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Co-Occurrence of Toxins and Taste-and-Odor Compounds in Cyanobacterial Blooms from the Midwestern United States

USGS Kansas Water Science Center Algal Toxin Team

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Overview

- Historical Studies
- Study Design and Approach
- Results
  - Limnological Conditions
  - Phytoplankton Community Structure
  - Toxin Occurrence
  - Microcystin Variants
  - Toxin and Taste-and-Odor Co-Occurrence
  - Concentrations
  - Relations among compounds
- Summary

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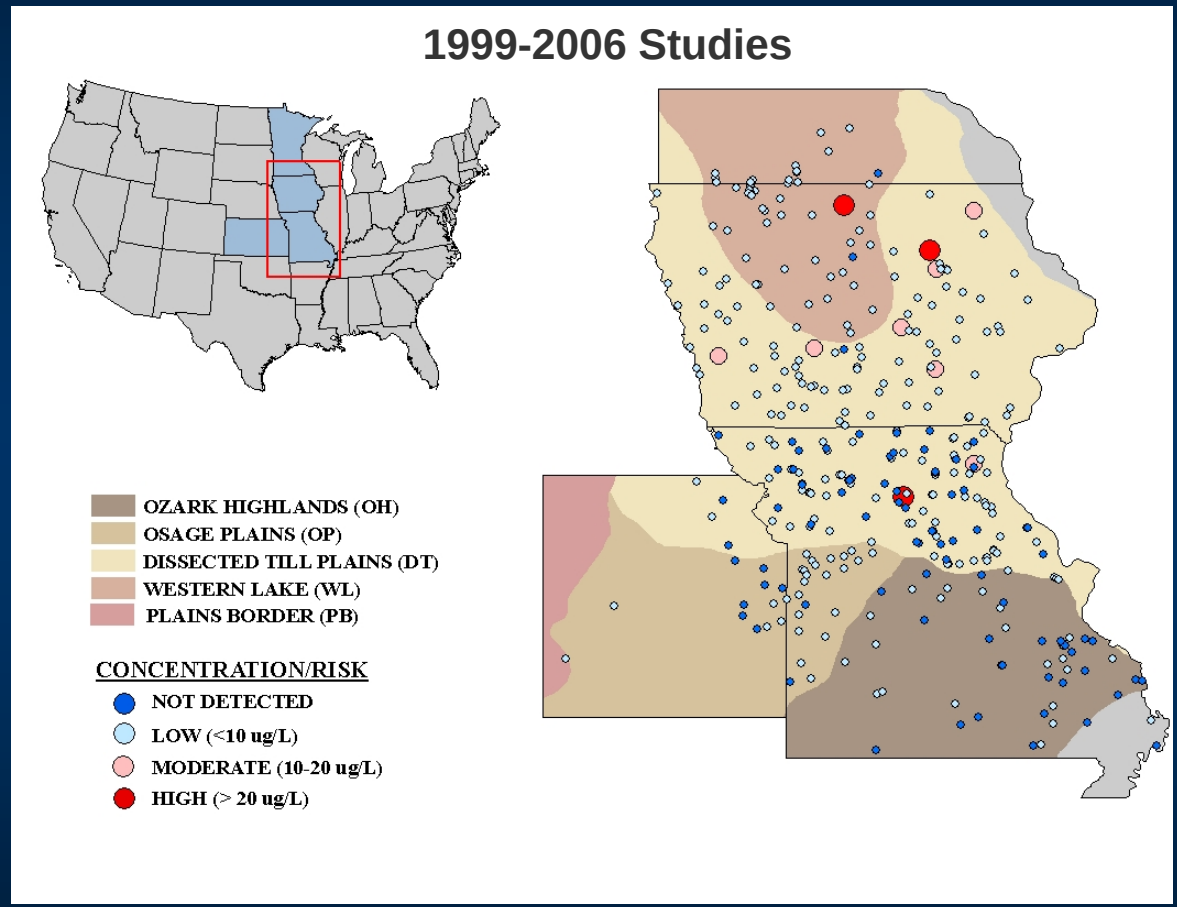
Microcystin is Common in the Midwest and May Reach Concentrations Great Enough to Cause Human Health Concerns

Sampling

- Integrated photic zone samples during summer
- Lakes were sampled multiple times (n=3-26)
- Microcystin measured by ELISA

Results

- 78% of lakes (n=359) had detectable concentrations of microcystin at least once
- Total concentrations ranged from <0.1 to 52 µg/L



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After Graham and others 2004 and 2006

2006 USGS Midwestern Cyanotoxin Reconnaissance – Objectives

- Document the occurrence and co-occurrence of cyanobacterial toxins and taste-and-odor compounds in the Midwest

- Identify the microcystin variants that commonly occur in the Midwest

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2006 USGS Midwestern Cyanotoxin Reconnaissance – Design

Targeted Sampling During August 2006

- Lakes and reservoirs (n=23) with a history of late summer cyanobacterial blooms
- Blooms and surface accumulations

USGS Cyanobacteria Sampling Guidelines:
http://pubs.usgs.gov/sir/2008/5038/

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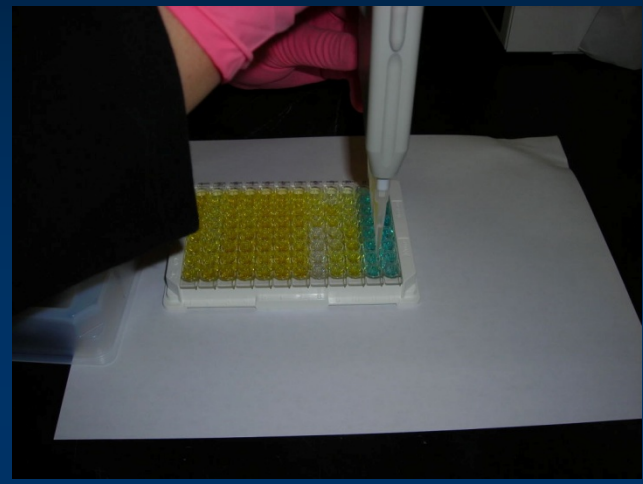
2006 USGS Midwestern Cyanotoxin Reconnaissance– Analyses

- Toxins – Total by Freeze/Thaw Extraction
  - **ELISA**: microcystins (ADDA), cylindrospermopsins, saxitoxins
  - **LC/MS/MS**: 7 microcystins (LR, RR, YR, LW, LA, LF, LY), Nodularin, Anatoxin-a, Cylindrospermopsin, Deoxycylindrospermopsin, Lyngbyatoxin-a
- Taste-and-Odor Compounds
  - **SPME GC/MS**: Geosmin, 2-methylisoborneol (MIB)
- Phytoplankton Community Composition
- Chlorophyll
- *In Situ* Water-Quality Measurements



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A Wide Range of Lake Types and Conditions Were Included in the 2006 USGS Midwestern Cyanotoxin Reconnaissance

- Physical Characteristics
  - Surface Area (Ha): 15-4,512
  - Volume (Ha m^{-1}): 41-25,800
  - Mean Depth (m): 0.8-6.5
  - Maximum Depth (m): 1.5-15.0
  - Drainage Area (Ha): 89-289,000
- Water Quality
  - Secchi Depth (m): 0.1-0.9
  - Temperature (ºC): 25.5-30.7
  - Specific Conductance (µS/cm): 197-694
  - Dissolved Oxygen (mg/L): 4.1-16.0
  - Turbidity (FNU): 7-179
  - CHLOROPHYLL (µg/L): 28-187,000

Chlorophyll = 28 µg/L

Chlorophyll = 187,000 µg/L

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Cyanobacterial Communities Were Dominated by *Anabaena*, *Aphanizomenon*, and/or *Microcystis*

	Blooms with Taxa Present (%)	Blooms with Taxa Dominant/ Co-Dominant (%)	Potential Toxins and Taste-and-Odor Compounds
Common Toxigenic Genera			
Anabaena	96	26	Anatoxin, Cylindrospermopsin, Geosmin, Microcystin, Saxitoxin
Aphanizomenon	96	43	Anatoxin, Cylindrospermopsin, Geosmin, Microcystin, Saxitoxin
Aphanocapsa	30	4	Microcystin
Cylindrospermopsis	43	22	Cylindrospermopsin, Saxitoxin
Microcystis	96	43	Microcystin
Pseudanabaena	48	0	Anatoxin, MIB, Microcystin
Planktothrix	35	9	Anatoxin, Geosmin, Lyngbyatoxin, MIB, Microcystin, Saxitoxin

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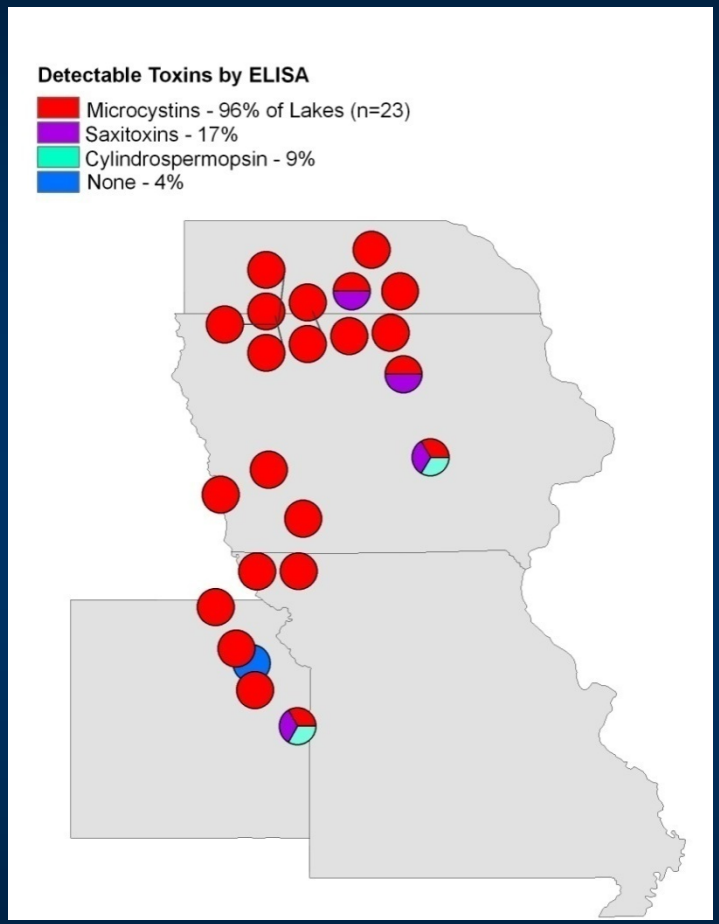
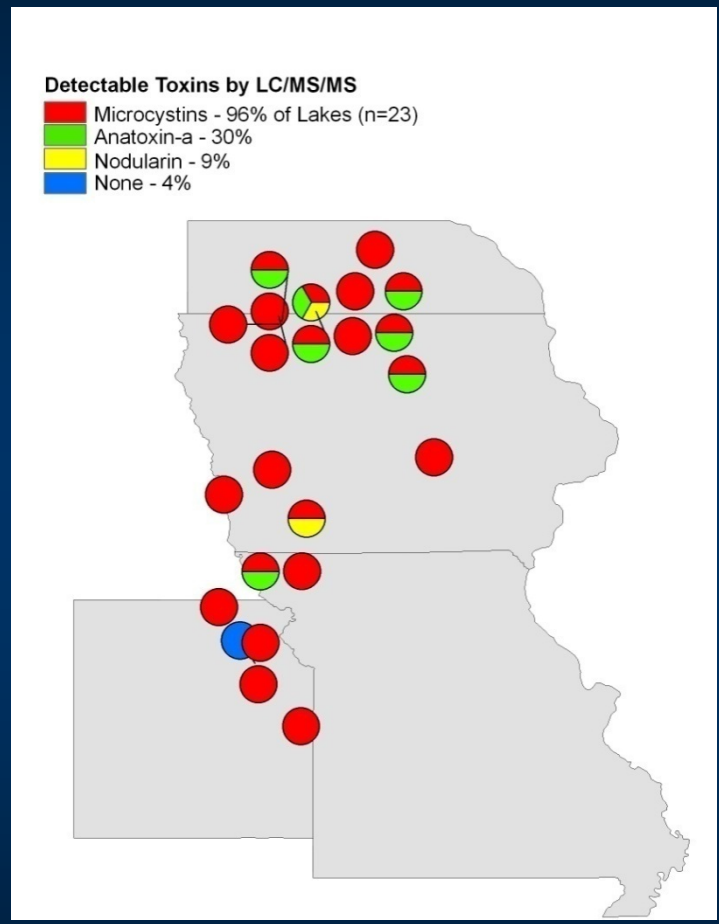
All Blooms Had Detectable Microcystins by Either ELISA or LC/MS/MS and 30% Had Detectable Anatoxin; Saxitoxins, Cylindrospermopsins, and Nodularin Were Less Common





- Microcystin was detected by both ELISA and LC/MS/MS in 96% of blooms.
- Cylindrospermopsin was detected by ELISA but not LC/MS/MS.

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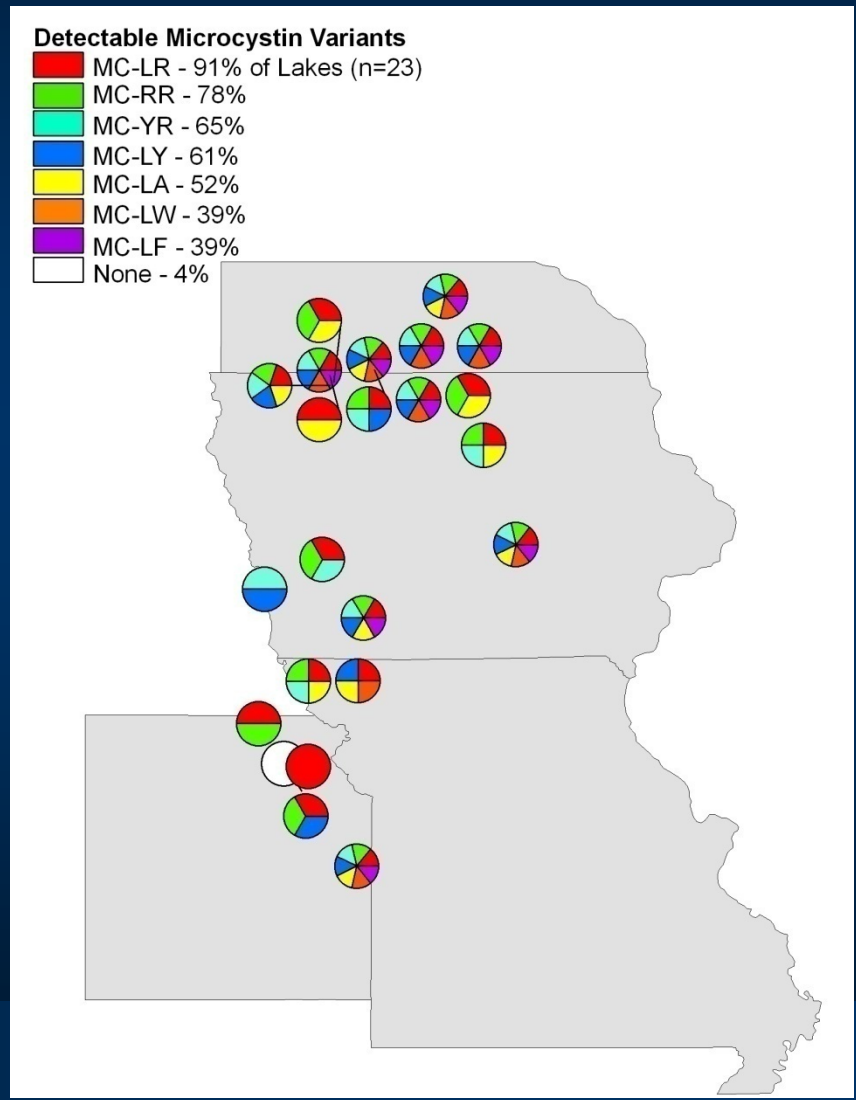
Microcystin-LR Was the Most Common Variant, But It Was Not Detected in ALL Blooms With Detectable Microcystin

- Microcystin-RR, -YR, and –LY also were relatively common.
- 91% of blooms had two or more microcystin variants present.
- 17% of blooms had all seven measured microcystin variants present.



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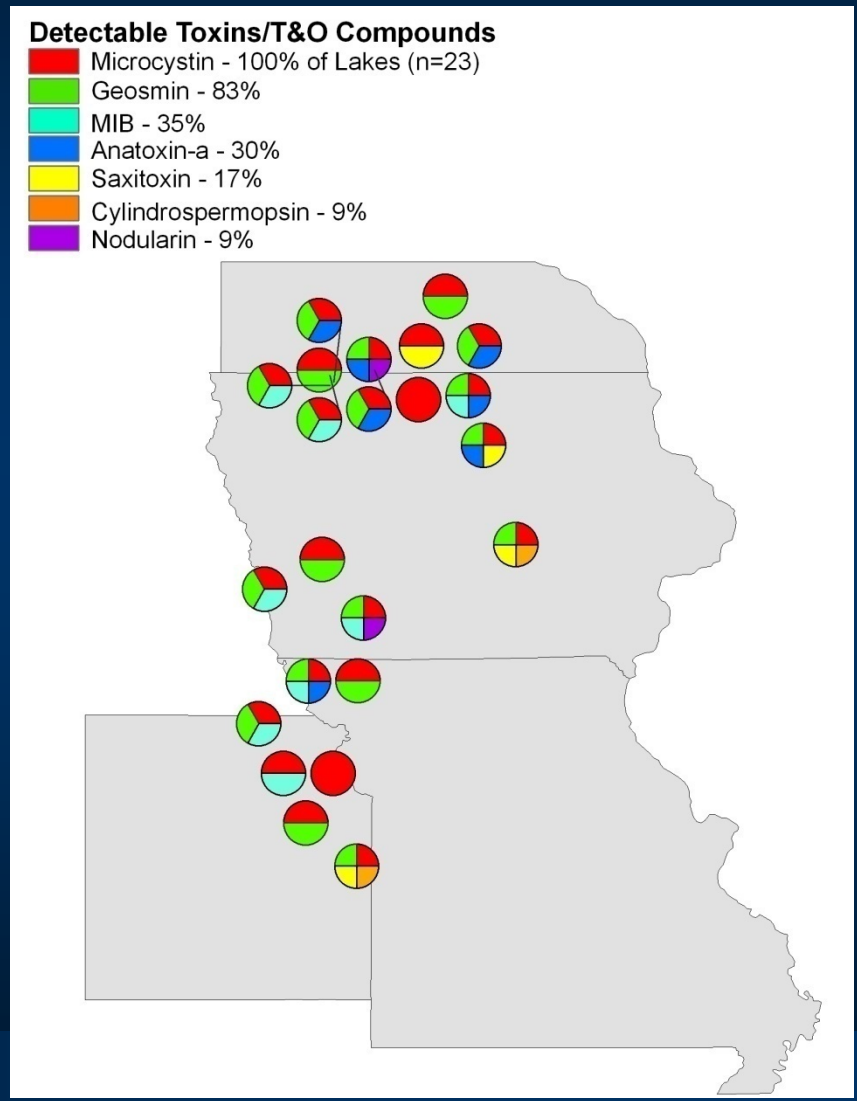
52% of Blooms Had Co-occurring Toxins and 87% Had Co-occurring Toxins and Taste-and-Odor Compounds

- Microcystin and geosmin co-occurred in 83% of blooms.
- When present, anatoxin always co-occurred with geosmin.
- When present, cylindrospermopsin always co-occurred with saxitoxin.
- When present, MIB co-occurred with geosmin in all blooms but one.
- Nodularin was the only compound that was detected with no known cyanobacterial producer present.



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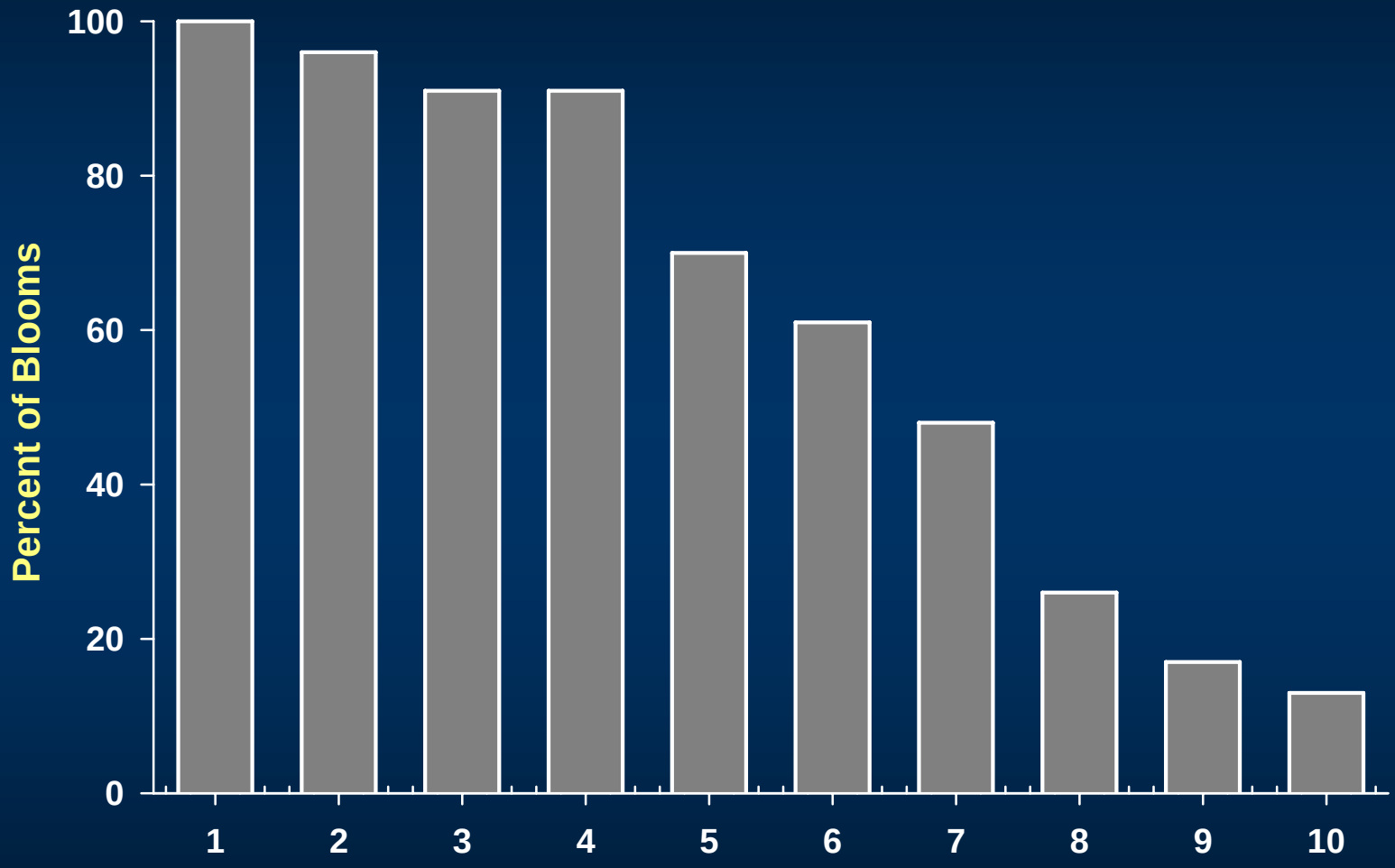
The Majority of Blooms Had At Least Two Measured Compounds Present, and 91% Had At Least Two Different Classes of Compounds



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Microcystin Concentrations Ranged From <0.01 µg/L to 19,000 µg/L, and 17% of Blooms (n=4) Had Concentrations Exceeding the World Health Organization Recreational Guideline of 20 µg/L

All Data (n=23)

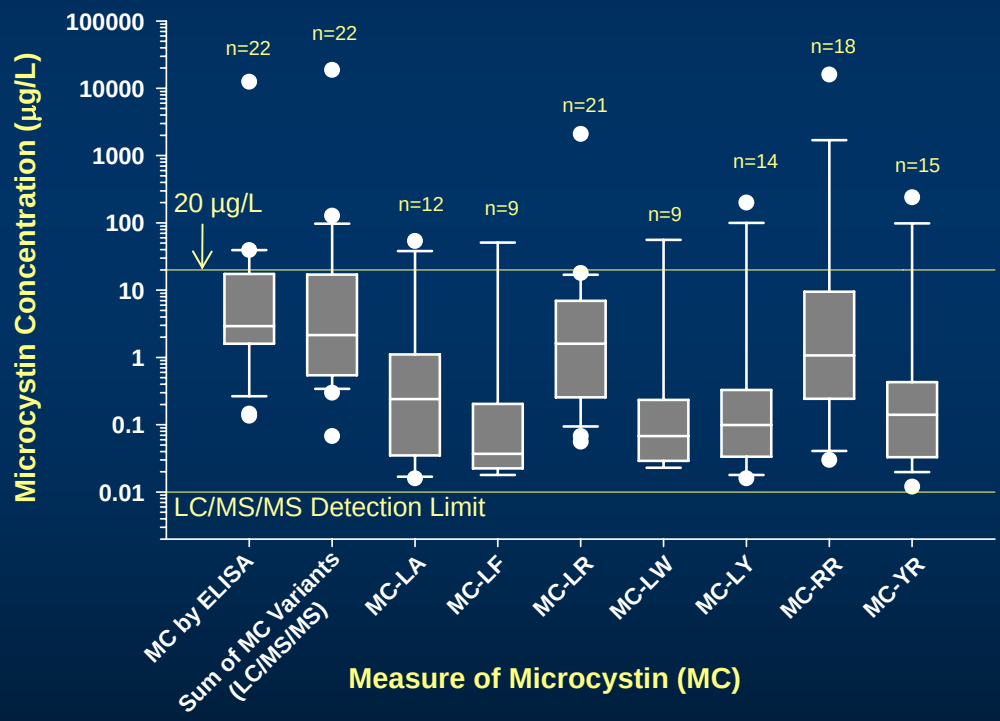
MC (ELISA): <0.1-13,000 µg/L (median=2.8)

Summed MC (LC/MS/MS): <0.01-19,000 µg/L (median=1.8)

MC Congeners:

MC-LA: <0.01-54 µg/L (median=0.02)
MC-LF: <0.01-51 µg/L (median<0.01)
MC-LR: <0.01-2,100 µg/L (median=1.1)
MC-LW: <0.01-56 µg/L (median<0.01)
MC-LY: <0.01-200 µg/L (median=0.02)
MC-RR: <0.01-16,000 µg/L (median=0.6)
MC-YR: <0.01-240 µg/L (median=0.03)

Detections Only



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Concentrations of Other Classes of Compounds Were Orders of Magnitude Less Than Microcystin

All Data (n=23)

Anatoxin: <0.01-10 µg/L (median<0.01)

Cylindrospermopsin: <0.04-0.1 µg/L (med<0.04)

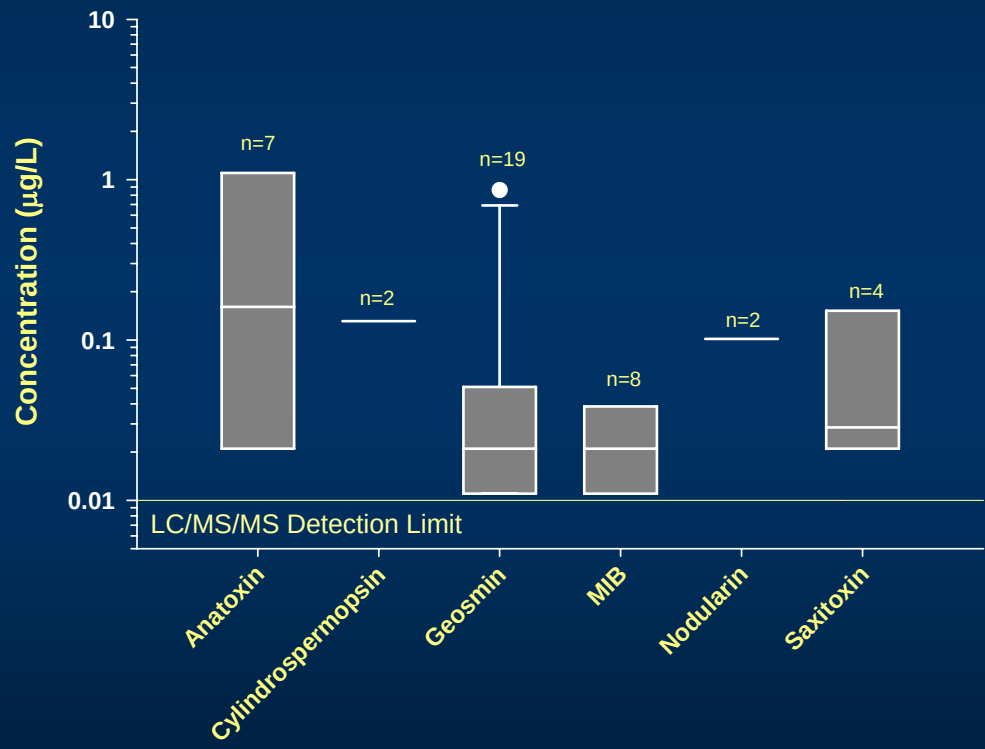
Geosmin: <0.005-0.9 µg/L (med=0.01)

MIB: <0.005-0.06 µg/L (med<0.005)

Nodularin: <0.04-0.2 µg/L (med<0.04)

Saxitoxin: <0.02-0.2 µg/L (med<0.02)

Detections Only



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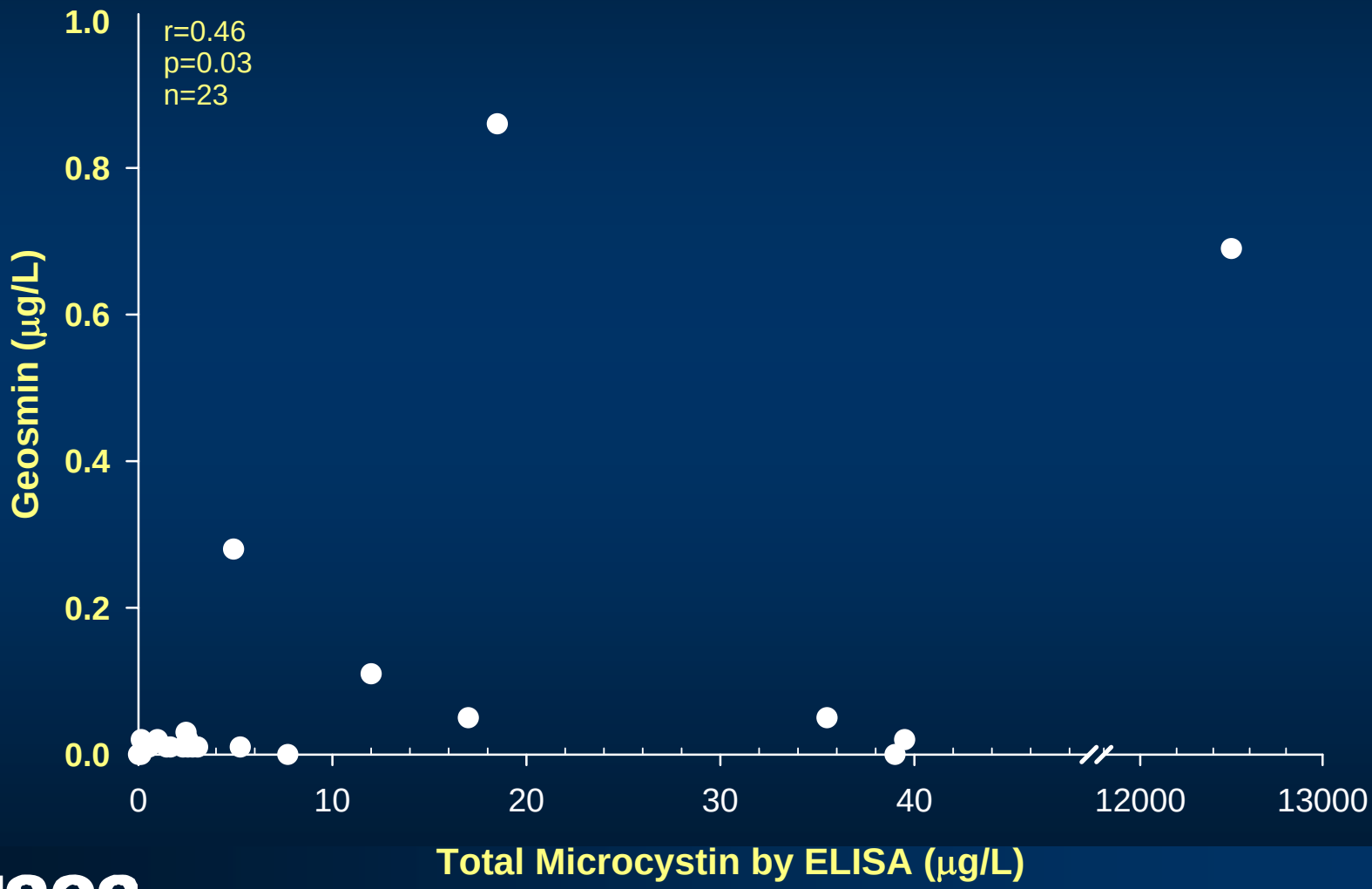
Although Toxins and Taste-and-Odor Compounds Frequently Co-Occurred Concentrations Were Not Linearly Related



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Summary

- Microcystin was detected in all Midwestern blooms sampled and 17% had concentrations great enough to cause human health concerns.
- The most commonly occurring microcystin variant was microcystin-LR.
- Anatoxin was also relatively common (30% detection) in Midwestern blooms.
- Multiple toxin classes co-occurred in 52% (n=12) of blooms and toxins and taste-and-odor compounds co-occurred in 87% (n=20).
- All blooms with detectable taste-and-odor compounds also had detectable toxins, but toxins also occurred without taste-and-odor compounds.
- Although toxin and taste-and-odor compounds frequently co-occurred concentrations were not linearly related.

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Additional Information Available on the Web:

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

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