Occurrence of Cyanobacteria and Associated Toxins in Surface Water, Relative Risk, and Potential Changes Due to Environmental Factors in the United States

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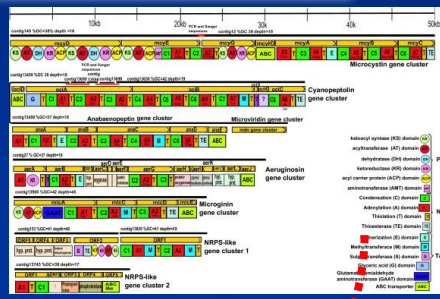

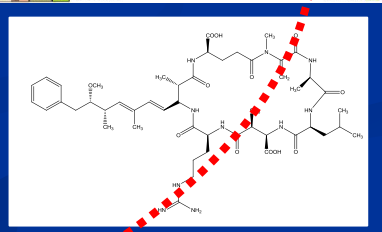

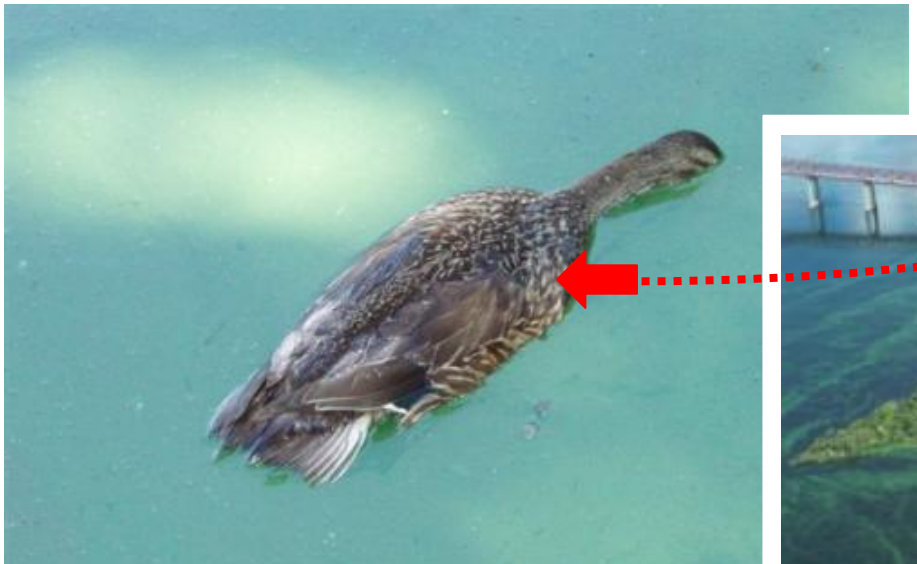

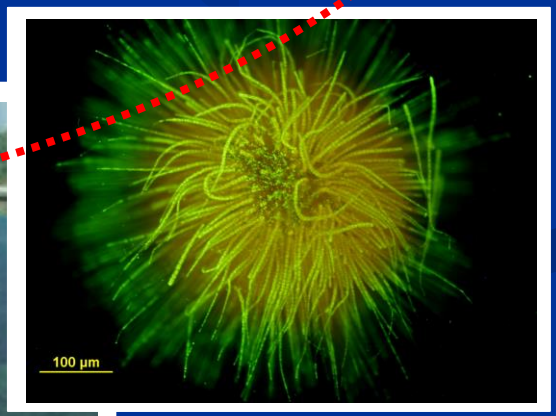

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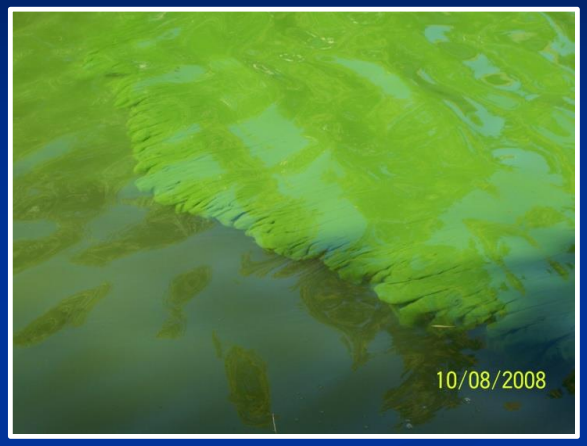
There are Numerous Examples of Successful Collaborative Partnerships and CWP Studies

- Co-Operative Studies Program
  - AR, FL, IA, IN, KS, LA, MI, MN, NE, NJ, OH, OR, NC, SC, SD, TX

  http://water.usgs.gov/coop/
- USGS Climate and Land Use Change, Environmental Health, Water, Ecosystems, National Research Program
- Federal Partners
  - USACE, BOR, CDC, EPA, FDA, FWS, NASA, NIH, NOAA, USDA
- University Partners



Kansas Stormwater Retention Pond
Photo Courtesy of Johnson County Stormwater

Weatherby Lake, Missouri
Photo Courtesy of Anonymous Source

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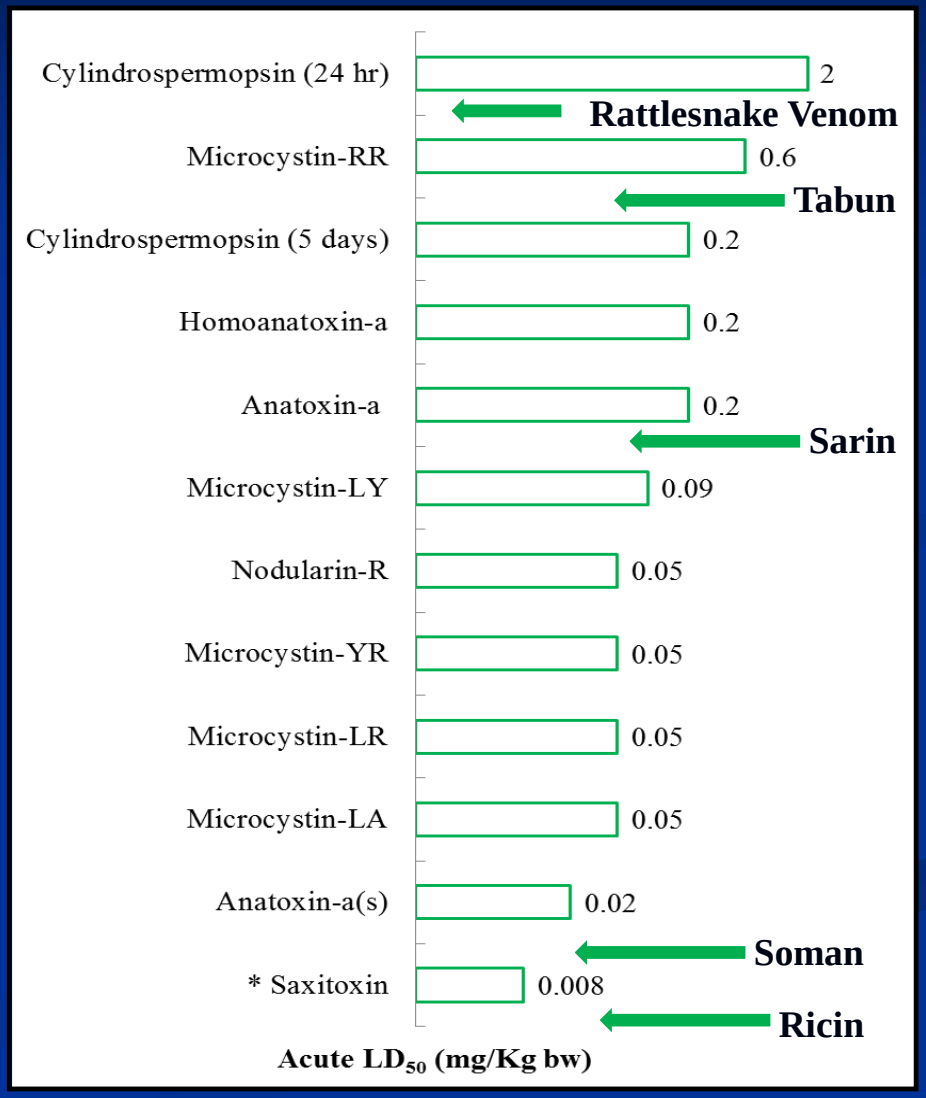
How Toxic are Cyanotoxins?

- Acute Toxicity
  - Cytotoxic
  - Dermatoxic
  - Hepatotoxic
  - Neurotoxic
- Chronic Toxicity
  - Carcinogen
  - Tumor Promotion
  - Mutagen
  - Teratogen
  - Embryolethality
  - Neurodegenerative Diseases



After Chorus and Bartram, 1999; various references

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Help Needed from the Toxicology Community!

- Toxicity investigations targeting cyanotoxin mixtures and their co-occurrence with other stressors needed (e.g. metals, organics, pathogens).
- Toxicity investigations need to target endpoints of concern:
  - Pregnant mothers/fetuses, children, immunocompromised
  - Healthy adults
  - Ecological species at various trophic levels
- Improved HAB risk-assessment and predictive, early warning tools.

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Important Regulations and 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 under the Safe Drinking Water Act
- Some states have implemented or implemented variations of the World Health Organization suggested Microcystin Recreational threshold values.

After Chorus and Bartram, 1999

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

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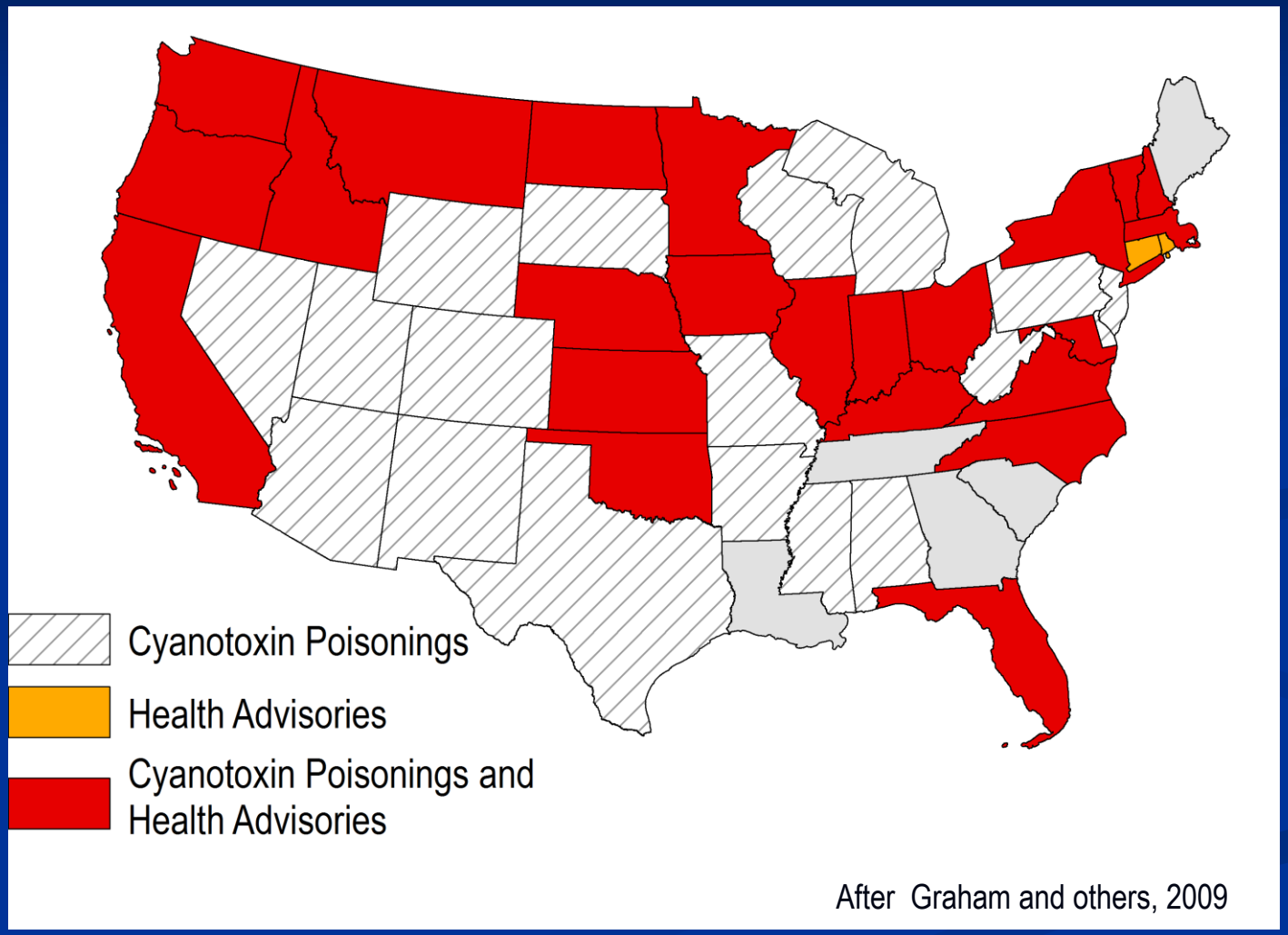
Toxic Cyanobacterial Blooms Are Widespread and Common Throughout the United States



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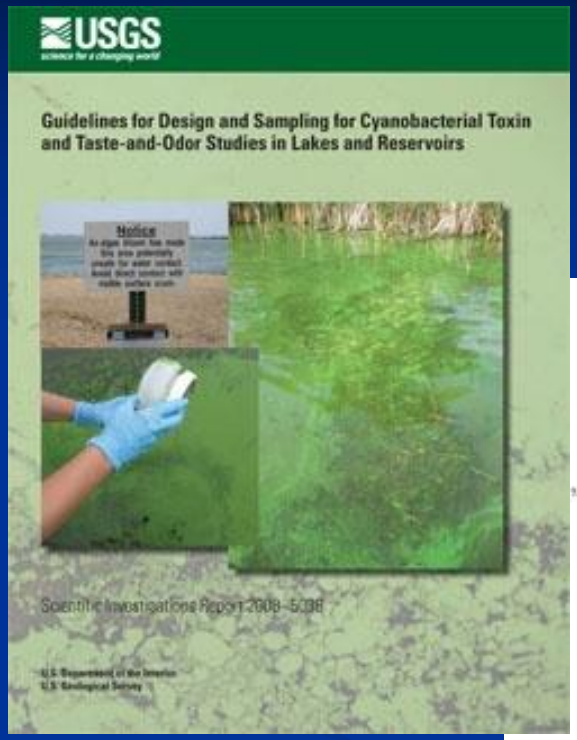
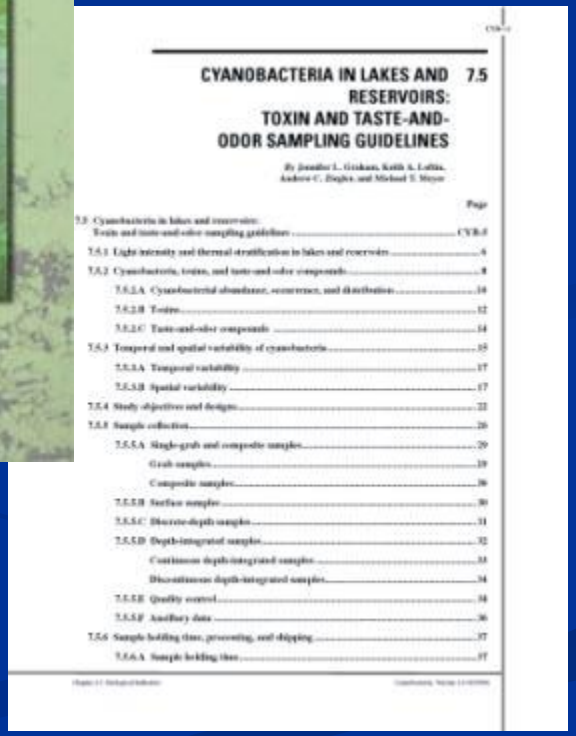
Study Design and Field Manual Resources

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

- USGS National Field Manual Chapter 7.5 Cyanobacteria in Lakes and Reservoirs: Toxin and Taste-and-Odor Sampling Guidelines





http://pubs.usgs.gov/sir/2008/5038/
http://water.usgs.gov/owq/FieldManual/Chapter7/7.5.html

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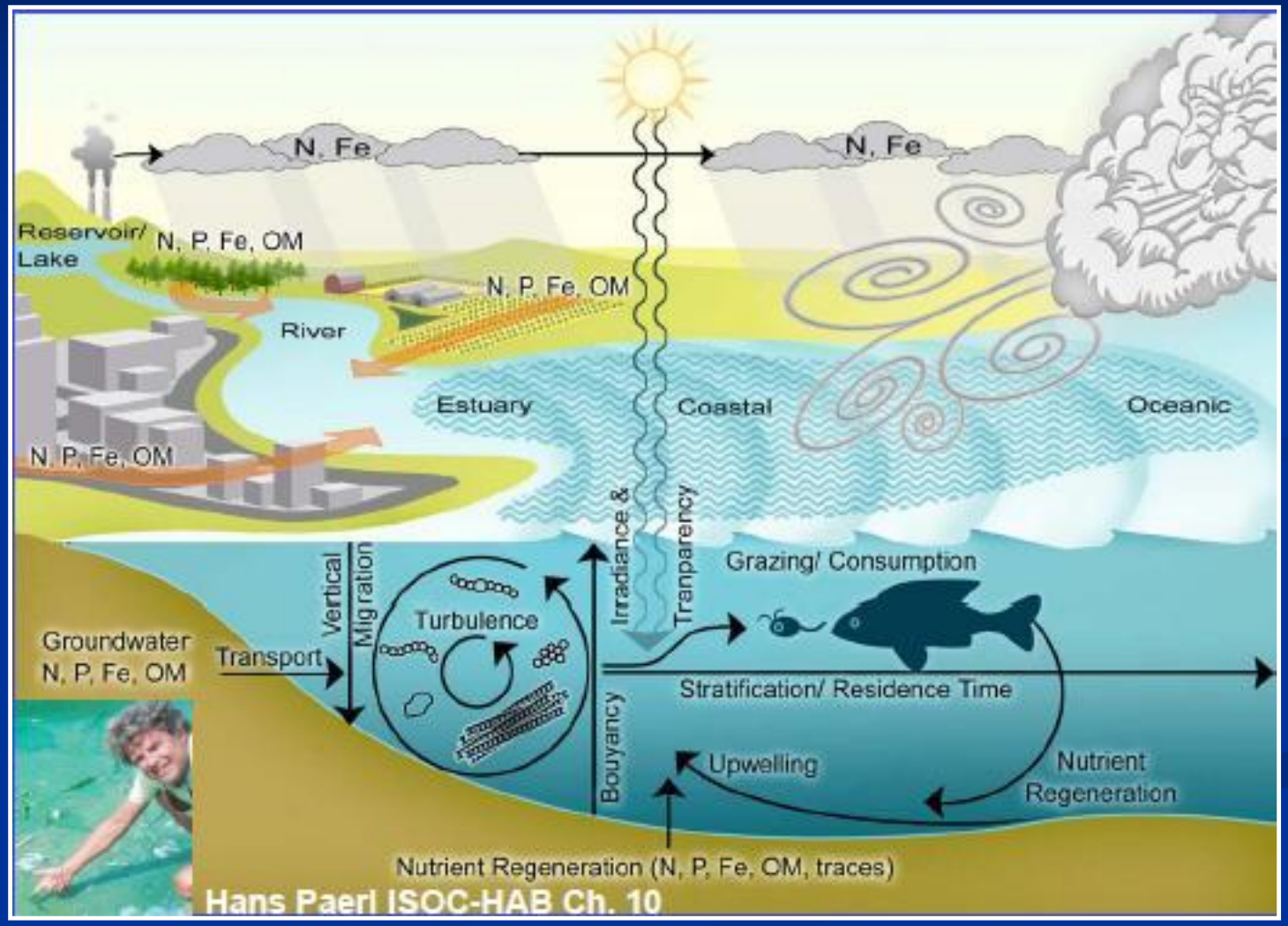
Harmful Algal Blooms are Effected by Global, Regional, and Local Environmental Factors!



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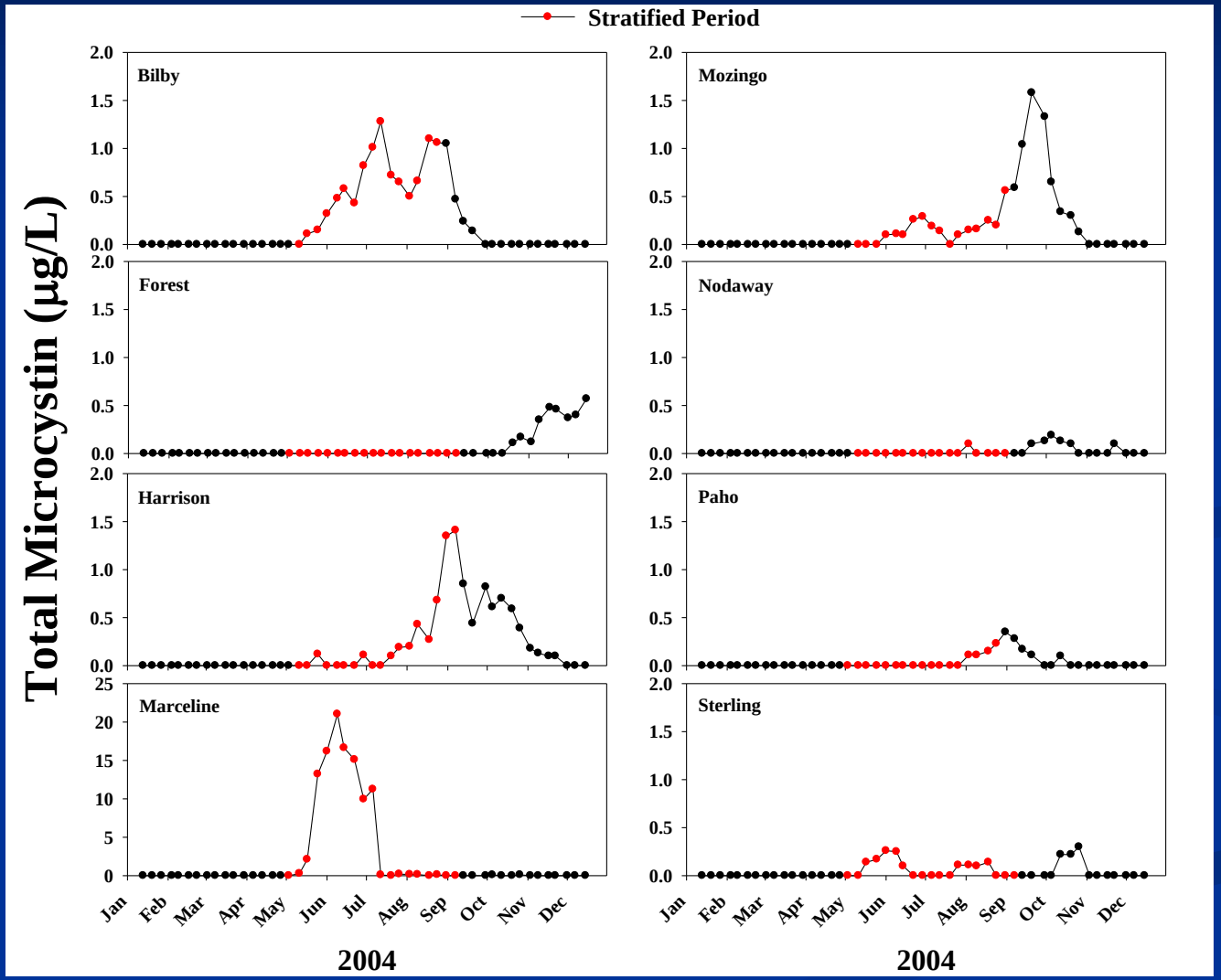
http://www.springer.com/biomed/neuroscience/book/978-0-387-75864-0

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



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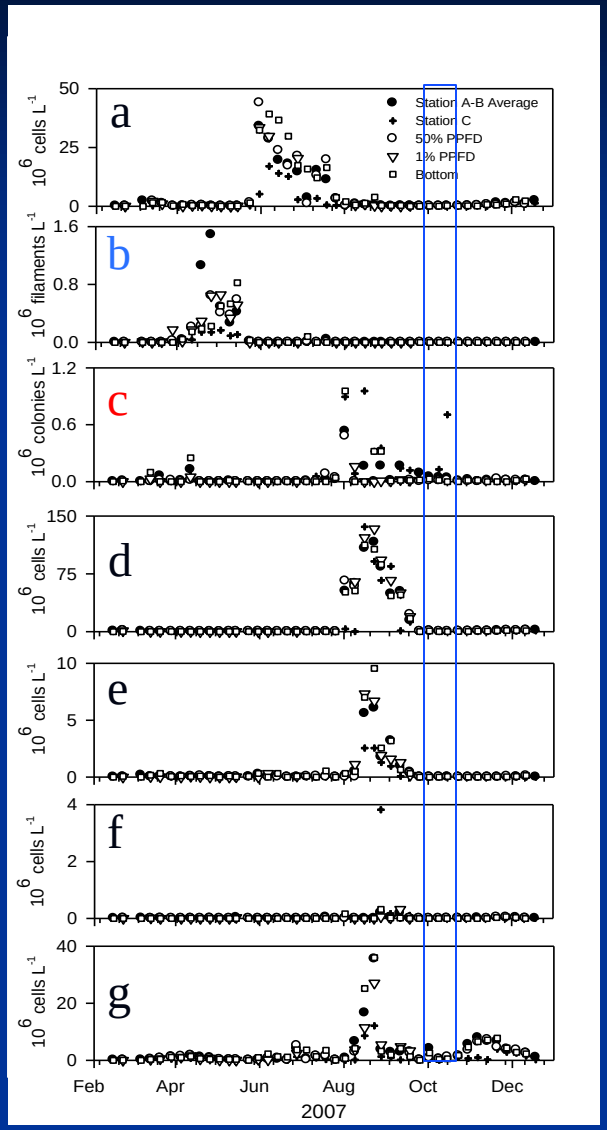
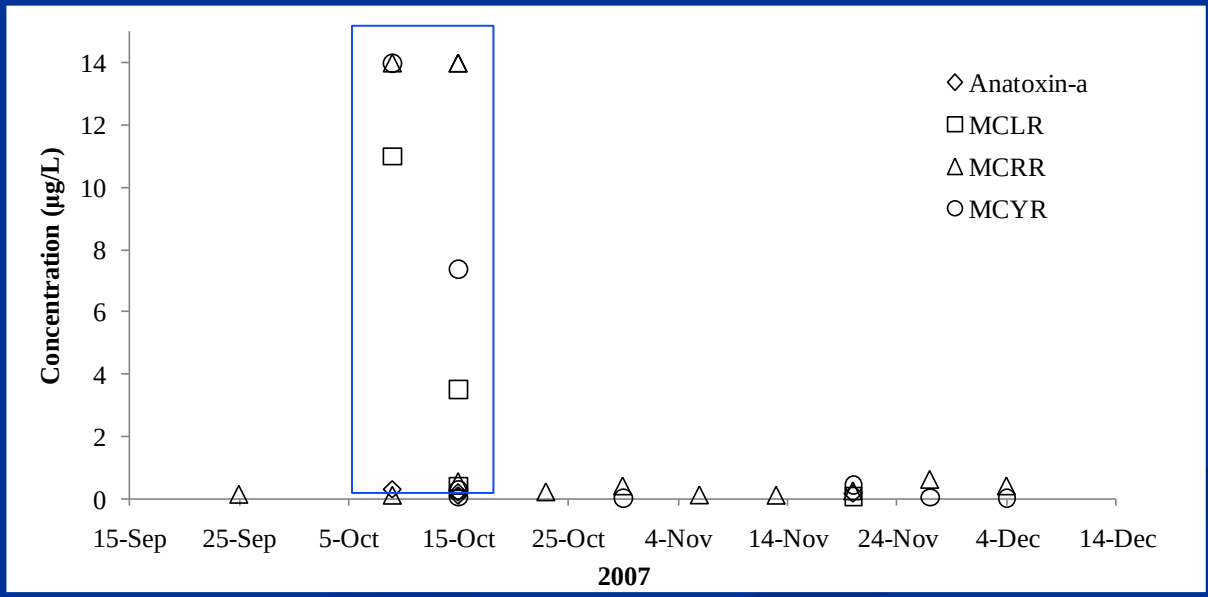
After Graham and others, 2006

Coastal Systems are Impacted by CyanoHABS

Rodeo Lagoon, Golden Gate National Park, CA, April – December 2007



a – Centric diatoms
b – *Nodularia spumigena*
c – *Microcystis aeruginosa*
d – flagellated protozoa
e – pennate diatoms
f – dinoflagellates
g - chlorophytes



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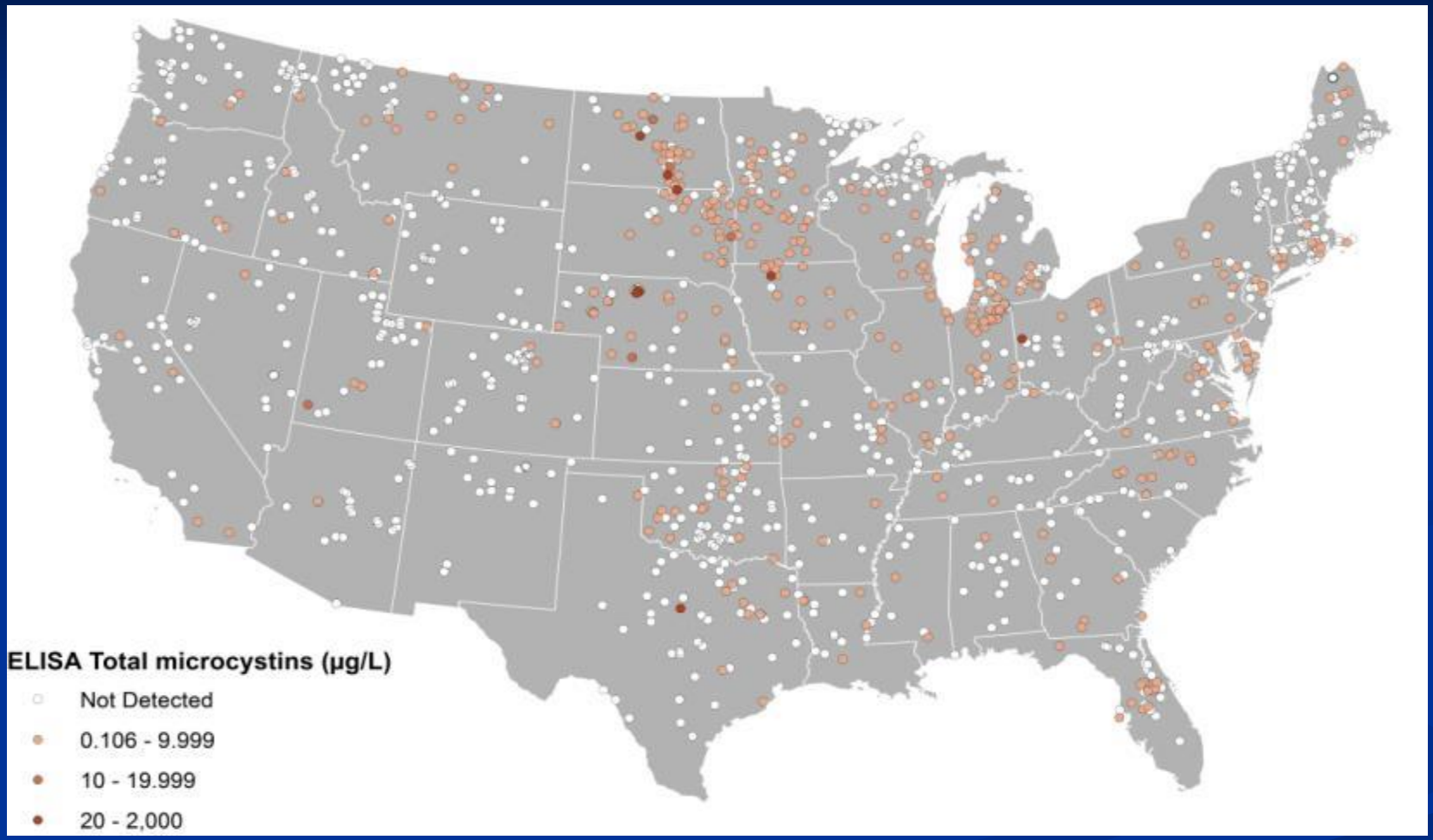
San Francisco State University

Berkeley University of California

Drake, J.L., et. al., 2010, Hydrobiologia, *654*, 177-192.

Microcystins were Detected in ~30% of 2007 National Lake Assessment Sites



- Microcystin Detection Summary Statistics:
  - Mean: ~1.0 µg/L
  - Maximum: 230 µg/L

EPA 841-R-09-001
Beaver and Others, 2014

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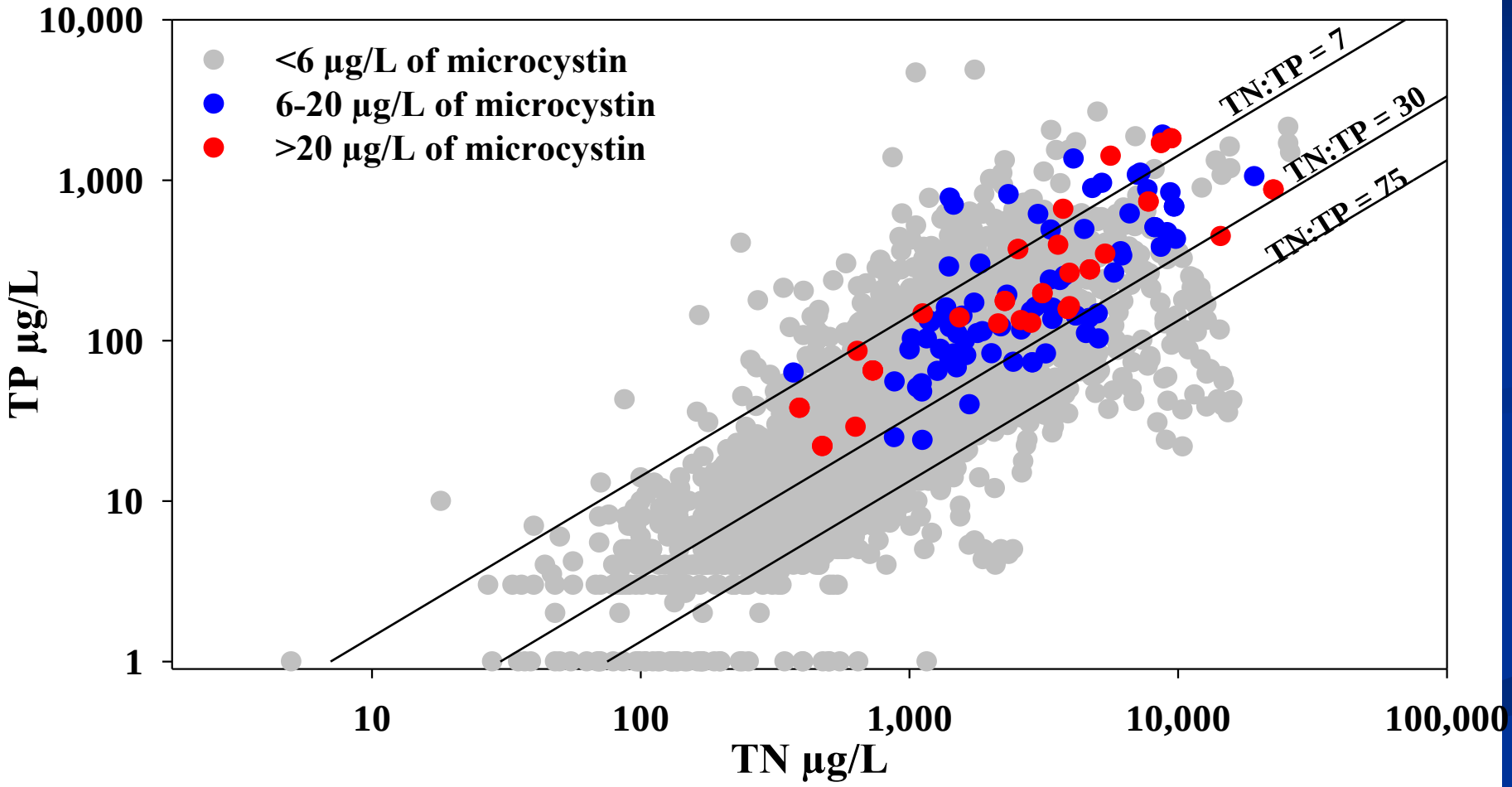
Globally, Microcystin Occurs in Lakes of All Trophic Status, But Occurrence and Concentration Increase with Trophic Status



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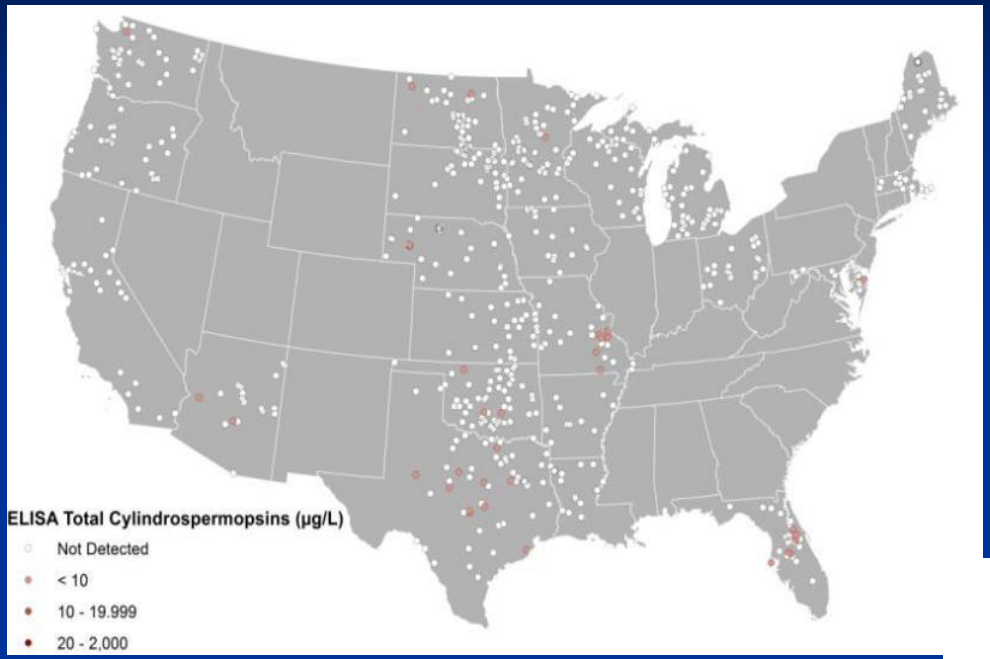
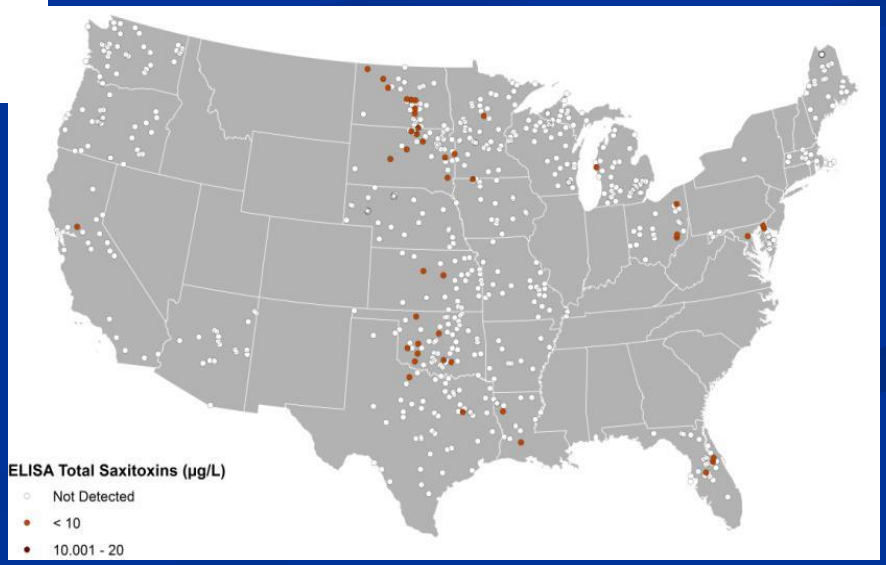
After Harris and others 2014

Cyanotoxin Mixtures are a Concern
2007 National Lake Assessment



Cylindrospermopsins detected in ~5 % of samples.

Saxitoxins detected in ~8 % of samples.



Loftin and others, in preparation

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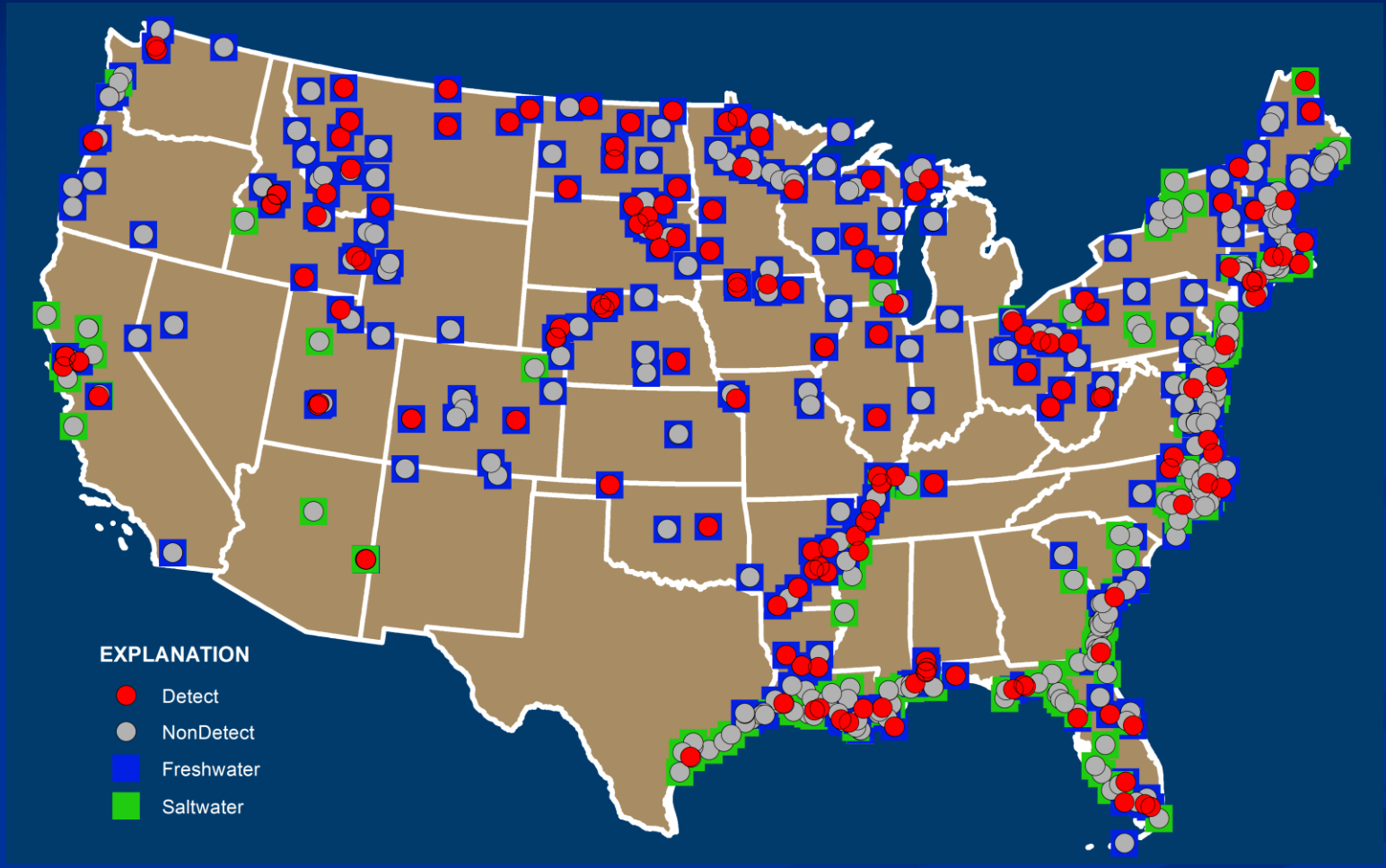
Microcystin Occurrence in 2011 National Wetland Condition Assessment



http://water.epa.gov/type/wetlands/assessment/survey/index.cfm

Loftin and others, in preparation

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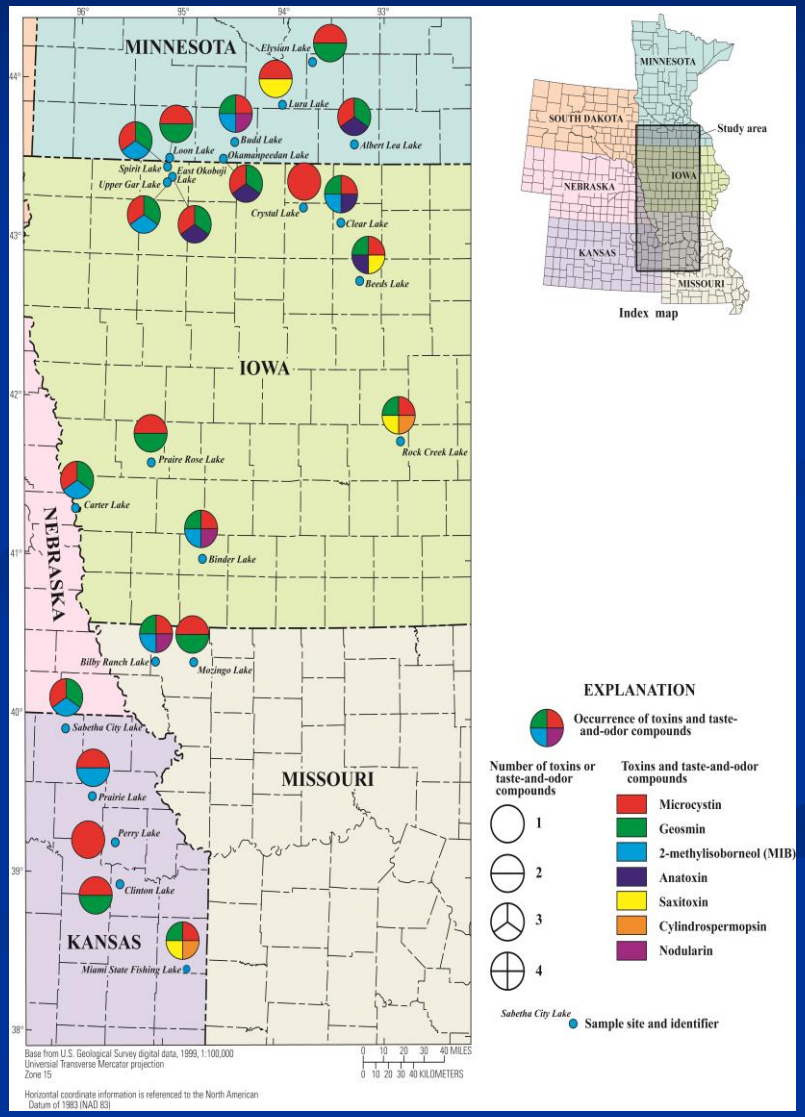
Co-Occurrence of Cyanotoxin Mixtures and Taste-and-Odor Compounds – August 2006

- Cyanotoxin mixtures were typical.
  - Anatoxin-a (30%)
  - Cylindrospermopsins (9%)
  - Microcystins (100%),
    - max value = 19,000 µg/L
  - Saxitoxins (17%)
- 17% of blooms had microcystin concentrations exceeding the WHO high risk recreational guideline of 20 µg/L.
- Toxins and taste-and-odor compounds co-occurred in 91% of bloom samples (n=23).
- Drinking water utilities frequently say that finished water is safe when taste-and-odor compounds are present.



Graham, J., et al., 2010, ES&T, *44*, 7361-7368.

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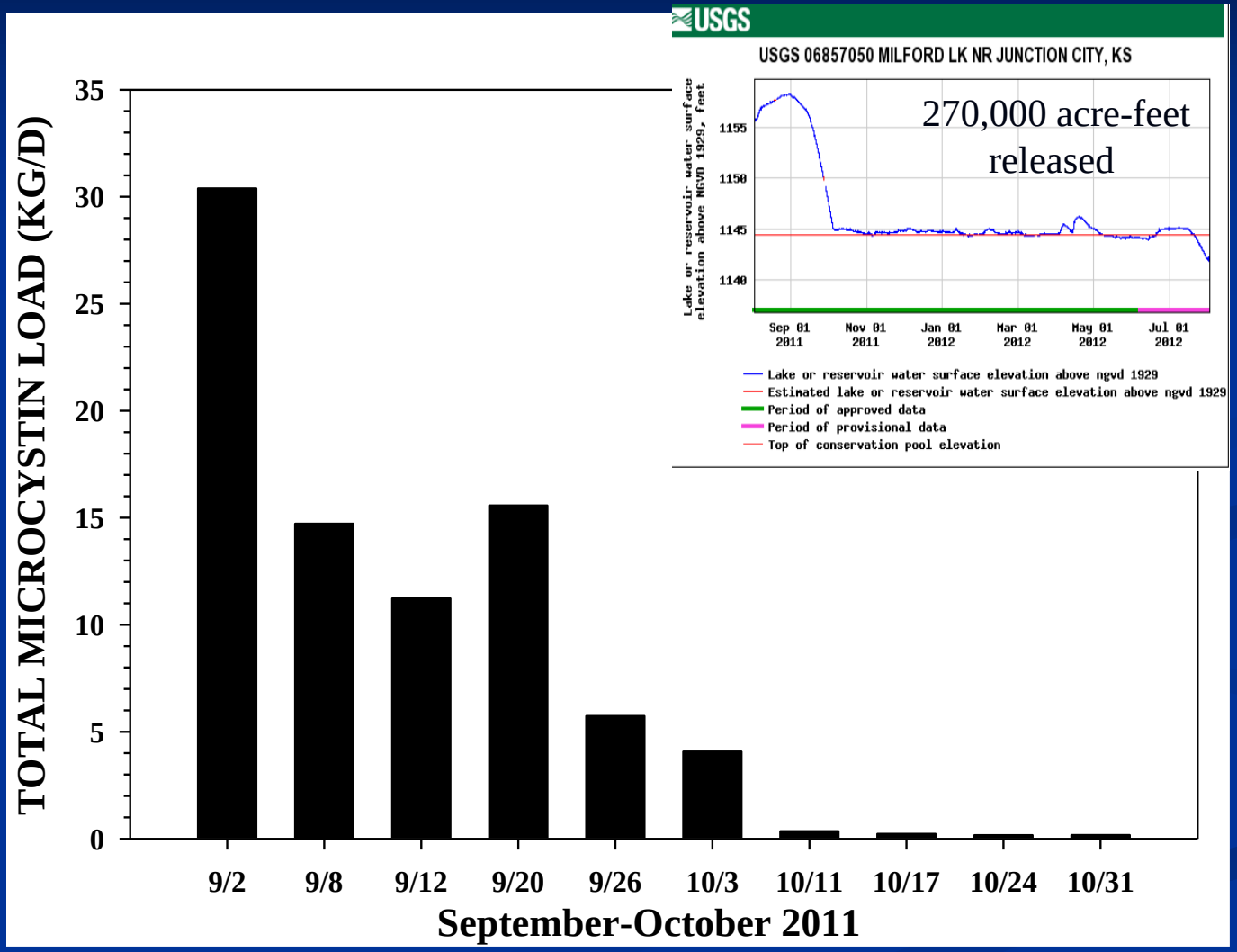
Microcystins and intact cyanobacteria traveled over 170 stream miles in the Kansas River.



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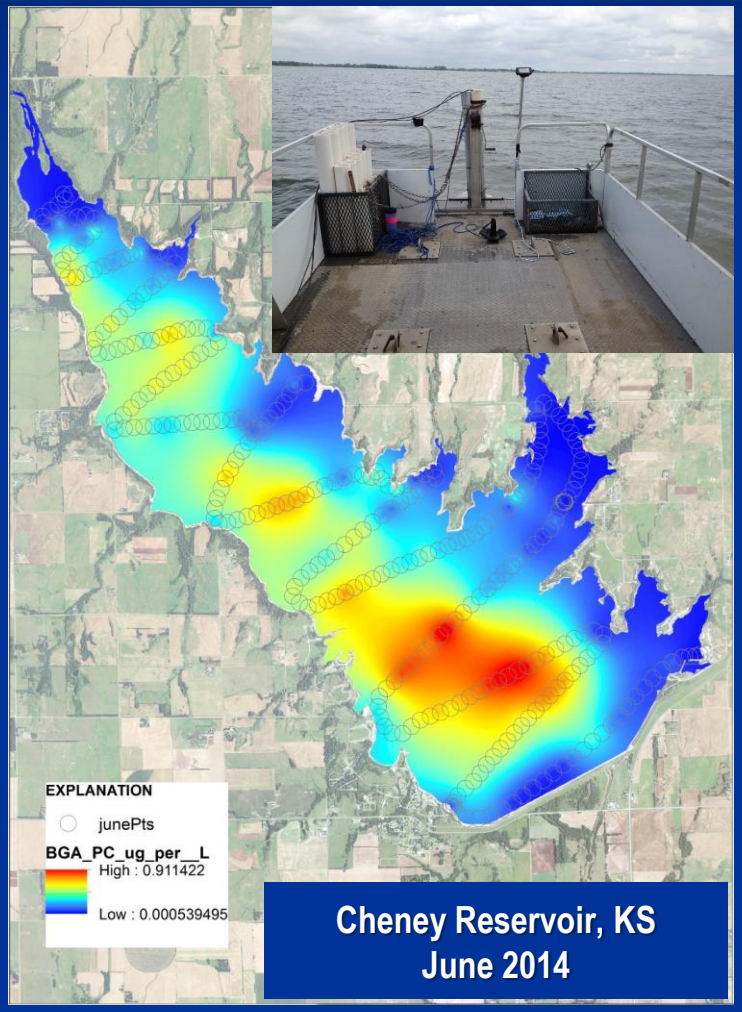
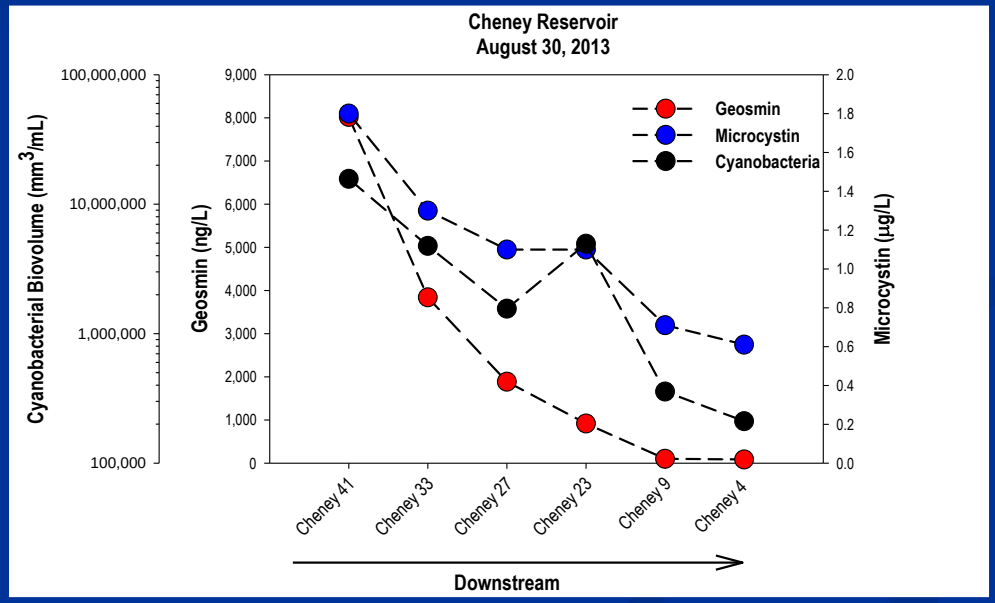
After Graham and others, 2012

Cyanobacteria and Associated Compounds May Vary Longitudinally in Reservoirs Due to Gradients in Water-Quality and Hydrologic Conditions



Foster and Graham, in preparation



Otten and others, in preparation

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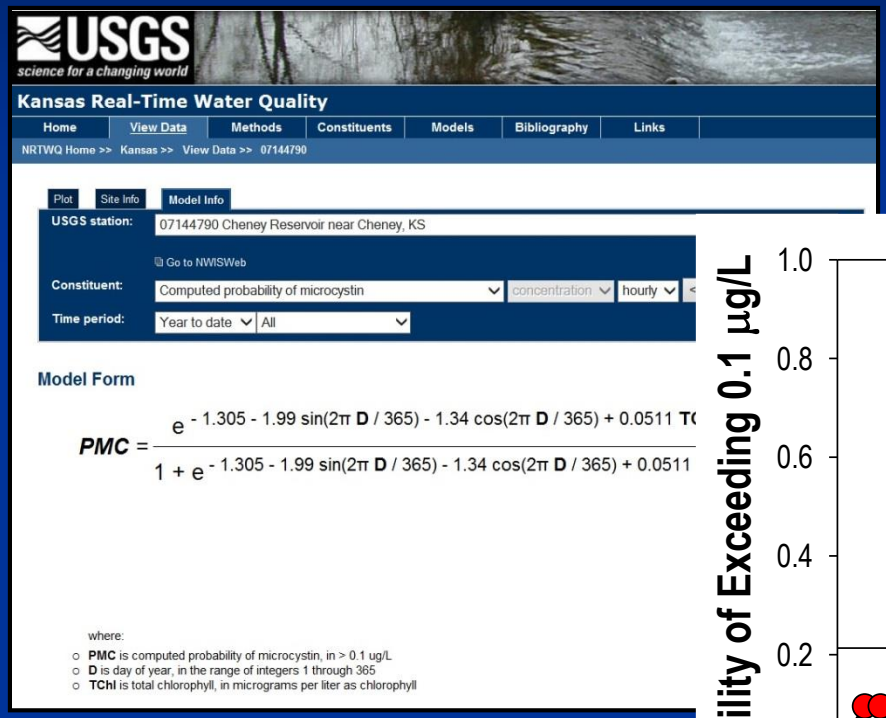
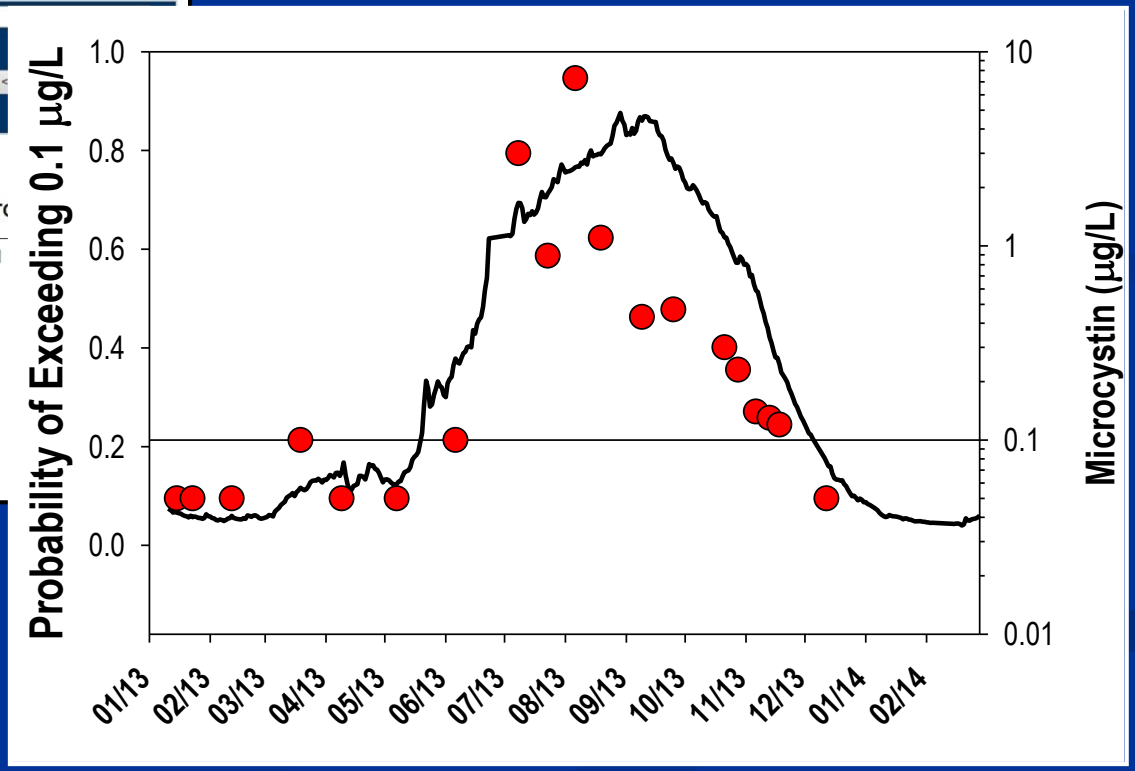
The Logistic Regression Model for Probability of Microcystin Concentrations > 0.1 µg/L in Cheney Reservoir Includes a Seasonal Component and Chlorophyll as Explanatory Variables





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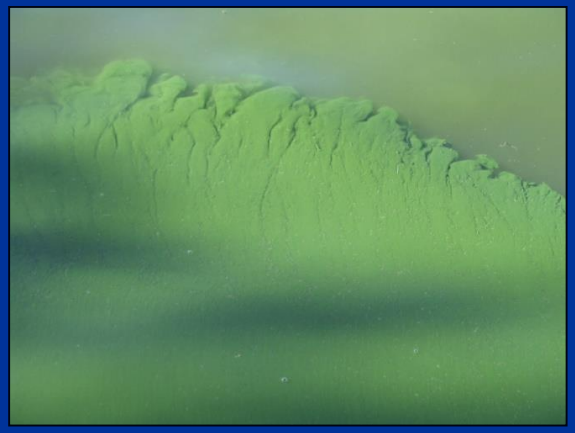
Stone and Graham, http://pubs.usgs.gov/of/2013/1123/

CyanoHAB Summary

- CyanoHABs can occur any time of year in all types of surface water.
- Cyanotoxin mixtures are somewhat common.
- We have understanding of environmental factors that control Cyanobacteria growth, but not as much about toxin production.
- Seasonality of cyanotoxin occurrence shows a strong dependence on weather patterns.
- Land-use and water quality strongly impact cyanoHAB occurrence.
- We need help on cyanotoxin risk assessment!



July 31, 2006

August 3, 2006

August 11, 2006

HAB Strategies Needed to Mitigate Environmental Health Problems

- Short Term Strategies: How do we protect life and resources during HABs (e.g. recreation, finished drinking water, ecosystems)?
  - Engineering controls
  - Alternate water sources

- Long Term Strategies: What management strategies will mitigate HAB occurrence?
  - Make sure our activities/behaviors don't interfere with:
    - Environmental controls
    - Engineering controls

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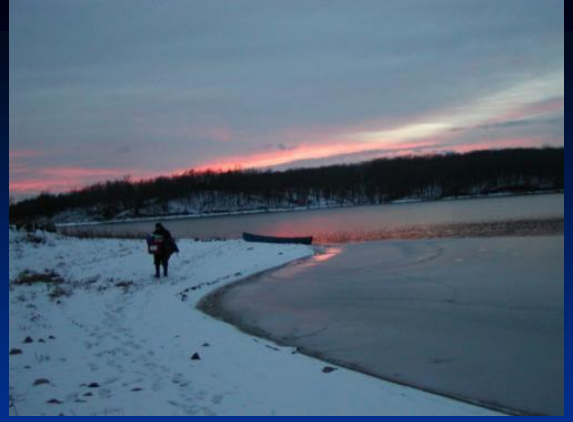

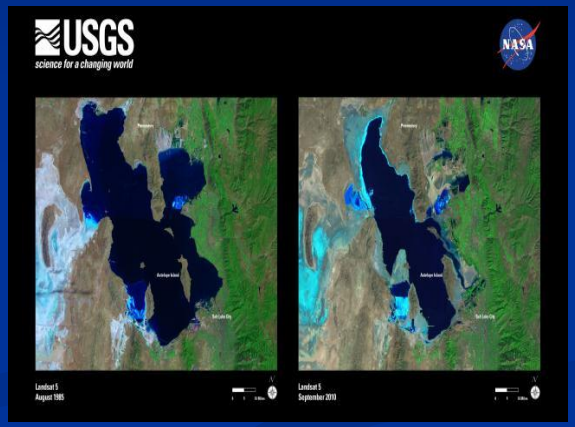

Additional Information:

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

http://www2.epa.gov/nutrient-policy-data/inland-hab-discussion-group

http://www.whoi.edu/page.do?pid=13935

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