Cyanobacterial Blooms: Tastes, Odors, and Toxins

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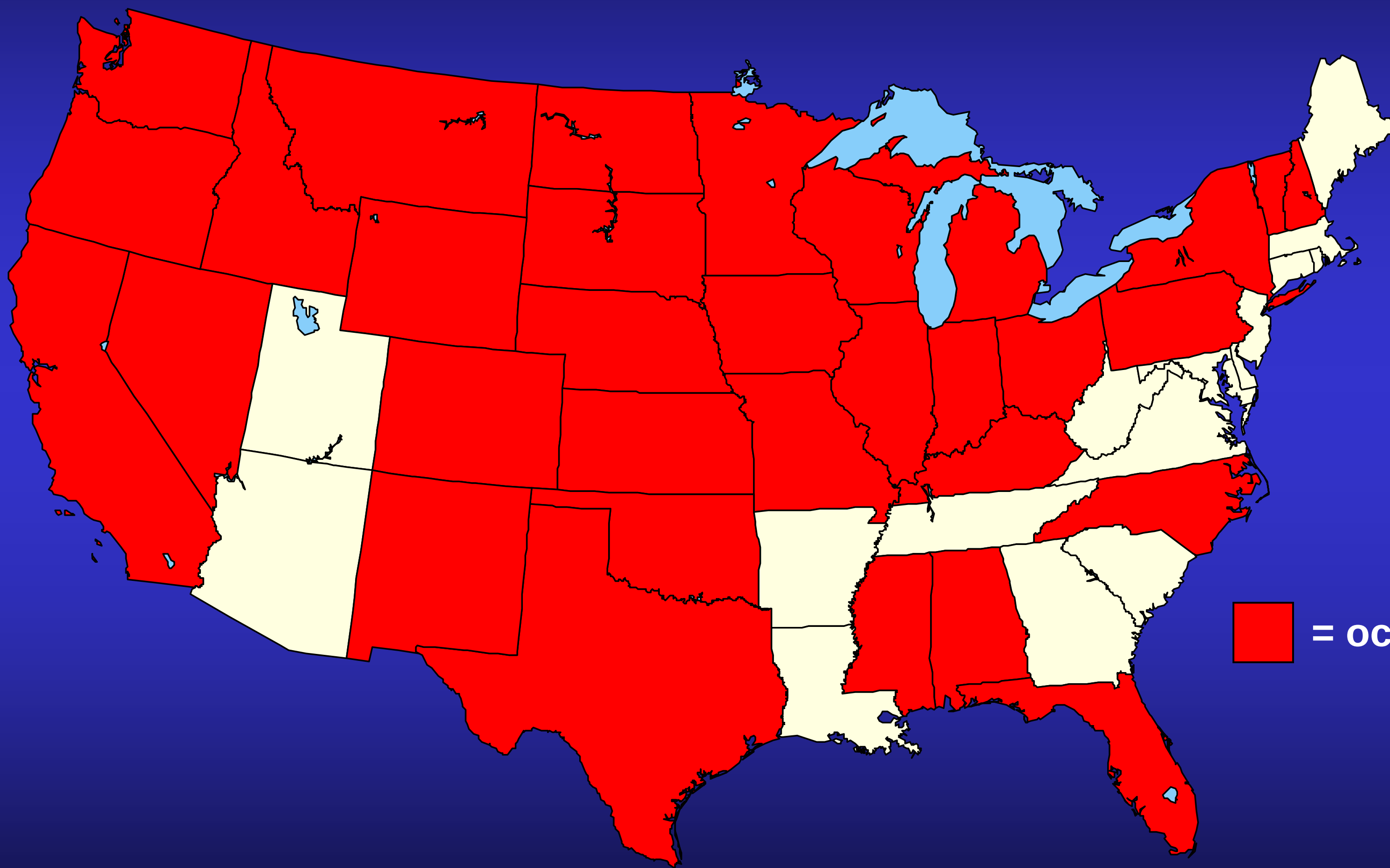
Known Occurrences of Toxic Freshwater Cyanobacteria in the United States



■ = occurrence

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Overview

- Cyanobacterial taste-and-odor and toxin compounds
- Midwest Occurrence
- USGS studies

Binder Lake, IA August 2006

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Taste, odor, and toxin compounds produced by cyanobacteria

	DERMATOXINS	HEPATOTOXINS		NEUROTOXINS			TASTES/ODORS	
		CYL	MC	ANA	BMAA	SAX	Geos	MIB
CYANOBACTERIA								
Colonial/Filamentous								
Anabaena	X	X	X	X	X	X	X	?
Aphanizomenon	X	X		X	X	X	X	?
Cylindrospermopsis	X	X			X	X		
Lyngbya	X				X	X	X	X
Microcystis	X		X		X			
Oscillatoria	X		X	X	X	X	X	X
Unicellular								
Synechococcus	X		X		X		X	X
Synechocystis	X		X		X			

Cyanobacterial taste-and-odor and toxin compounds are not produced by the same biochemical pathway but patterns in occurrence are similar

- **Extreme spatiotemporal variability**
- **Lack of relation with cyanobacterial community composition or chlorophyll concentration**
- **Coupling with lake processes as influenced by physiochemical, biological, hydrological, and meteorological factors**

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- **Economic Concerns**
  - Added drinking water treatment costs
  - Loss of recreational revenue

- **Health Concerns**
  - Tastes-and-Odors
    - Olfactory sensitivity at low concentrations (< 0.01 µg/L)
    - Chronic effects?
  - Toxins
    - Human and animal illness and death
    - EPA contaminant candidate list
    - Drinking water - microcystin
      - WHO guideline – 1.0 µg/L
      - Drinking-water treatment processes effectively remove most toxins
    - Recreational water - microcystin
      - Low Risk - < 10 µg/L
      - Moderate Risk - 10-20 µg/L
      - High Risk - > 20 µg/L
    - Known chronic effects

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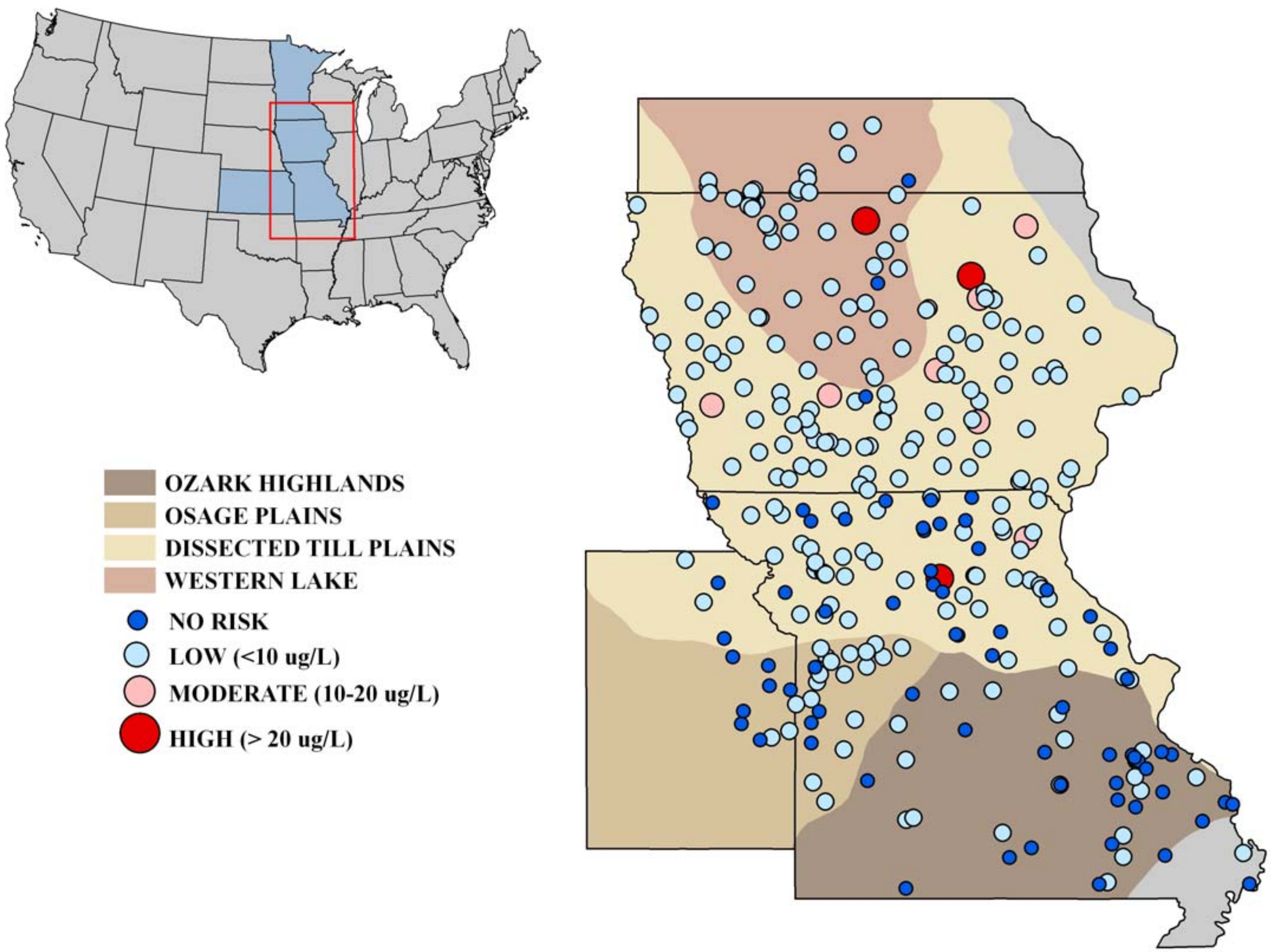
1999-2005 Research Objectives

- Document occurrence, distribution, and concentration of microcystin in midwestern lakes and reservoirs
- Determine spatial and temporal variation in microcystin concentration
- Develop empirical relations between environmental variables and microcystin concentration

Mozingo Lake, MO October 2001

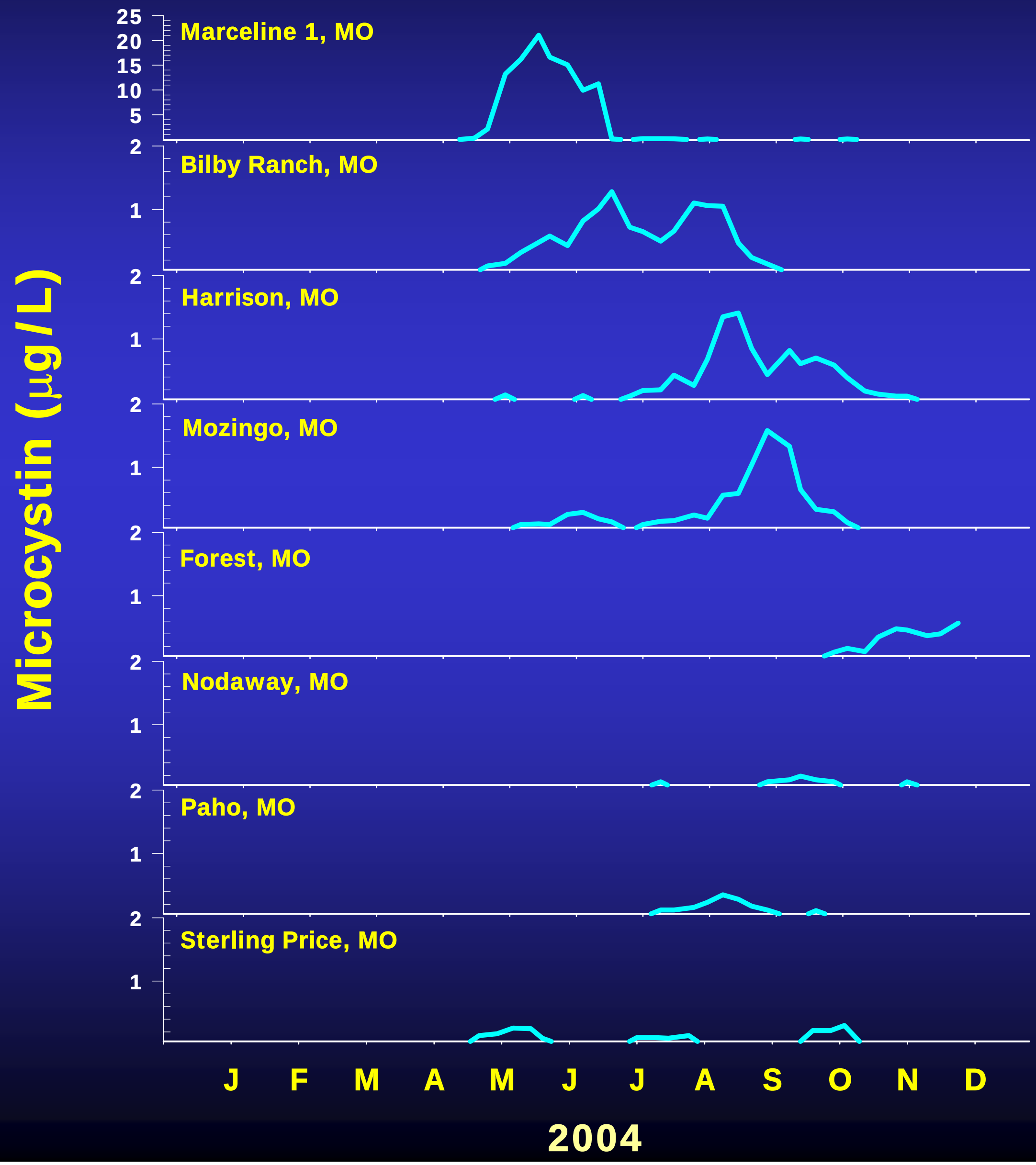
Storm Lake, IA August 1999

During 1999-2005 microcystin was detected in 72% of lakes sampled (n=305) and concentrations ranged from <0.1 to 52 µg/L

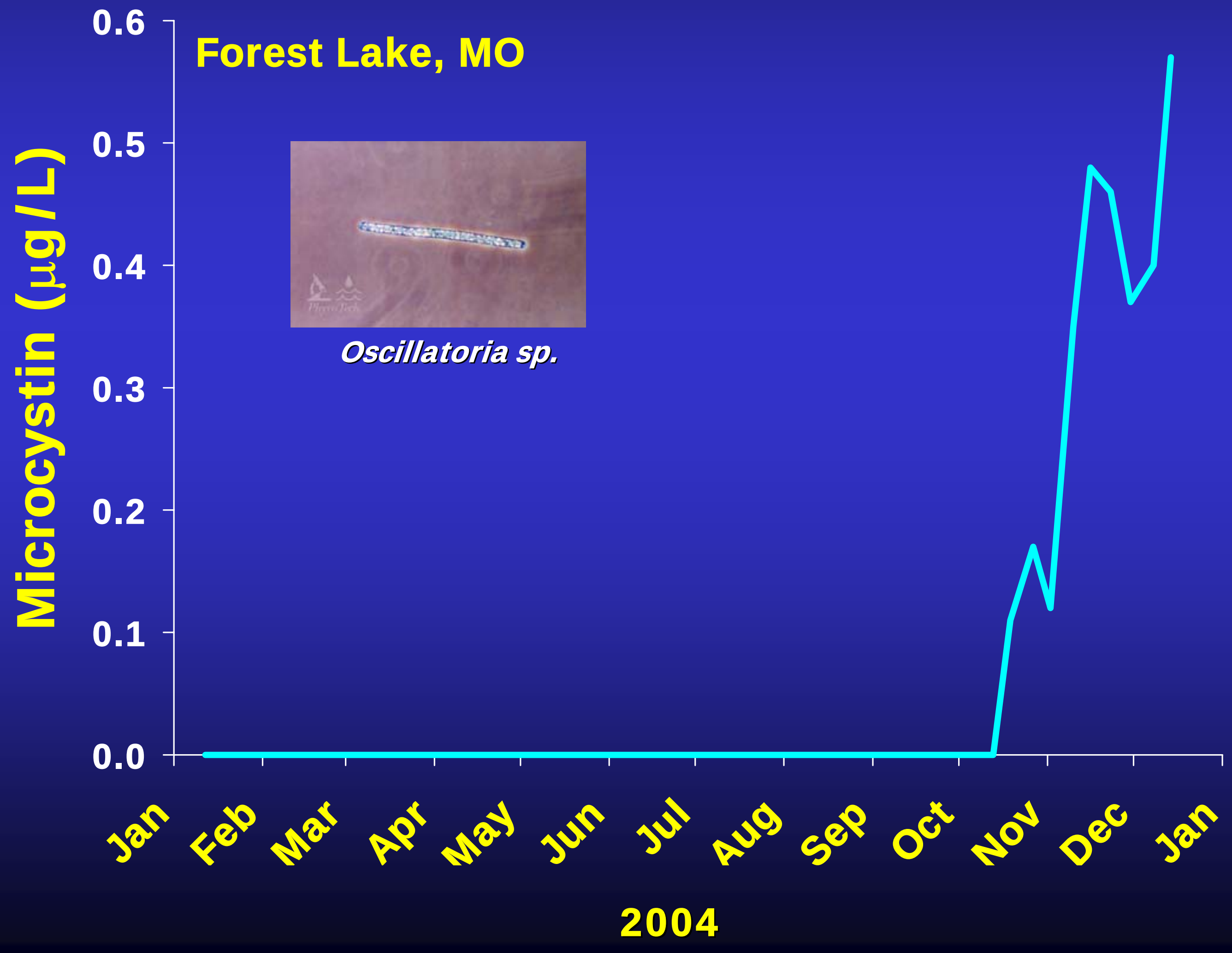


After Graham et al., 2004

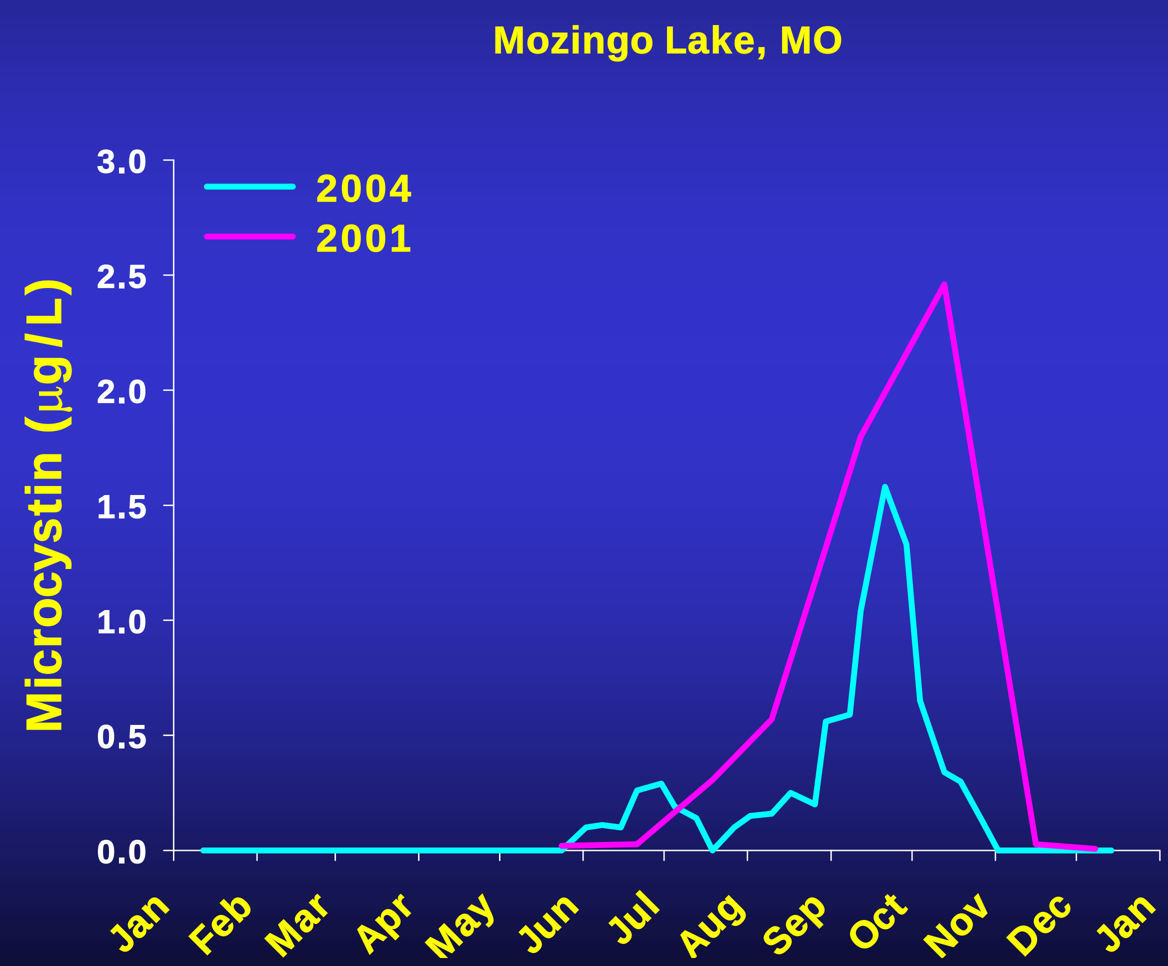
Seasonal patterns in microcystin concentration were unique to individual lakes and peaks occurred anytime from May-December



Peak microcystin values occurred in the winter



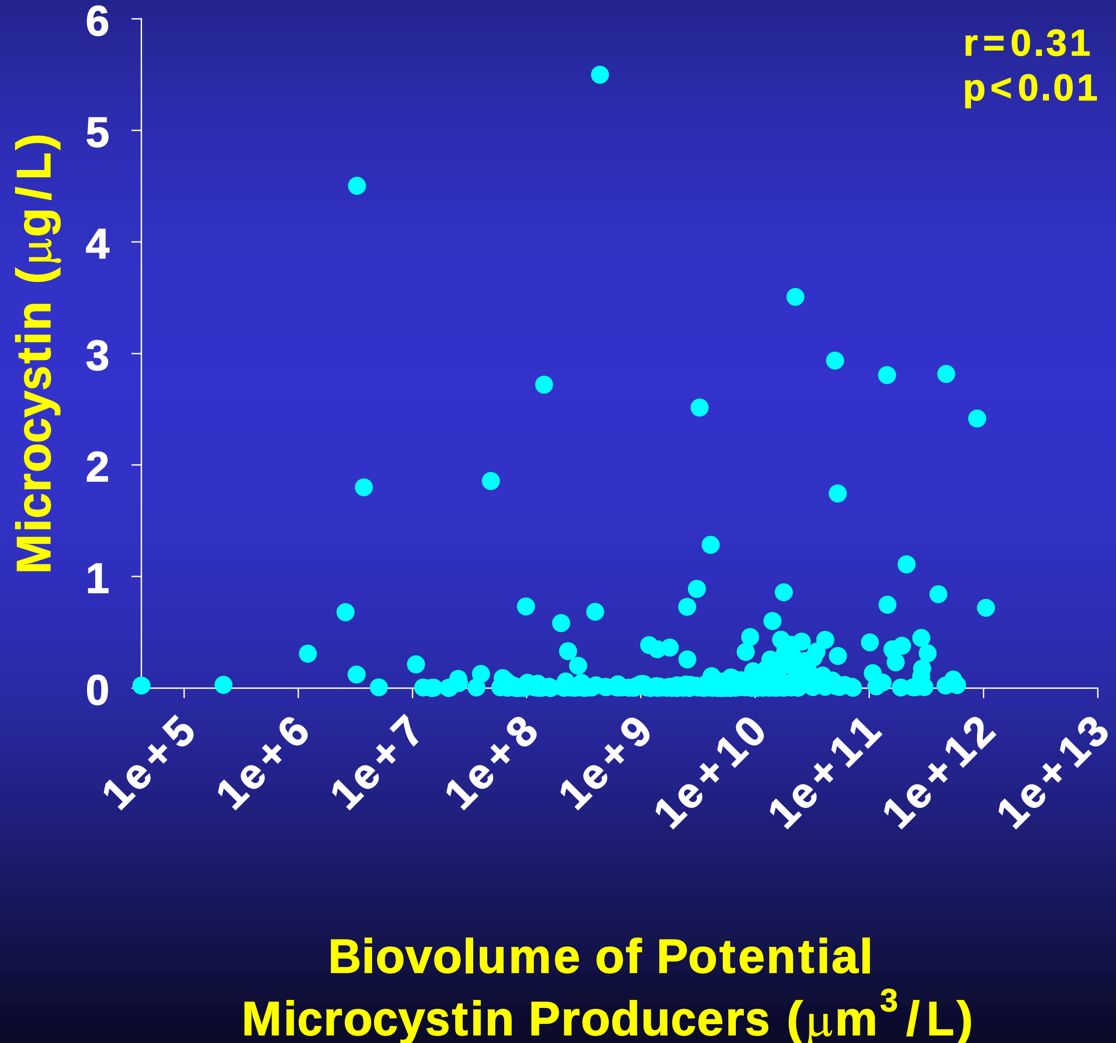
Seasonal patterns were relatively consistent between years in some lakes



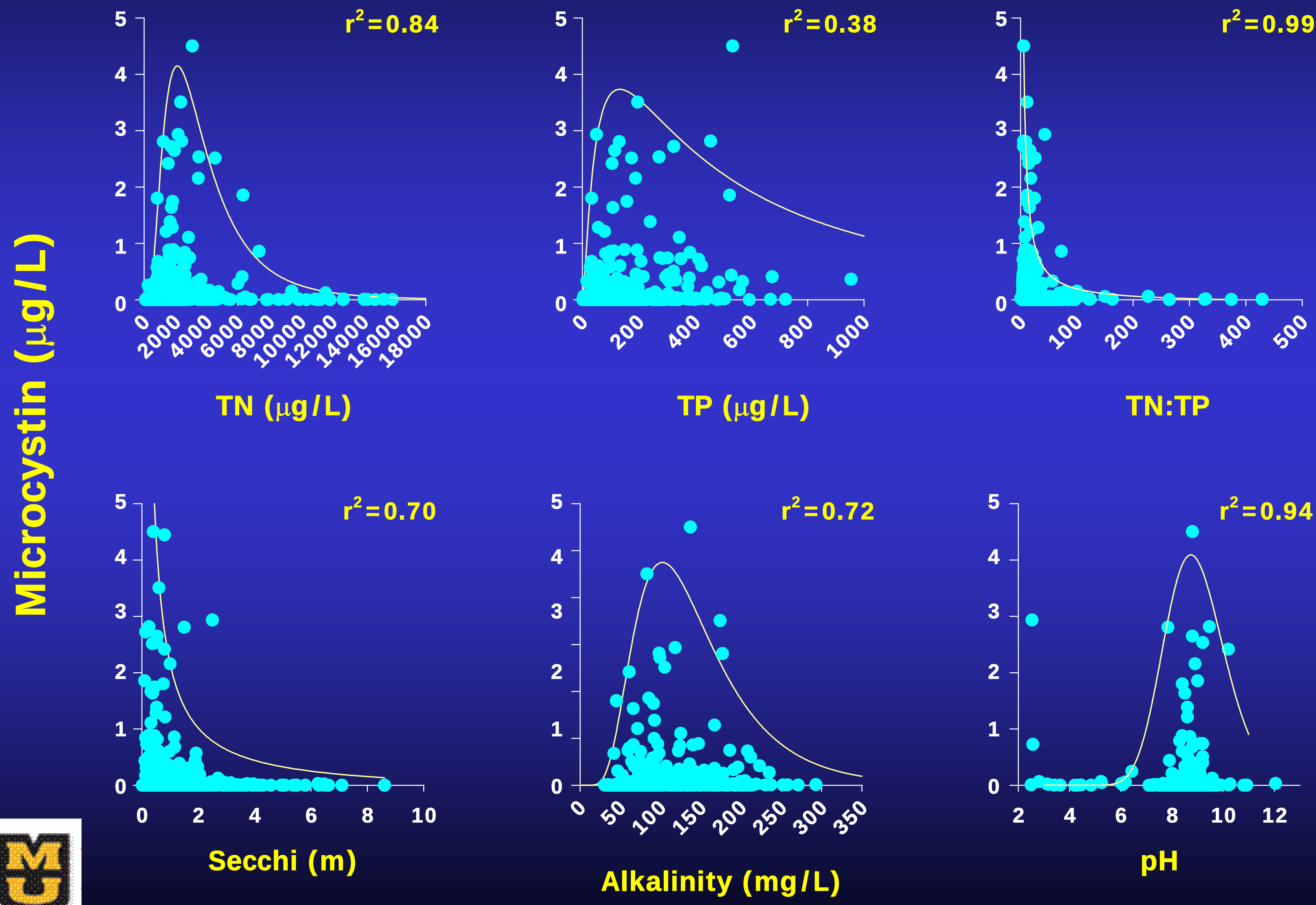
Regionally, microcystin was significantly correlated with factors that affect cyanobacterial growth

Variable	r_s	p-value	n
Latitude	0.66	<0.01	800
Total Nitrogen (TN)	0.58	<0.01	795
Total Phosphorus (TP)	0.46	<0.01	795
Secchi	-0.27	<0.01	796
pH	0.17	<0.01	507
Alkalinity	0.15	<0.01	432
TN:TP	-0.15	<0.01	791

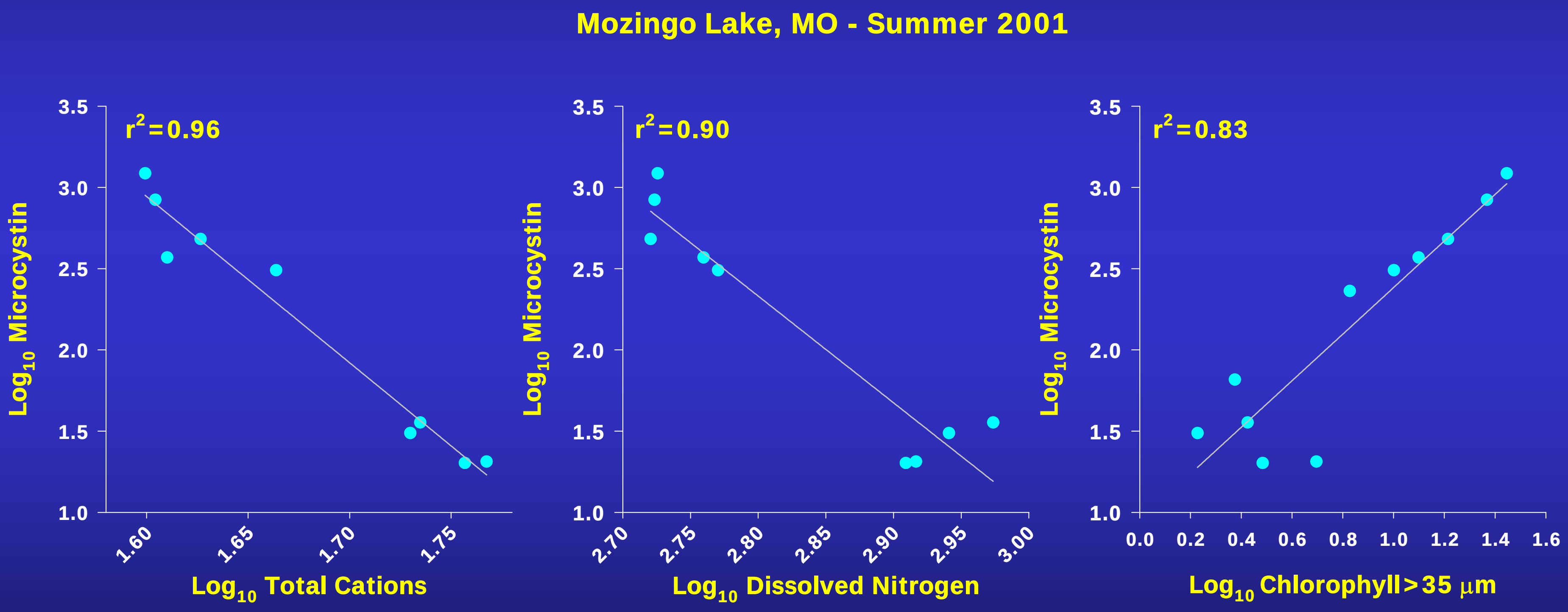
Regionally, microcystin was not strongly correlated with measures of the cyanobacterial community (data from 1999-2001)



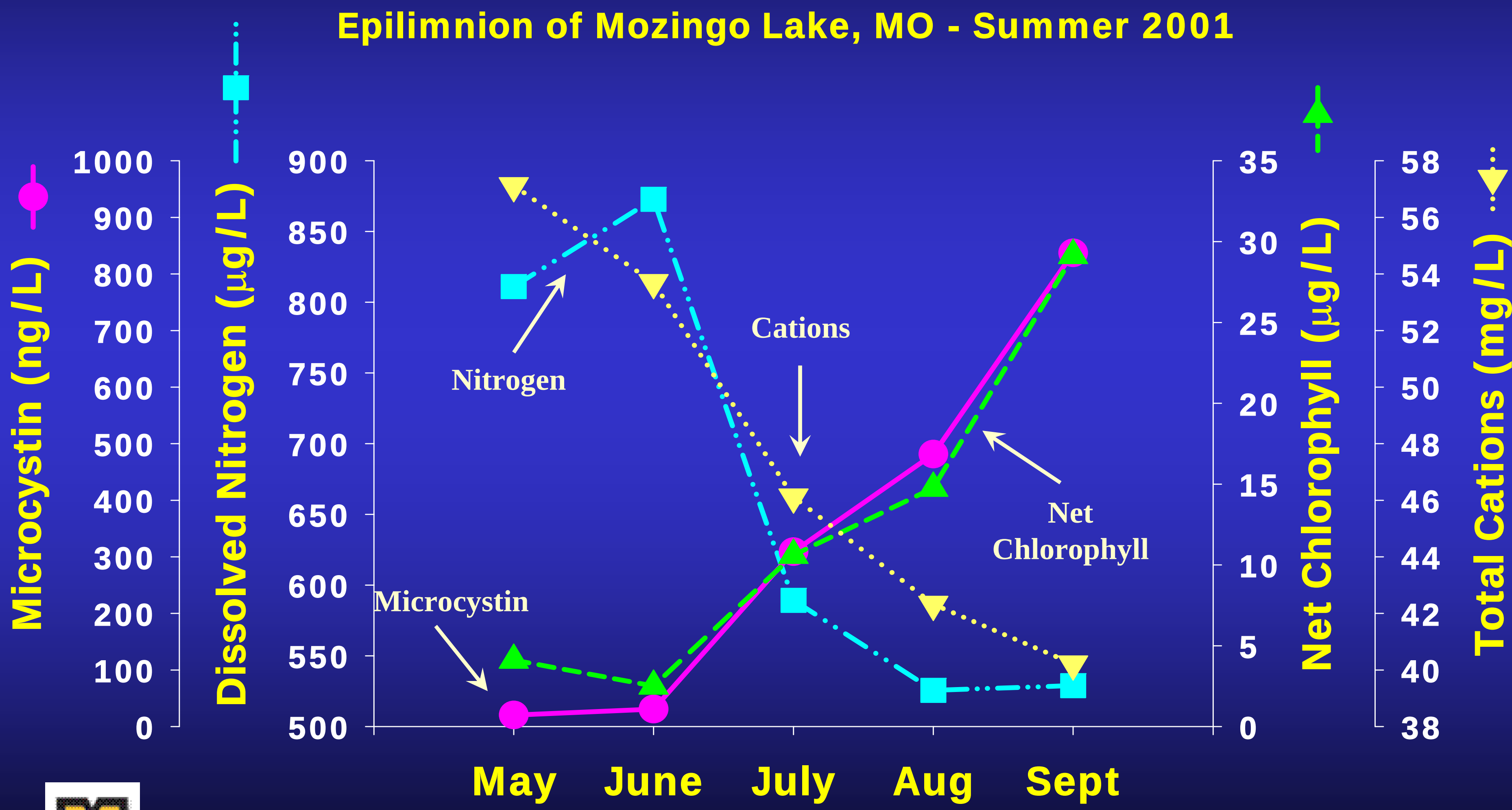
Regional relations between microcystin and environmental variables were not linear (data from 1999-2001)



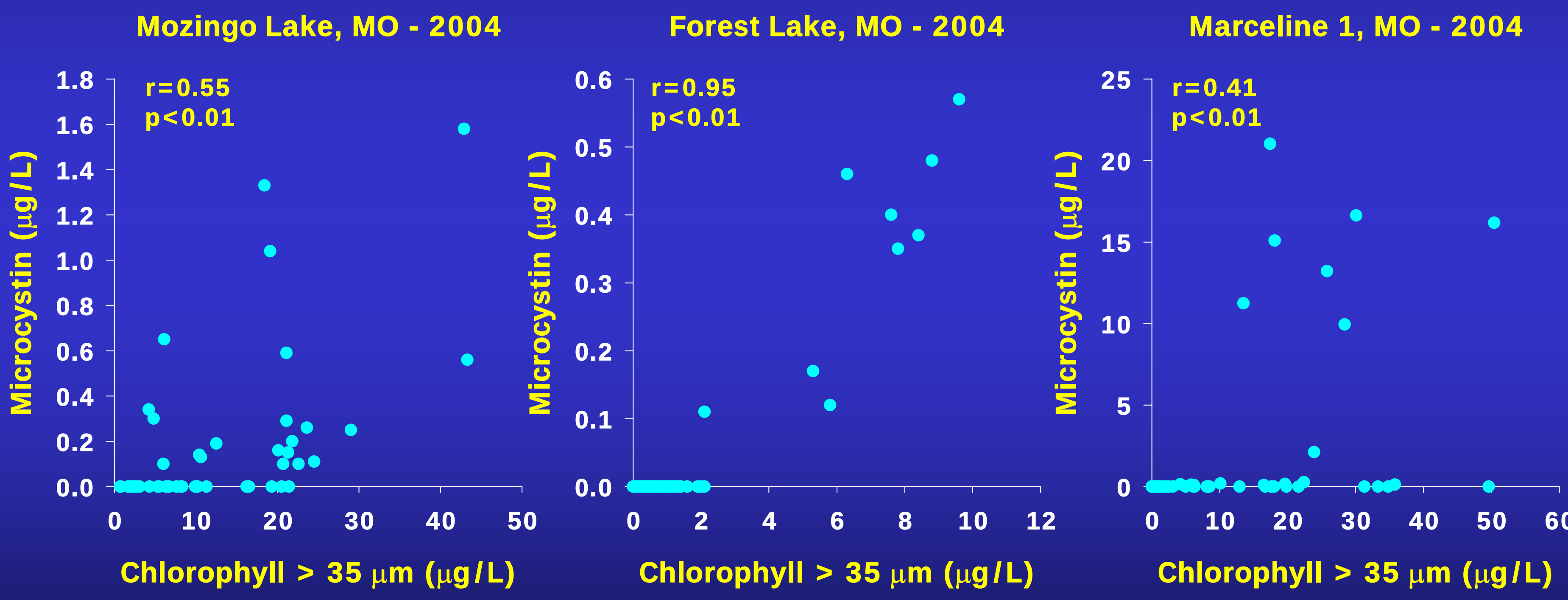
Individual lake correlations between microcystin and environmental variables were linear



Coupling with seasonal lake processes, including stratification and nutrient loss from the epilimnion



Factors most strongly correlated with microcystin vary among lakes and years



Microcystin in Midwestern Lakes - Conclusions

- Microcystin is common in Midwestern lakes and reservoirs and may reach levels that can cause health concerns
- Seasonal patterns in microcystin concentration are unique to individual lakes and maxima may occur in any season
- Regional relations between microcystin and environmental variables are non-linear, and suggest optima for maximum microcystin concentrations
- Microcystin and environmental variables may be tightly coupled in individual lakes, but relations vary among lakes and years

Research Needs and Progress

- Expanded Lake and River Monitoring
- Reliable Analytical Techniques
- Long-Term Studies
- Methods for Early Detection
- Predictive Models

East Okoboji, IA June 2000

Cheney Reservoir, KS June 2003
Photo Courtesy of KDHE

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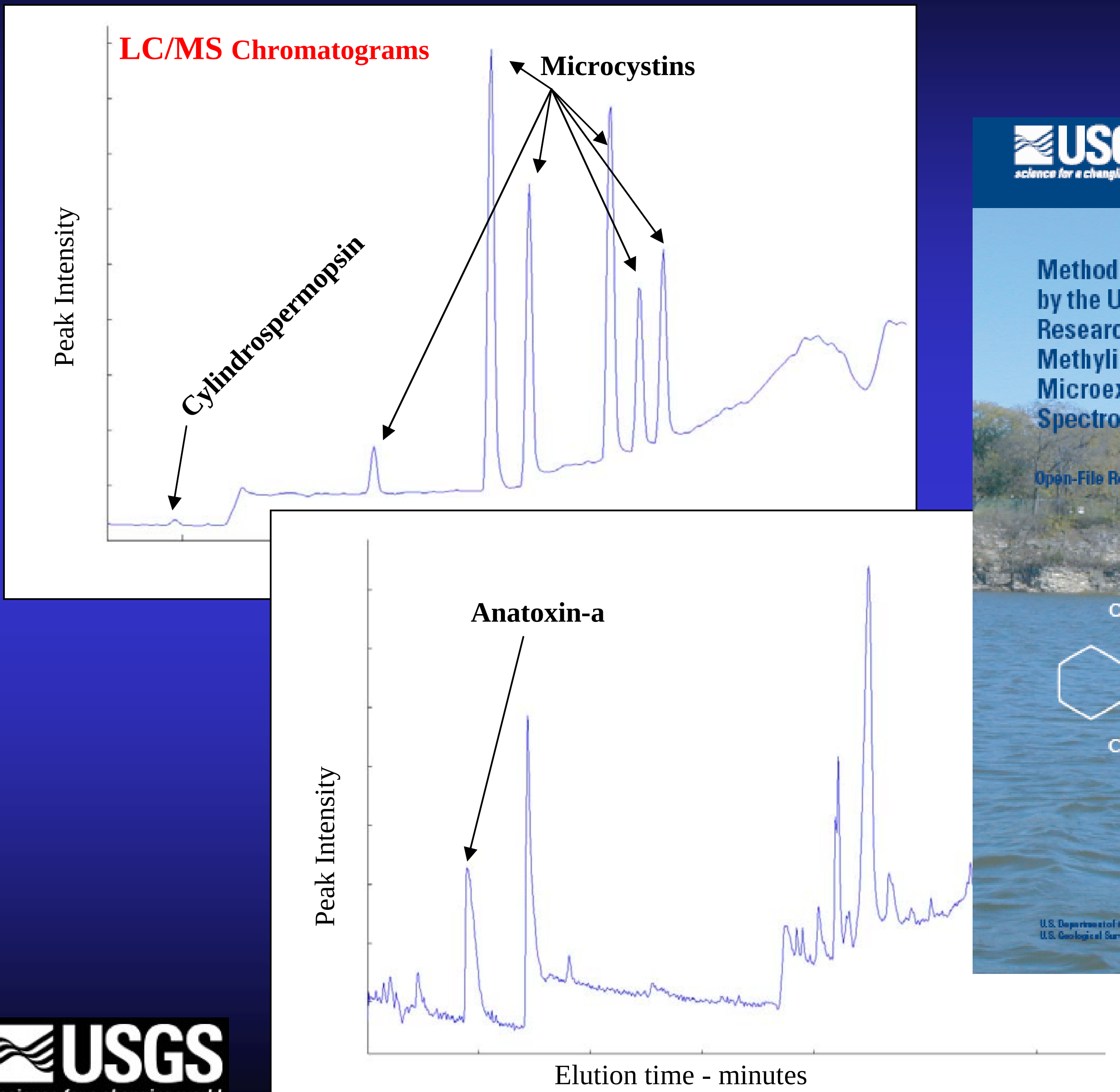
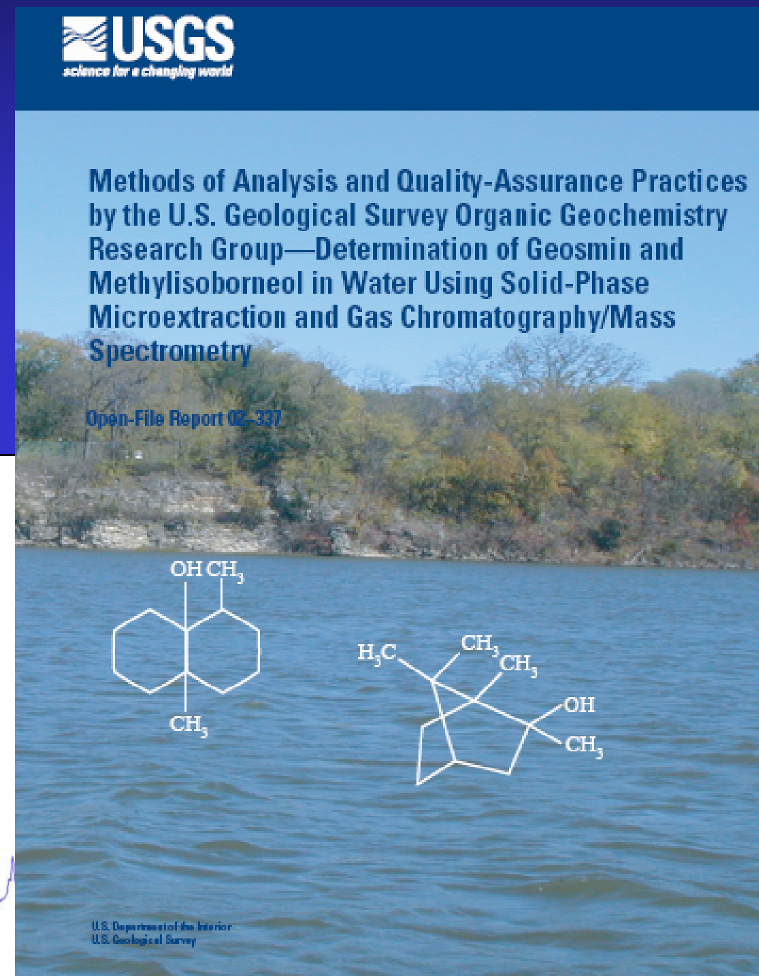
Expanded monitoring and reliable analytical techniques





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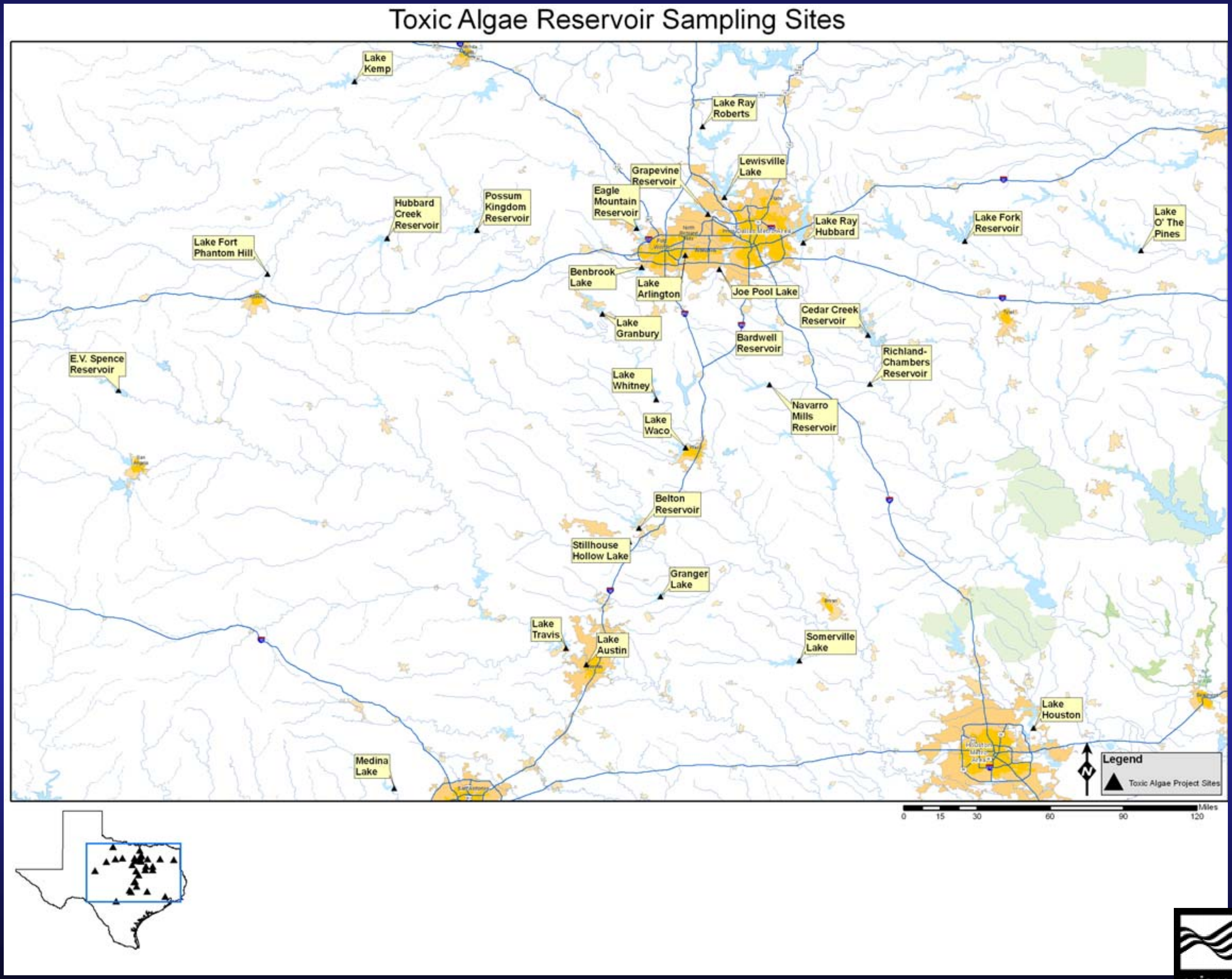
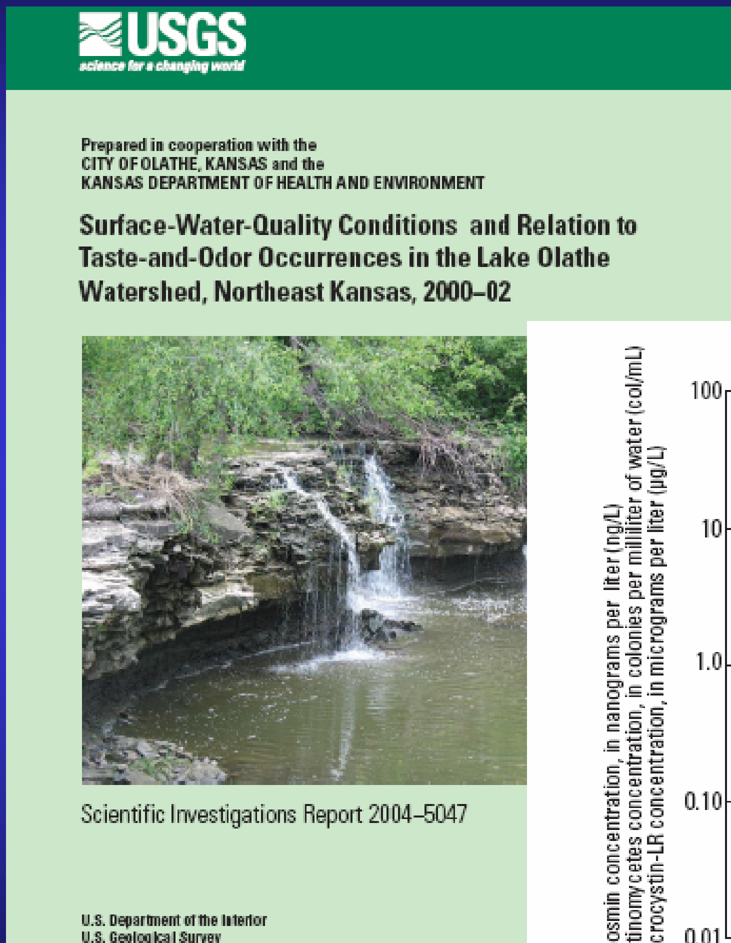
Texas toxin and taste-and-odor occurrence studies



Actinomycetes bacteria also produce geosmin and MIB and may contribute to taste-and-odor problems in reservoirs



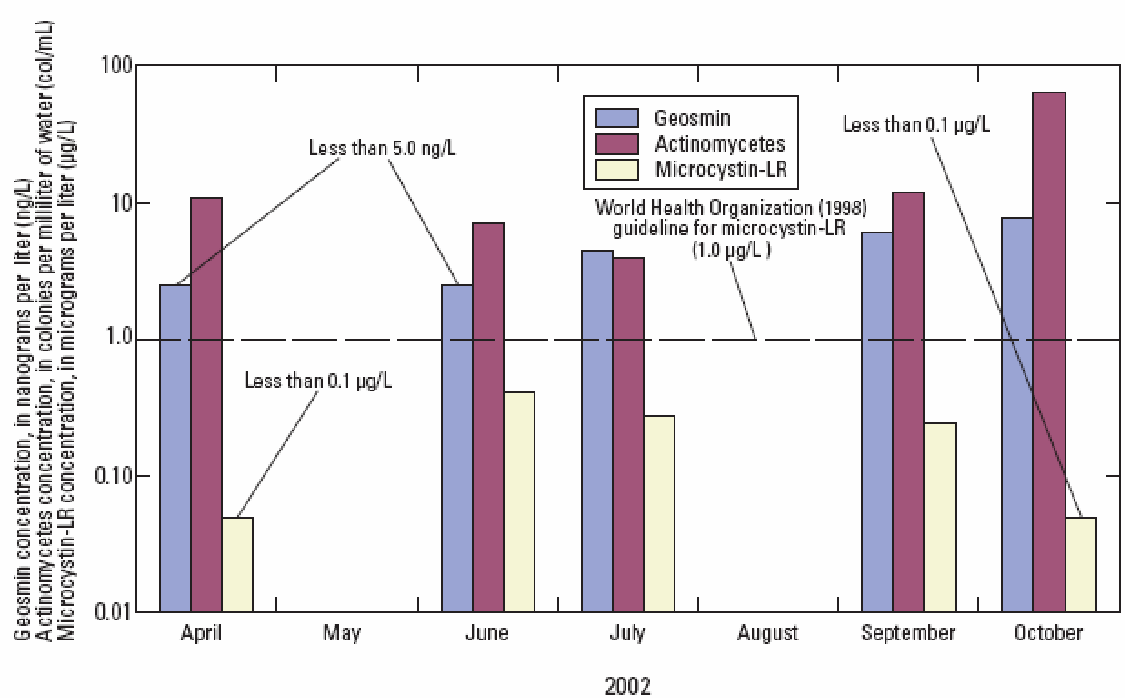


Figure 14. Concentrations of geosmin, actinomycetes, and microcystin in Lake Olathe near dam (site 2), April–October 2002.

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Long Term Studies – Assessment of Water Quality in the North Fork Ninnescah River and Cheney Reservoir, 1997-present

- **Concerns**
  - Taste-and-odor occurrences related to algal blooms
  - Relation between watershed inputs and taste-and-odor causing algae
- **Approach**
  - Describe current and historical loading inflow to Cheney Reservoir using reservoir and watershed sediment studies and continuous water-quality monitoring
  - Describe physical, chemical, and biological processes associated with the proliferation of algae and production of algal by-products using a combination of discrete samples and real-time monitors

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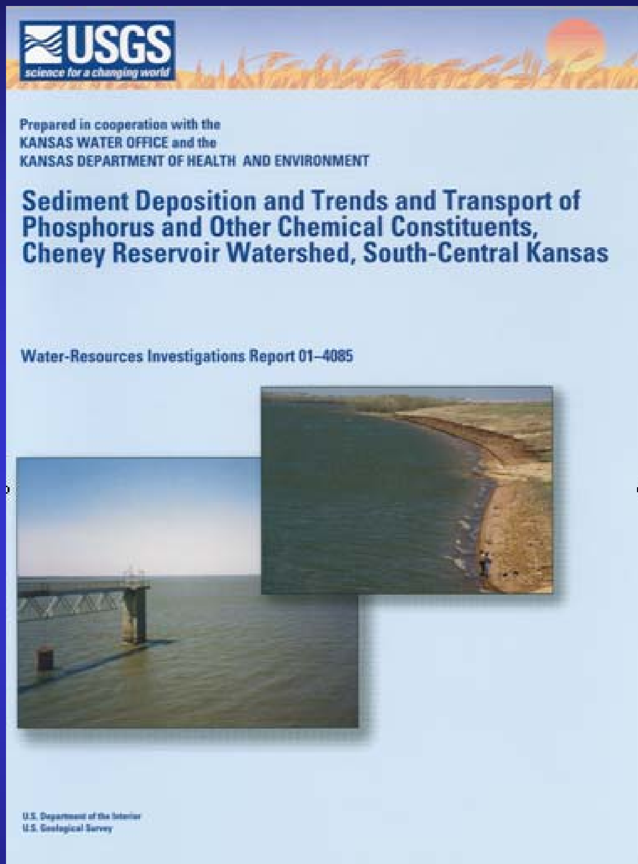
Sediment cores show increasing phosphorus trend over time in Cheney Reservoir



Sediment Core Analyses

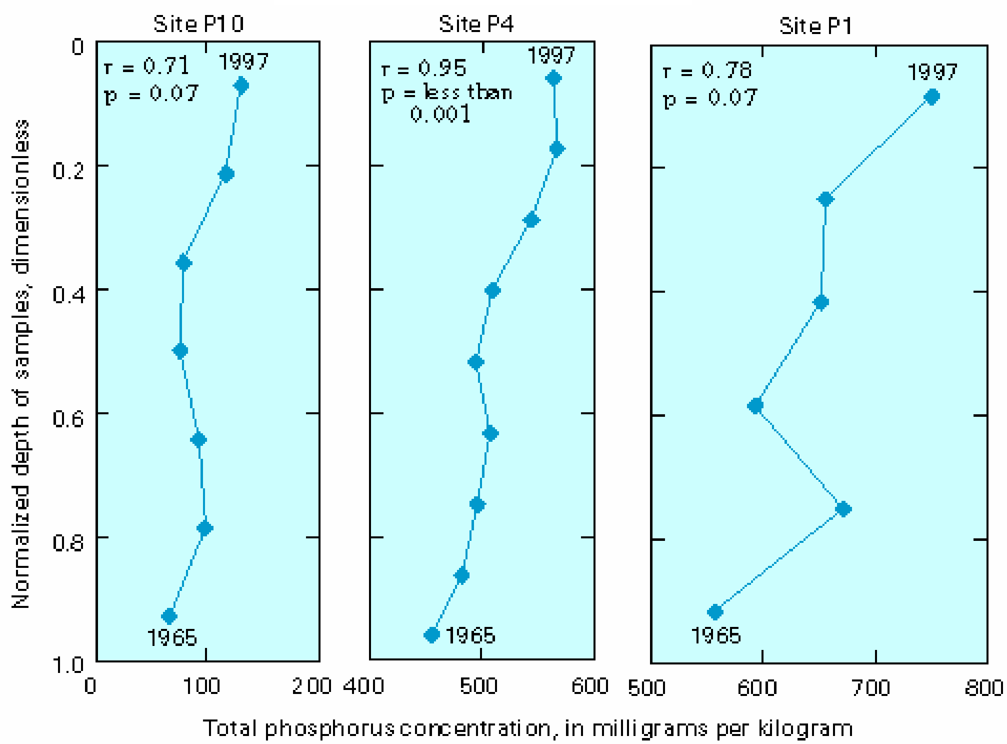


Figure 9. Relation between total phosphorus concentrations in bottom-sediment core samples and normalized depth of samples from selected coring sites in Cheney Reservoir, 1965-97 (modified from Pope, 1998, fig. 10). Sediment cores were collected in August 1997.

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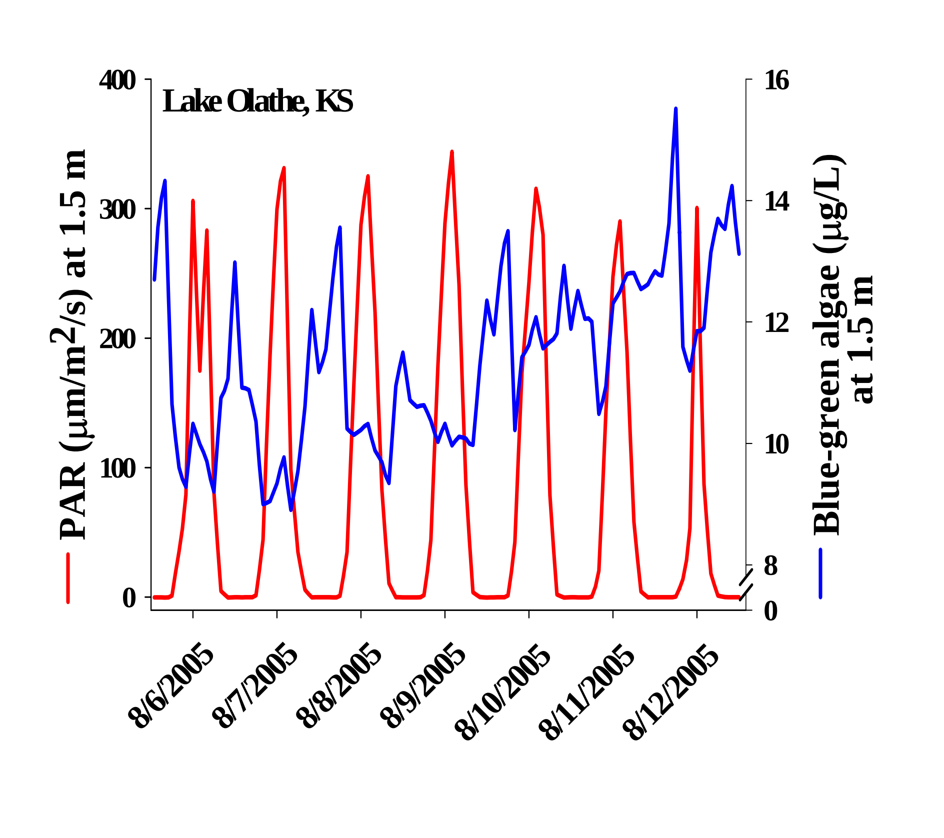
Early detection, predictive models, and continuous water-quality monitors



- Specific conductance, pH, water temperature, turbidity, dissolved oxygen
- Chlorophyll
- PAR (light)
- Blue-green algae (Hydrolab,
- YSI, SCUFA)
- Nitrate (ISUS)

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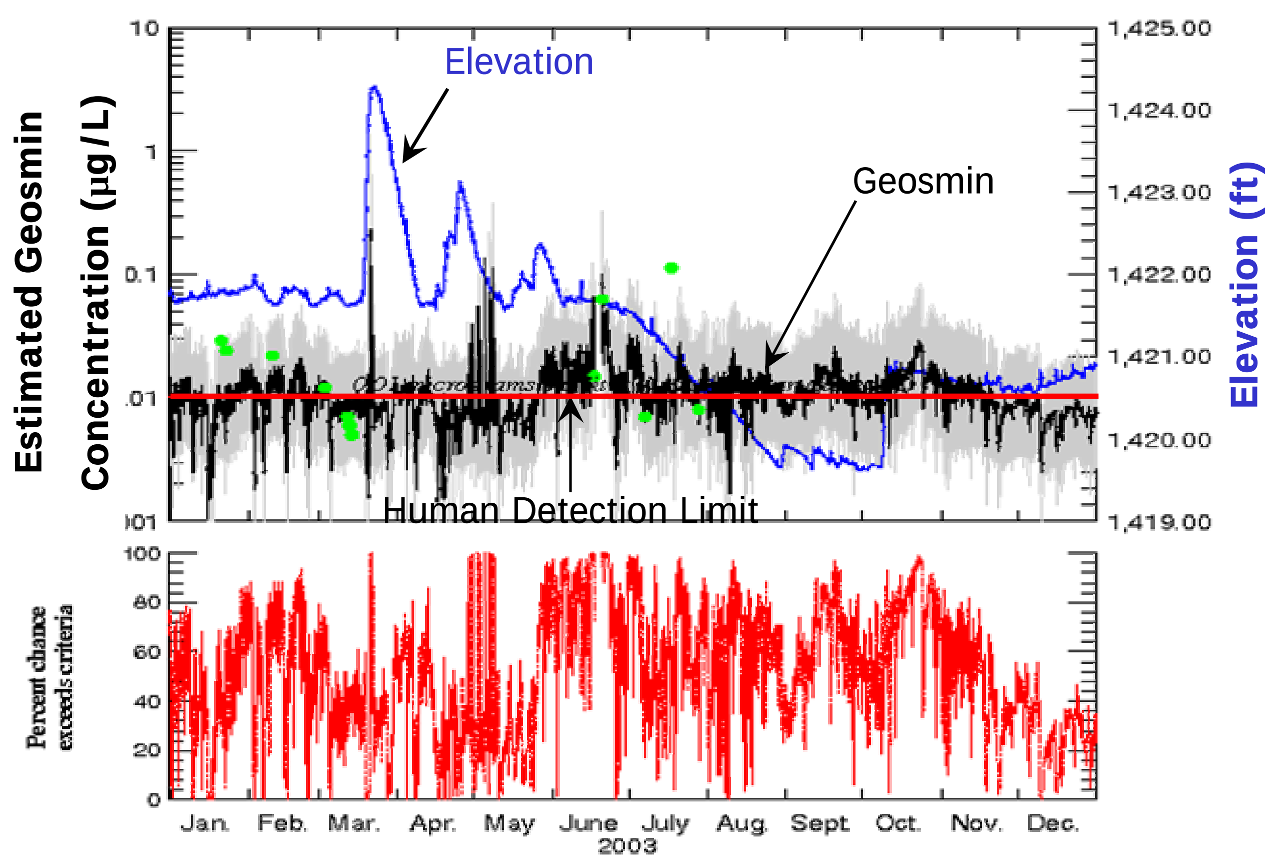
Early Detection - Geosmin concentrations in Cheney Reservoir frequently exceed the human detection limit of 10 ng/L

log10(Geo) = 7.2310 - 1.0664 log10(Turb) - 0.0097 SC
r^2=0.71



Estimated Geosmin Concentration 2003

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Thomas Lake, NE May 2006

Mozingo Lake, MO June 2000

Elysian Lake, MN August 2006

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Additional Information Available on the Web:

RTQW - http://ks.water.usgs.gov/Kansas/rtqw/index.shtml
Cheney - http://ks.water.usgs.gov/Kansas/studies/qw/cheney
Olathe - http://ks.water.usgs.gov/Kansas/studies/qw/olathe
Cyanobacteria - http://ks.water.usgs.gov/Kansas/studies/qw/cyanobacteria