Preliminary Reassessment of Cyanotoxin Mixtures in the 2007 US EPA National Lakes Asssessment

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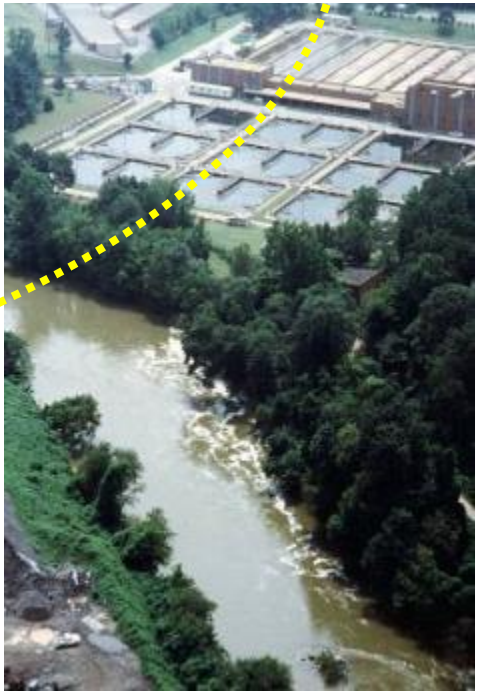
1 USGS Kansas WSC, 2 US EPA NHERL, 3 US EPA OWOW



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Harmful Algal Bloom Overview

- Introduction
- 2007 National Lakes Assessment (NLA): Occurrence of Chlorophyll, Cyanobacteria, and Toxins
- Big Picture

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

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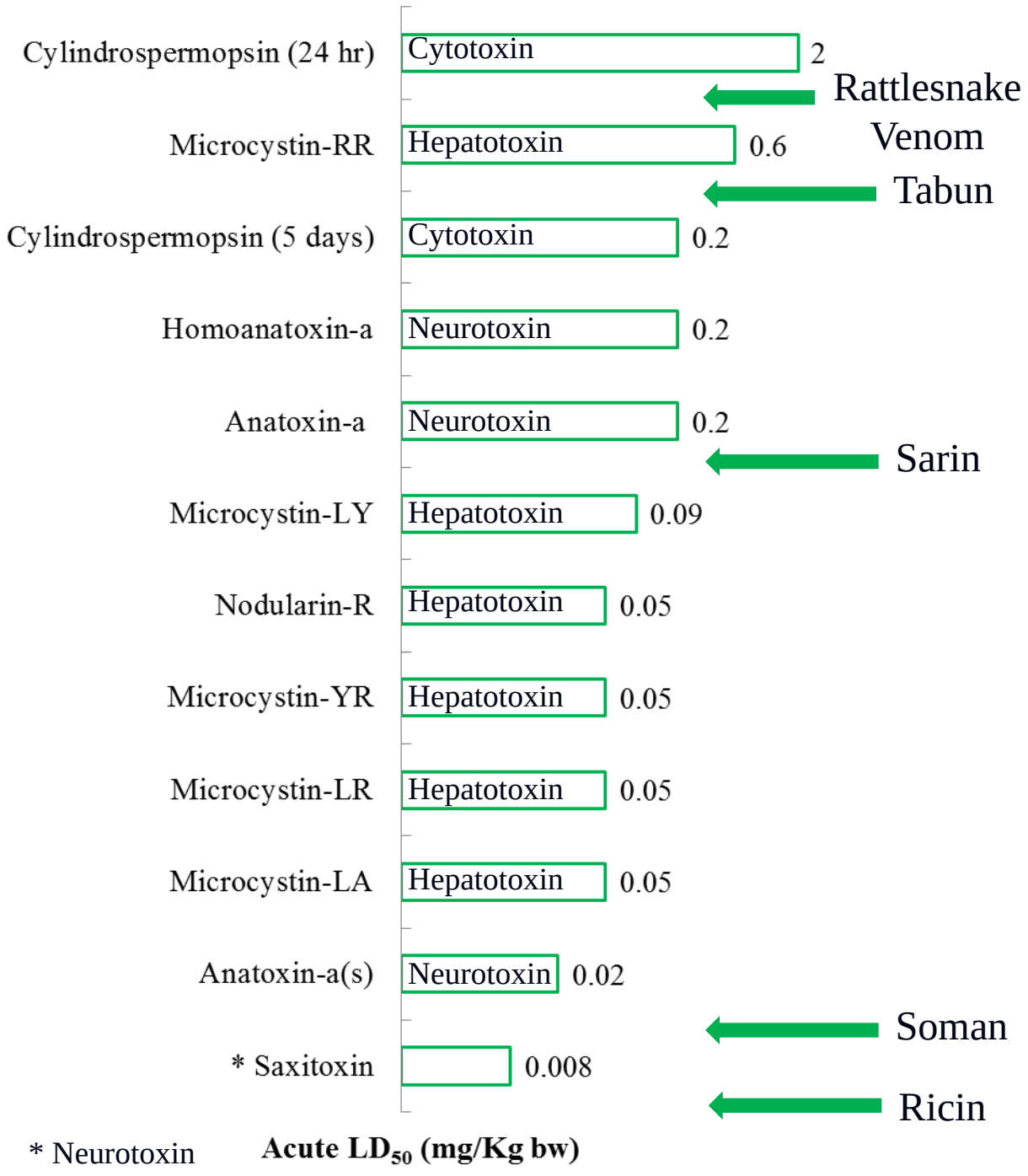
Toxicity of Known Cyanotoxins

- **Acute Toxicity**
  - Cytotoxic
  - Neurotoxic
  - Hepatotoxic
  - Dermatoxic
  - Respiratory Distress
- **Chronic Toxicity**
  - Carcinogen
  - Tumor Promotion
  - Mutagen
  - Teratogen
  - Embryolethality



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Important Thresholds

- No Current U.S. Federal Regulations for Recreation or Drinking Water Exposure
  - Occurrence and Risk Assessment Phase
  - US EPA Office of Water listed Anatoxin-a, Cylindrospermopsin , and Microcystin-LR or selected producers on CCL2 and CCL3.
  - World Health Organization (WHO) suggested provisional microcystin recreational threshold values are usually adopted by countries and U.S. states or something very similiar.

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	< 10	< 10
Moderate	20,000 - 99,999	10 - 19.9	10 - 49.9
High	100,000-9,999,999	20 - 1999	50 - 4999
Very High	≥ 10,000,000	≥ 2000	≥ 5000

Chorus and Bartram, 1999

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What are the Neighbors Doing?

- In addition to cyanobacterial cell counts and/or microcystin assessment:
- Some countries and U.S. states are now acknowledging the presence of cyanotoxins mixtures and guidelines are being used for anatoxin-a, anatoxin-a(s), cylindrospermopsins, and saxitoxins in addition to microcystins and/or cyanobacterial cell counts.
- Several U.S. states, Native American tribes, and countries have recreational and/or drinking water guidance documents that include other cyanotoxin classes.
- California has recreational guidance document that includes toxin mixtures and deals with fish consumption, livestock, and pets.

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Cyanobacterial Lipopolysaccharides (LPS)

- There is much left to learn on this topic!
- Suggested LPS Exposure Symptoms (some are yet to be scientifically linked):
  - Oral – testing seems to indicate this may be of less concern
  - Inhalation – Seems to be route of most concern at this point
  - Dermal - Not clear what compounds are causing rashes
  - Notch et al. (2010) implicated cyanobacterial LPS coadministered with cadmium as more toxic than either constituent given individually to zebrafish embryos.
- WHO suggests use of the 20,000 cells/mL cyanobacteria criteria as a human recreational threshold for LPS contact based on research studies.

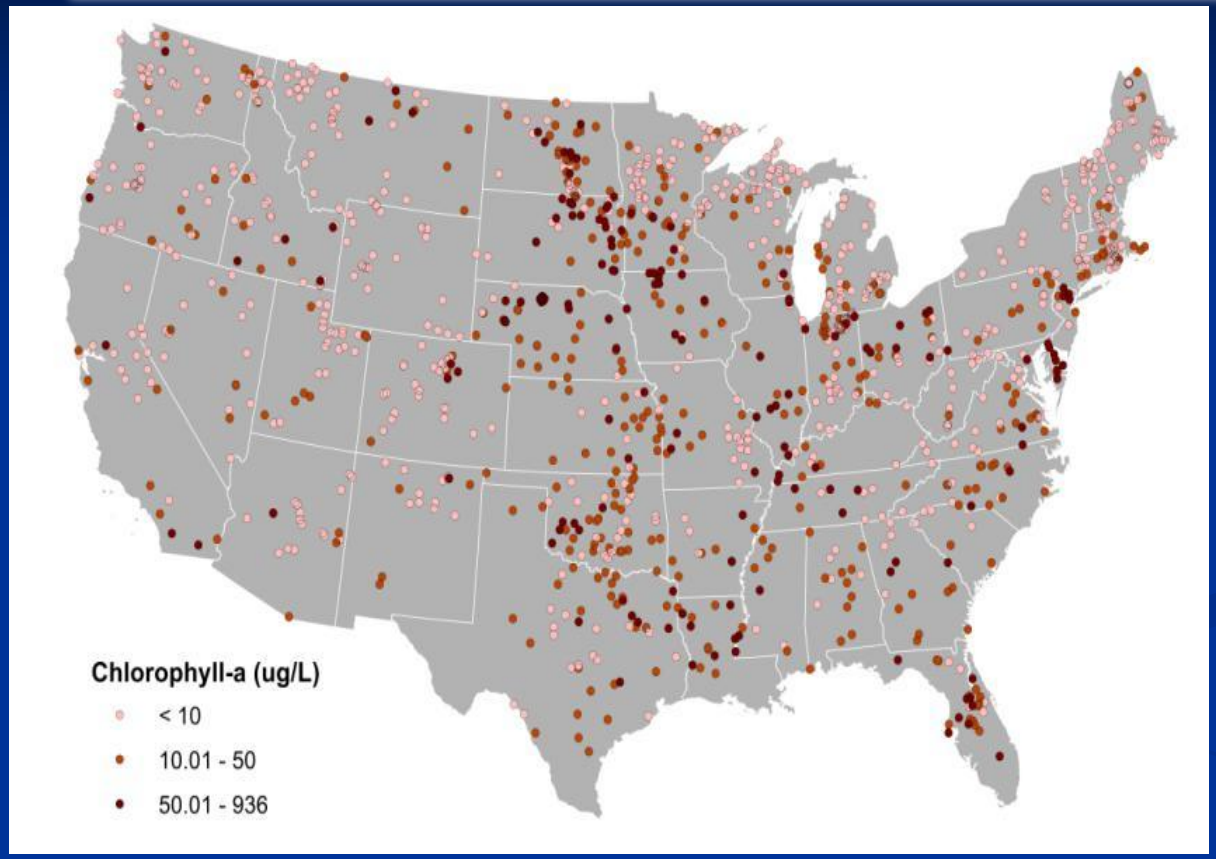
Stewart, I. et al., 2006, Environ. Health Persp. 5, 7. (http://www.ehjournal.net/content/pdf/1476-069X-5-7.pdf)
Notch, E.G., et al., 2010, Environ. Toxicol., 26:498-505.
http://www.who.int/water_sanitation_health/bathing/srwe1-chap8.pdf

A Few Words on the 2007 National Lakes Assessment

- Larger reservoirs were not numerous due to study design.
- There is a temporal signal in the data set (samples collected May to October 2007).
- Weather patterns can be different from year to year for each region.
- This study represents a snapshot in time.
- It is the first attempt at a national assessment of cyanotoxins in the U.S.

- Cylindrospermopsin and Saxitoxin ELISA results are preliminary and are being completed outside of the National Lakes Assessment in collaboration with USGS Toxic Substance Hydrology Program, US EPA NHERL, and US EPA OWOW.

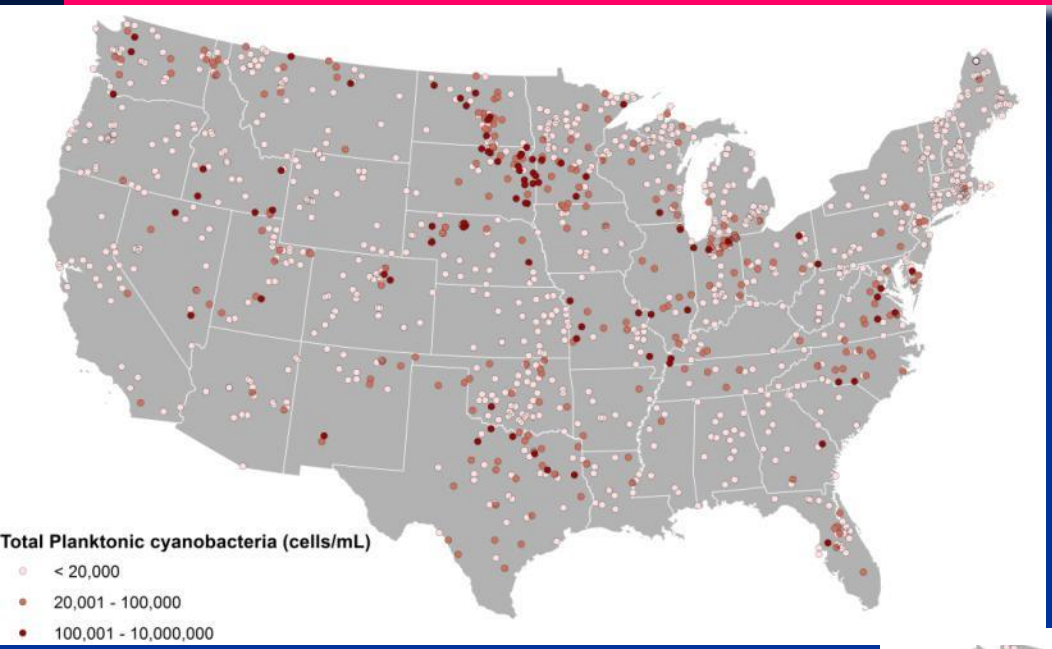
2007 National Lake Assessment and Cyanotoxins – Integrated Photic Zone - Chlorophyll



- ~42% of samples exceeded WHO Moderate Microcystin Health Risk (>10 µg/L).
- ~27% of samples exceeded WHO High Microcystin Health Risk (>10 µg/L).

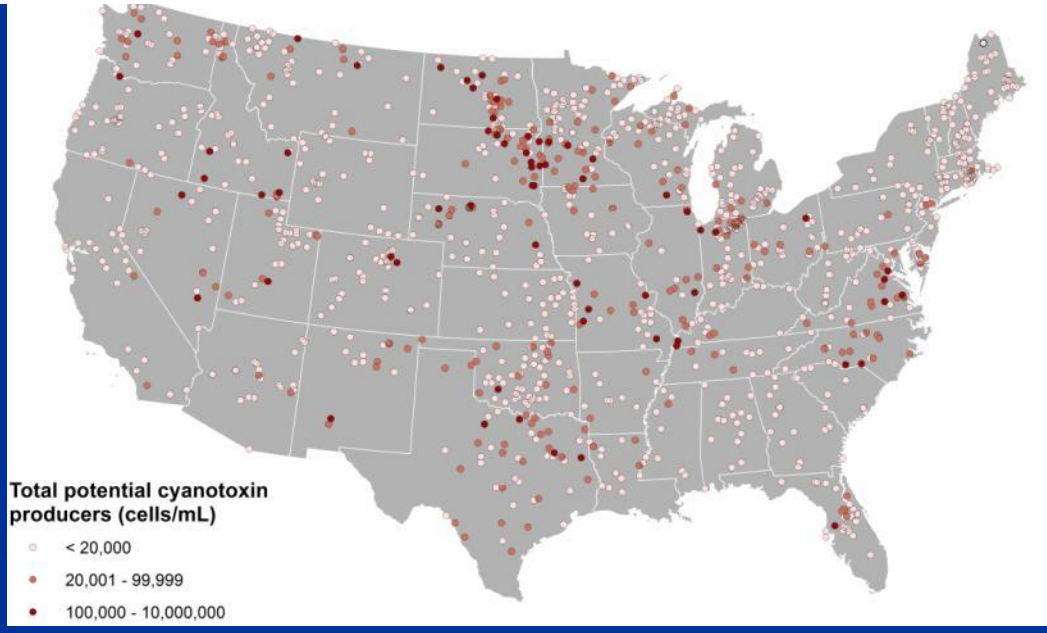
- Chlorophyll was detected most frequently and typically at larger concentrations East of the Rocky Mountains.

2007 National Lake Assessment and Cyanotoxins
Integrated Photic Zone – Total Cyanobacteria



- The most abundant phytoplankton species were usually potentially toxic cyanobacteria.

- ~26 % of samples exceeded WHO Moderate Microcystin Health Risk 20,000 cells/mL).
- ~6 % of samples exceeded WHO High Microcystin Health Risk 100,000 cells/mL).



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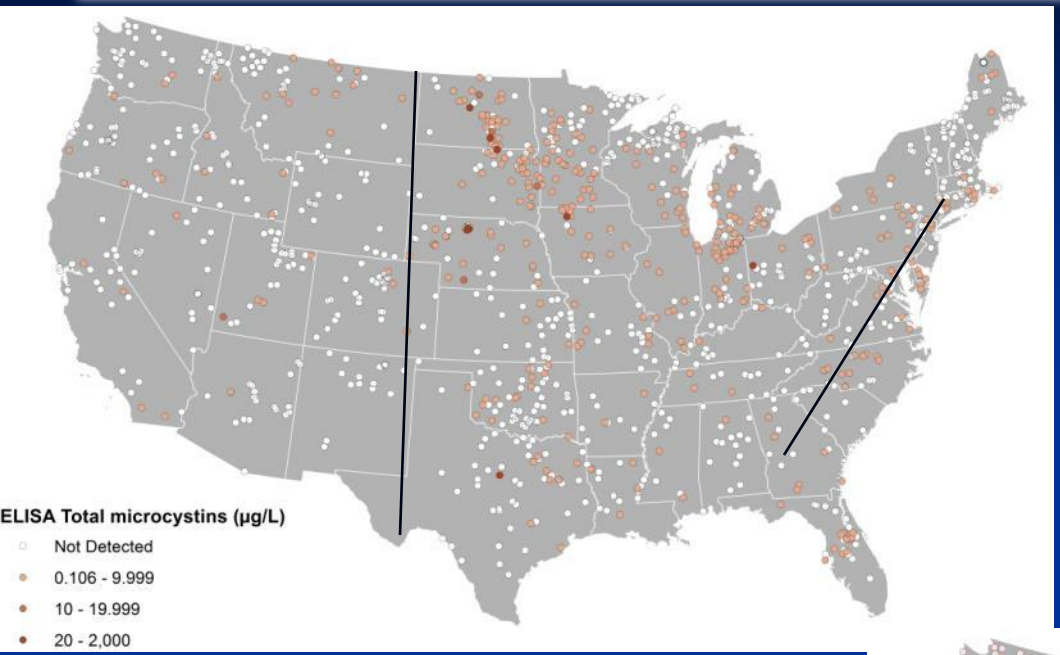
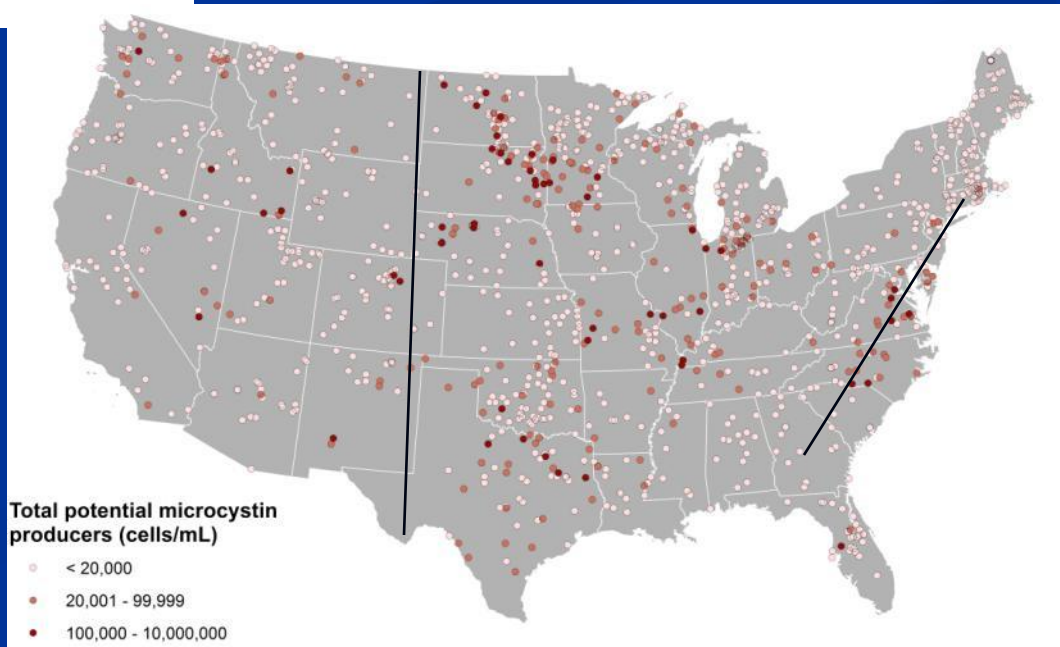
EPA 841-R-09-001

2007 National Lake Assessment and Cyanotoxins
Integrated Photic Zone – Microcystins (ELISA)



- Microcystins were detected in 30% of lakes.
- Microcystin detections were approximately equal in natural and Man-made lakes.
- Microcystin Detection Summary Statistics:
  - Mean: ~1.0 µg/L
  - Maximum: 230 µg/L

- ~1 % of samples exceeded WHO Moderate Microcystin Health Risk (>10 µg/L).
- ~1 % of samples exceeded WHO High Microcystin Health Risk (>20 µg/L).



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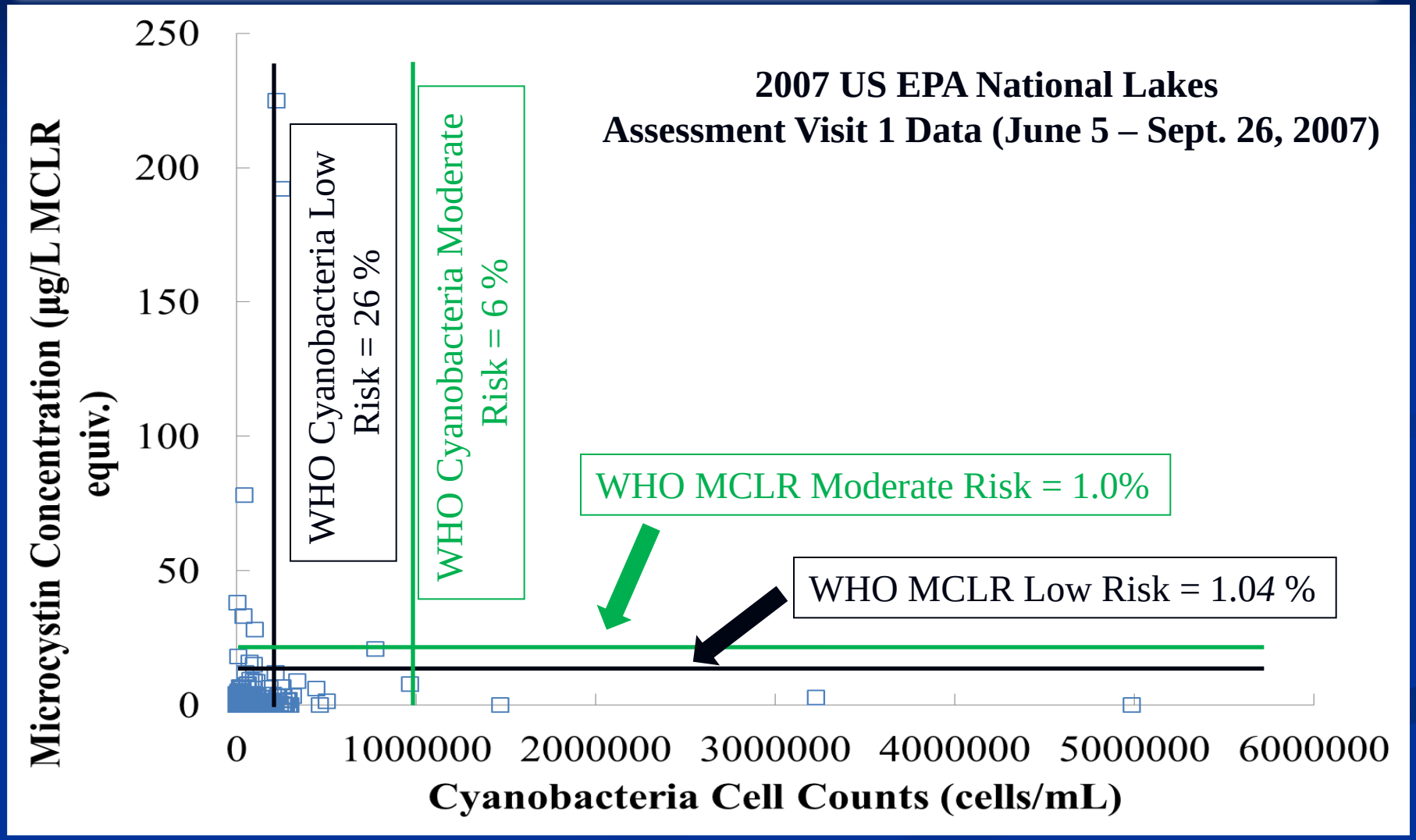
National Snapshot (2007 NLA) WHO Recreational Guideline Exceedances



WHO risk designations are probability of an adverse health risk during recreation.

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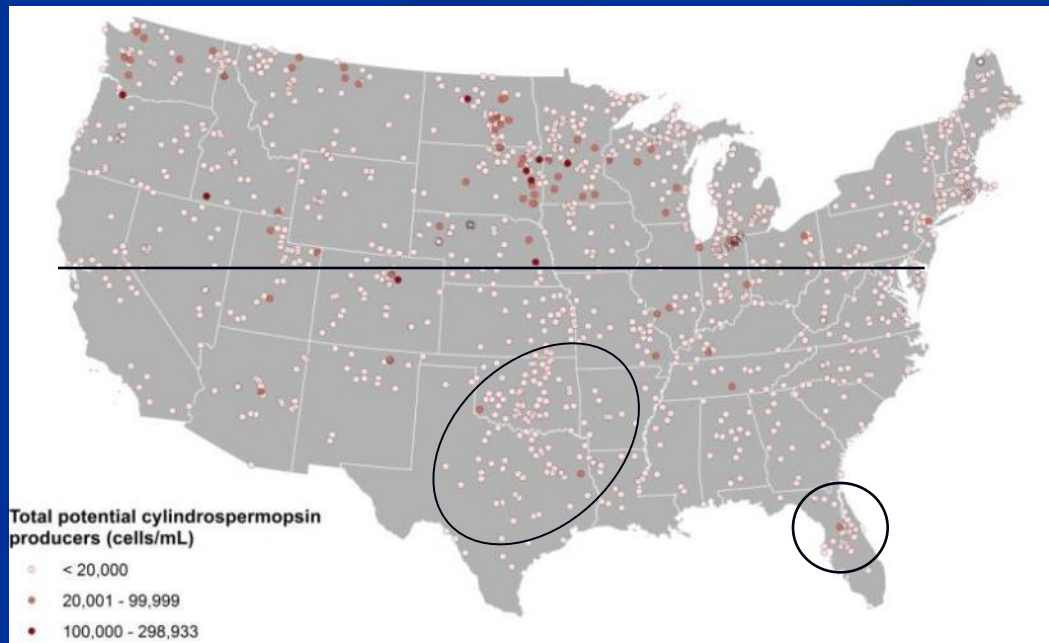
2007 National Lake Assessment and Cyanotoxins
Integrated Photic Zone – Preliminary Cylindrospermopsins (ELISA)

- Cylindrospermopsins were detected in ~ 5 % of lakes of analyzed lakes (n= 659).
- Cylindrospermopsis blooms tend to be subsurface.
- Cylindrospermopsin Detection Summary Statistics:
  - Mean: 0.44 µg/L
  - Maximum: 3.4 µg/L

- Samples archived frozen.
- Completion of the remaining samples expected summer FY12.



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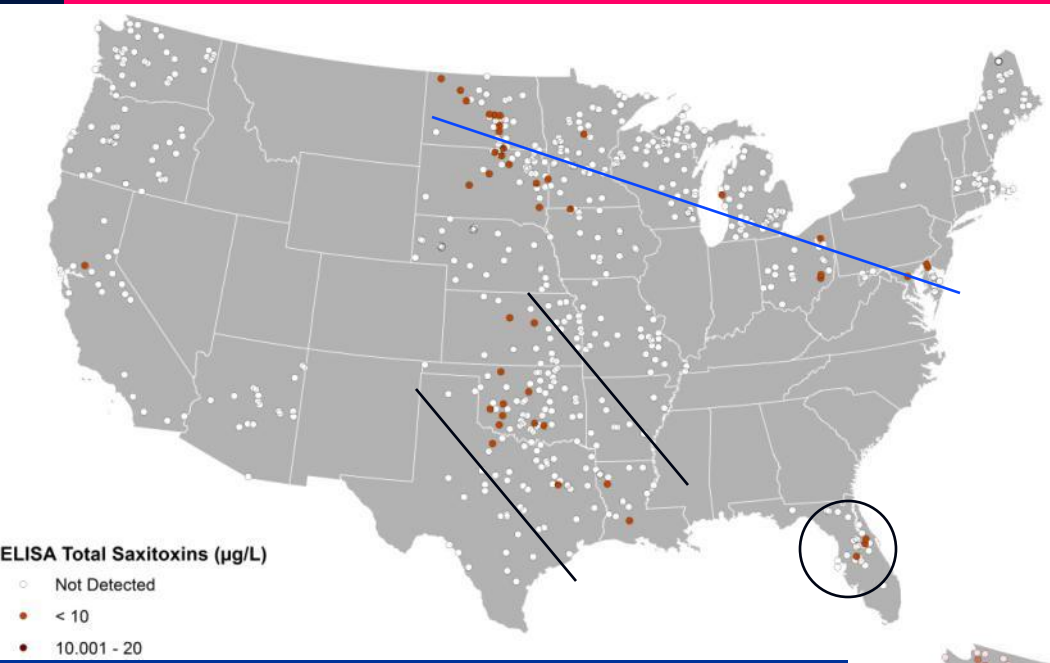
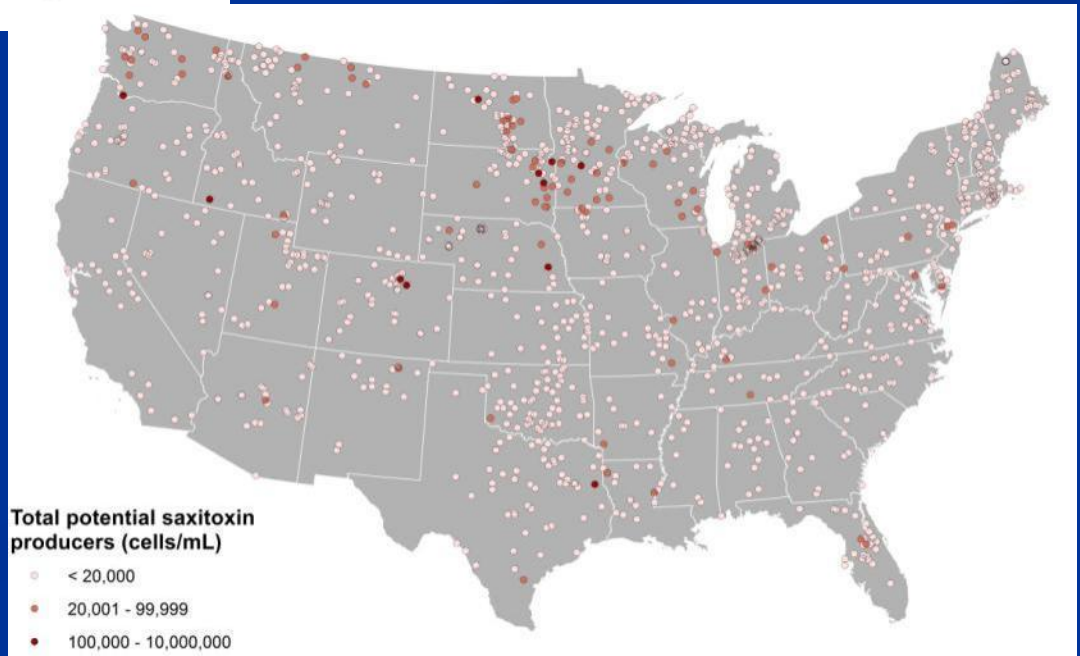
2007 National Lake Assessment and Cyanotoxins
Preliminary Saxitoxins (ELISA)



- Saxitoxins were detected in 8% of lakes of analyzed lakes (n=678).
- Traditionally, thought of as marine toxins. Perhaps not anymore….
- Saxitoxin Detection Summary Statistics:
  - Mean: 0.05 µg/L
  - Maximum: 0.38 µg/L

- Samples archived frozen.
- Completion of the remaining samples expected summer FY12.



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2007 National Lake Assessment and Cyanotoxins Integrated Photic Zone – Microcystins and Nodularin-R (LC/MS/MS)

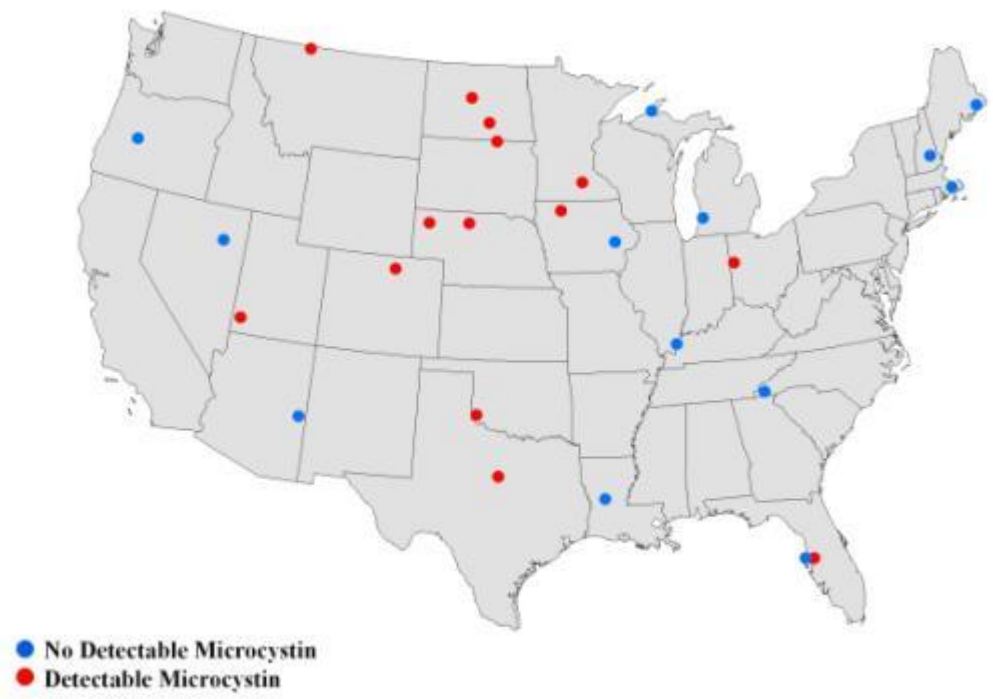
Sample selection included 13 of 27 (48%) detections by Microcystin ELISA

LC/MS/MS Results:

Microcystins detected:
14 of 27 (59%) samples

Nodularin-R detected:
1 of 27 (3.7%) in Texas

Nodularin-R is known as a brackish water toxin.



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2007 National Lake Assessment and Cyanotoxins Integrated Photic Zone – Anatoxin-A (LC/MS/MS) (Preliminary)

Sample selection included 13 of 27 (48%) detections by Microcystin ELISA

Anatoxin-a detected:
4 of 27 (15%) samples

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Big Picture on HABs and Monitoring Guidelines

- Unknown cyanotoxins will continue to be an issue of concern for the foreseeable future.
- Researchers are still identifying new toxins and environmental scenarios that help produce toxins that are explained only by nutrients, climate, water quality, etc.
- No low cost assays that are specific to anatoxin-a with sufficient sensitivity, must use a chromatographic technique (more expensive).
- No commercially available chemical standards for anatoxin-a(s) or LPS
- Cyanobacterial blooms are dynamic and toxin production can change rapidly.

Big Picture on HABs

- Cyanotoxins have been known to be lethal to humans and animals under certain exposure scenarios and concentrations.
- Cyanotoxin mixtures can be measured frequently in the United States and at concentrations of concern for human and ecosystem health.
- Cyanobacteria and associated toxin production may be a good indicator of water quality, ecosystem health, and recreational exposure for a variety of inorganic and organic chemicals. They are environmental integrators and distributors.
- Continued collection of both cyanobacteria cell counts and toxin analyses provides a means to retrospectively aid in assessing changes in HABs and produced toxins.
- HABs are still an active area of research and there is much we still do not understand.

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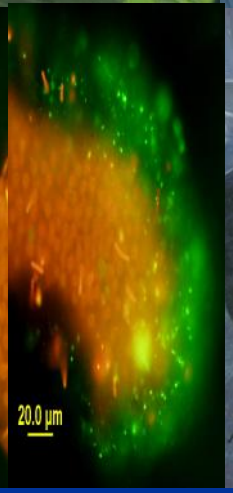

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Additional Information:

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

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