Cyanobacteria Toxins within the Lower Great Lakes Region

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Faculty of Chemistry

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MERHAB-LGL

Harmful Algal Bloom

Monitoring and Event Response in the Lower Great Lakes

Sodus Bay September 2010

Lake Erie 2009

Lake algae may be killing animals, birds

Authorities: Don't fish or touch the water. Water samples to be tested.

By Delen Goldberg
Staff writer

A dog climbed out of Lake Neatahwanta in Fulton after a short swim Tuesday night, broke into convulsions and began vomiting.

Within minutes, the Labrador

While the toxin is unlikely to be fatal to humans, officials said high levels of the poison can cause liver and nervous system damage.

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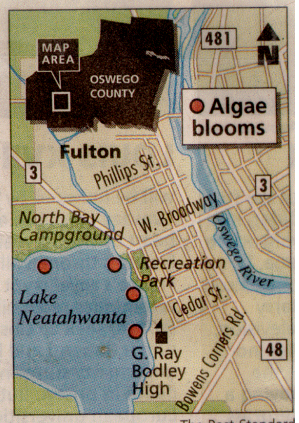


The Post-Standard

Two DEC biologists, wearing

Lake Champlain 2008

Things to cover

- Introduction to the toxins
- Sample Strategy
- Large Lakes
  - Lake Champlain
  - Lake Ontario
  - Lake Erie
- Inland lakes of New York

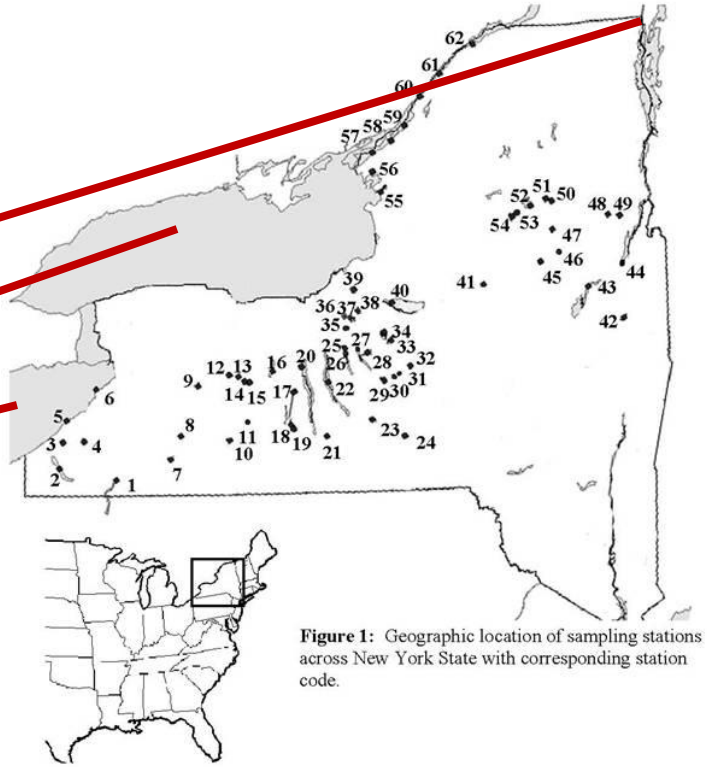
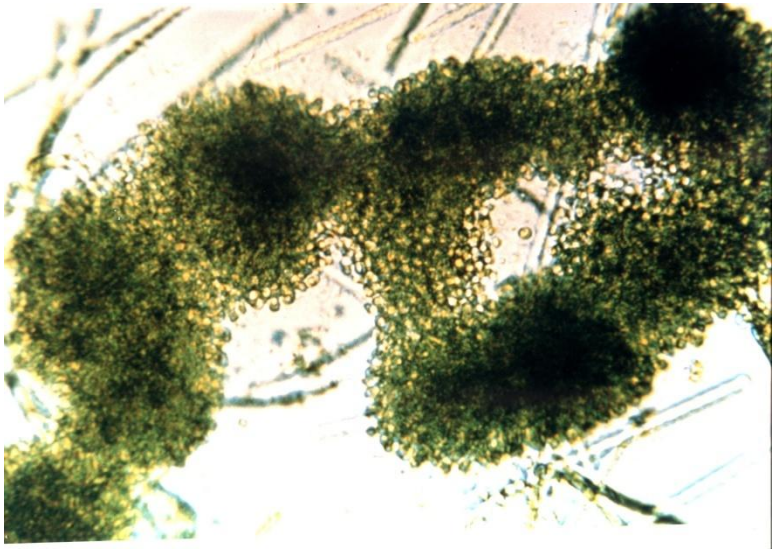


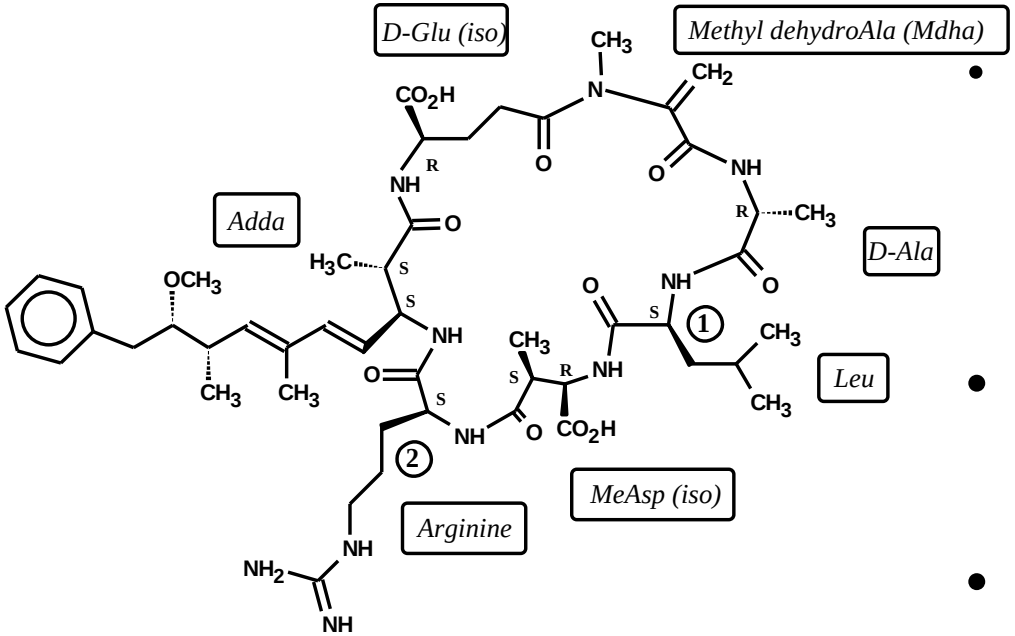
Figure 1: Geographic location of sampling stations across New York State with corresponding station code.

- Take home message: not that different



Microcystins

- *Microcystis aeruginosa*
- non-N fixer.
- Very common
  - Also produced by a number of other species.



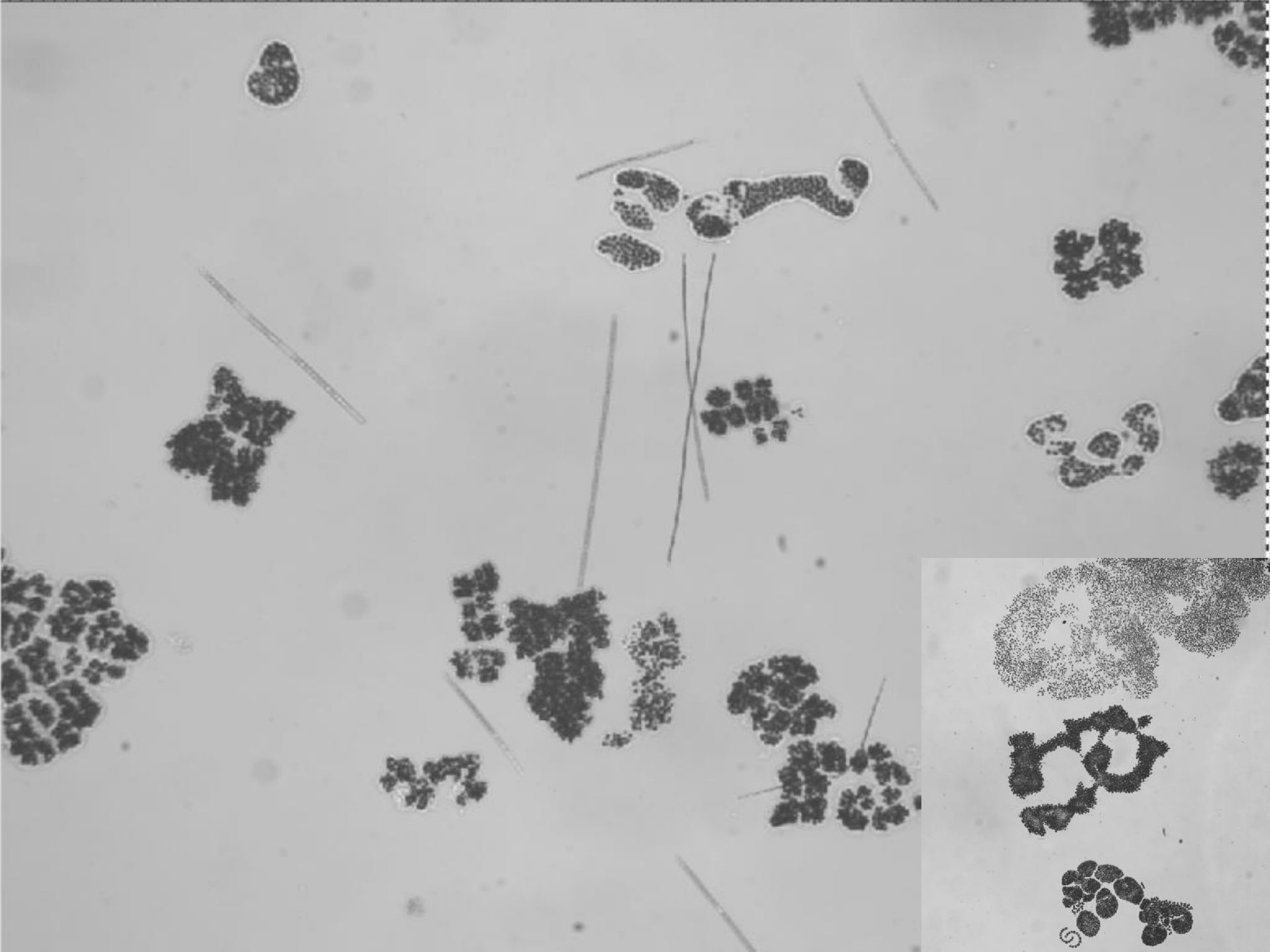
- Peptide hepato-Toxin:
  90+ structural variants +
  100-200 other bioactives (anabaenapeptins, etc.)
- Called "fast death factor"
  Potent carcinogen
- WHO guideline value:
  1 μg/L for drinking water
  20 ug/L recreational contact

Never trust a name!

Microcystin-producing strains include:

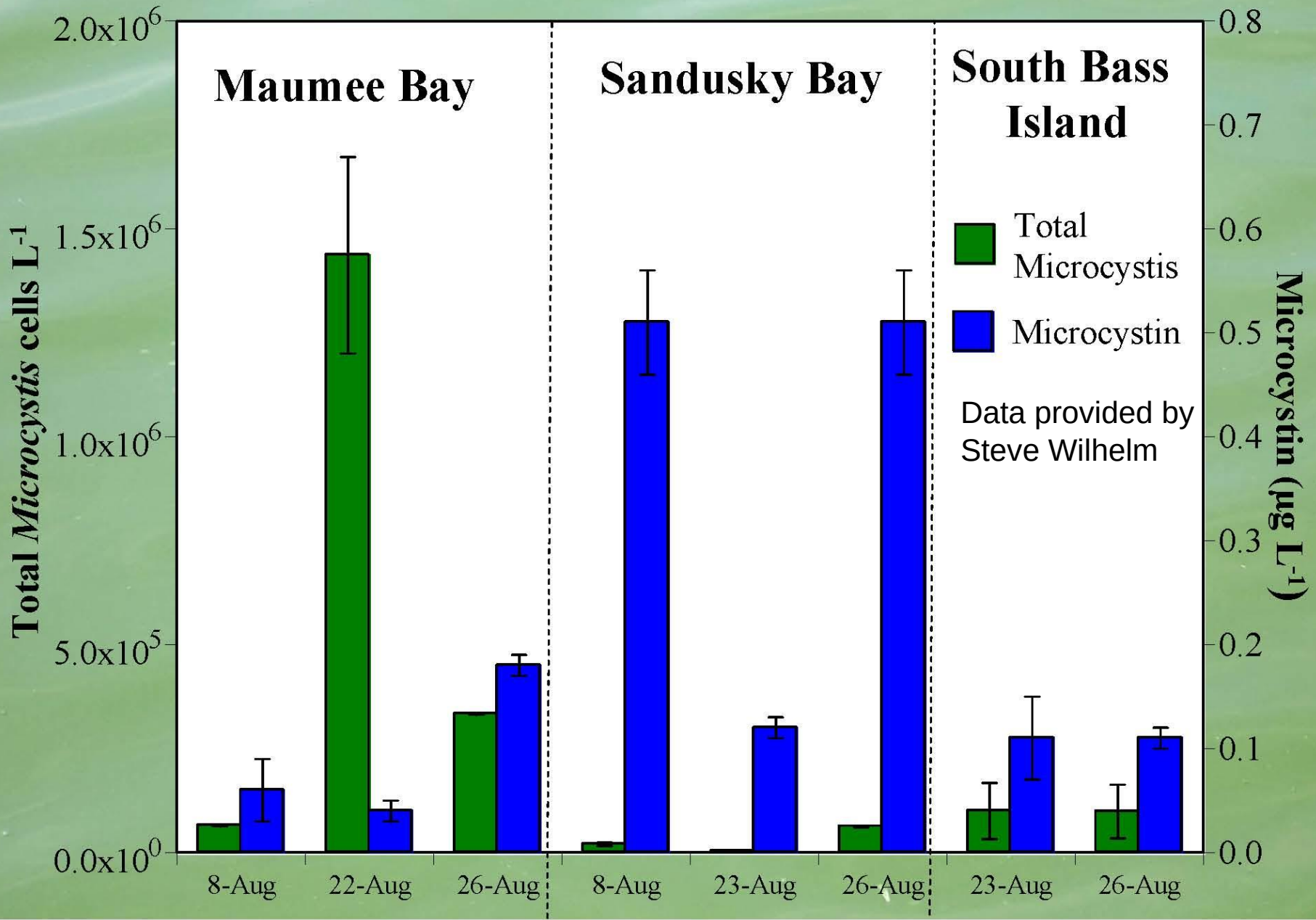
- *Microcystis aeruginosa*
- *M. veridis*
- *M. botrys*
- *Oscillatoria limosa*
- *Anabaena flos-aquae*
- *A. lemmermannii*
- *A. circinalis*
- *Planktothrix agardhii*
- *P. mougeotii*
- *Nostoc spumigena*
- *N. species*
- *Anabaenopsis millerii*
- *Haphalosiphon hibermicus*

i.e. Biology is a mess!

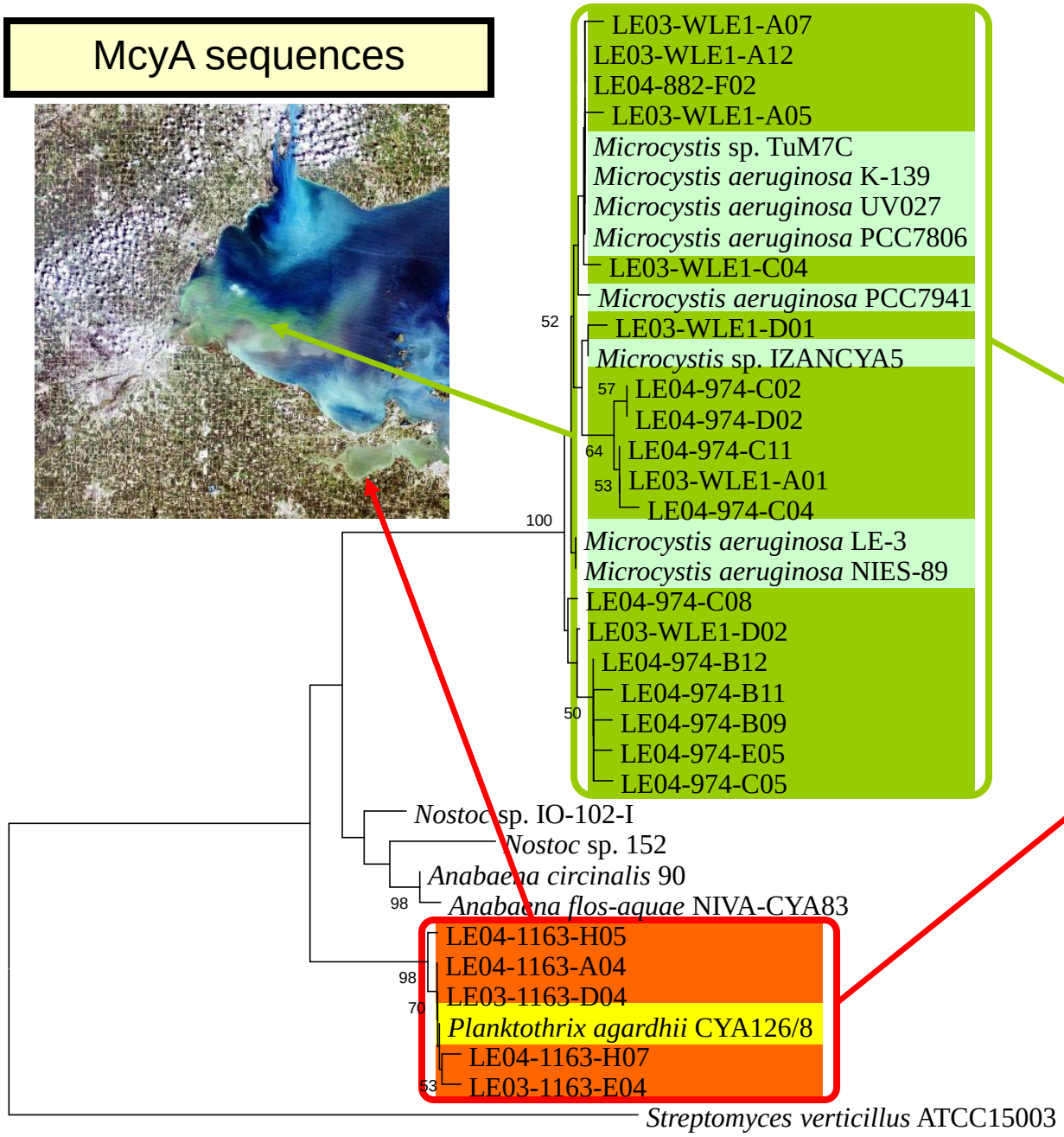


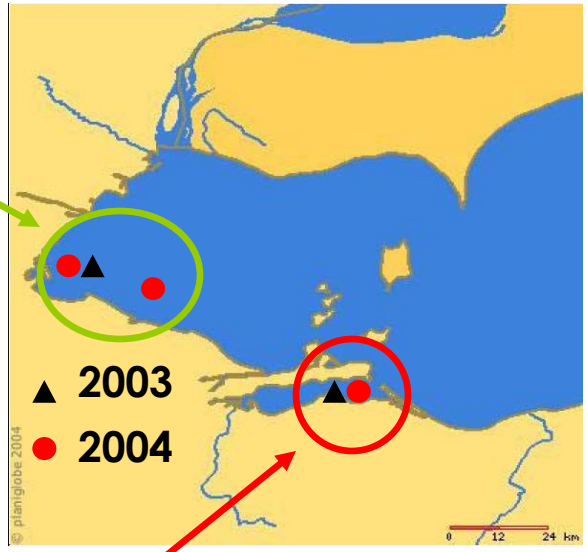
Difficult to use taxonomy to predict toxicity

Western Lake Erie, 2005



McyA sequences





2 different populations producing the same toxin!!

Rinta-Kanto and Wilhelm, 2006, AEM 72:5083

Sampling Strategy

- Not a response to a bloom (not bloom chasing)
- Uniform extraction protocol (50% MeOH)
- Single sample (1-20L) split for analysis
  - Microcystins: PPIA assay (total toxicity)
    - Confirm by LCMS or LC-MS/MS if needed
  - Anatoxin-a and homoAnatoxin-a: LCMS
  - Cylindrospermopsin, deoxyCYL: LCMS
  - BMAA: LCMS and confirm by LC-MS/MS
  - PSP toxins: HPLC-Fluorescence
  - ATX-a(S): not done
- <u>Sporatic</u> supporting information collected
  - Molecular biology, visuals,
  - Water Quality and nutrients
  -

Occurrence of Microcystins as measured by PPIA (2000 – 2004)	NY Totals	L. Ontario	L. Erie	L. Champlain	Finger Lakes	Local Lakes
# Analyzed:	2513	736	308	590	138	741
> 0.01ug/L	1223 (53%)	155 (28%)	117 (40%)	296 (51%)	113 (82%)	542 (73%)
> 0.1 ug/L	829 (36%)	61 (14%)	84 (29%)	190 (33%)	23 (17%)	471 (64%)
> 1 ug/L	326 (14%)	4 (1%)	11 (4%)	71 (12%)	1 (1%)	239 (32%)

Boyer, Lake Res. Managem, 2007

Data Mining Other Toxins

Thresholds and samples number	NY Totals	L. Ontario	L. Erie	L. Champlain	Finger Lakes	Local Lakes
ATX (>0.1 ug/L) (n>3,000)	29 (1%)	2 (<1%)	2 (1%)	12 (2%)	2 (1%)	11 (2%)
ATX (>0.01 ug/L) (n>3,000)	75 (3%)	14 (5%)	14 (5%)	24 (4%)	2 (1%)	21 (3%)
CYL (>0.01ug/L) (n>2,500)	8 ? (<1%)	1 ? (<1%)	2 ? (0%)	0 (0%)	-	5 ? (2%)
PSP (>0.01ug/L) (n>2,500)	2 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	1 (1%)

Modified from Boyer, 2007

Summary of the Occurrence

- Microcystins are the most common
  - Detectable levels in about 50% of the lakes
    - Great Lakes study 2000-2004: 53%
    - NYSDEC CSLAP study 2011: 13% (OW) – 35%
    - NYS fishing access sites 2001: 50%
  - Exceed 1 ug/L about 15% of the time
  - Exceed 20 ug/L about 1-5% of the time
- Anatoxin-a is certain present in NYS
  - 1-5% of samples have detectable levels of ATX-a
- Cylindrospermopsins and BMAA are absent

Fishing Access Site Survey of 62 water bodies throughout NYS:

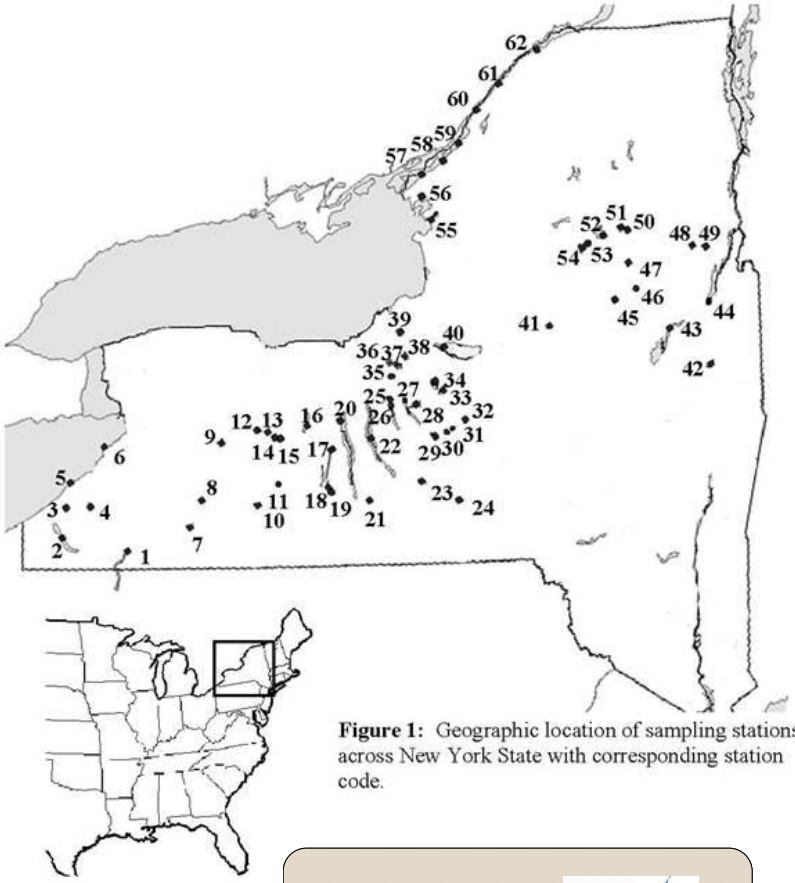


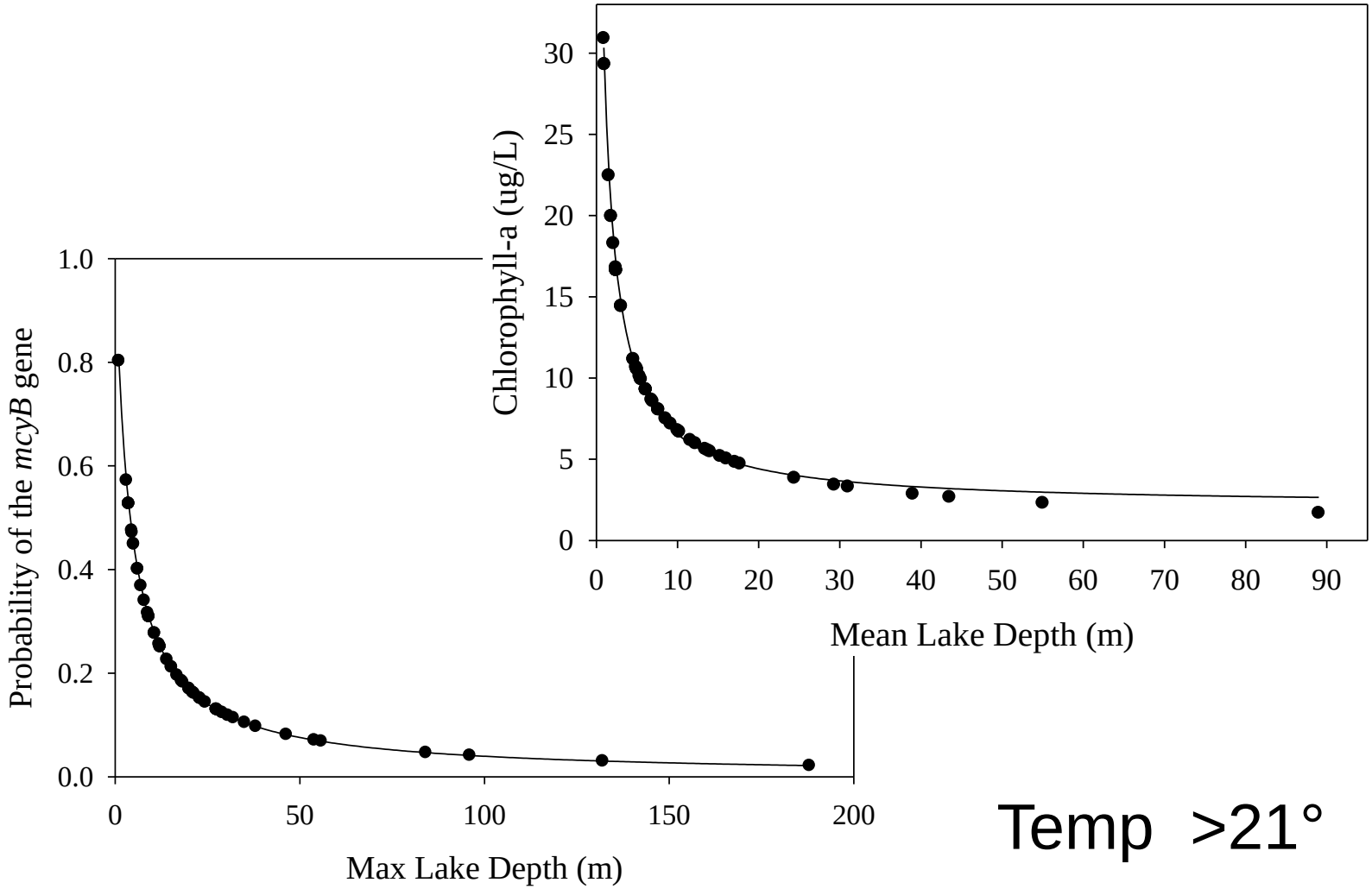
Figure 1: Geographic location of sampling stations across New York State with corresponding station code.

MERHAB-LGL
Harmful Algal Bloom
Monitoring and Event Response in the Lower Great Lakes

- Presence of Cyanobacteria (77%)
- Presence of toxic species (*Microcystis* 40%)
- Presence of toxin genes (50%)
- Presence of toxins (50% with 5% >1ug/L)
  - Toxic species
  - Non-toxic species
  - Potentially toxic (Toxigenic)
- Correlate this with easily-to-measure parameters.

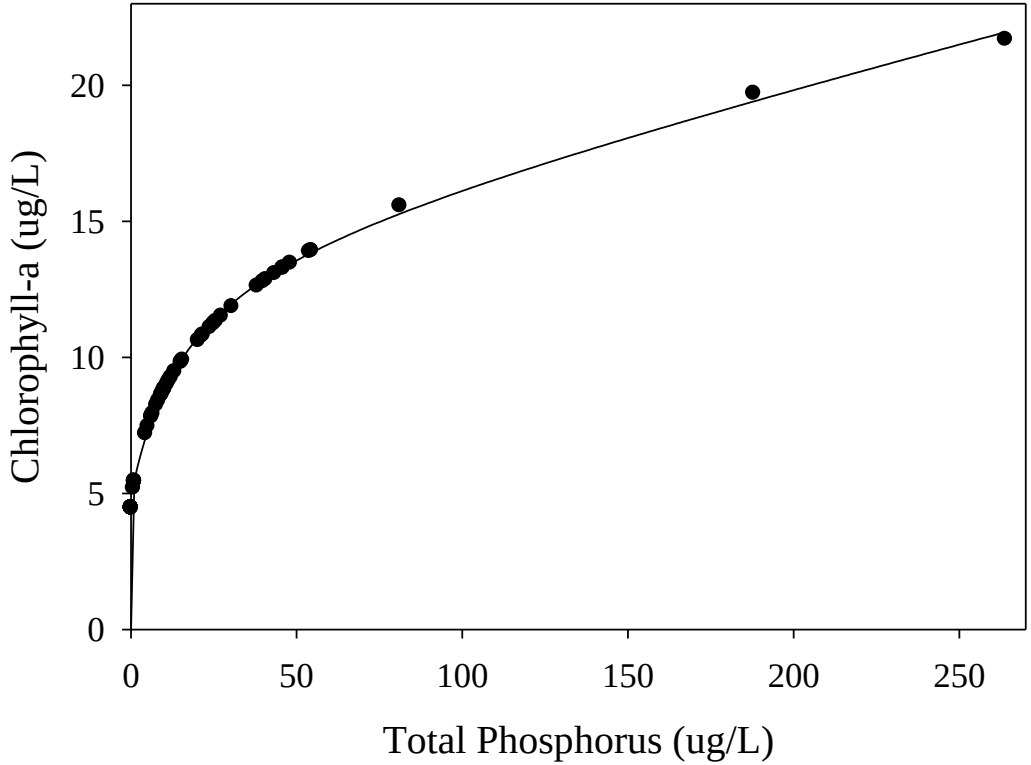
Hotto et al., 2007

Most blooms were associated with shallower waters



Temp >21°

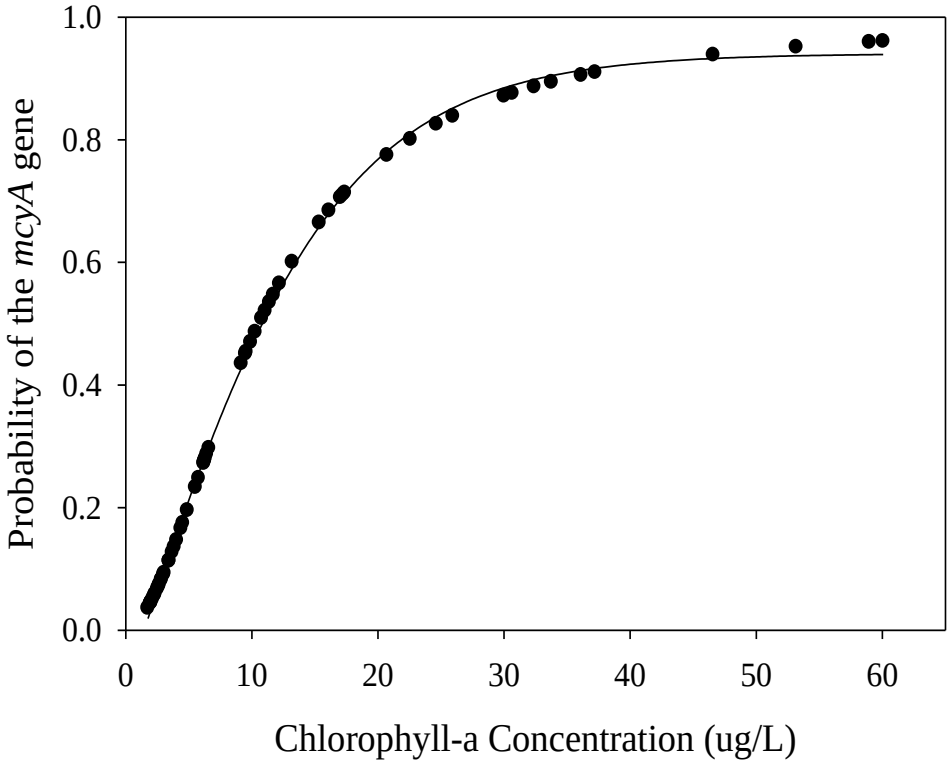
Good correlation between nutrients and algal biomass



There was a weak correlation between the presence of toxins and nutrients

Toxin $\not\Rightarrow$ growth

Increased biomass increased the chance of a toxigenic bloom



Oligrotrophic waters <5%

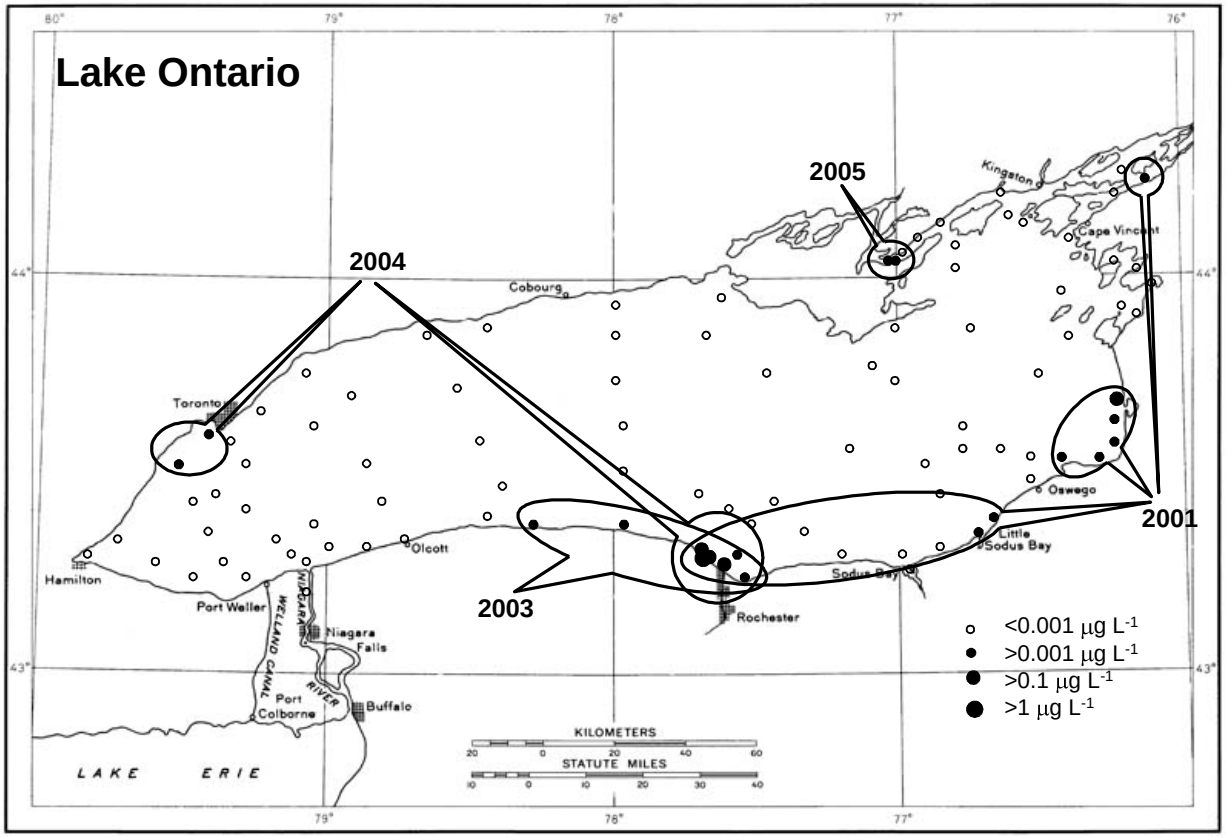
Mesotrophic waters ~20-40%

Hypereutrophic waters >90%

Source water protection works!

>95% chance of toxigenic species at Chl-a > 30 ug/L

What about ATX Distribution?



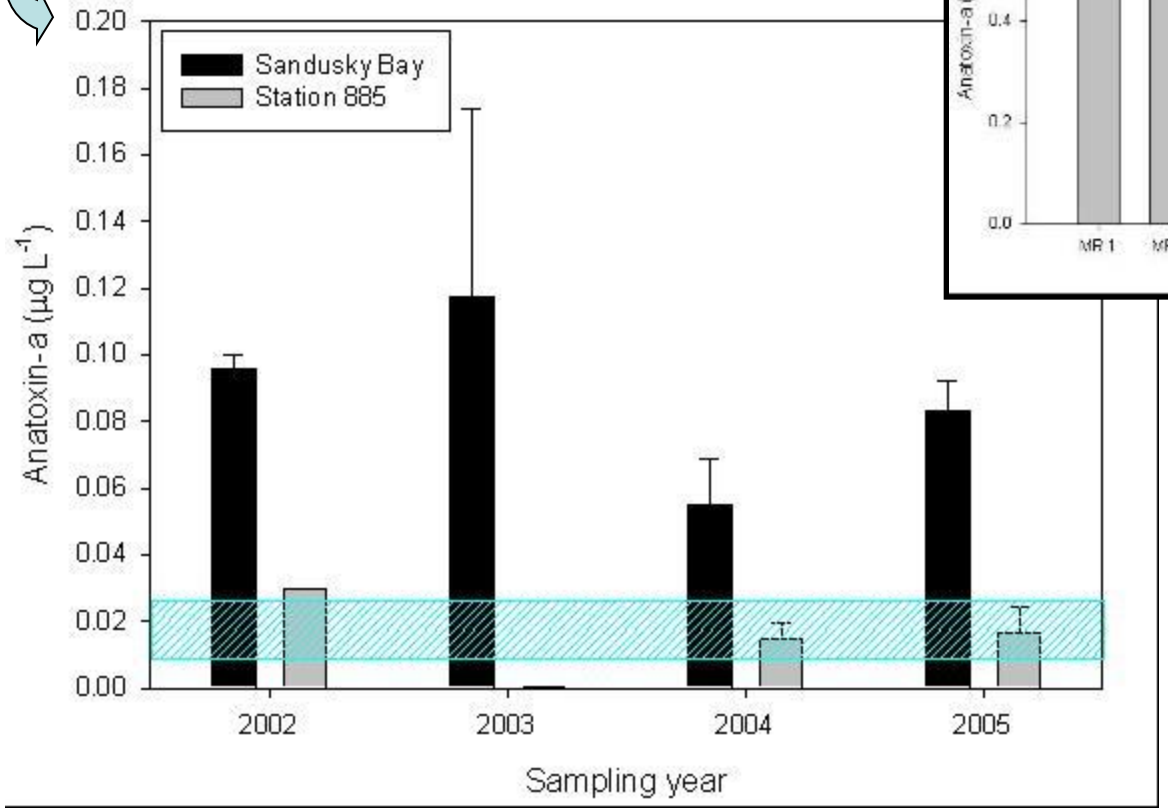
Distribution of Anatoxin-a in Lake Ontario (n= 940)

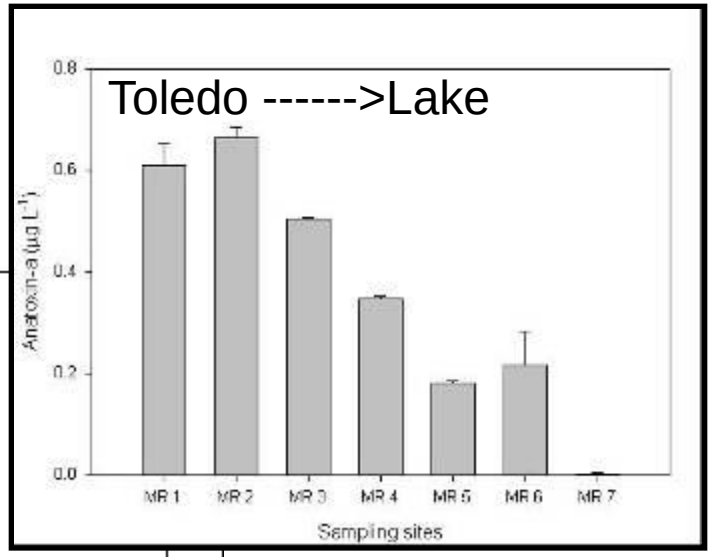
- Widespread
- Ephemeral
- Not correlated with *Microcystis* - different genus - different ecology.

Who is the producer ?

Anatoxin-a tended to be localized in the embayments.

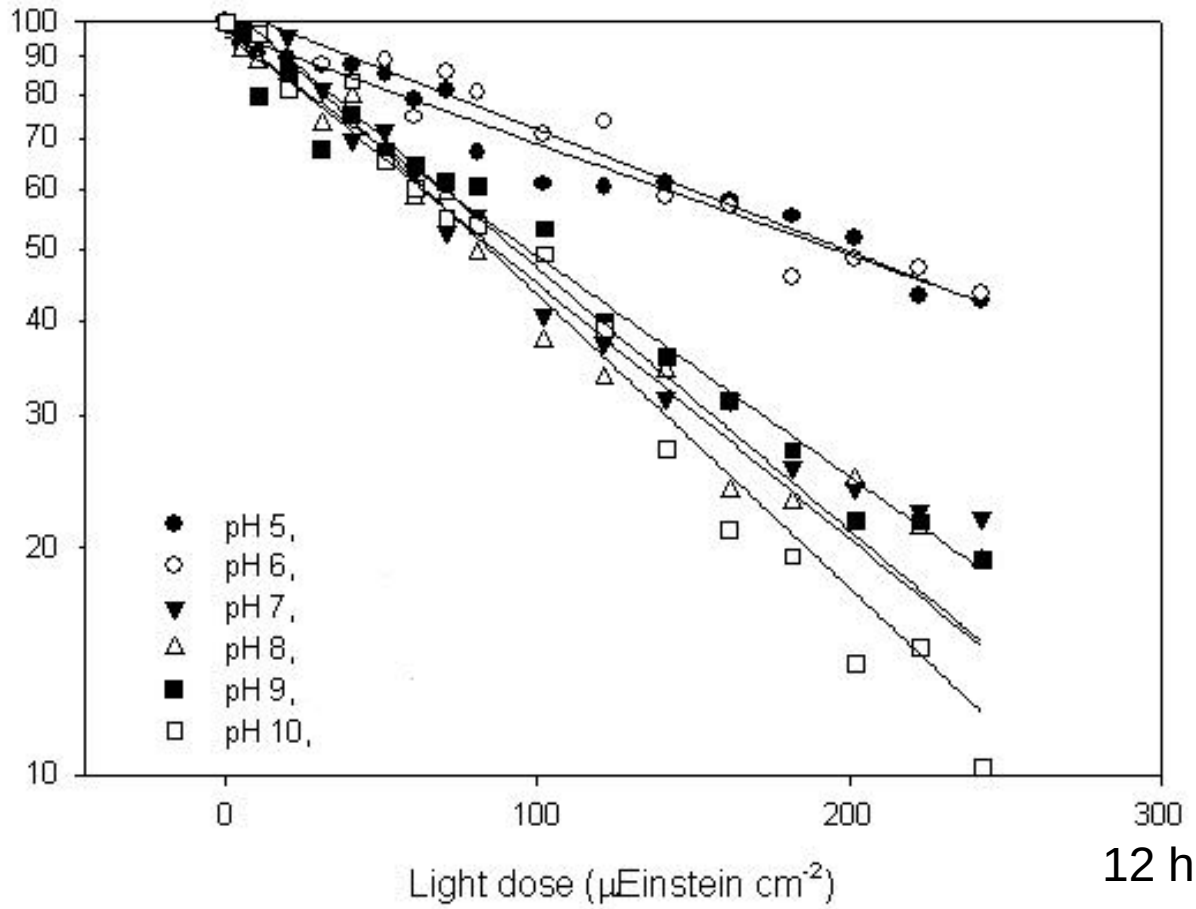
Sandusky Bay v.s. Sandusky basin





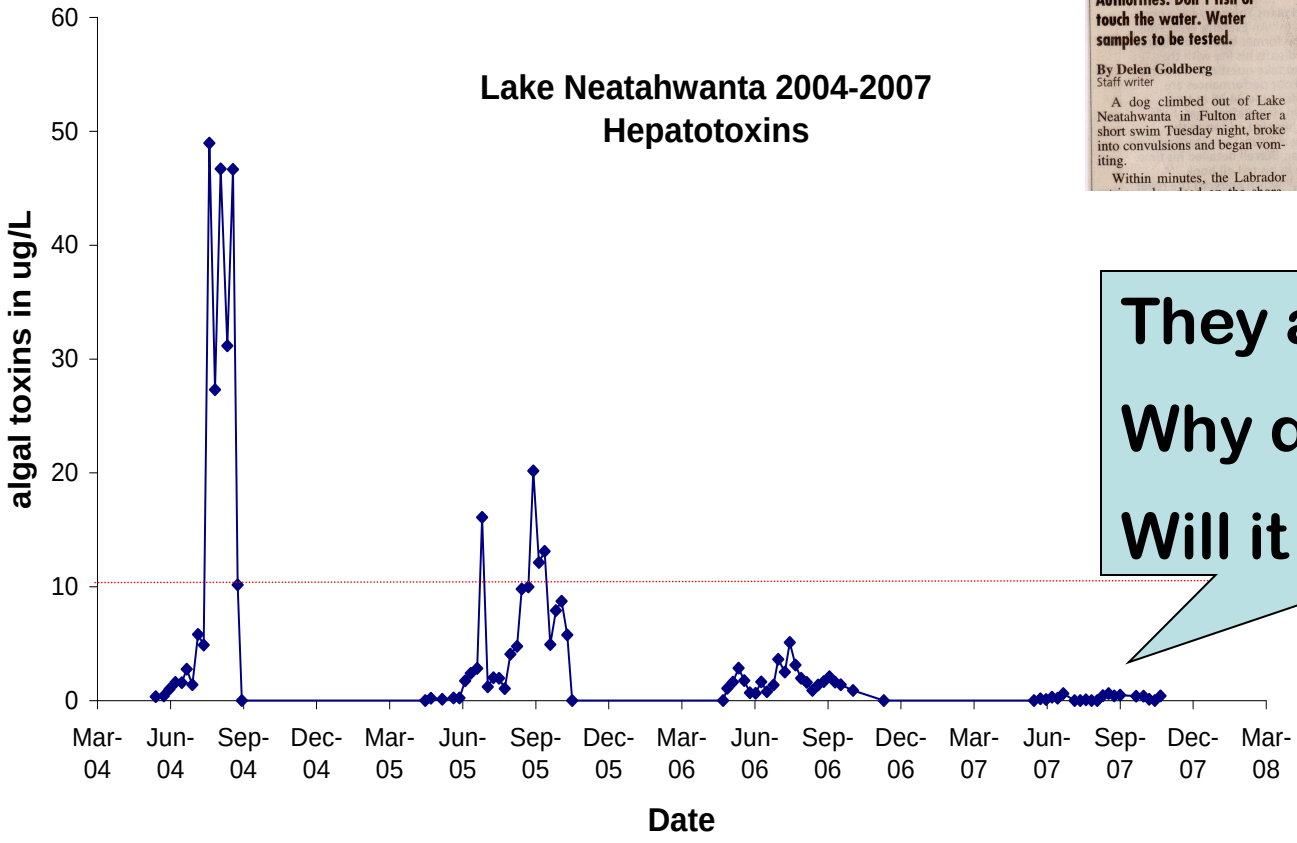
Maumee River 2004

Stability of Anatoxin-a influenced by pH and light intensity



12 hr experiments

Lake Neatahwanta



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"Until we find out for sure what is going on, it's better that people stay away," said Evan Walsh, associate public health sanitarian for the county Health Department.

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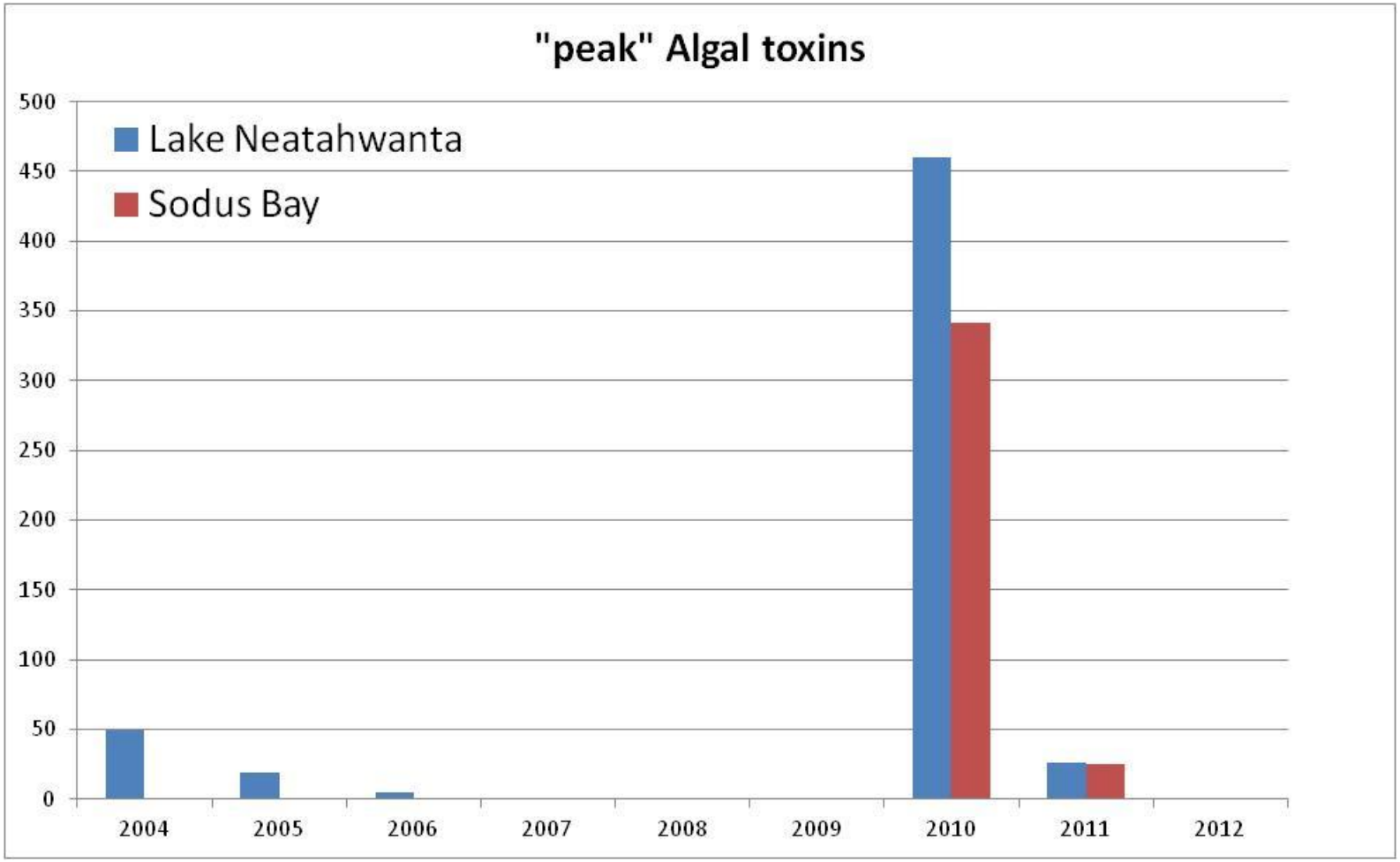
They are gone!

Why did it go away?

Will it come back?

Lake Neatahwanta



Its Back!

Summary

- Cyanobacteria produce a number of toxins but not all species are toxic.
  - Toxic species, potentially toxic species and non-toxic species
- Hepatotoxic microcystins are probably the toxin of most concern for human health in New York State.
- Different toxins can be produced by a number of different species making visual monitoring difficult.
- We do not understand the spatial, temporal and environmental factors affecting cyanobacterial toxin production.
- Source water protection remains our best tool for controlling the incidence of toxic cyanobacterial blooms within New York State.

People who did the work:

SUNY-ESF, Syracuse

- Mike Satchwell (Forestry)
- Margaret Pavlac (Environ. Chem.)
- Jeremy Sullivan (Biochemistry)
- George Westby (GLOS liason)
- Katherine Perry (Environ. Chem.)

Gone by not forgotten

- **Amber Hotto (Biochemistry)**
- Xingye Yang (Biochemistry)
- Pauline Stevens (Remote sensing)
- Juliette Smith (Fish biology)
- Karen Howard (Analytical Chem.)
- Elizabeth Konopko (Environ. Chem.)
- Steve Ragonese (technical support)
- Guozhang Zou (biochemistry)
- Sean Thomas (Environmental Science)

- A whole host of undergraduates!

Univ. of Tennessee

- Steven Wilhelm (Molecular biol)
- Johanna Rinta-Kanto
- Jenn DeBruyn

Lake Champlain.

- Tim Mihuc (LCRI)
- Mary Watzin (UVM)

SUNY-Brockport

- Joe Makarewicz

SUNY-Buffalo

- Joe Atkinson

SUNY Stony Brook

- Chris Gobler
- Tim Davis

Environment Canada

- Susan Watson
- Captain & Crew of CCGS *Limnos*