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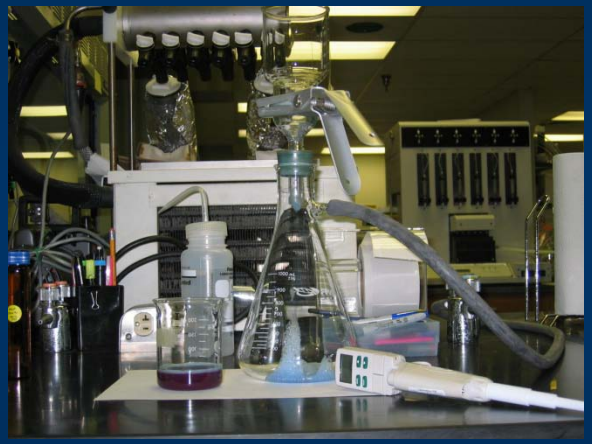
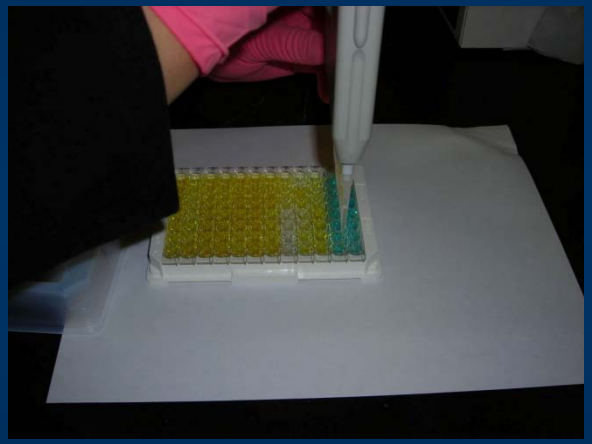
Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs

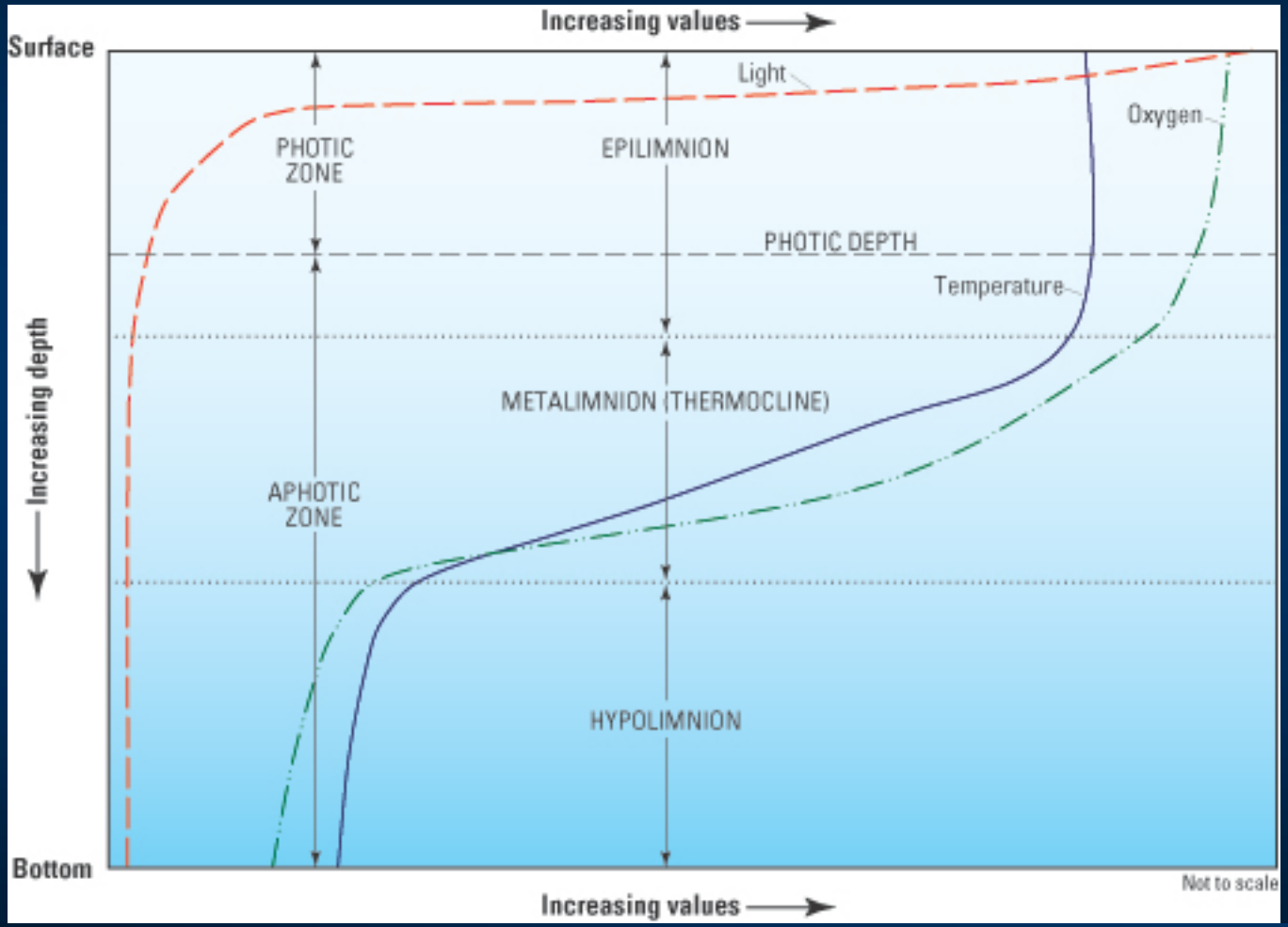
Jennifer L. Graham, Keith A. Loftin, Barry H. Rosen, and Ann St. Amand

National Water Quality Monitoring Conference Workshop
April 25, 2010

Overview

- Spatial and temporal variability of cyanobacterial populations
- Sample collection approaches
- Common study types, objectives, designs, and approaches

Lakes are Characterized by Vertical Gradients Caused by Light and Thermal Stratification. Cyanobacteria Can Exploit These Gradients and Maintain a Position in the Water Column that is Optimal for Growth.



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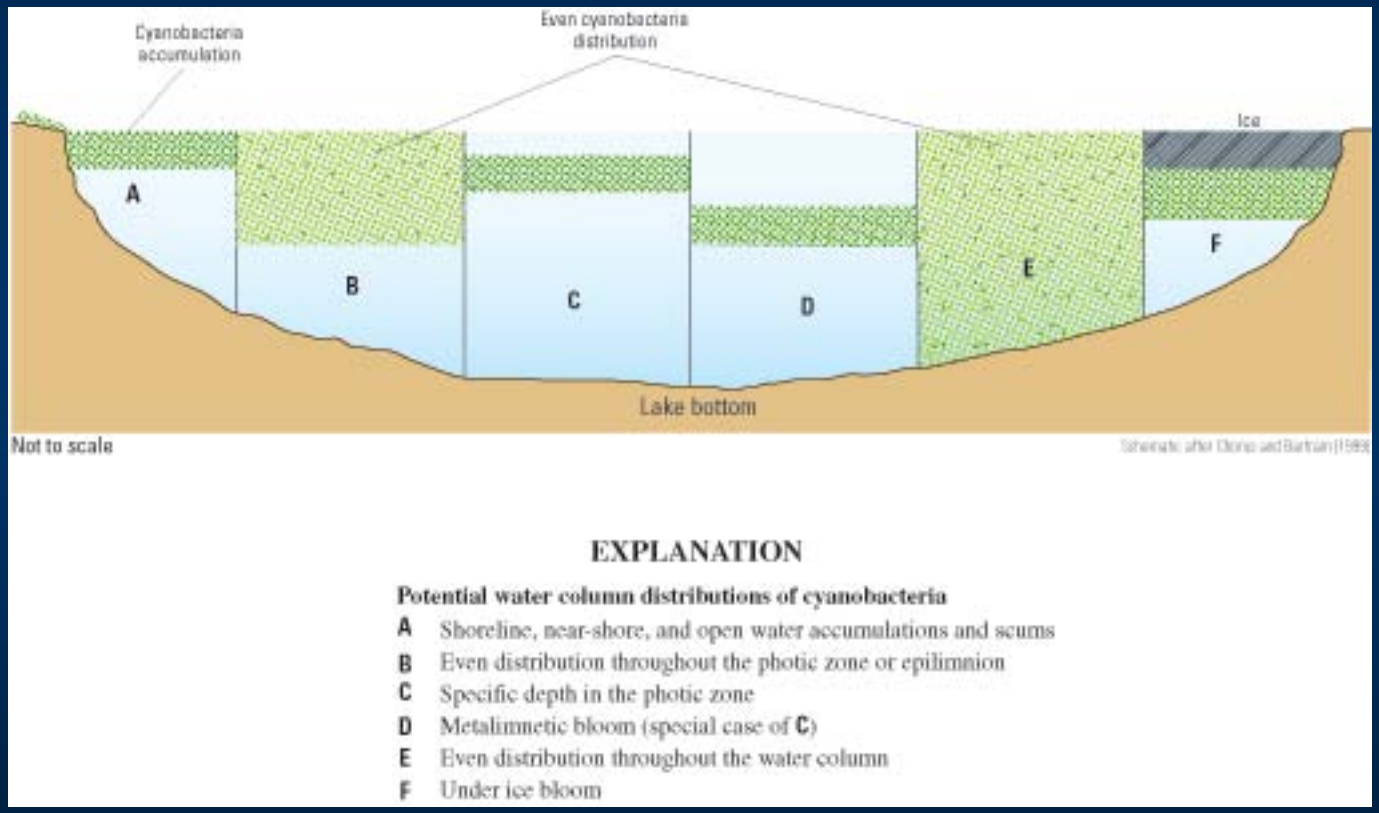
Sample Location Relative to the Distribution of Cyanobacteria May Substantially Affect Results



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Concentrations of Toxins and Taste-and-Odor Compounds May Vary by Orders of Magnitude at Different Sample Locations Within a Lake

Microcystin: 13 µg/L
Geosmin: 0.25 µg/L

Microcystin: 4 µg/L
Geosmin: Not Detected

Samples collected about 50 m apart

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Vertical Migration or Wind Movement of Surface Accumulations May Rapidly Change the Aerial Distribution of Cyanobacteria

Rock Creek Lake, Iowa
2006 Beach Closure Event

Beach Area
Monday
July 31

Photos Courtesy of IA DNR

Beach Area
Thursday
August 3

Photo Courtesy of IA DNR

Boat Ramps
Friday
August 11

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Vertical Migration or Wind Movement of Surface Accumulations May Rapidly Change the Aerial Distribution of Cyanobacteria

Rock Creek Lake, Iowa
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Beach Area

Beach Area
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WHERE DID THE CYANOBACTERIA GO?

Photos Courtesy of IA DNR

Photo Courtesy of IA DNR

Boat Ramps
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Vertical Migration or Wind Movement of Surface Accumulations May Rapidly Change the Aerial Distribution of Cyanobacteria

Rock Creek Lake, Iowa
2006 Beach Closure Event

Beach Area

Beach Area
Thursday
August 3

WHERE DID THE CYANOBACTERIA GO?

Most likely explanation is redistribution in the water column

Photos Courtesy of IA DNR

Boat Ramps
Friday
August 11

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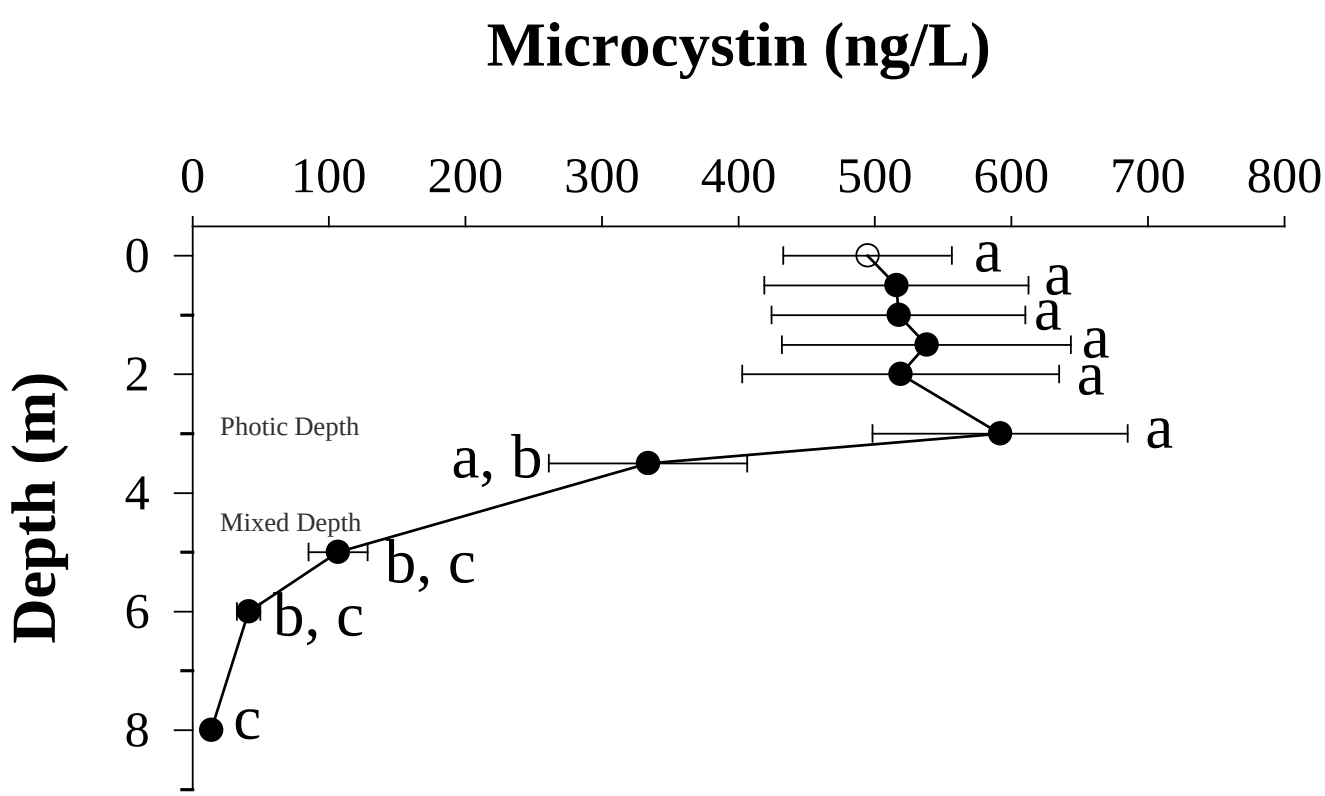
Concentrations of Toxins and Taste-and-Odor Compounds May Vary Considerably With Depth in the Water Column



Mozingo Lake, MO August 2001

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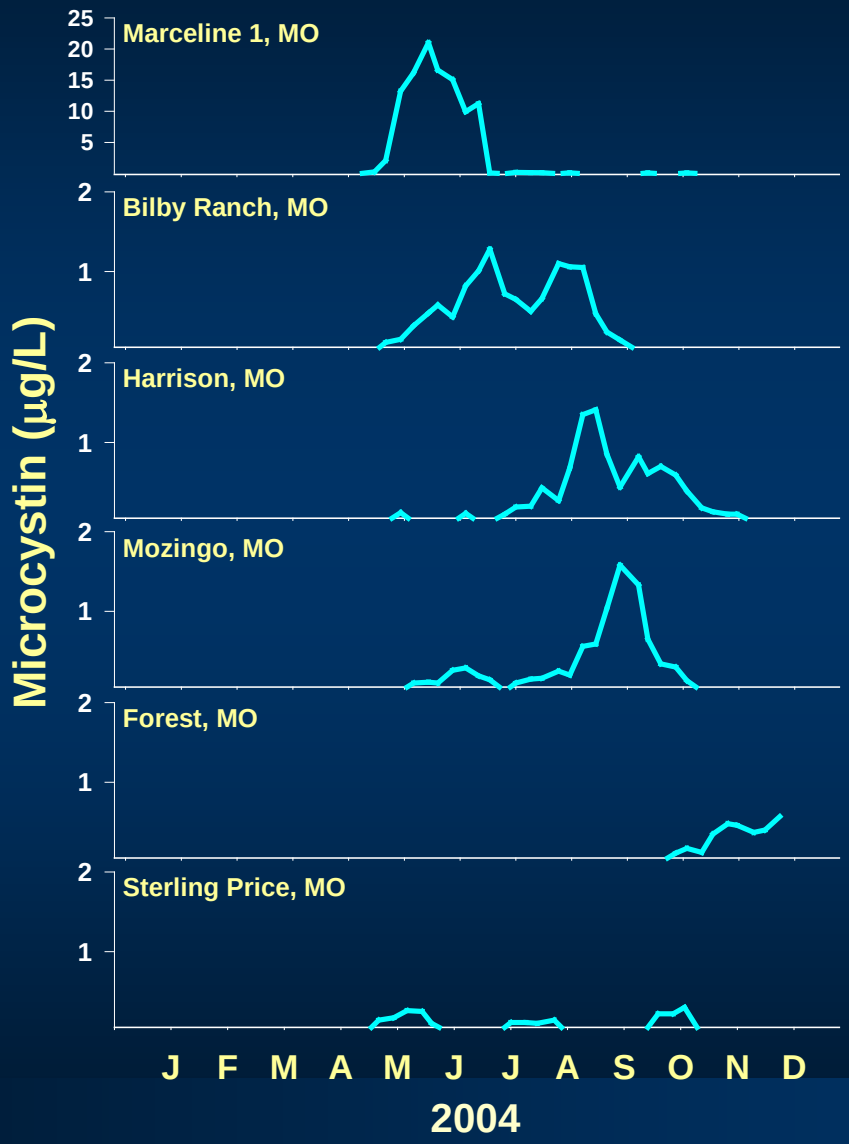
After Graham and others, 2006

Seasonal Patterns in Microcystin Concentration are Unique to Individual Lakes and Peaks May Occur Anytime Throughout the Year



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After Graham and others, 2006

Considerations When Choosing Sampling Locations and Approaches

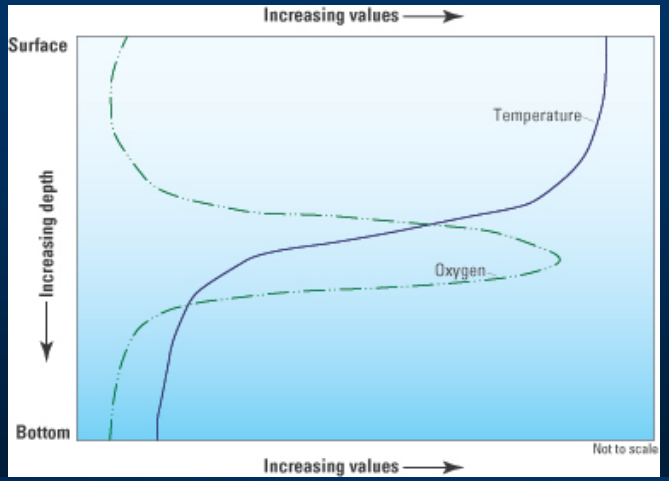
- Specific study objectives
- Stratification
- Aerial and water-column distribution of cyanobacteria
- Flexibility of sampling plans
  - Where and how to collect samples often is decided in the field

Determining the Location of Cyanobacteria in the Water Column

- Visual assessment

- Vertical profiles
  - Photic depth
  - Stratification
  - Mixed depth
  - Photosynthetic activity

- Signs of photosynthetic activity include:
  - Sharp increases in pH and dissolved oxygen
  - Increased fluorescence



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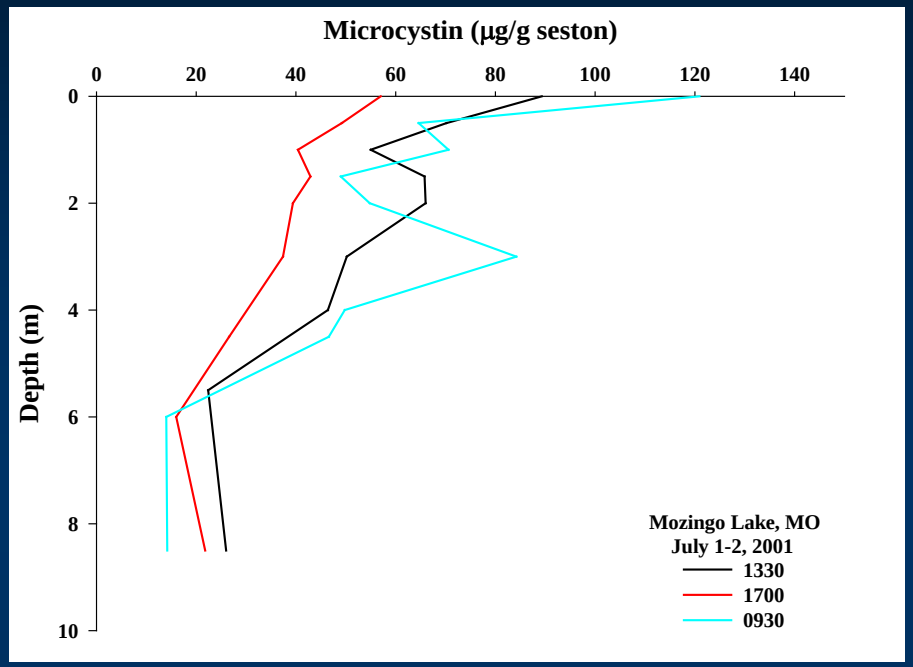
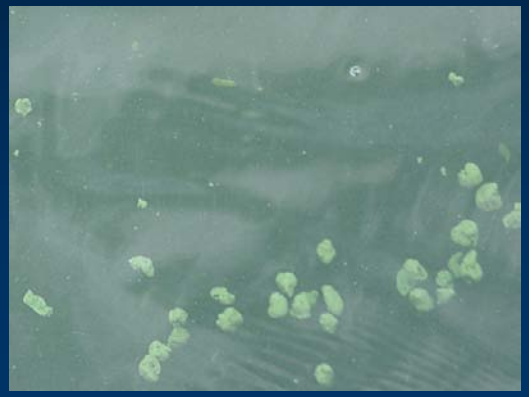
Common Types of Samples

- Surface samples
- Discrete-depth samples
  - Location of the cyanobacterial community is known
  - Structure of interest at depth
  - Vertical water column distribution of interest
- Depth-integrated samples
  - Integrated photic zone
  - Integrated epilimnion
  - Integrated water column

Sample Concentrations Can Vary Considerably Depending on When, Where, and How Samples Are Collected





Microcystis aeruginosa colonies

	Sample Type and Microcystin Concentration (µg/g Seston)			
Time	Surface	Integrated Photic Zone	Integrated Epilimnion	Integrated Water Column
0930	121	68	71	57
1330	89	58	66	55
1700	57	39	42	37

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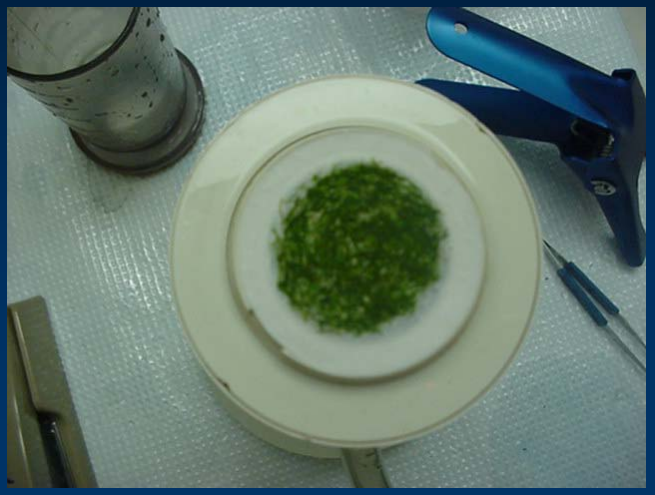
After Graham and others, 2006

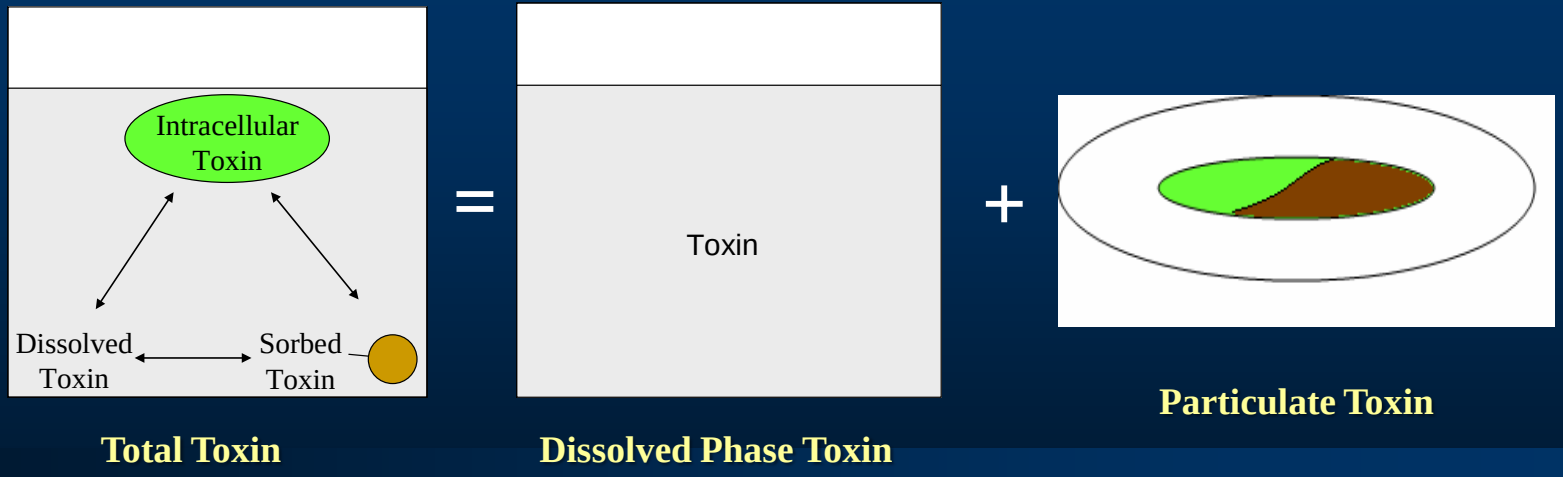
Common Sampling Approaches

Plankton Net Sampling

Whole Water Sampling



Filter/Filtrate Sampling



Total Toxin

Dissolved Phase Toxin

Particulate Toxin

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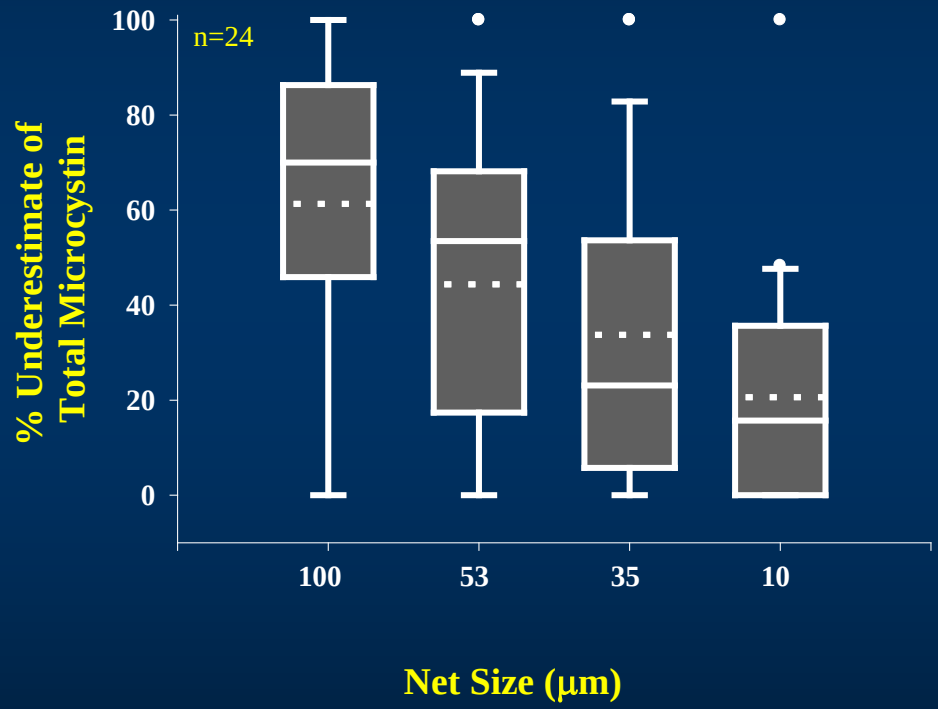
Plankton Nets May Substantially Underestimate Concentrations of Toxins and Taste and Odor Compounds

East Okoboji, IA

Total Microcystin – 7.0 µg/L

Microcystin > 100 µm – 6.4 µg/L

Net Microcystin > 100 µm – 2.3 µg/L



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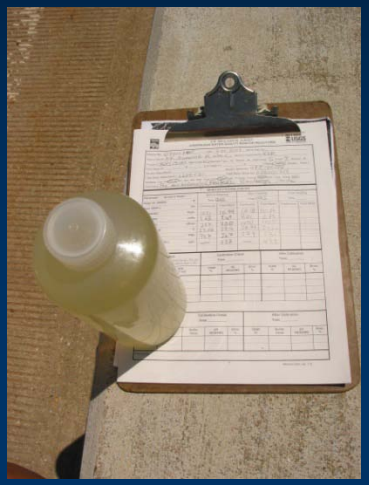
After Graham and Jones, 2007

Clear Understanding of Study Objectives is Essential to Selecting the Appropriate Sampling Approach

- **Study objectives dictate:**
  - **When, where, and how samples are collected**
  - **Variables measured**
  - **Ancillary data collected**



Reconnaissance Studies

Assess Occurrence, Distribution, and Concentration

General objective	Site location	Sample frequency	Sample type
Regional studies			
Spatial variability			
Emphasis on presence/absence	Single representative site, typically an open, deep water site	Single point in time when most cyanobacterial-related issues occur	Integrated photic zone Integrated epilimnion Surface sample
	Site will be determined based on the location of surface accumulations and scums	During known surface bloom events	Surface sample
Spatial and temporal variability			
Emphasis on presence/absence and changes in concentration with time	Single representative site, typically an open, deep water site	Multiple times during the period when most cyanobacterial-related issues occur • Weekly • Bi-weekly • Monthly • Annually	Integrated photic zone Integrated epilimnion Surface sample
Single-system studies			
Spatial variability			
Emphasis on presence/absence	Multiple sites	Single point in time when a cyanobacterial bloom is occurring	Integrated photic zone Integrated epilimnion Integrated water column Surface sample
Spatial and temporal variability			
Emphasis on presence/absence and changes in concentration over time	Multiple sites	Multiple times during the period when most cyanobacterial-related issues occur • Weekly • Bi-weekly • Monthly	Integrated photic zone Integrated epilimnion Integrated water column Surface sample
Emphasis on spatial changes within the lake or water column over relatively short periods of time	Single representative site Multiple sites	Multiple points in time when a cyanobacterial bloom is occurring • Hourly • Daily	Integrated photic zone Integrated epilimnion Integrated water column Surface sample Discrete depth

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When, Where, and How Samples Are Collected is Important

Study	Sample Location	Sample Type	n	% Samples with MC	Maximum MC (µg/L)
Graham and others 1999-2006	Open Water, Integrated Photic	Total	2546	39	52
Midwest Recon 2006	Targeted Blooms, Bloom Grab	Total	23	96	13,000
Texas Recon 2006	Open Water, Surface Grab	Dissolved	67	22	0.2
EPA NLA 2007	Open Water, Integrated Photic	Total	1332	33	230

Microcystin was measured by ELISA in all studies

Monitoring Studies

Evaluate the Potential for Human Health Risks and Taste-and-Odor Events

General objective	Site location	Sample frequency	Sample type
Recreational areas	Beaches Open water areas used for full-body contact recreation Bay or cove areas used for full-body contact recreation Public access sites	Routine basis during periods of peak recreational use • Daily • Weekly	Surface sample Integrated photic zone
Drinking-water supplies	Location relevant to the drinking-water intake(s)	Routine basis • Daily • Weekly During periods when events have historically occurred During events	Discrete depth Integrated photic zone Integrated epilimnion Integrated water column

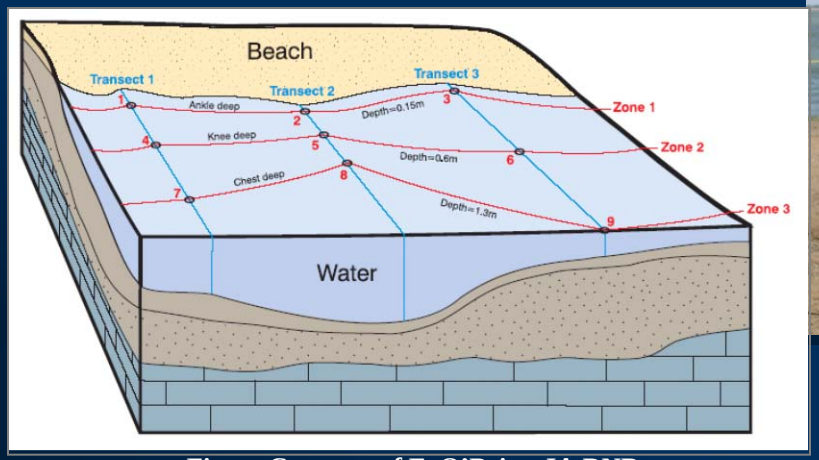

Figure Courtesy of E. O'Brien, IA DNR

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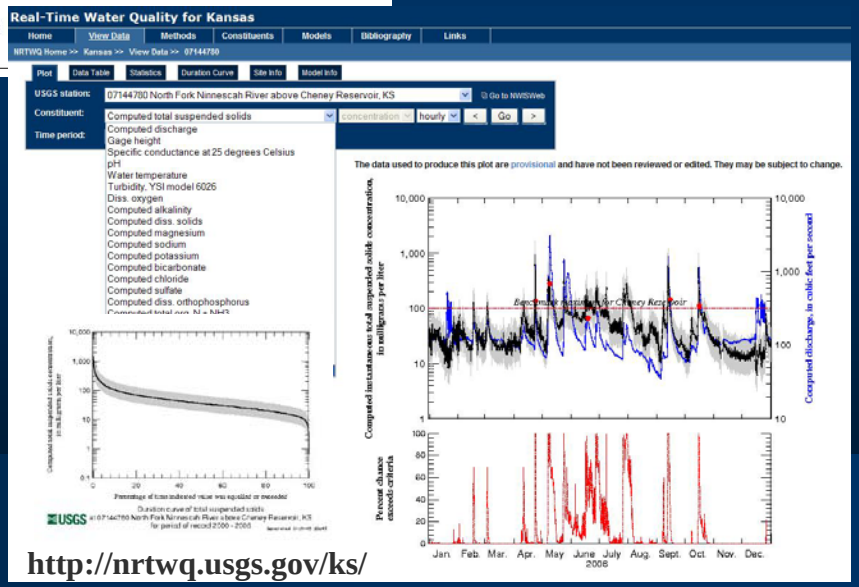
Interpretive Studies

Assess the Processes that Affect the Spatial and Temporal Distribution and Abundance of Cyanobacteria and Associated By-Products

General objective	Site location	Sample frequency	Sample type
Environmental factors influencing spatial and/or temporal occurrence Real-time estimation of occurrence/concentration Predictive models	Single representative site, typically an open, deep water site • Sites for drinking-water studies are typically located near intakes Multiple sites • Sites where cyanobacterial blooms are known to initiate • Sites where cyanobacteria are typically abundant • Inflow sites[1]	Routine basis • Weekly • Bi-weekly • Monthly	Integrated photic zone Integrated epilimnion Integrated water column Discrete depth
	Sites where surface accumulations/scums are located	Event samples Sampling plans need to be flexible enough to respond to events	Surface sample



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

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Summary

- **Understanding the Effects of Sampling Approach on Results is Critical to Data Interpretation and Analysis**
  - **Clear understanding of study objectives is essential to selecting the appropriate sampling approach**
  - **Sample location relative to the distribution of cyanobacteria may substantially affect results**
  - **Sample type (total, dissolved, particulate) can affect results and comparability to other studies**
  - **Results may vary considerably depending on when, where, and how samples are collected**

Photo Courtesy of KDHE

Sample Collection Guidance

USGS National Field Manual Chapter 7.5

Cyanobacteria in Lakes and Reservoirs: Toxin and Taste-and-Odor Sampling Guidelines

http://water.usgs.gov/owq/FieldManual/Chapter7/7.5.html

SIR 2008-5038 ***Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs***

http://pubs.usgs.gov/sir/2008/5038

Additional Information:

http://ks.water.usgs.gov/studies/qw/cyanobacteria/

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