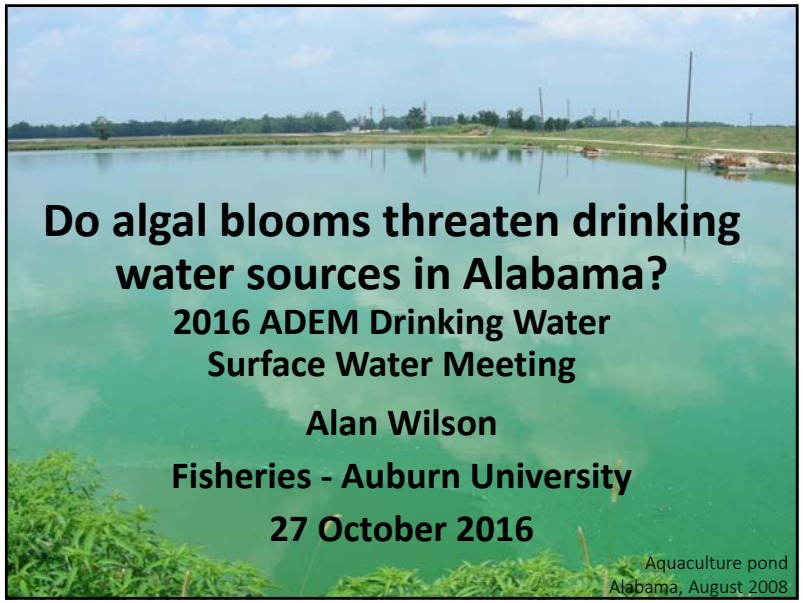

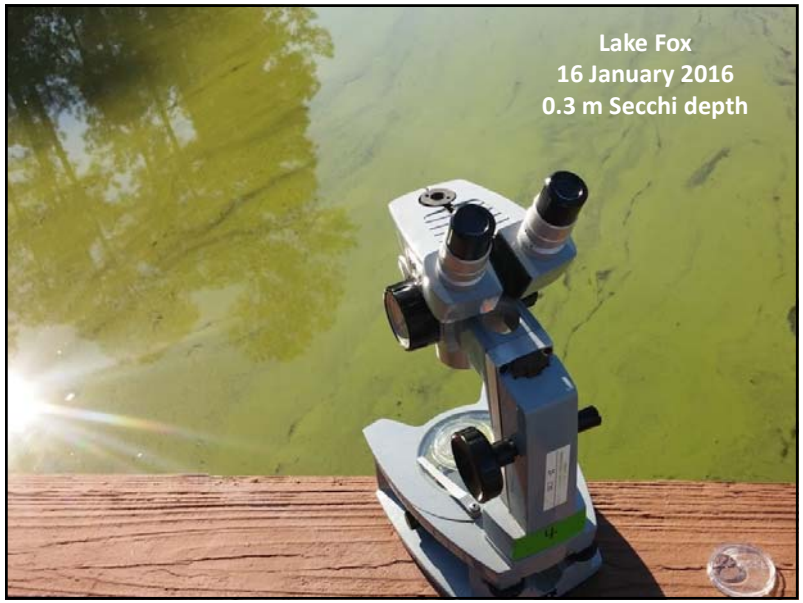

Outline

- Historical record of eutrophication issues in AL
  - ADEM reports (Trophic State Index)
  - STORET historical (chlorophyll)
  - 2007 EPA National Lakes Assessment
  - 2008-2010 WilsonLab survey
  - 2014 USGS stream survey
- Off-flavor research in drinking water reservoirs
- New project to study algal toxins in the State's drinking water sources

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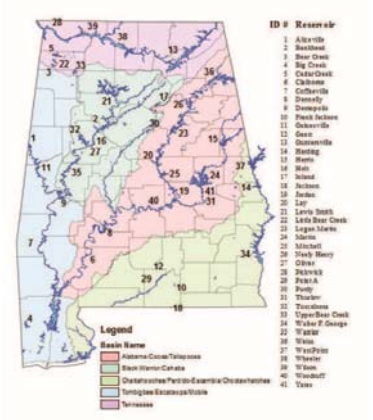
ADEM water quality reports



http://www.adem.state.al.us/programs/water/waterquality.cnt

ADEM reservoir water quality

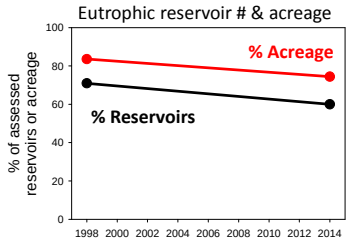
Table 3-1 Trophic Status of Significant Publicly Owned Lakes

2014	Number of Lakes		Acreage of Lakes	
Total	41		479,470	
Assessed	40		471,170	
Oligotrophic	8	20%	36,875	8%
Mesotrophic	8	20%	83,487	17%
Eutrophic	24	58%	350,808	73%
Hypereutrophic	0	0%	0	0%
Dystrophic	0	0%	0	0%
Unknown	1	2%	8,300	2%

http://www.adem.state.al.us/programs/water/waterquality.cnt

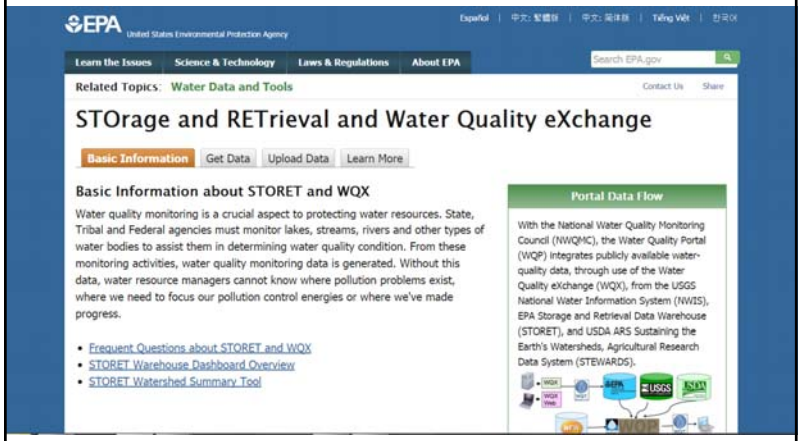
ADEM reservoir water quality

Trends: 1997-2013	Number of Lakes		Acreage of Lakes	
Assessed for Trends	41		479,470	
Improving	8	20%	68,062	14%
Stable	33	80%	411,408	86%
Degrading	0	0%	0	0%
Trend Unknown	0	0%	0	0%



http://www.adem.state.al.us/programs/water/waterquality.cnt

EPA STORET DATABASE



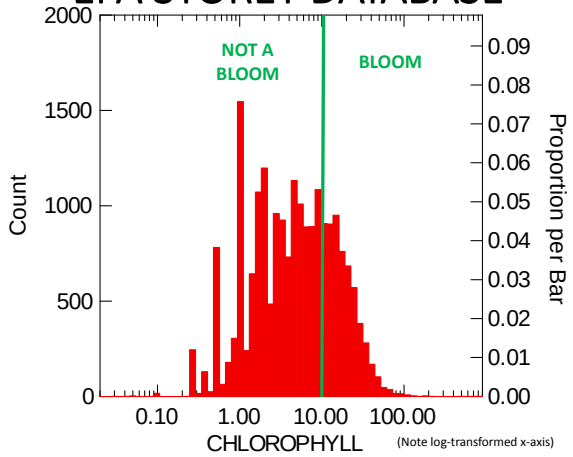
http://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange

EPA STORET DATABASE

- Downloaded all chlorophyll data (µg/L) available in STORET for Alabama on 19 Jan 2016
- 20,424 records available from 1990-2015
- 1,775 unique stations IDs
- 69 counties
- Many waterbodies sampled repeatedly over time and space

http://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange

EPA STORET DATABASE



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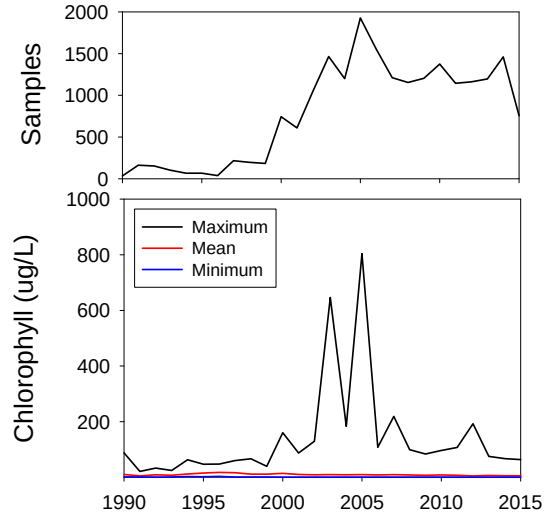
EPA STORET DATABASE



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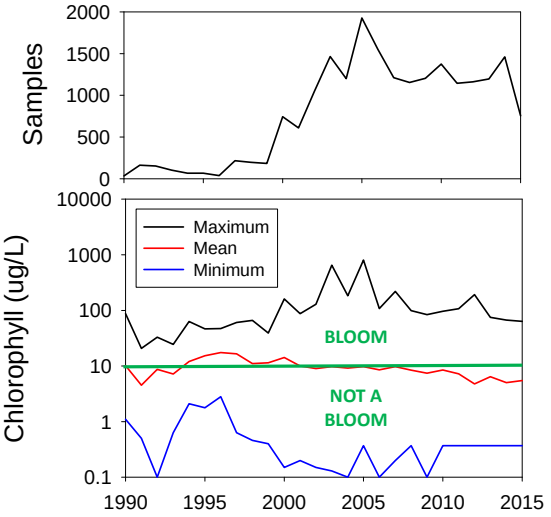
EPA STORET DATABASE



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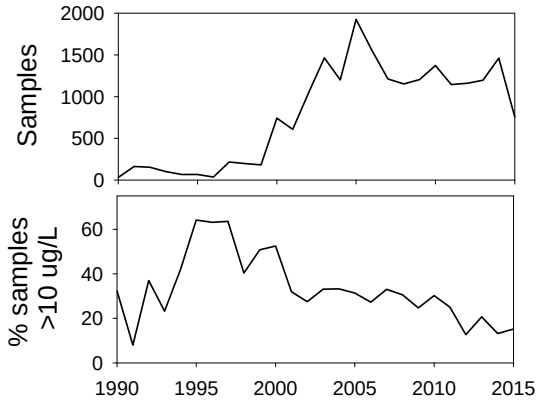
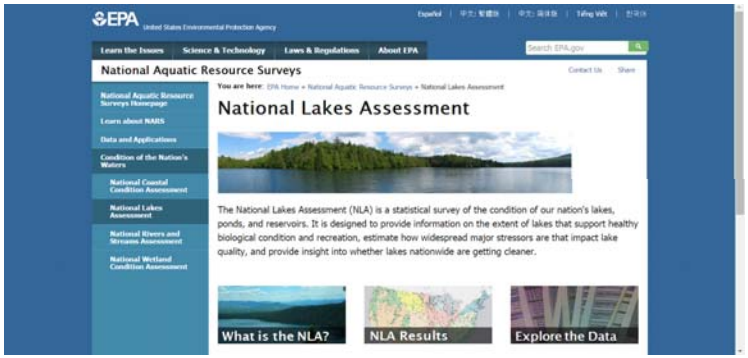


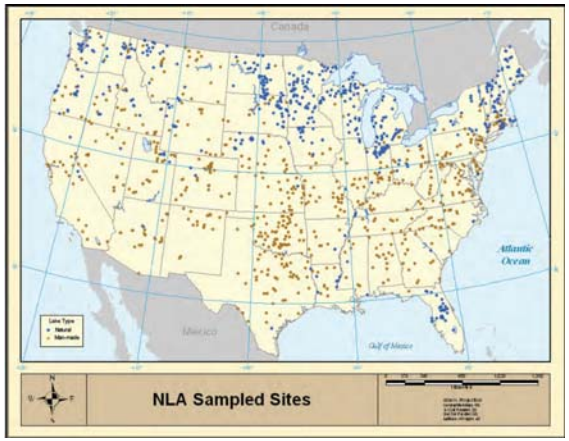
http://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange

2007 EPA National Lakes Assessment



http://www.epa.gov/national-aquatic-resource-surveys/nla

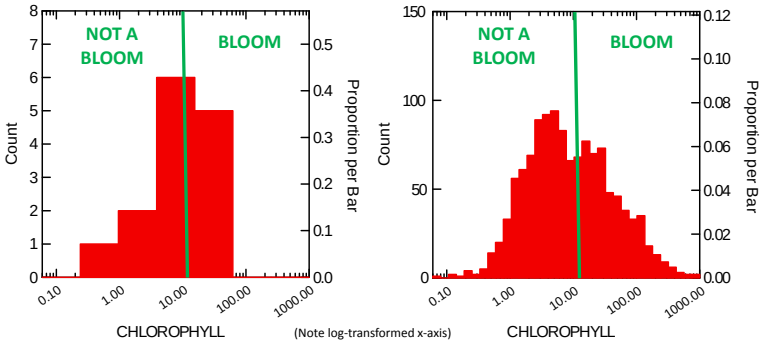
2007 EPA National Lakes Assessment



http://www.epa.gov/national-aquatic-resource-surveys/nla

Chlorophyll

2007 EPA National Lakes Assessment



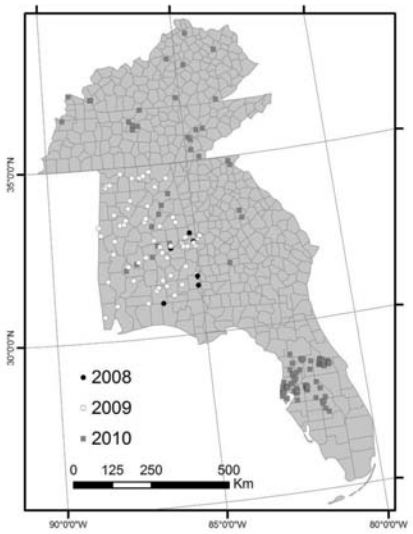
Alabama
N = 14 (1% of total sites)
Range = 0.8 – 46 µg/L
Median = 14 µg/L
% blooms (>10 µg/L) = 64% (9/14)

Other states
N = 1233
Range = 0.07 – 936 µg/L
Median = 8 µg/L
% blooms (>10 µg/L) = 56% (686/1233)

2012 EPA National Lakes Assessment

http://www.epa.gov/national-aquatic-resource-surveys/nla

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

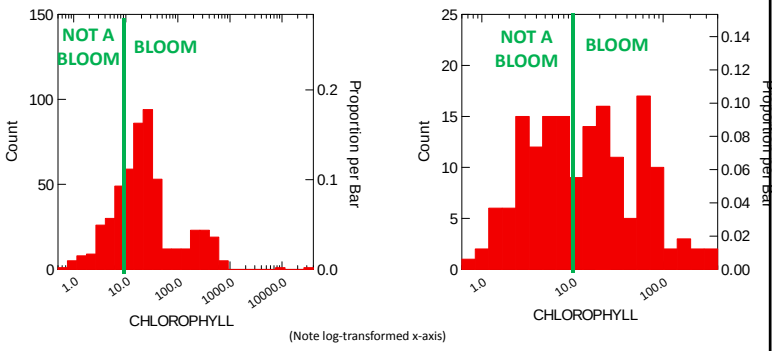
Georgia
Centers for Disease Control
Georgia Power, Southern Company
Georgia Southwestern State Univ
New Echota Rivers Alliance

Kentucky
KY Division of Water

Tennessee
TN Dept of Environment and Conservation
TN Division of Water Pollution Control

Chlorophyll

2008-2010 WilsonLab survey

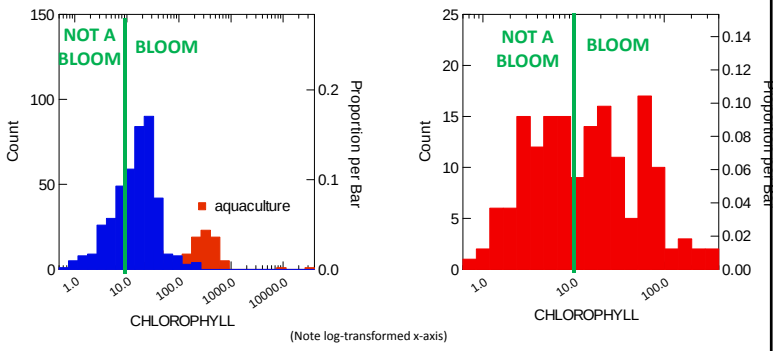


Alabama
N = 528 (76% of total sites)
Range = 0.5 – 32,170 µg/L
Median = 20 µg/L
% blooms (>10 µg/L) = 74% (390/528)

Other states
N = 163
Range = 0.64 – 315 µg/L
Median = 14 µg/L
% blooms (>10 µg/L) = 55% (90/163)

Chlorophyll

2008-2010 WilsonLab survey



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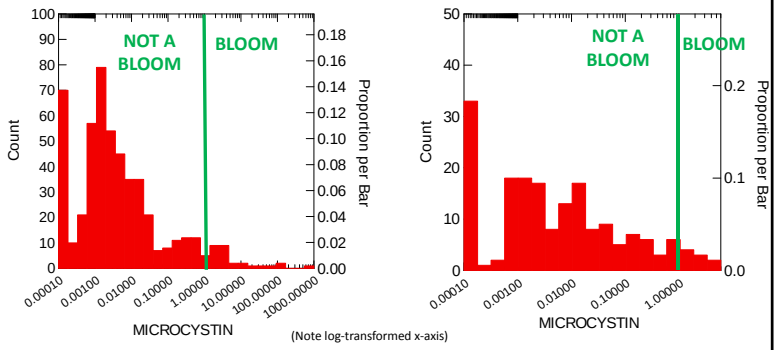
Microcystin

2008-2010 WilsonLab survey

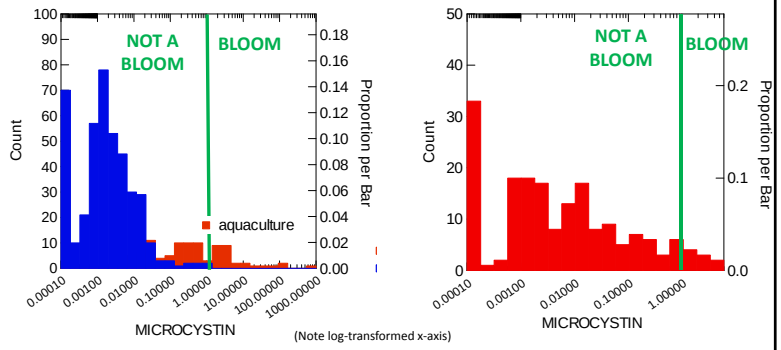


Alabama
N = 510 (% of total sites)
Range = 0 – 963 µg/L
Median = 0.002 µg/L
% blooms (>1 µg/L) = 6% (30/510)

Other states
N = 180
Range = 0 – 5 µg/L
Median = 0.003 µg/L
% blooms (>1 µg/L) = 7% (12/180)

Microcystin

2008-2010 WilsonLab survey



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Median = 0.003 µg/L
% blooms (>1 µg/L) = 7% (12/180)

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 at Orlando workshops

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

Project information

- Project period: 2011-2015
- Sampling: July-August, 2012-2014
- Objective: Create network of scientists (agencies, academia, industry) interested in forecasting cyanobacterial blooms throughout Southeast
- Collaborative nature: data and sample sharing

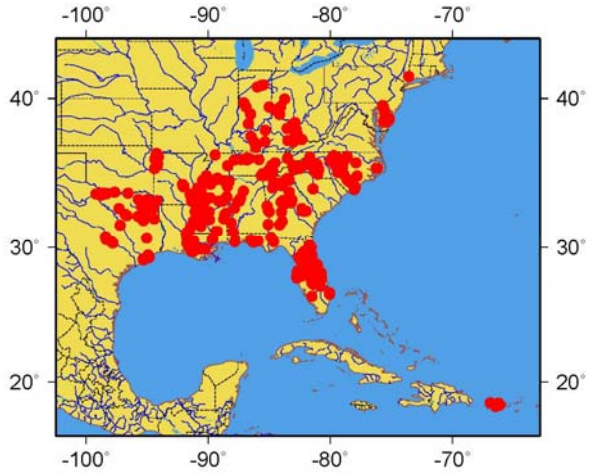
http://wilsonlab.com/bloom_network/

Project participants

- Alabama – AU, ADEM, ADCNR, USGS
- Arkansas – AUEX, UofArk, Central Ark Utility, Beaver Water Utility, Fort Smith Utility
- Delaware – DNREC
- Florida – DEP, Pinellas, Seminole County, OCFL, FWC, SWFWMD, Altamonte, NWFSC, Lakeland
- Georgia – UGA, Southern Co., DNR, EPA, North Georgia College, Valdosta State, Columbus WaterWorks, East Georgia College
- Kansas – Kansas Kickapoo Tribe
- Kentucky – DEP
- Louisiana – Army Corps, LSU
- Mississippi – FWS, DEQ, USDA, Jackson State Univ
- New York – NYCEP
- North Carolina –DENR, NCSU, Mecklenburg County Water, USFWS
- Puerto Rico – UPR-Mayaguez
- South Carolina – USC
- Tennessee – DEC, Carson-Newman College, Tennessee Tech
- Texas - LCRA, TCEQ, Waco, Trinity, Red River Water Authority

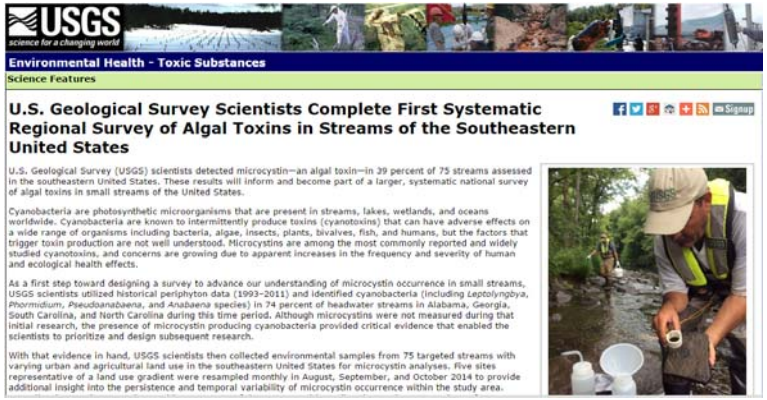
http://wilsonlab.com/bloom_network/

Sample site map



http://wilsonlab.com/bloom_network/

2014 USGS stream survey


USGS
science for a changing world

Environmental Health - Toxic Substances

Science Features

U.S. Geological Survey Scientists Complete First Systematic Regional Survey of Algal Toxins in Streams of the Southeastern United States

U.S. Geological Survey (USGS) scientists detected microcystin—an algal toxin—in 39 percent of 75 streams assessed in the southeastern United States. These results will inform and become part of a larger, systematic national survey of algal toxins in small streams of the United States.

Cyanobacteria are photosynthetic microorganisms that are present in streams, lakes, wetlands, and oceans worldwide. Cyanobacteria are known to intermittently produce toxins (cyanotoxins) that can have adverse effects on a wide range of organisms including bacteria, algae, insects, plants, bivalves, fish, and humans, but the factors that trigger toxin production are not well understood. Microcystins are among the most commonly reported and widely studied cyanotoxins, and concerns are growing due to apparent increases in the frequency and severity of human and ecological health effects.

As a first step toward designing a survey to advance our understanding of microcystin occurrence in small streams, USGS scientists utilized historical periphyton data (1993–2011) and identified cyanobacteria (including *Leptolyngbya*, *Phormidium*, *Pseudoanabaena*, and *Anabaena* species) in 74 percent of headwater streams in Alabama, Georgia, South Carolina, and North Carolina during this time period. Although microcystins were not measured during that initial research, the presence of microcystin producing cyanobacteria provided critical evidence that enabled the scientists to prioritize and design subsequent research.

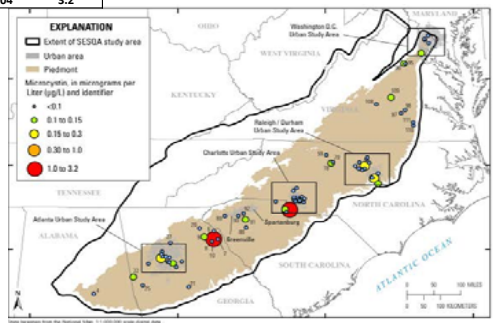
With that evidence in hand, USGS scientists then collected environmental samples from 75 targeted streams with varying urban and agricultural land use in the southeastern United States for microcystin analyses. Five sites representative of a land use gradient were resampled monthly in August, September, and October 2014 to provide additional insight into the persistence and temporal variability of microcystin occurrence within the study area.

http://www.usgs.gov/newsroom/article.asp?ID=4455#.VuyDVeIrLIV

2014 USGS stream survey

Table 1. Summary of MC sample numbers (n), detections (%) and concentration (µg/L) statistics by state and total during June 2014 Piedmont synoptic.

State	Sample size	Detections	Mean	Median	Maximum
AL	1	0	--	--	--
GA	23	43	0.20	0.04	3.2
SC	9	44	0.24	0.03	1.8
NC	30	30	0.08	0.06	0.25
VA	13	46	0.10	0.10	0.12
Total	**75**	**39**	**0.13**	**0.04**	**3.2**



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Outline

- Historical record of eutrophication issues in AL
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  - STORET historical (chlorophyll)
  - 2007 EPA National Lakes Assessment
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- **Off-flavor research in drinking water reservoirs**
- New project to study algal toxins in the State's drinking water sources

COMMON OFF-FLAVOR COMPOUNDS

1. Geosmin
2. 2-methylisoborneol (MIB)

Cyanobacteria

Oscillatoria

Anabaena

Table 7.5–1. Common genera of planktonic cyanobacteria that contain toxin and taste-and-odor producing strains.

[All data included in this table are based on documented production in laboratory cultures; data based on circumstantial evidence, such as co-occurrence of genera and toxin or taste-and-odor compounds in environmental samples, were not included. LYN, lyngbyatoxin-a; APL, aplysiatoxins; LPS, lipopolysaccharides; CYL, cylindrospermopsins; MC, microcystins; NOD, nodularins; ATX, anatoxins; BMAA, β-N-methylamino-L-alanine; NEO, neosaxitoxins; SAX, saxitoxins; GEOS, geosmin; MIB, 2-methylisoborneol]

	Dermatoxins			Hepatotoxins			Neurotoxins				Tastes and odors	
Cyanobacterial Genera	LYN	APL	LPS	CYL	MC	NOD	ATX	BMAA	NEO	SAX	GEOS	MIB
Colonial/Filamentous												
Anabaena			X	X	X		X	X	X	X	X	
Anabaenopsis			X		X							
Aphanizomenon			X	X			X	X	X	X	X	
Aphanocapsa			X		X							
Cylindrospermopsis			X	X				X		X		
Microcystis			X		X			X				
Nodularia			X			X		X				
Oscillatoria (Planktothrix)	X	X	X		X		X	X		X	X	X
Pseudanabaena			X		X		X				X	X
Raphidiopsis			X	X			X					
Unicellular												
Synechococcus			X		X			X			X	X
Synechocystis			X		X			X				

Sources: Wu and others (1991), Wiorowski (1992), Blevins and others (1995), Carmichael (1997), Ilhita and Martalek (1999), Chorus and Bartram (1999), Domingos and others (1999), Saadoun and others (2001), Ouahi and others (2002), Watson (2003), Hausman and others (2004), and others (2005). A comprehensive list of known cyanobacterial toxin and taste-and-odor producers is not currently (2008) available in the literature. Combined, the references used to create this table may be used to create a fairly complete list of planktonic and benthic producers.

Graham et al. 2008 USGS report

COMMON OFF-FLAVOR COMPOUNDS

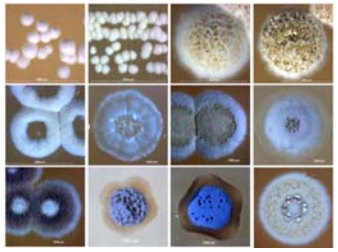
1. Geosmin
2. 2-methylisoborneol (MIB)

Cyanobacteria

Oscillatoria

Anabaena

Actinomycetes



COMMON OFF-FLAVOR COMPOUNDS

Measured by SPME - GC/MS

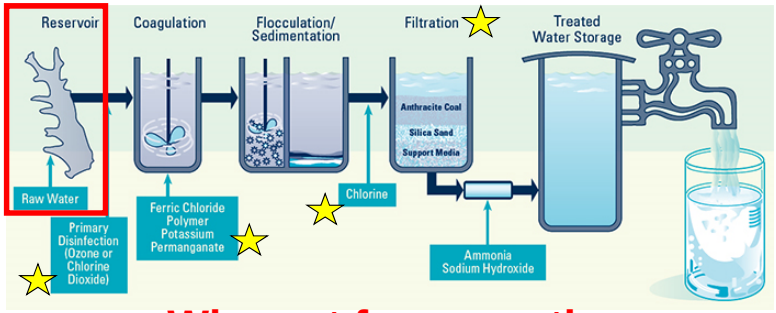
Human detection limits: MIB (10 ng/L); geosmin (30 ng/L)

Study Name	Location	MIB (ng/L)	Geosmin (ng/L)
Hosaka *et al.*, 1995	Tokyo, Japan	3,300	---
Olsen *et al.*, In prep.	this study	380	78
Westerhoff *et al.*, 2005	Phoenix, AZ	105	---
Lin *et al.*, 2002	Kaohsiung, Taiwan	100	---
Proulx *et al.*, 2012	Quebec City, Quebec	87	318
Hu *et al.*, 2003	Phoenix, AZ	70	20

>20% complaints at drinking water utilities are associated with off-flavors

Huge costs associated with removal via water treatments, including infrastructure, maintenance, testing, and human resources, that may be ineffective or dangerous

WATER TREATMENT PROCESS

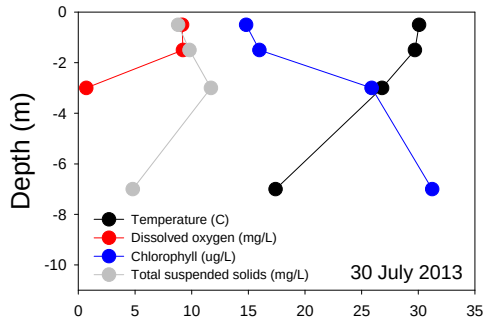


Why not focus on the beginning of the process?

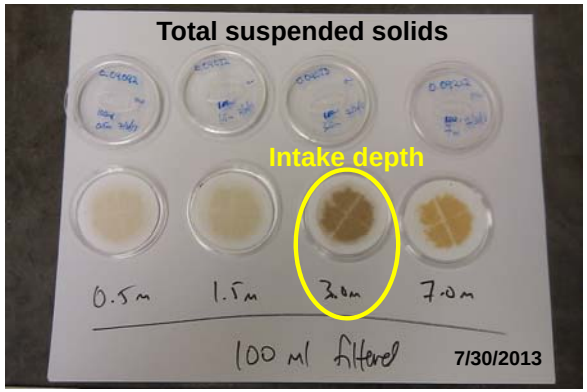
http://www.sandiego.gov/water/quality/report/treatment.shtml

INITIAL RESERVOIR WATER QUALITY

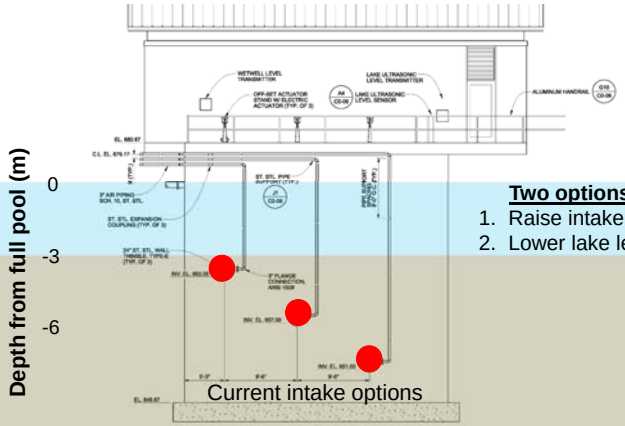
First visit to facility – 29 July 2013
First sampling event – 30 July 2013



INITIAL RESERVOIR WATER QUALITY

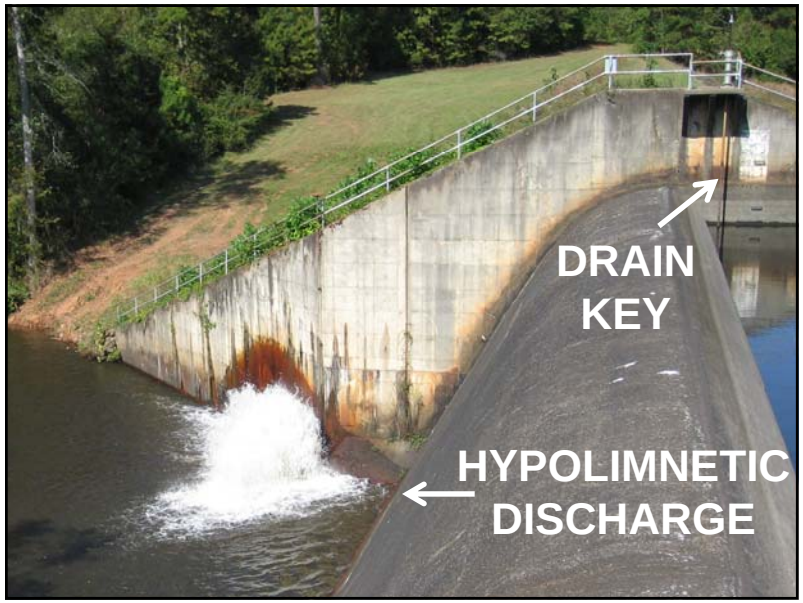


FACILITY INTAKE

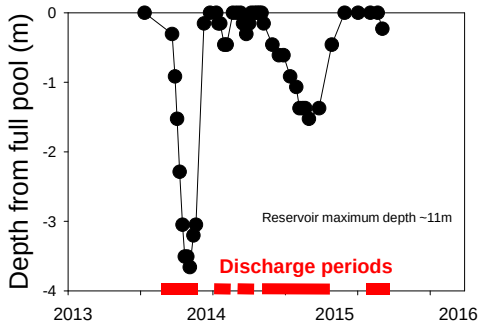


Two options

1. Raise intake
2. Lower lake level

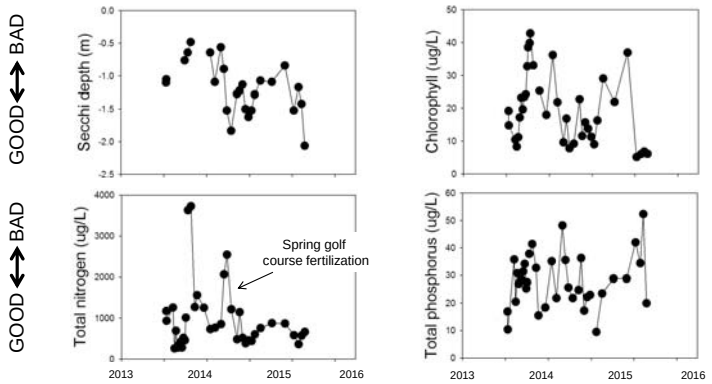


RESERVOIR DEPTH



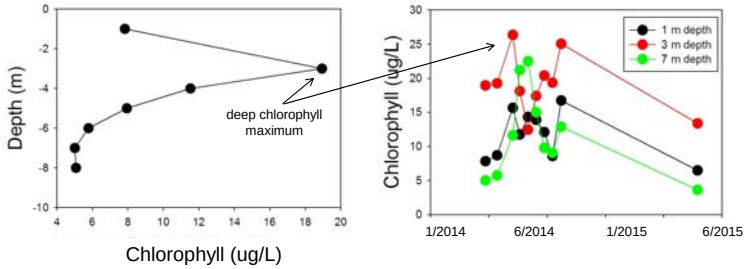
Consider hypolimnetic discharge

RESERVOIR WATER QUALITY TRENDS



Regularly monitor water quality

DEPTH PROFILES



Avoid hypolimnion during summer

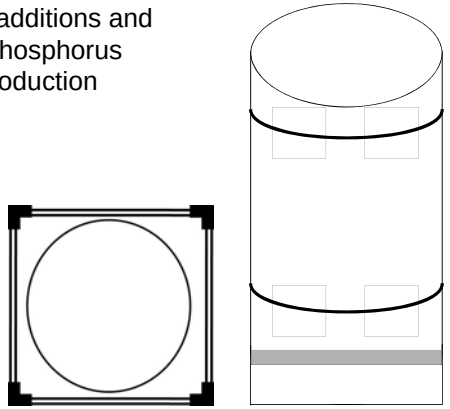
LESSONS LEARNED FROM MONITORING

- Consider hypolimnetic discharge
- Conduct regular monitoring
- Consider sampling across space, time, and depth
- Avoid hypolimnion during periods of stratification

FIELD EXPERIMENT

Test role of nitrogen additions and varying nitrogen-to-phosphorus ratios on off-flavor production

Experimental design
7 week duration
3,000 L limnocorrals

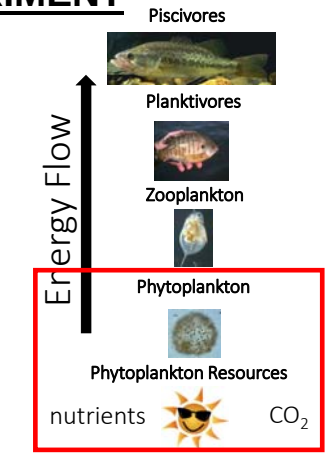


Olsen et al. 2016 Water Research

FIELD EXPERIMENT

Test role of nitrogen additions and varying nitrogen-to-phosphorus ratios on off-flavor production

Experimental design
7 week duration
3,000 L limnocorrals
Main treatments (4 reps/)
N conc = 300, 1000, 3000 ug/L
N:P = 2, 10, 33, 90



Olsen et al. 2016 Water Research

FIELD EXPERIMENT

Test role of nitrogen additions and varying nitrogen-to-phosphorus ratios on off-flavor production

Experimental design
7 week duration
3,000 L limnocorrals
Main treatments (4 reps/)
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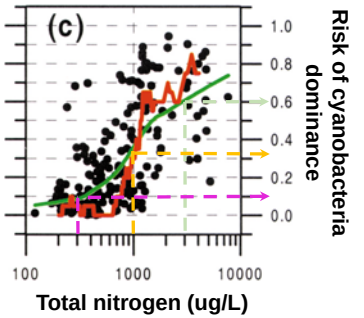

Downing et al. 2001

Olsen et al. 2016 Water Research

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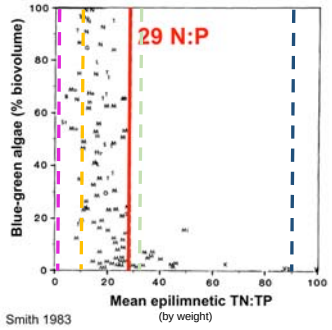

Olsen et al. 2016 Water Research

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Main treatments (4 reps/)

N conc = 300, 1000, 3000 ug/L

N:P = 2, 10, 33, 90

Hypotheses

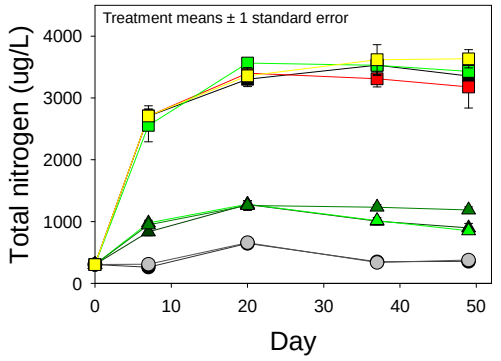
Off-flavors will increase with

1) Elevated N
2) Reduced N:P

Nitrogen (ug/L)	N:P (weight)	Nutrients added
300	2:1	P only
300	10:1	None
1000	2:1	N and P
1000	10:1	N and P
1000	33:1	N only
3000	2:1	N and P
3000	10:1	N and P
3000	33:1	N and P
3000	90:1	N only

Olsen et al. 2016 Water Research

TOTAL NITROGEN



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3000	33:1	N and P
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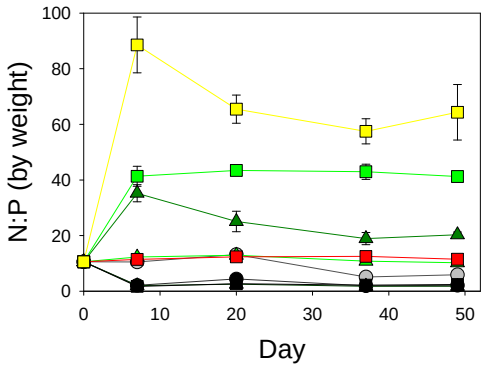
Olsen et al. 2016 Water Research

NITROGEN-TO-PHOSPHORUS RATIO



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3000	10:1	N and P
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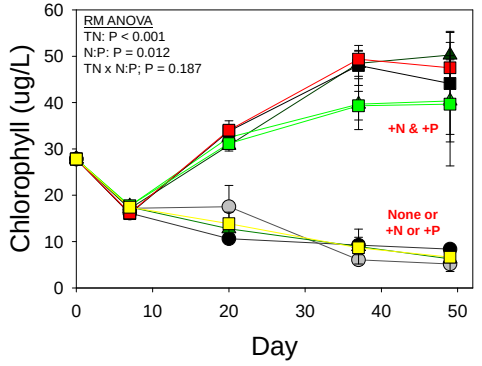
CHLOROPHYLL



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3000	2:1	N and P
3000	10:1	N and P
3000	33:1	N and P
3000	90:1	N only

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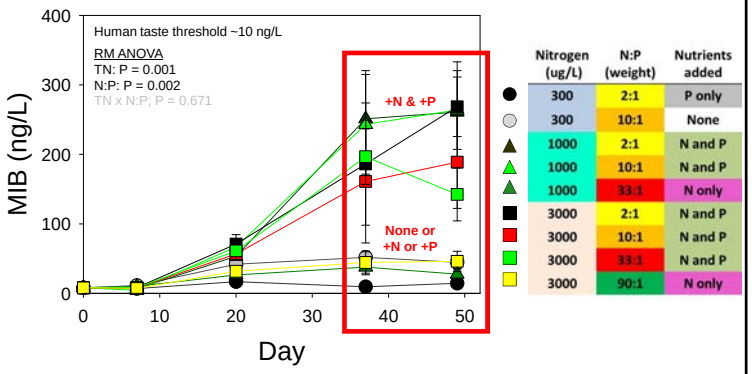
MIB



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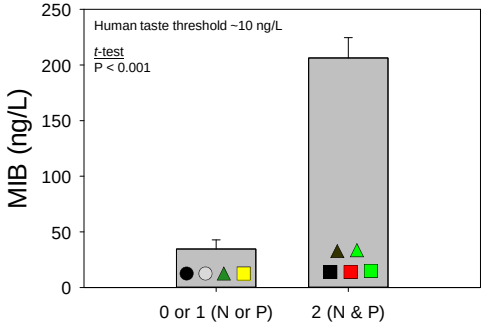

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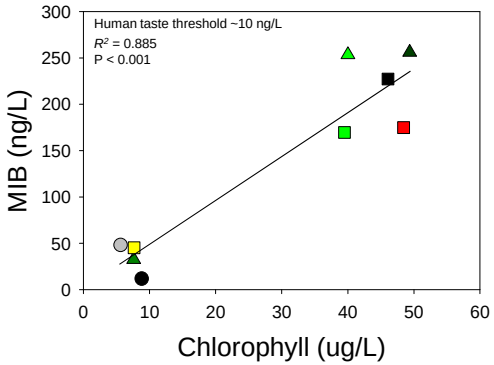
Treatment means; final 2 sampling dates

Olsen et al. 2016 Water Research

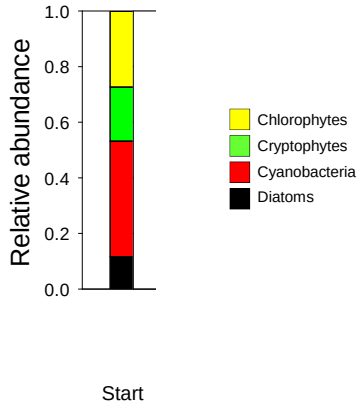
MIB vs CHLOROPHYLL



Treatment means; final 2 sampling dates

Olsen et al. 2016 Water Research

PHYTOPLANKTON DIVERSITY



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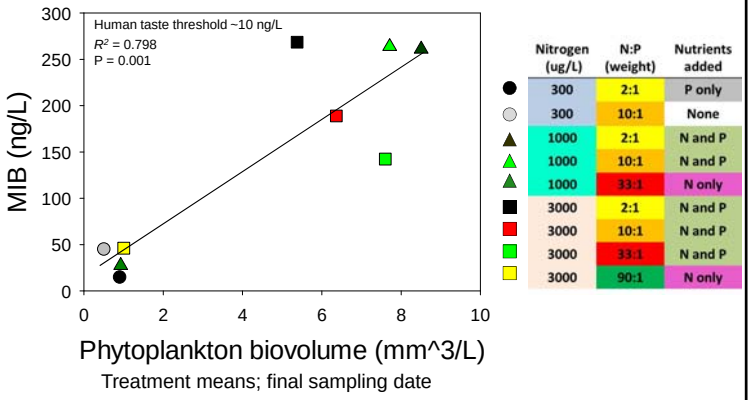
MIB VS. PHYTOPLANKTON



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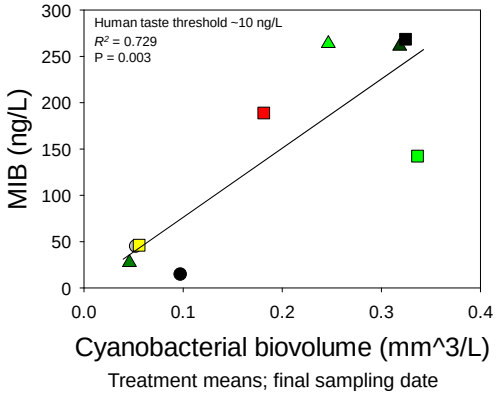
MIB VS. CYANOBACTERIA



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300	2:1	P only
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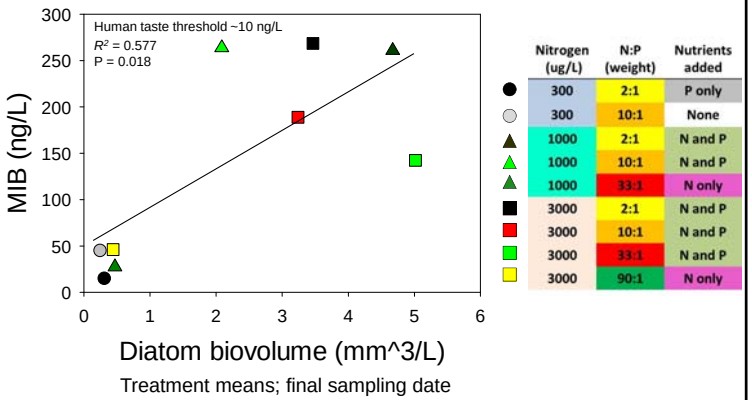
MIB VS. DIATOMS



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300	2:1	P only
300	10:1	None
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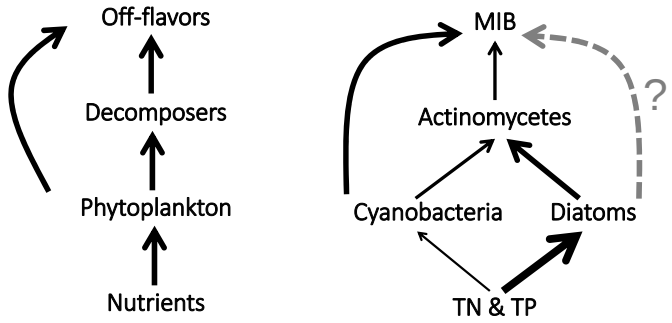
MECHANISMS MEDIATING MIB



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Outline

- Historical record of eutrophication issues in AL
  - ADEM reports (Trophic State Index)
  - STORET historical (chlorophyll)
  - 2007 EPA National Lakes Assessment
  - 2008-2010 WilsonLab survey
  - 2014 USGS stream survey
- Off-flavor research in drinking water reservoirs
- **New project to study algal toxins in the State's drinking water sources**

EPA United States Environmental Protection Agency

Office of Water
820F15003
June 2015

2015 Drinking Water Health Advisories for Two Cyanobacterial Toxins

Summary

EPA has issued 10-Day Drinking Water Health Advisories (HAs) for the cyanobacterial toxins microcystins and cylindrospermopsin.

EPA recommends HA levels at or below 0.3 micrograms per liter for microcystins and 0.7 micrograms per liter for cylindrospermopsin in drinking water for children pre-school age and younger (less than six years old). For school-age children through adults, the recommended HA levels for drinking water are at or below 1.6 micrograms per liter for microcystins and 3.0 micrograms per liter for cylindrospermopsin. Young children are more susceptible than older children and adults as (cyanobacterial toxins or "cyanotoxins") that are harmful to the environment, animals and human health. Winds and water currents can transport cyanobacterial blooms within proximity to drinking water intakes at treatment plants that, if not removed during treatment, can cause odor, taste and color problems in treated drinking water and can be harmful to human health.

What is a health advisory?

The Safe Drinking Water Act provides the authority for EPA to publish health advisories for contaminants not subject to any national primary drinking water regulation. Health advisories describe non-regulatory concentrations of drinking water

New Related Project

- **Title: Do toxic cyanobacteria threaten Alabama's drinking water reservoirs?**
- **Collaborator: Dennis Harrison, ADEM Drinking Water Branch Chief**
- **Source: AAES AgR-SEED program**
- **Oct 2016 - Sept 2018**

Project Objectives

- To **gather baseline data** about the presence and concentration of cyanobacterial toxins and off-flavors in Alabama's drinking water reservoirs.
- To **develop models that forecast toxic cyanobacterial blooms and off-flavor events** in Alabama drinking water reservoirs.
- To **train water utility professionals** in the proper techniques to identify toxigenic cyanobacteria and analyze samples for cyanobacterial toxins.
- To **train graduate and undergraduate students** on field sampling and laboratory-based water quality analytical analyses.

LOOKING FOR MORE COLLABORATORS

Project details

- 2 year project
- 116 intakes (focus on larger)
- 11 basins (focus on 8 eutrophic systems)

Public water supply basins

Basin	# supply sites	% eutrophic reservoirs (ADEM 2014)
Alabama	1	67% (2/3)
Black Warrior	22	43% (3/7)
Cahaba	3	100 % (1/1)
Chattahoochee	4	67% (2/3)
Coosa	23	83% (5/6)
Escatawpa	1	0% (0/1)
Lower Tombigbee	5	100% (1/1)
Mobile	3	25% (1/4)
Tallapoosa	21	0% (0/4)
Tennessee	24	100% (8/8)
Upper Tombigbee	9	67% (2/3)

Project details

- 2 year project
- 116 intakes (focus on larger)
- 11 basins (focus on 8 eutrophic systems)
- Summer (focus but also collect samples during other seasons for some systems)
- Workshops – 2x/year
  - Sample collection, analysis
  - Phytoplankton and toxins

Project timeline

Period	Activities
Oct to Dec 2016	Recruit graduate and undergraduate students
January to April 2017	Communicate with utilities about summer sampling
March 2017	**Water quality training workshop in Montgomery, AL**
May to August 2017	**Drinking water reservoir sampling**
September 2017	Sample processing and reporting to utilities and ADEM
October 2017	**Water quality training workshop in Birmingham, AL**
January to April 2018	Communicate with utilities about summer sampling
March 2018	**Water quality training workshop in Auburn, AL**
May to August 2018	**Drinking water reservoir sampling**
September 2018	Sample processing and reporting to utilities and ADEM
September 2018	**Water quality training workshop in Huntsville, AL**
Jan 2018 to Sept 2018	Prepare manuscripts and present results at conferences

Sampling details

- Utilities collect temp, dissolved oxygen, conductivity, and pH from intake during collection
- Samples processed for each intake sample
  - Nutrients – total phosphorus and total nitrogen
  - Phytoplankton – whole water, chlorophyll, phycocyanin
  - Toxins – microcystin, cylindrospermopsin, saxitoxin
  - Off-flavors – geosmin, MIB

Available Opportunities

Collaborations and Student Openings

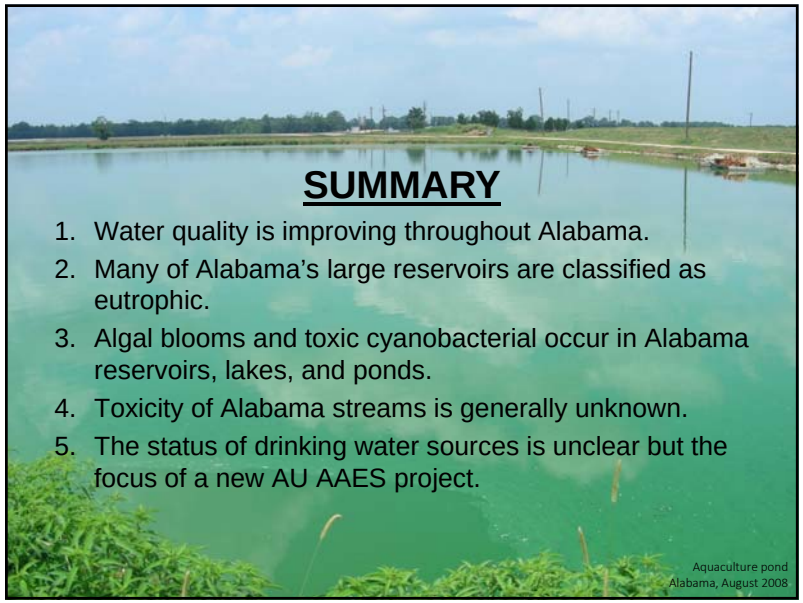
Water Quality Sampling and Analyses

Phytoplankton, Toxin, and Off-flavor Analyses

Training at AU and your facility

SUMMARY

1. Water quality is improving throughout Alabama.
2. Many of Alabama's large reservoirs are classified as eutrophic.
3. Algal blooms and toxic cyanobacterial occur in Alabama reservoirs, lakes, and ponds.
4. Toxicity of Alabama streams is generally unknown.
5. The status of drinking water sources is unclear but the focus of a new AU AAES project.



Contact information

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http://wilsonlab.com/