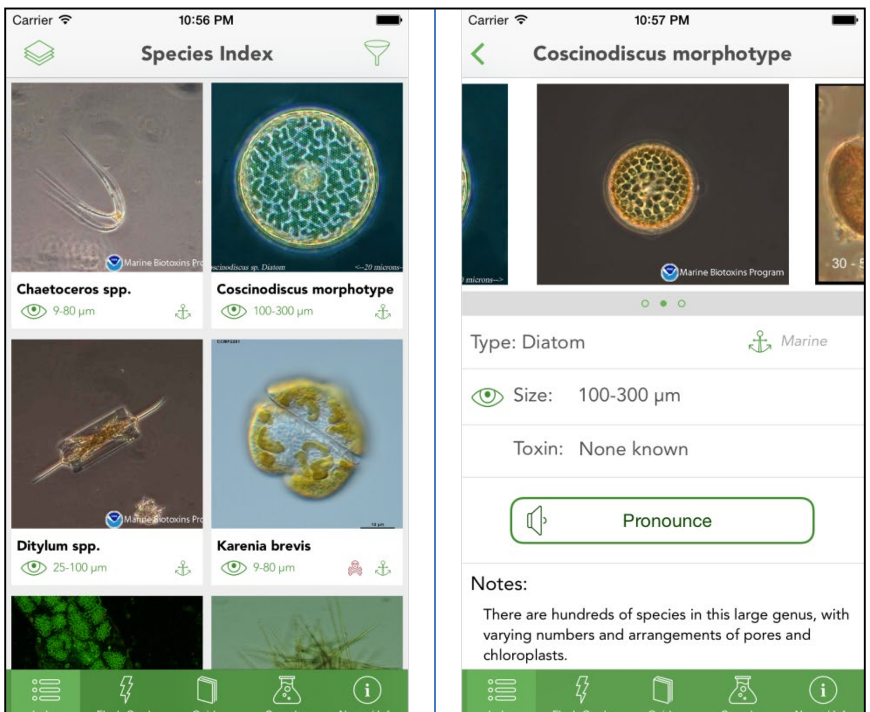
- Usually done remotely
- Background of algae/cyanos
- What puts the H in HAB?
- Sampling protocols
- How to ID Target species

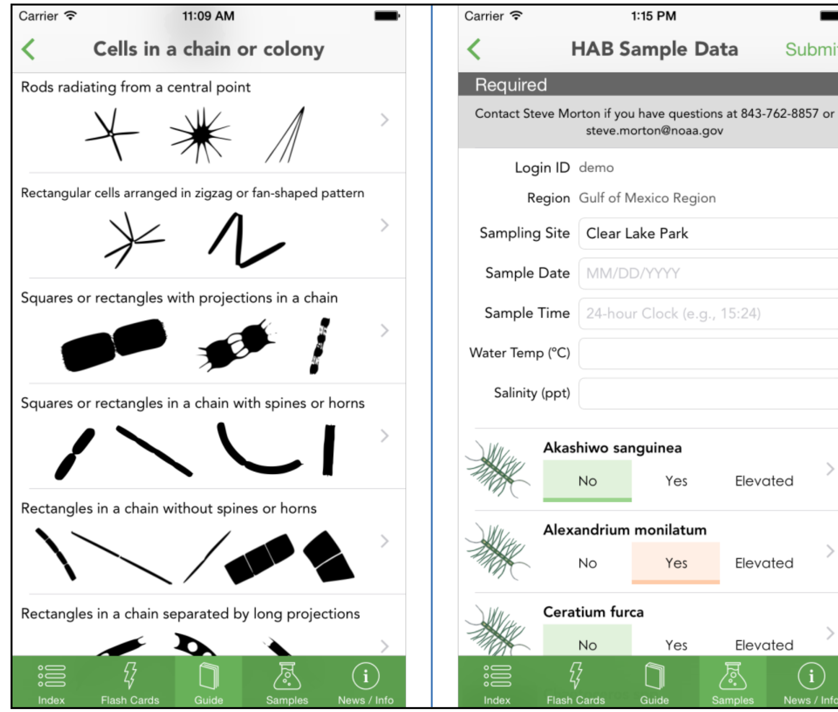
Training

- Volunteers must do practice sampling
- IDs are confirmed by PMN staff via photos and/or mailed in samples

Phyto app version 2- *Now Live!*

-Includes freshwater species!
-More pictures!
-More pronunciations!
-Can enter data from iPhone or iPad!
(sorry Android users… not quite ready yet!)





http://youtu.be/ItzxoB06De0

Developed by PMN volunteer Shawn Gano to assist with and improve volunteer's identification skills of marine algae & cyanos

Phytoplankton Monitoring Network

Volunteer Requirements:

1) ***Collect sample*** at least once every two weeks during the sampling season
2) ***Analyze sample*** identifying target algae/cyanos
3) ***Take*** digital pictures to send into the PMN
4) ***Input*** data into the PMN database
5) ***Ship*** sample to PMN as required

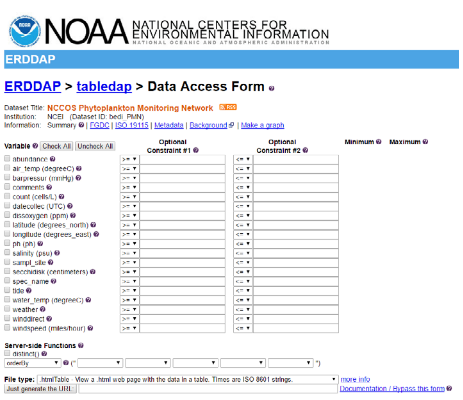
DATA ENTRY

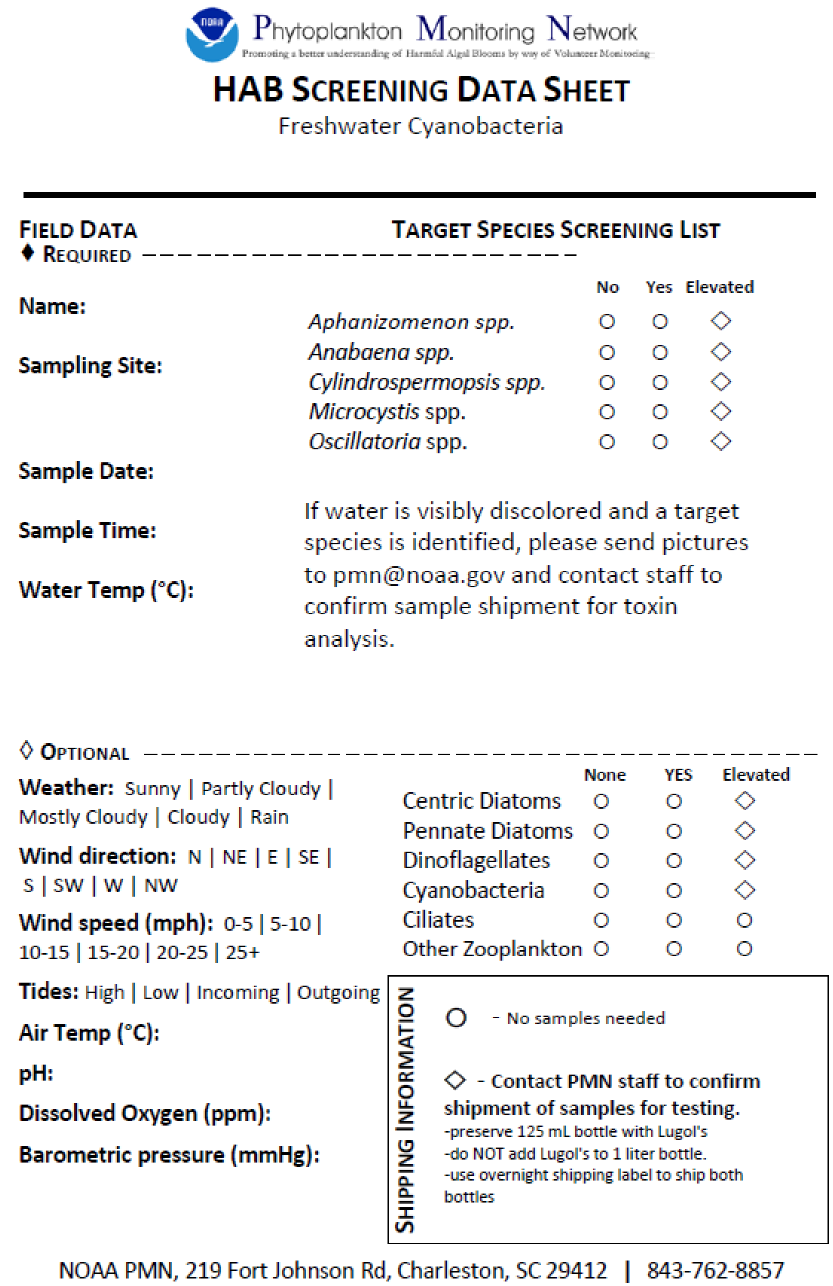
- **Data entered online for each sample**
  - Whether target spp. found or not
- **No counting of cells**

  No= zip, zilch, zero

  Yes= 0-65% slide coverage

  Elevated = >65% with discoloration
- **Final data entered into NCEI BEDI database**





Phytoplankton Monitoring Network

Promoting a better understanding of Harmful Algal Blooms by way of Volunteer Monitoring

HAB SCREENING DATA SHEET

Freshwater Cyanobacteria

FIELD DATA

♦ REQUIRED

Name:

Sampling Site:

Sample Date:

Sample Time:

Water Temp (°C):

TARGET SPECIES SCREENING LIST

	No	Yes	Elevated
Aphanizomenon spp.	○	○	◇
Anabaena spp.	○	○	◇
Cylindrospermopsis spp.	○	○	◇
Microcystis spp.	○	○	◇
Oscillatoria spp.	○	○	◇

If water is visibly discolored and a target species is identified, please send pictures to pmn@noaa.gov and contact staff to confirm sample shipment for toxin analysis.

◊ OPTIONAL

Weather: Sunny | Partly Cloudy | Mostly Cloudy | Cloudy | Rain

Wind direction: N | NE | E | SE | S | SW | W | NW

Wind speed (mph): 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25+

Tides: High | Low | Incoming | Outgoing

Air Temp (°C):

pH:

Dissolved Oxygen (ppm):

Barometric pressure (mmHg):

	None	YES	Elevated
Centric Diatoms	○	○	◇
Pennate Diatoms	○	○	◇
Dinoflagellates	○	○	◇
Cyanobacteria	○	○	◇
Ciliates	○	○	○
Other Zooplankton	○	○	○

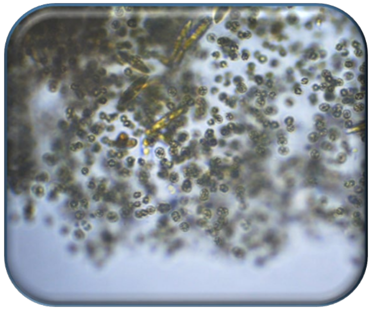
SHIPPING INFORMATION

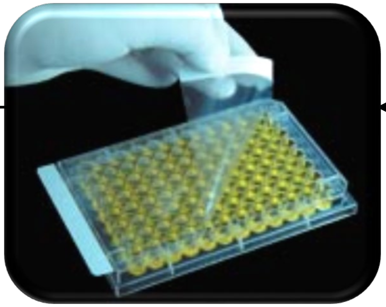
○ - No samples needed

◇ - **Contact PMN staff to confirm shipment of samples for testing.**
-preserve 125 mL bottle with Lugol's
-do NOT add Lugol's to 1 liter bottle.
-use overnight shipping label to ship both bottles

NOAA PMN, 219 Fort Johnson Rd, Charleston, SC 29412 | 843-762-8857

When a bloom is reported

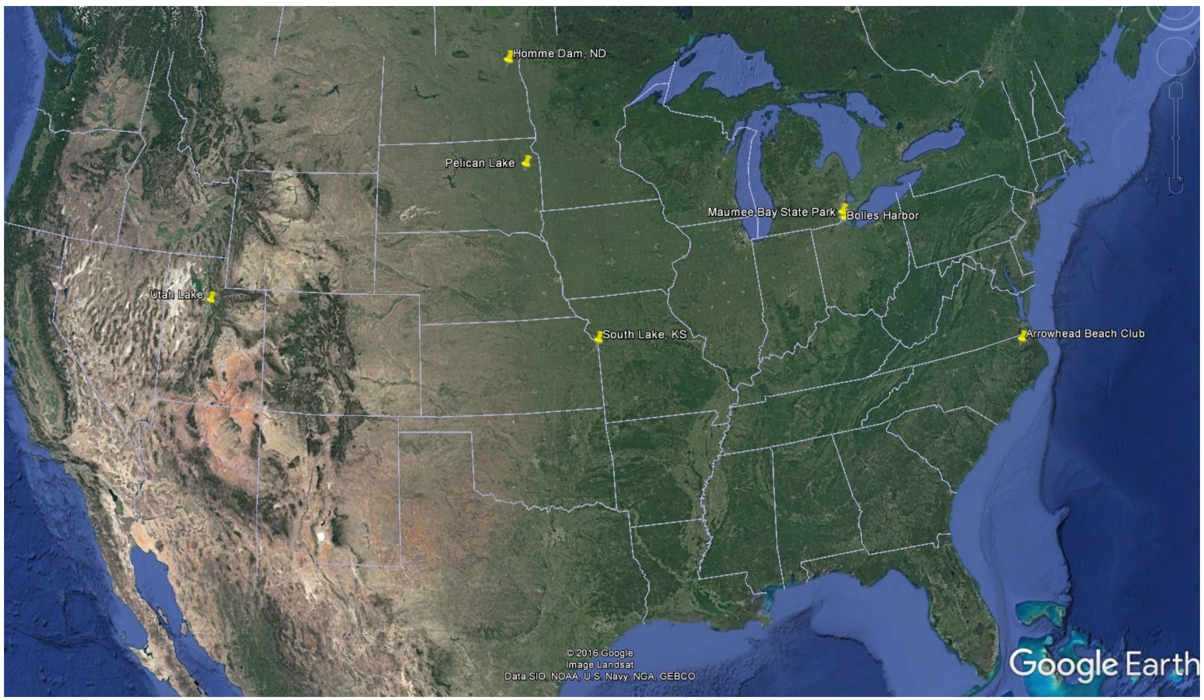




Managers
Stakeholders

Phytoplankton Monitoring Network

Freshwater
Bloom Events 2016



Volunteer Reported Blooms = 7

Potentially toxic species = 4

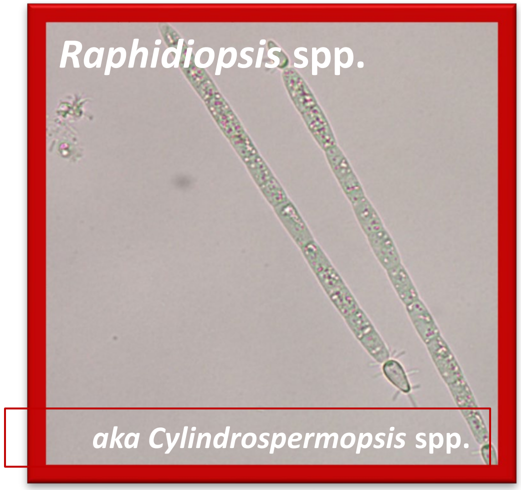
Confirmed toxic events = 4

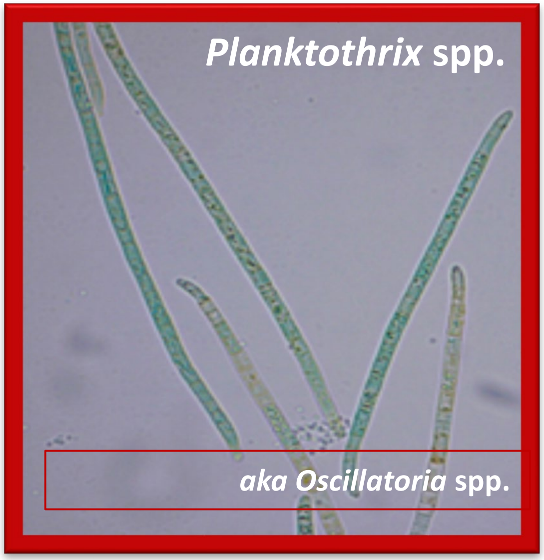
- Microcystis (MI/OH, MN)
- Aphanizomenon (ND)
- Dolichospermum (CO)

Non-Toxic blooms

- Anabaena/Dolichospermum
  - MN = 1
  - NC = 1
  - Kansas = 1
  - Utah=1
- Aphanizomenon
  - MN, NC
- Planktothrix/Oscillatoria
  - KS, MN
- Microcystis
  - MN, NC

Target Freshwater Algae





Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring, and management, World Health Organization, 1999

Funding partners

Many thanks to Andrew Chapman at Greenwater Labs for supplying cultures for todays demo

Morphology basics

Aerotopes- gas vesicles

Akinete(s)- thick walled resting spore

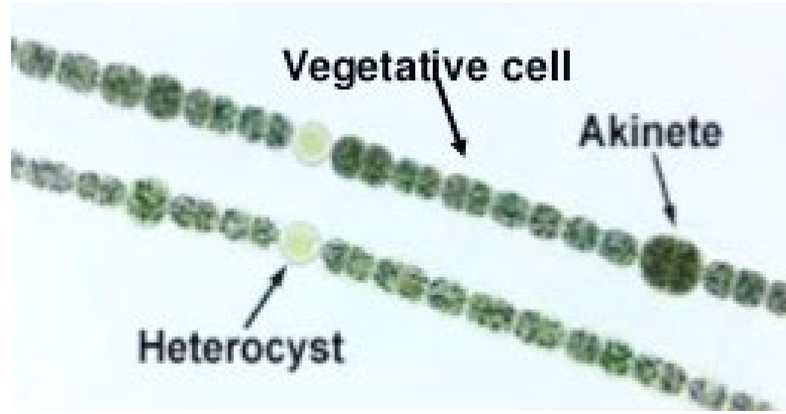
Heterocyte(s)- site of nitrogen fixation; also thick walled but clear

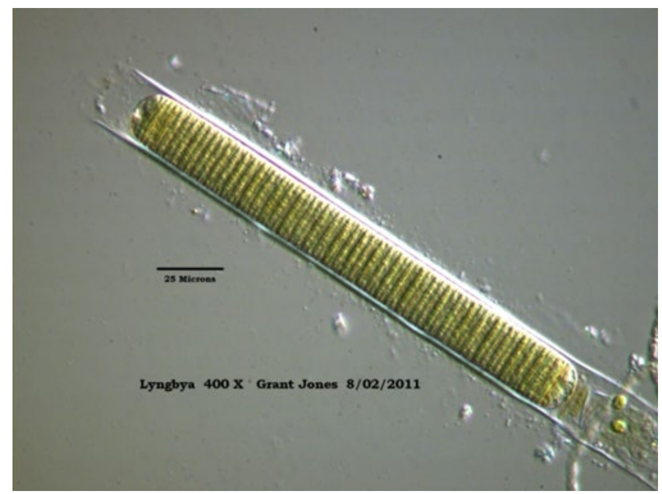
Trichome(s)- a row of cells which are connected

Unbranched- trichome does not have offshoots

Untapered- cells at end of trichome are generally same size as rest of cells

Sheath- outer covering of entire trichome made of polysaccharides



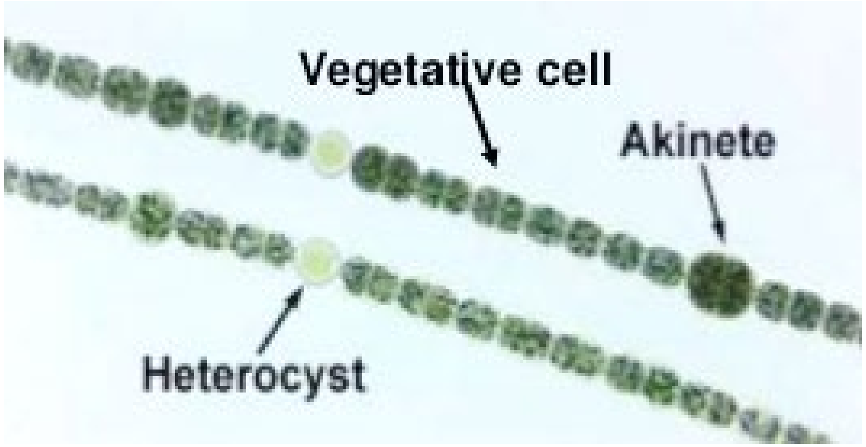


N-Fixer

Dolichospermum spp.

Anabaena has now been re-classified by some as *Dolichospermum*

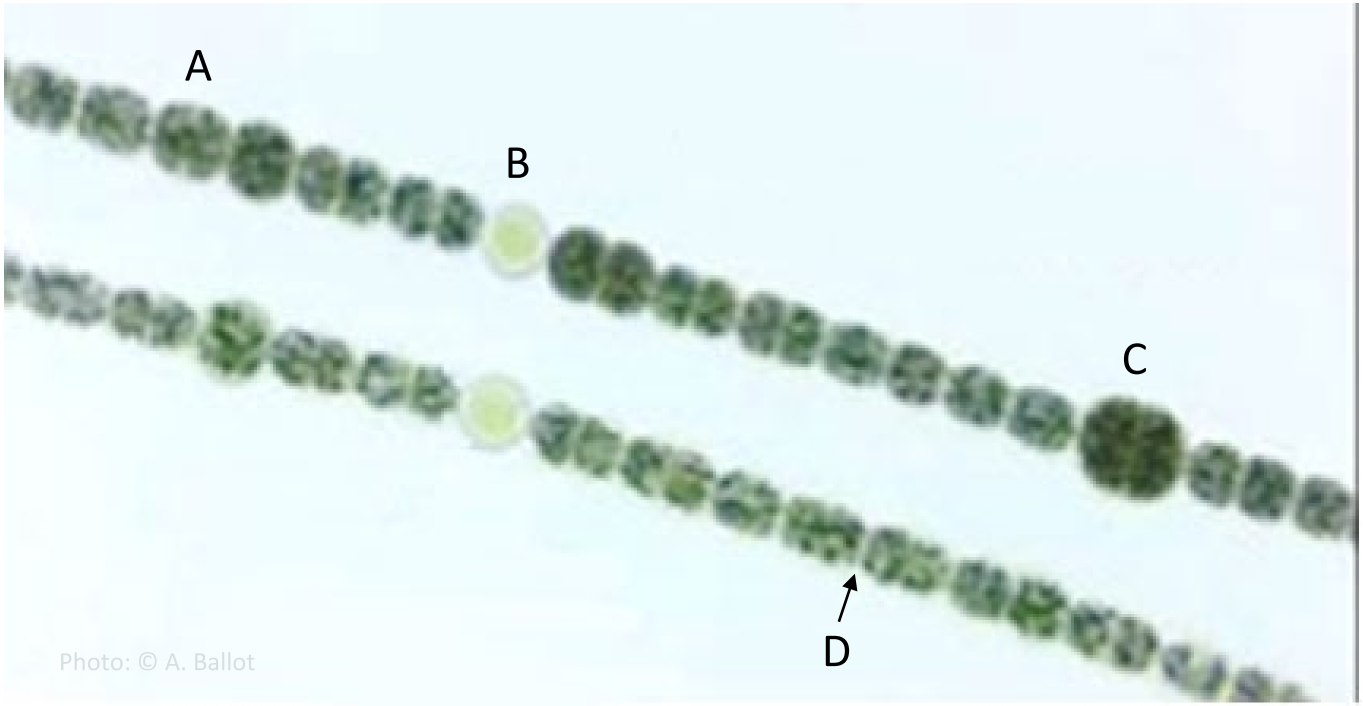
- Filamentous
- Unbranched & untapered
- Trichomes usually solitary
- No sheath*
- Can be straight, curved or spirally coiled



DOLICHOSPERMUM

Things to look for:

A. Cells rounded or barrel shaped with aerotopes
B. Heterocytes are intercalary
C. Akinetes are intercalary
D. Cells constricted at cross walls

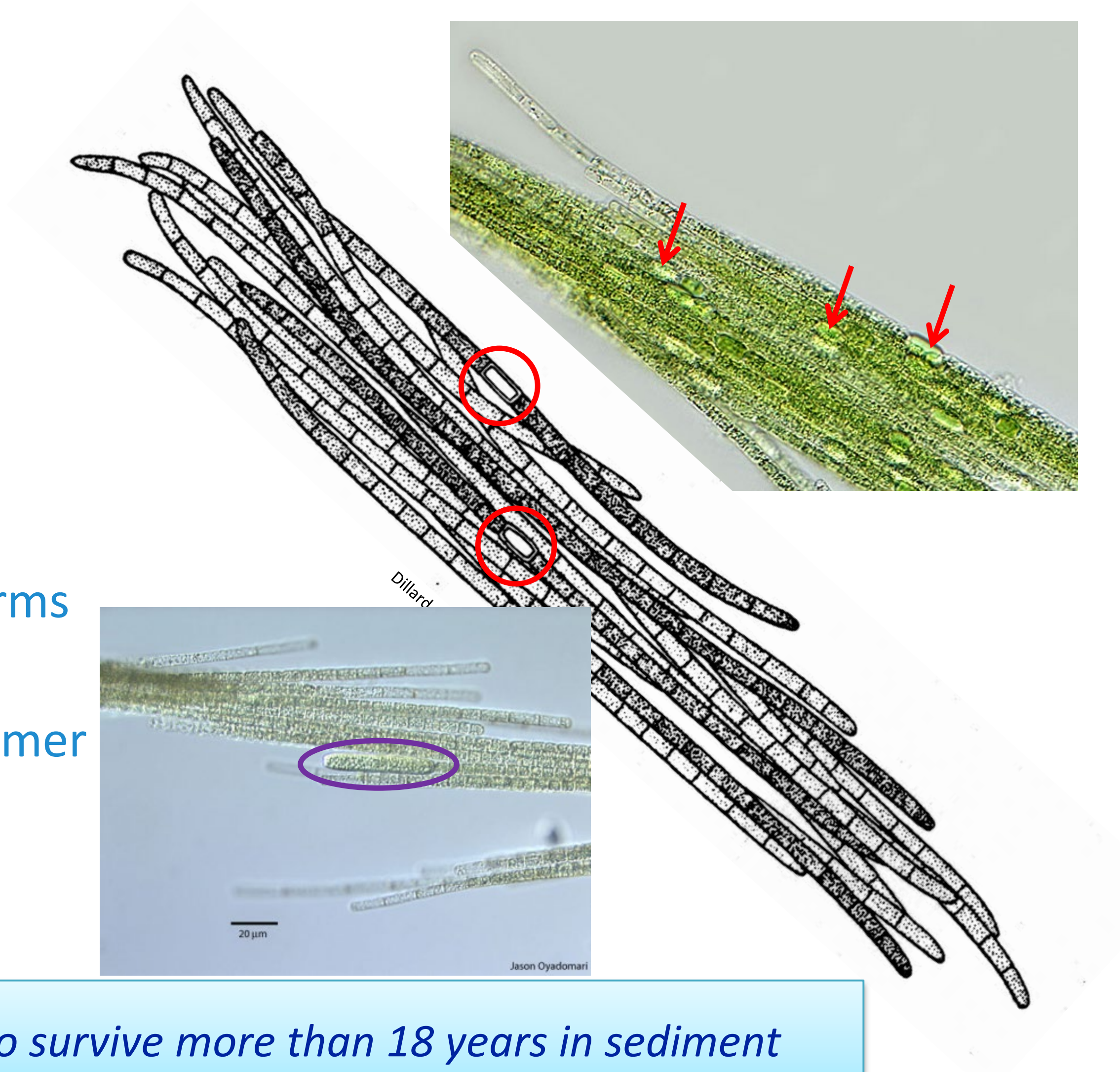


Aphanizomenon spp.

N-Fixer

Approximately 15 known species

- Filamentous, straight, unbranched trichomes
- Tapered at both ends
- No sheath
- Trichomes arranged in parallel layers.
- Has heterocysts and forms akinetes
- Can form winter & summer blooms



Akinetes known to survive more than 18 years in sediment

Aphanizomenon

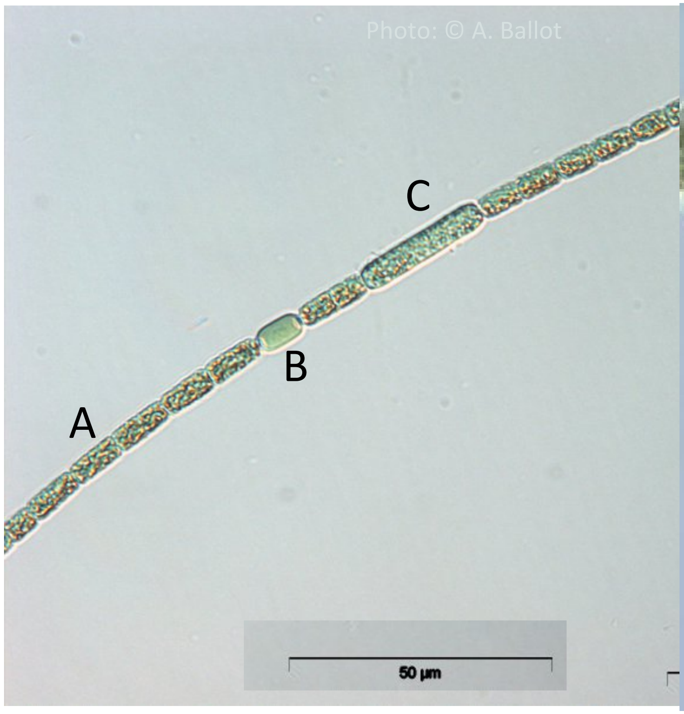
Things to look for:

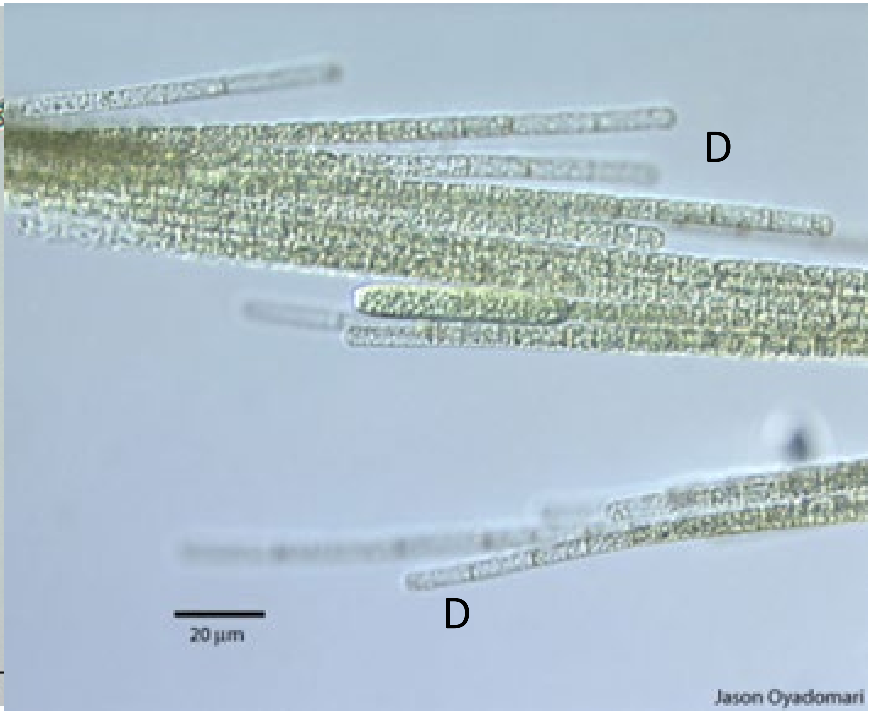
A. Aerotopes (facultative)

B. Heterocytes are intercalary (facultative)

C. Akinetes usually cylindrical and intercalary

D. Terminal ends are elongated and may be "empty" looking



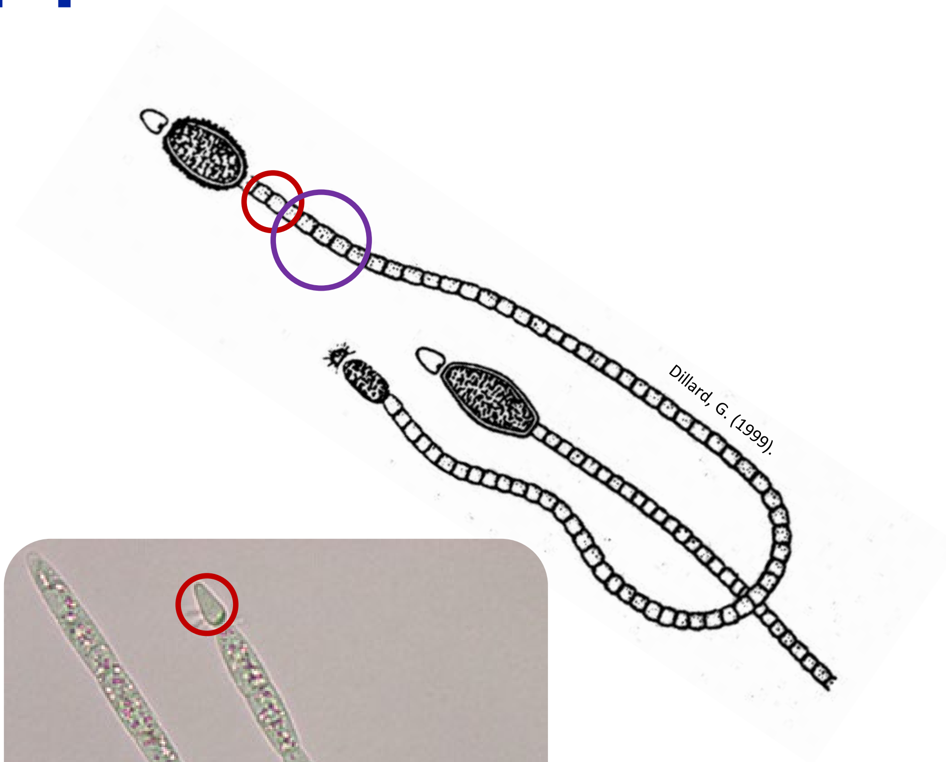


Raphidiopsis spp.

N-Fixer

Cylindrospermopsis has now been re-classified as *Raphidiopsis*

- Filamentous, unbranched
- Trichomes are straight, curved or coiled; solitary
- No sheath
- Heterocysts always terminal!
- Akinetes form behind or slightly distant from heterocysts (gives asymmetric appearance)



RAPHIDIOPSIS

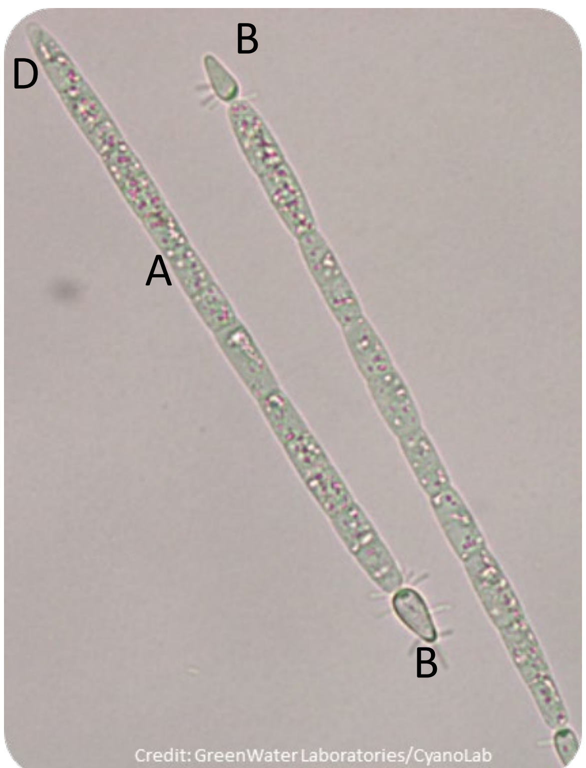
Things to look for:

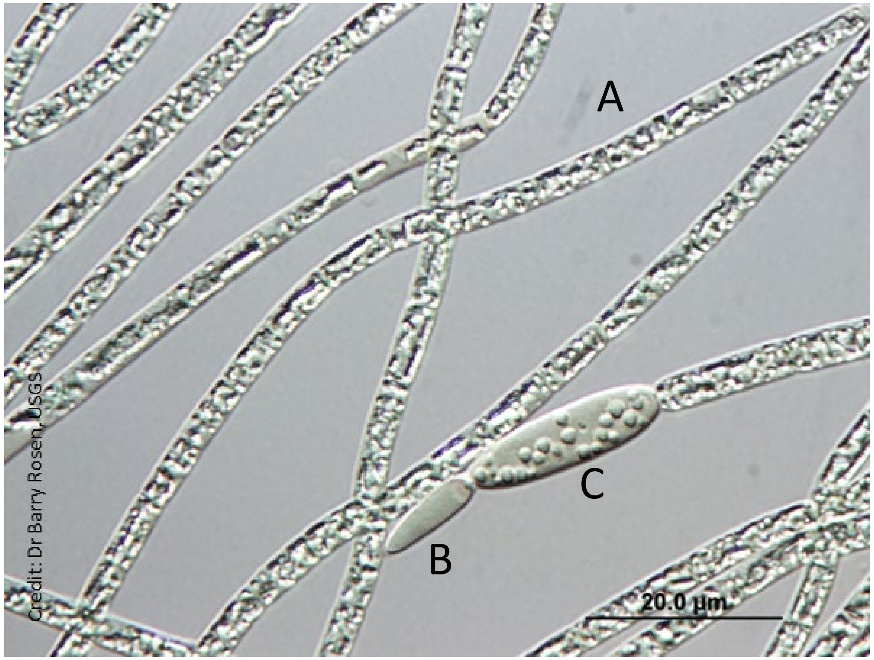
A. Cells cylindrical with aerotopes

B. Heterocytes (when present) are always terminal at one or both ends

C. Akinetes (when present) usually 1-3 cells back from heterocytes

D. Terminal cells conical or pointy when lacking heterocyte(s).



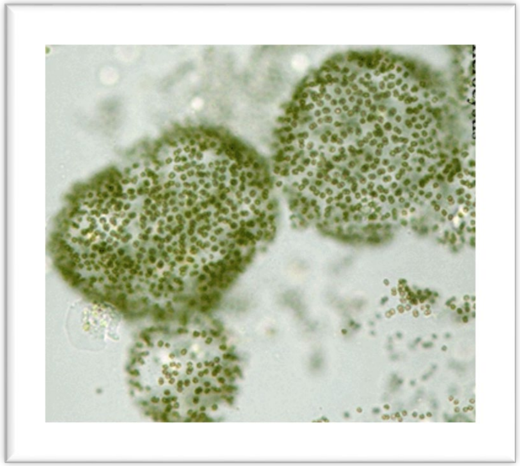


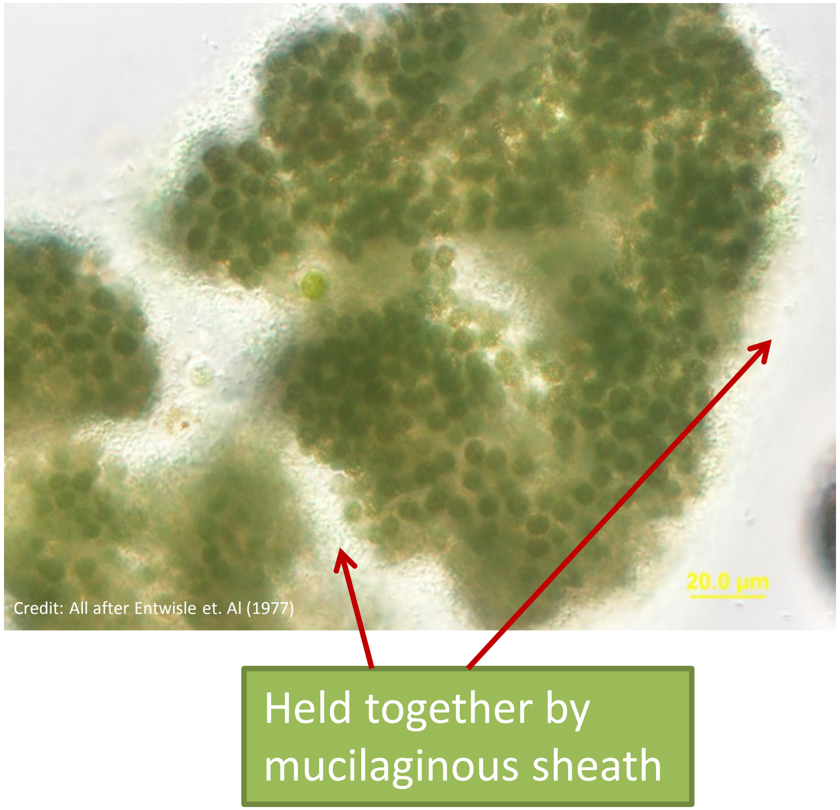
Freshwater Cyanobacteria

Microcystis spp.

Approximately 25 known species

- Colonial
- Unicellular but held together by snotty sheath
- Colonies are irregular, cloud-like (3D) with hollow spaces
- Buoyant due to gas vesicles
- Smells bad!
- Zebra mussels selectively reject Microcystis cells





Microcystis

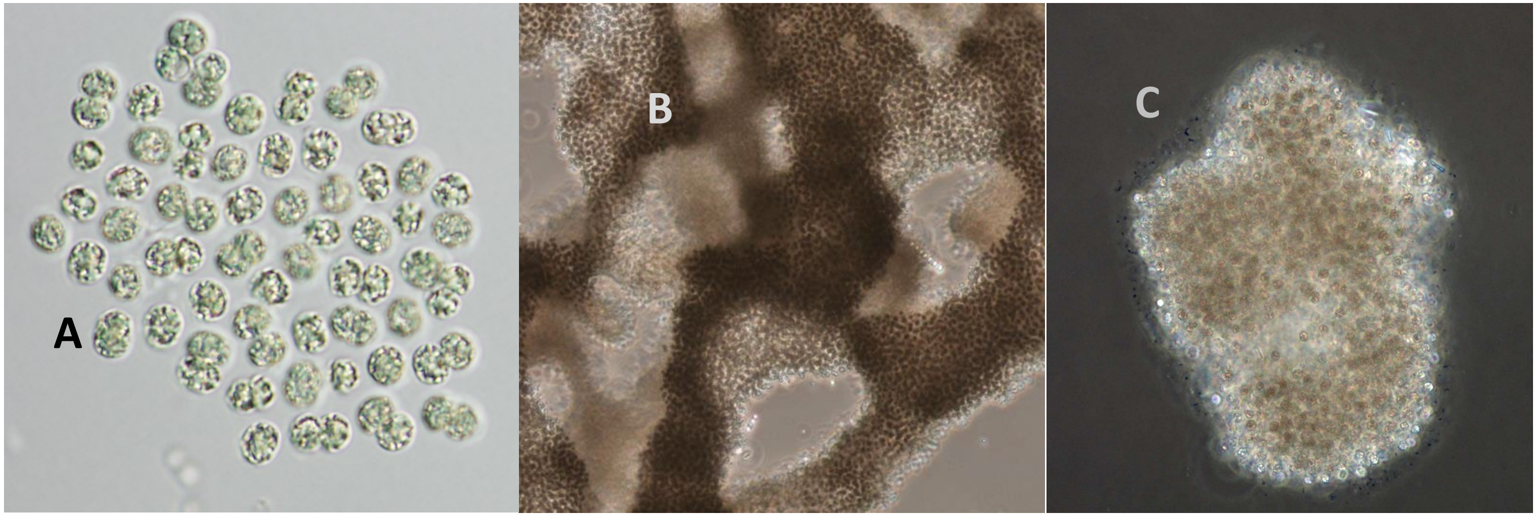
Things to look for:

A. Rounded cells with aerotopes

Cells in colony may be

- A. loosely associated
- B. clathrate
- C. densely packed

Mucilage can vary in thickness

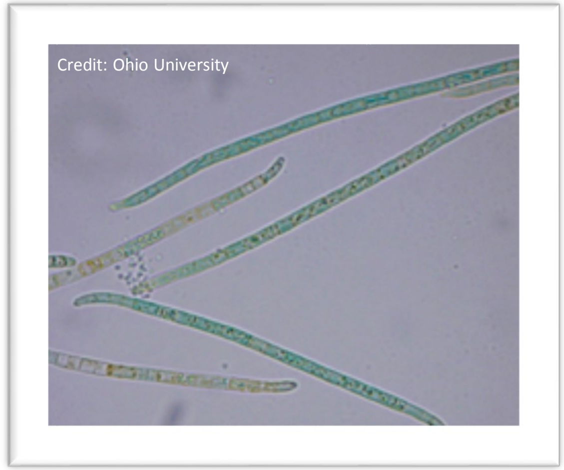


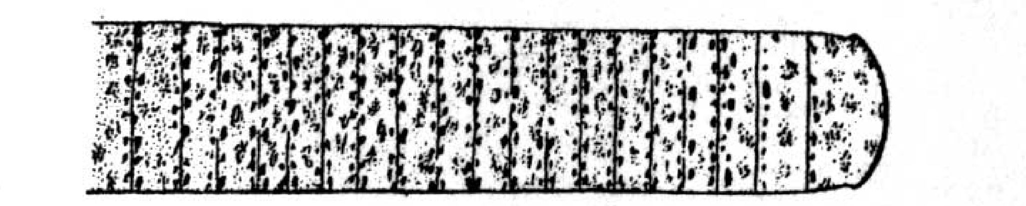
Planktothrix morphotype

More than 100 known species

Formerly classified as Oscillatoria

- Filamentous, unbranched
- Trichomes cylindrical, straight or slightly wavy
- No sheath
- No heterocysts
- No akinetes
- Motile with gliding oscillations





Dillard, G. (1999).

PLANKTOTHRIX

Things to look for:

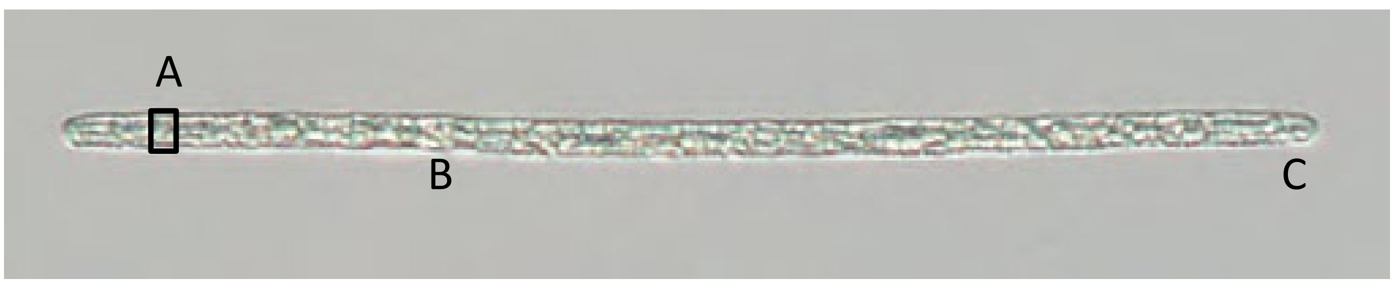
A. Cells cylindrical; mostly wider than long

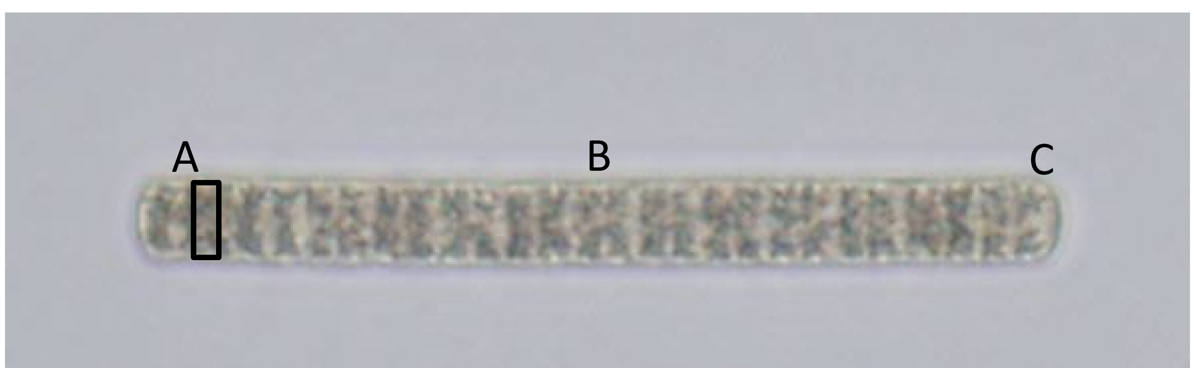
B. LOTS of aerotopes throughout cells

C. Terminal cells rounded

- No heterocytes (not a N_2 fixer)

- No akinetes





For more information

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PMN@noaa.gov

Web site: www.pmn.noaa.gov
(will re-direct you!)