Cyanobacteria and their Toxins in NY and Great Lakes Waters

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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.

"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.

Authorities posted signs Thursday on parts of the lake's

Lake Champlain 2008

Things to cover

- Introduction to the toxins
- Large Lakes
  - Lake Champlain
  - Lake Ontario
  - Lake Erie
- Inland lakes of New York
- Take home message: not that different

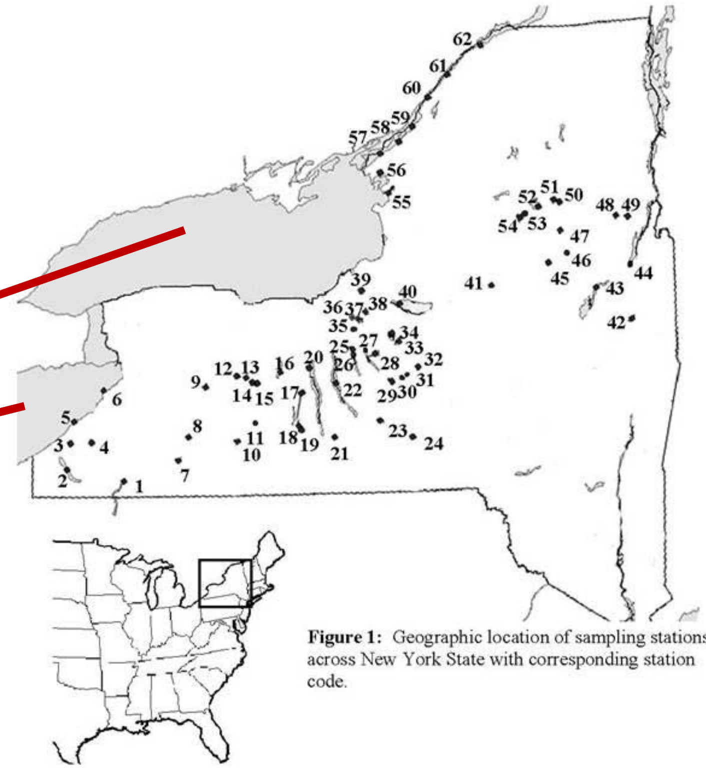
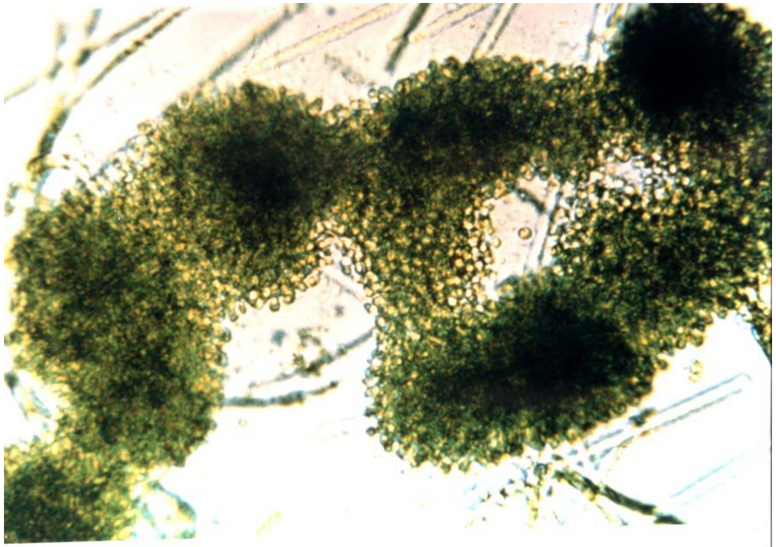
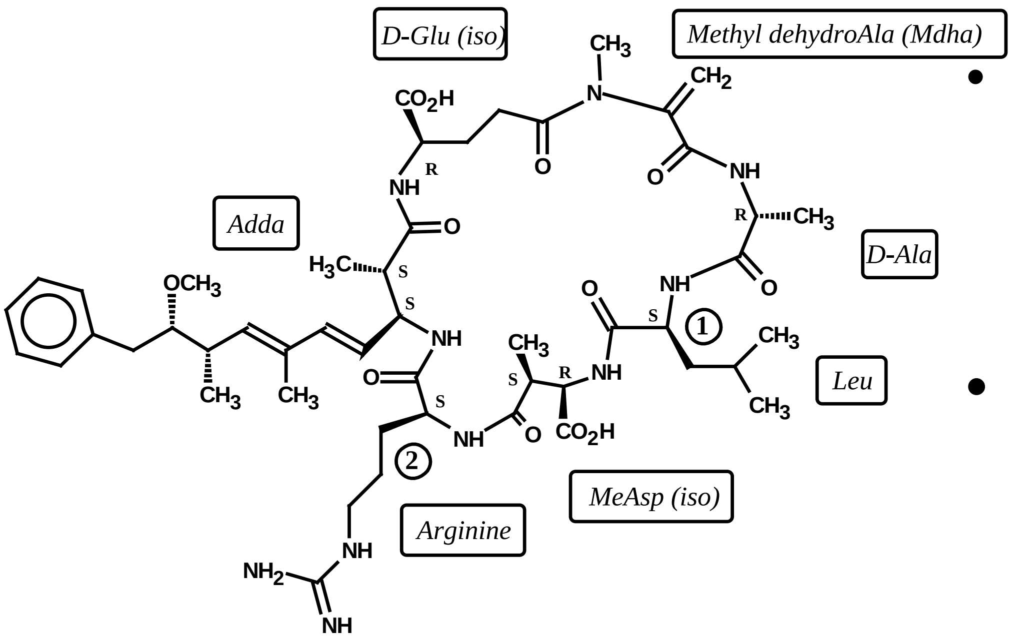


Figure 1: Geographic location of sampling stations across New York State with corresponding station code.



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"**
  - LD-50: 25-60 μg kg^{-1}
    Potent carcinogen

- WHO guideline value is 1 μg/L for drinking water

Never trust a name!

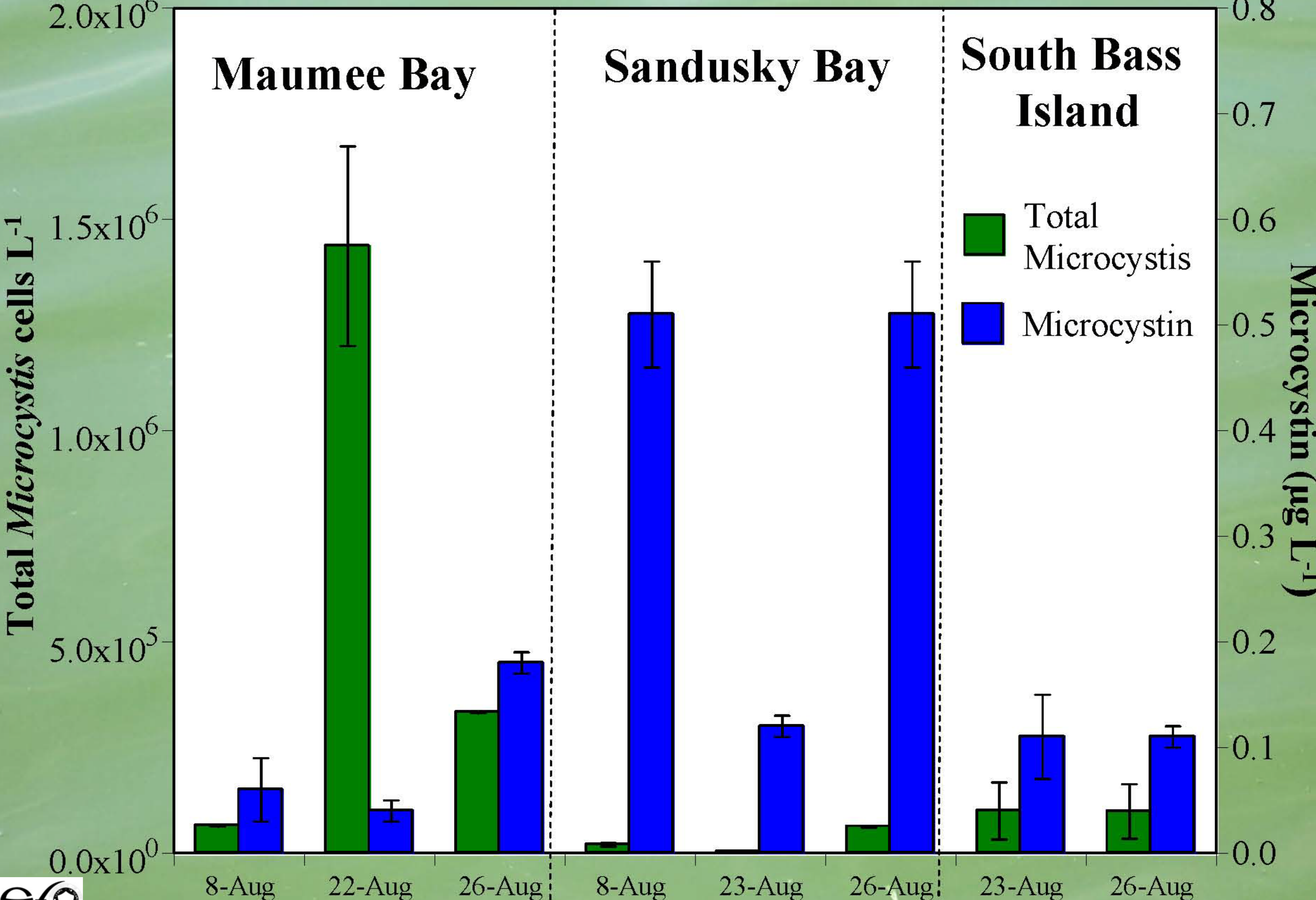
Microcystin-producing strains include:

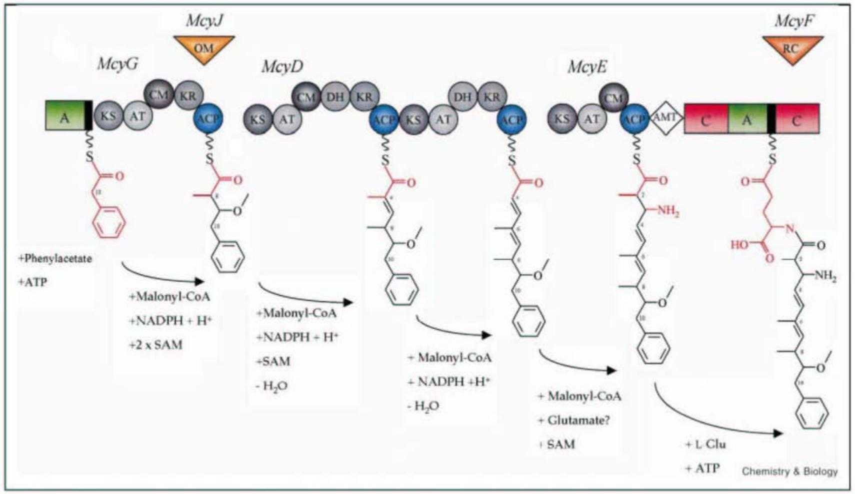
- *Microcystis aeruginosa*
- *M. veridis*
- *M. botrys*
- *Oscillatoria limosa*
- *Anabaena flos-aquae*
- *A. lemmermannii*
- *A. circinalis*
- *Planktothrix agardhii*
- *P. mougeotii*
- *Nostoc spumigena*
- *N. species*
- *Anabaenopsis millerii*
- *Haphalosiphon hibermicus*

i.e. Biology is a mess!

Difficult to use taxonomy to predict toxicity

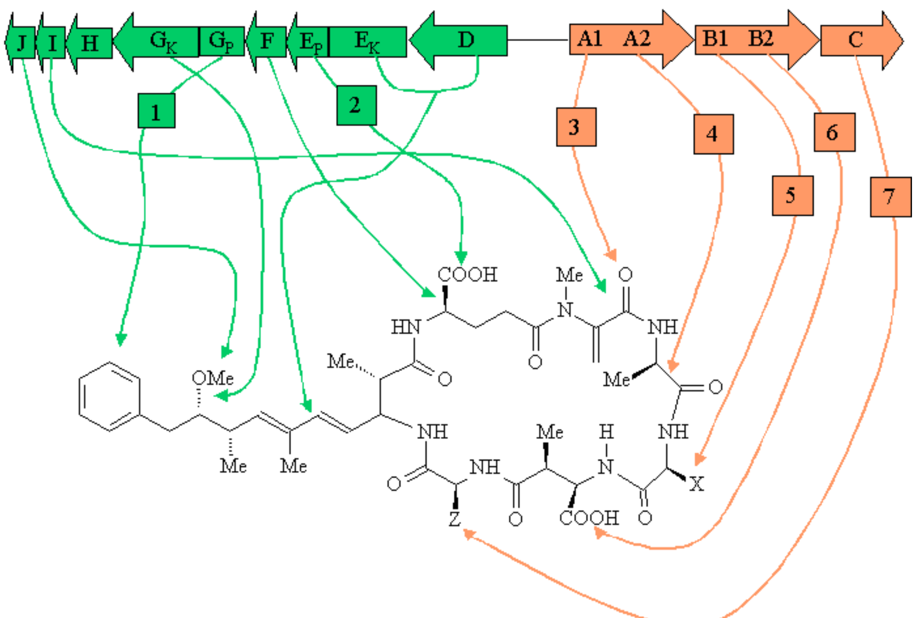
Western Lake Erie, 2005

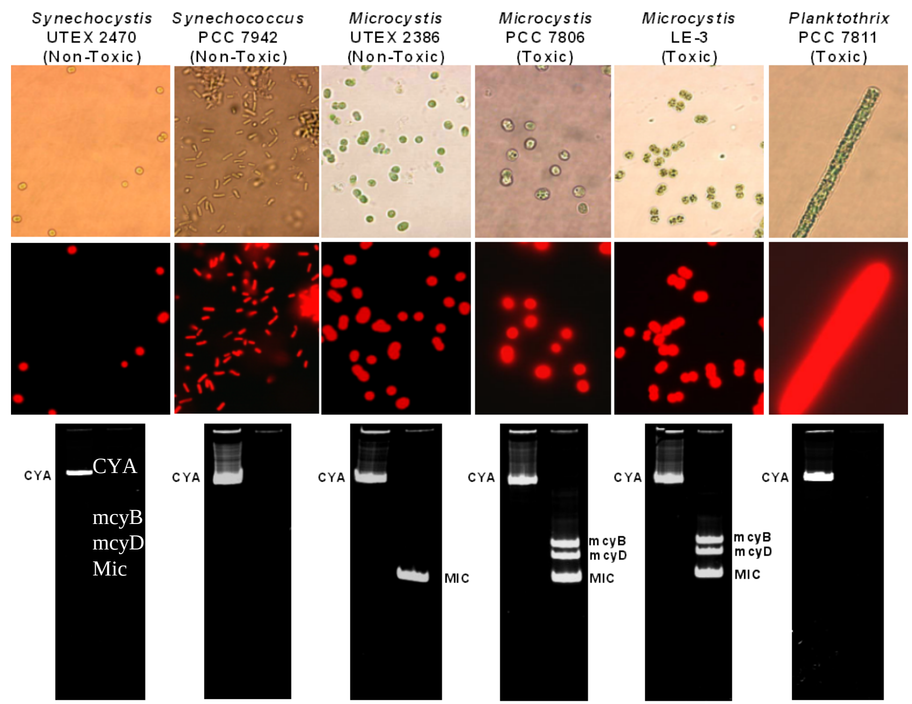




So how do you tell who is making the toxin?

DNA based probes!

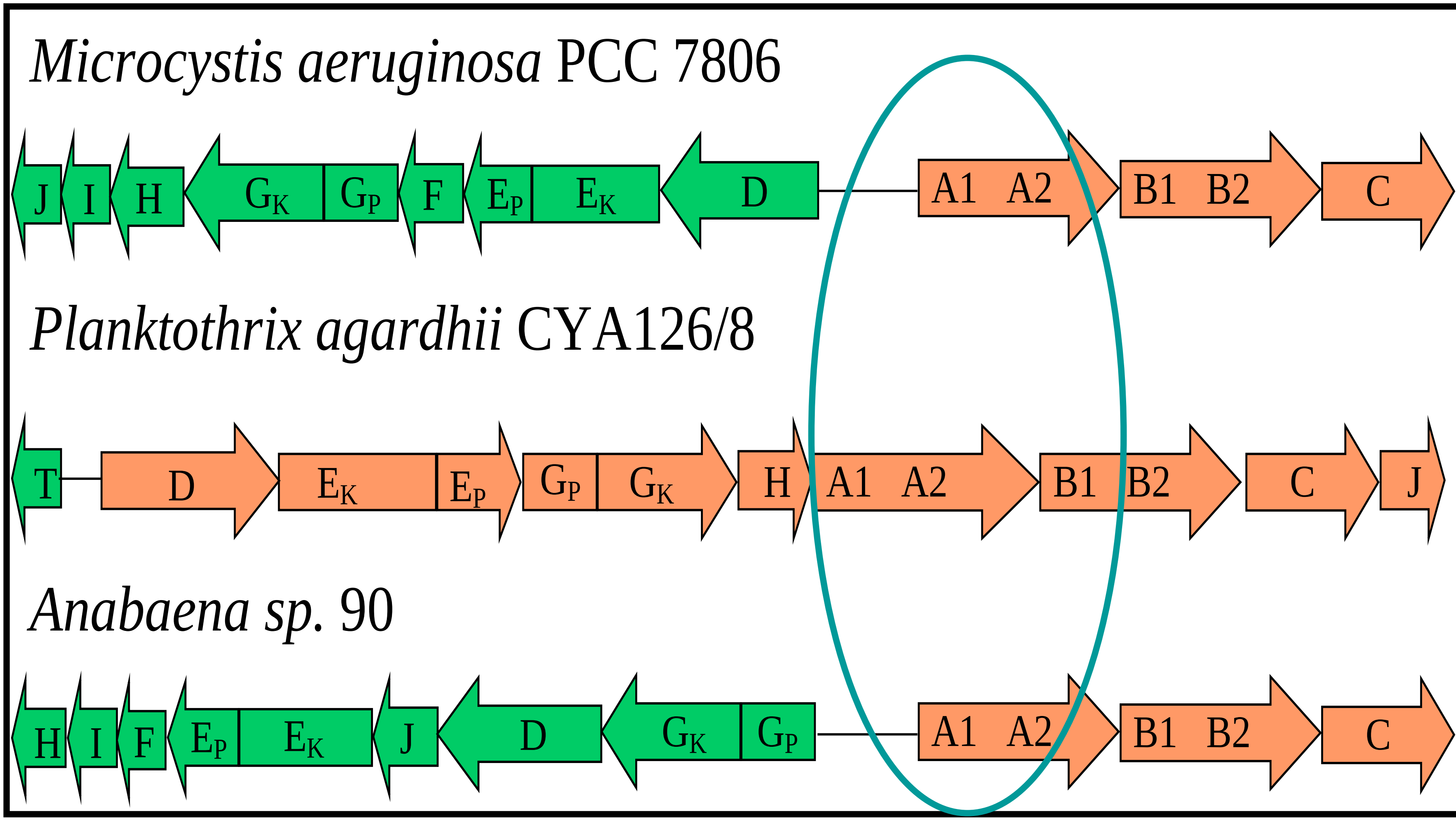




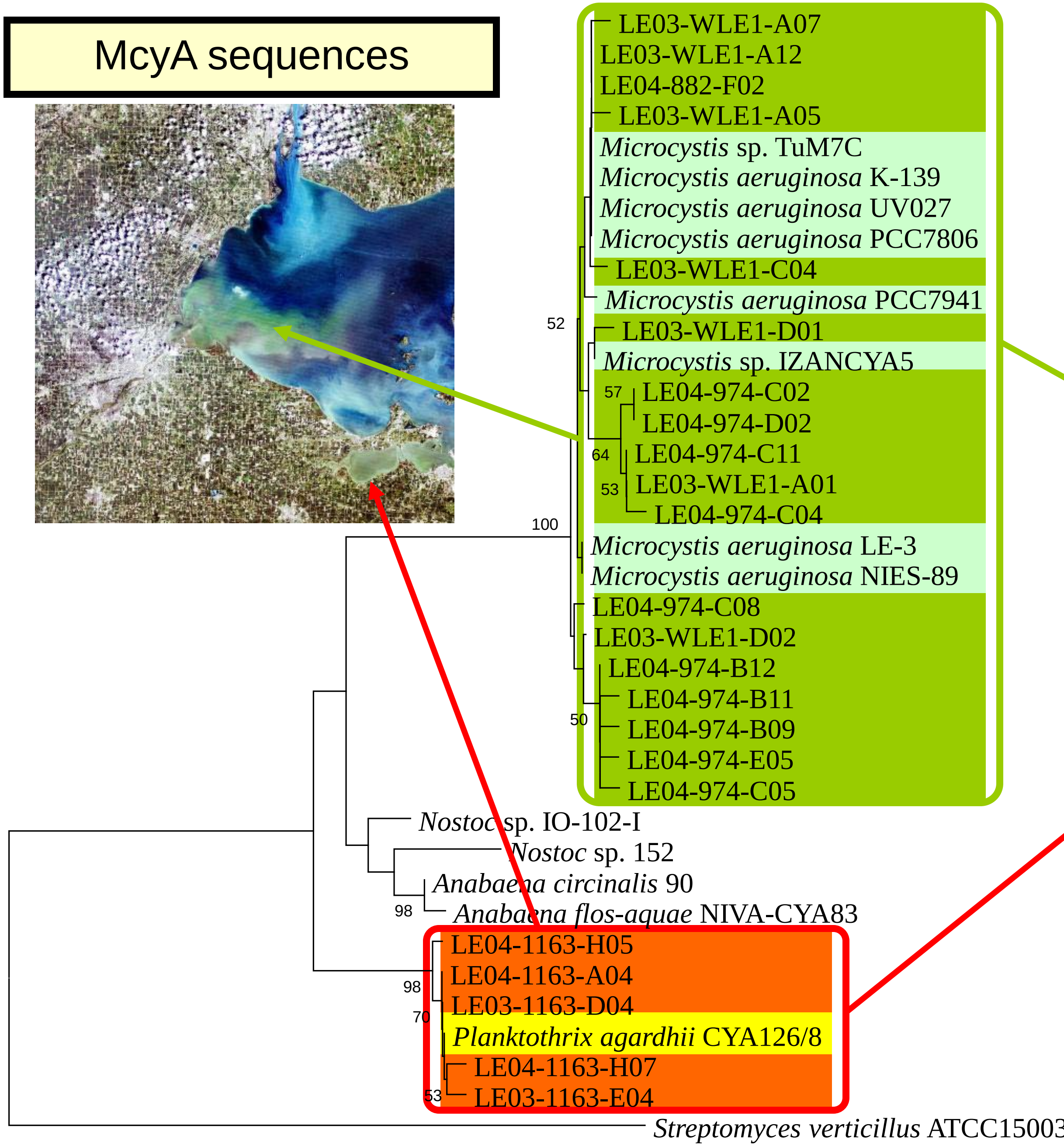
Tillett et al, 2000

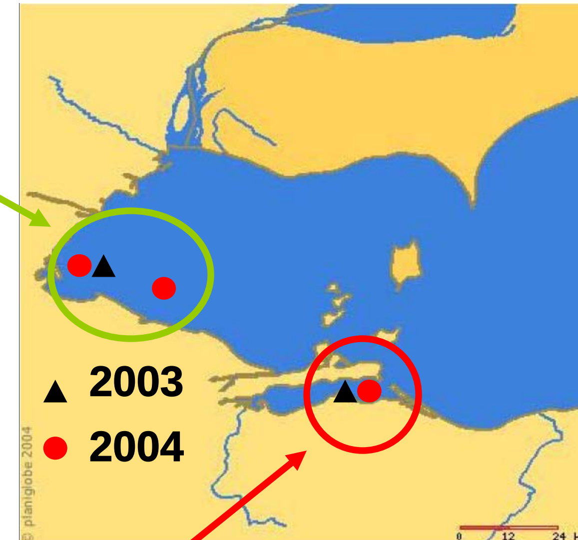
Image courtesy of S. Wilhelm

Microcystin Biosynthetic Gene Cluster



McyA sequences

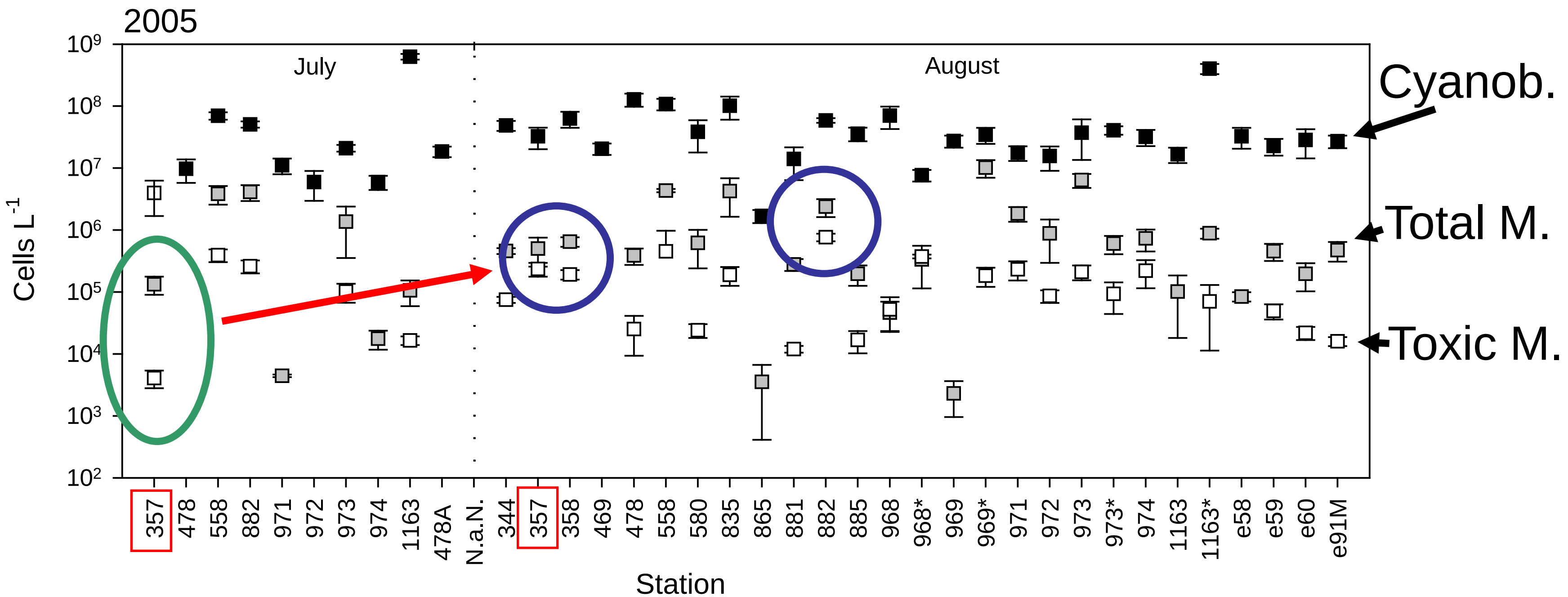




2 different populations producing the same toxin!!

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

Changes in total and toxic *Microcystis* in Lake Erie



Toxigenic *Microcystis* can account for >95% of the total *Microcystis*

Toxigenic *Microcystis* can account for <10% of the total *Microcystis*

These numbers can change with time.

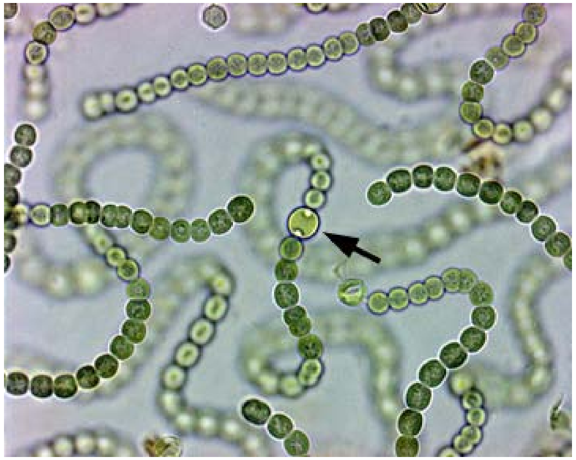
Rinta-Kanto et al, Harmful Algae, 2009

Cyanobacteria blooms in the Great Lakes

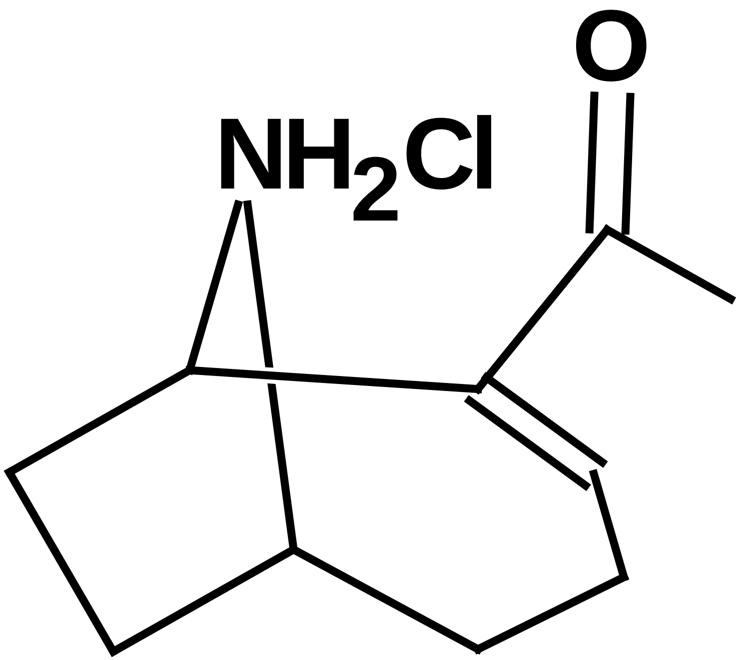
From Watson et al., 2008

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



Anatoxin-a



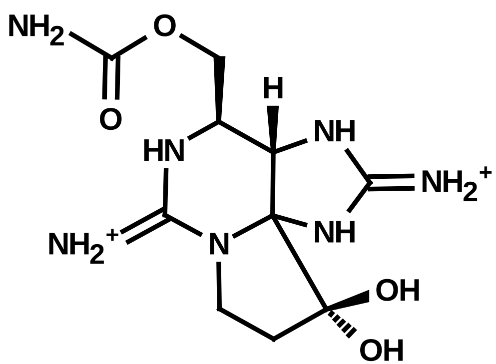
- **Potent Neurotoxin.**
  - **(very fast Death Factor)**
- **LD-50: 200 $\mu g\ kg^{-1}$**
- **Causative organisms include:**
  - ***Anabaena species (many)***
  - ***Oscillatoria sp.***
  - ***Aphanizomenon sp.***
  - ***Planktothrix sp.***
- **Responsible for the Lake Champlain animal fatalities in 2000 and 2001.**

Saxitoxin Family

Potent neurotoxins

Responsible for Paralytic Shellfish Poisoning (PSP)

LD-50: 10 μg kg^{-1}

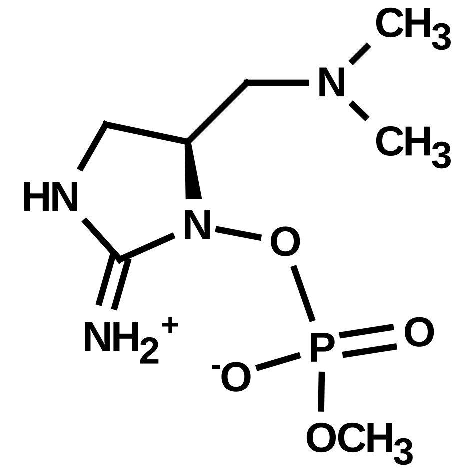


Anatoxin-a(S)

Organophosphate Neurotoxin.

cholinesterase inhibitor

LD-50: 20 μg kg^{-1}



Cylindrospermopsin

LD-50: 300 μg kg^{-1}

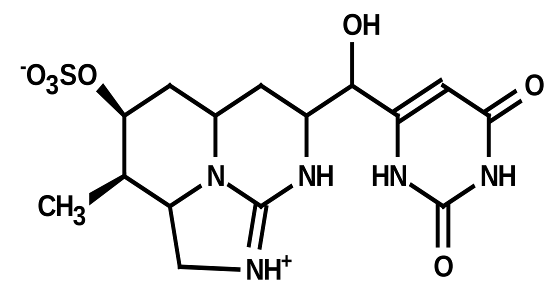
Causative species:

C. raciborskii

Aph. ovalisporum

Umezakia natans

Very common in Florida



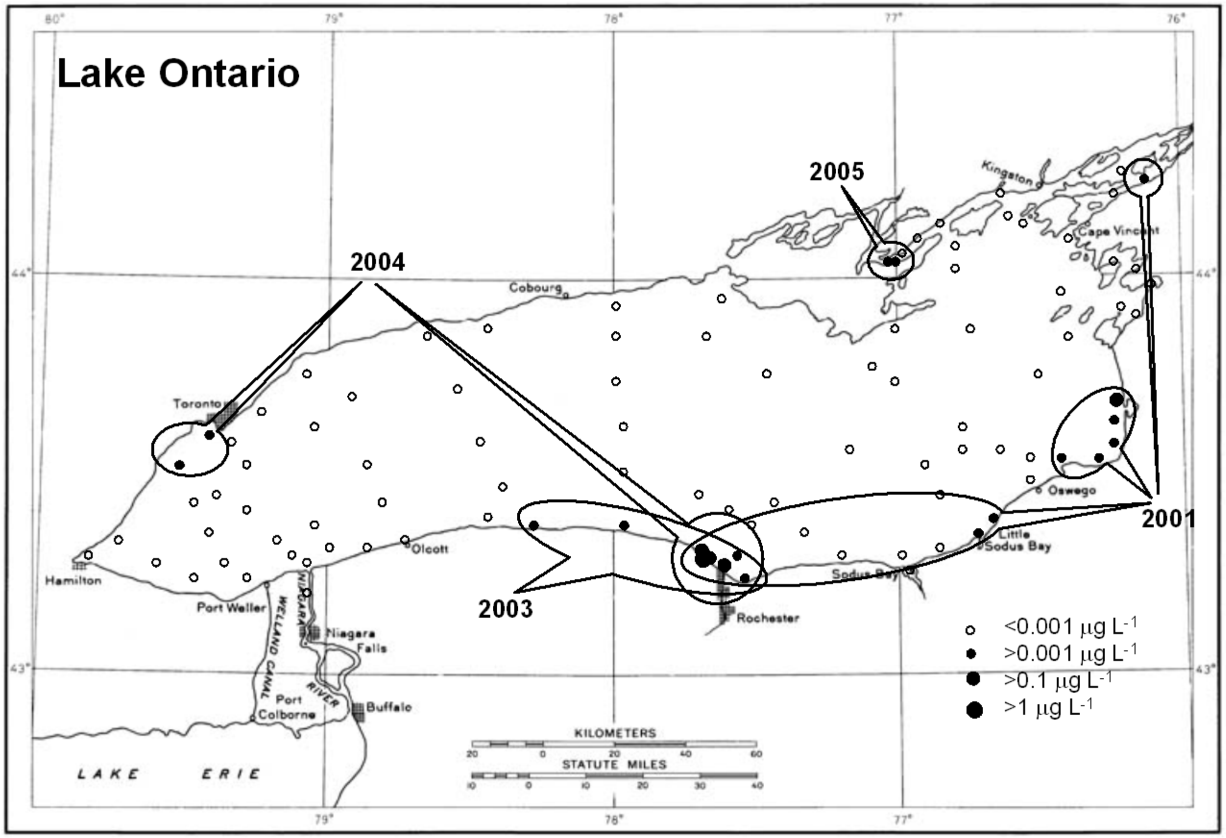
To date, these other toxins are very rare in our region……..

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

What about ATX Distribution?



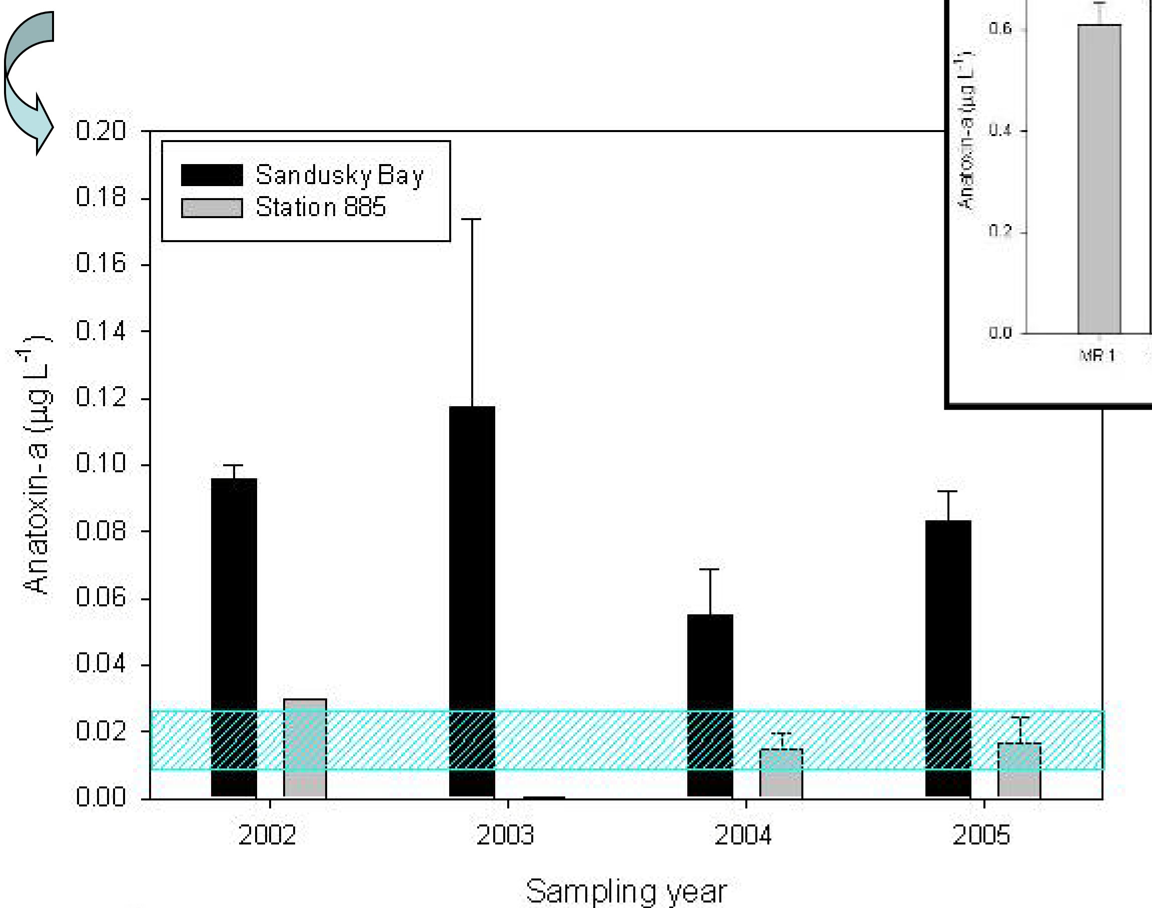
Distribution of Anatoxin-a in Lake Ontario (n= 940)

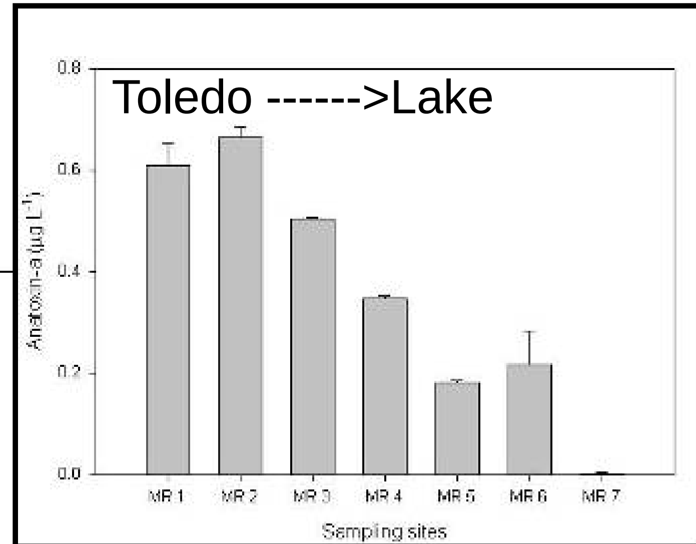
- Widespread
- Ephemeral
- Not correlated with *Microcystis* - different genus - different ecology.

Who is the producer ?

Anatoxin-a tended to be localized in the embayments.

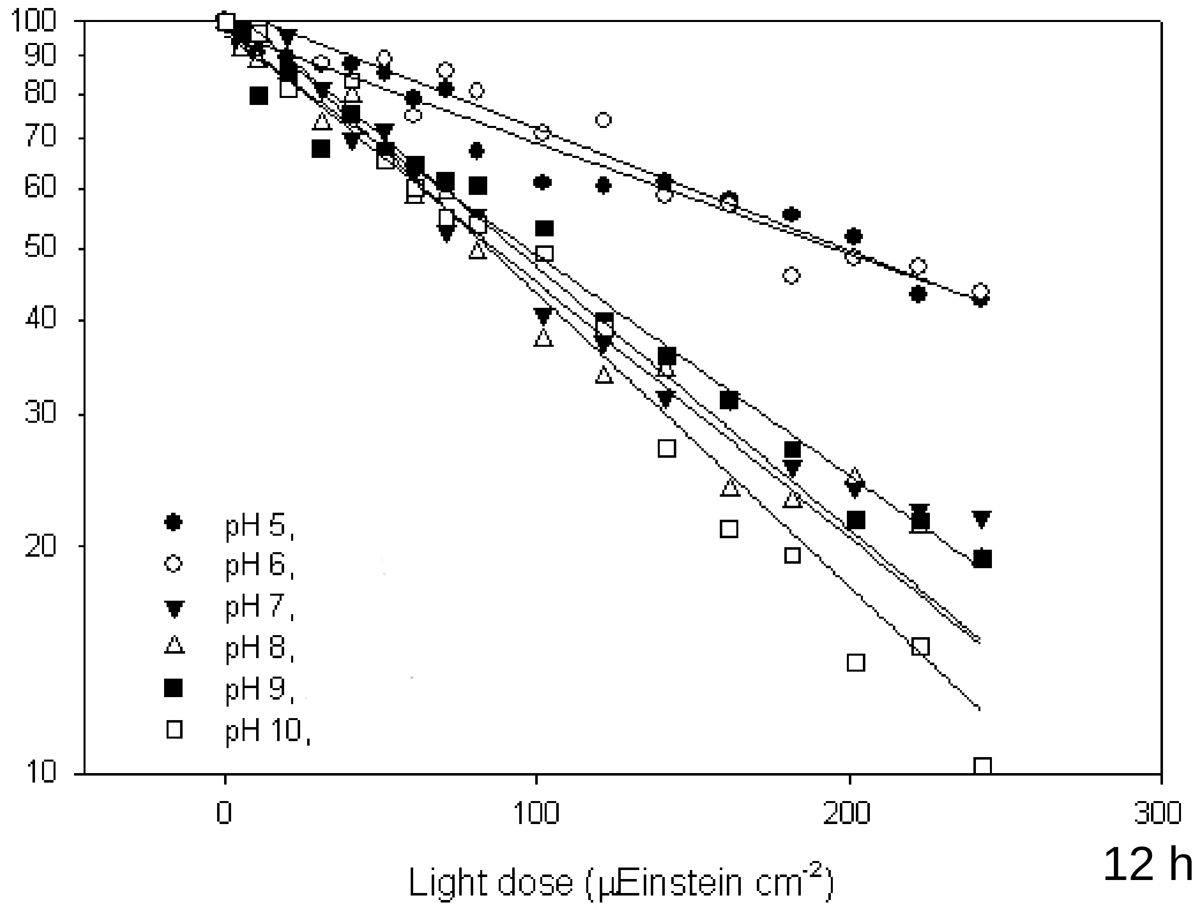
Sandusky Bay v.s. Sandusky basin





Maumee River 2004

Stability of Anatoxin-a influenced by pH and light intensity



12 hr experiments

Survey of 62 water bodies throughout NYS:

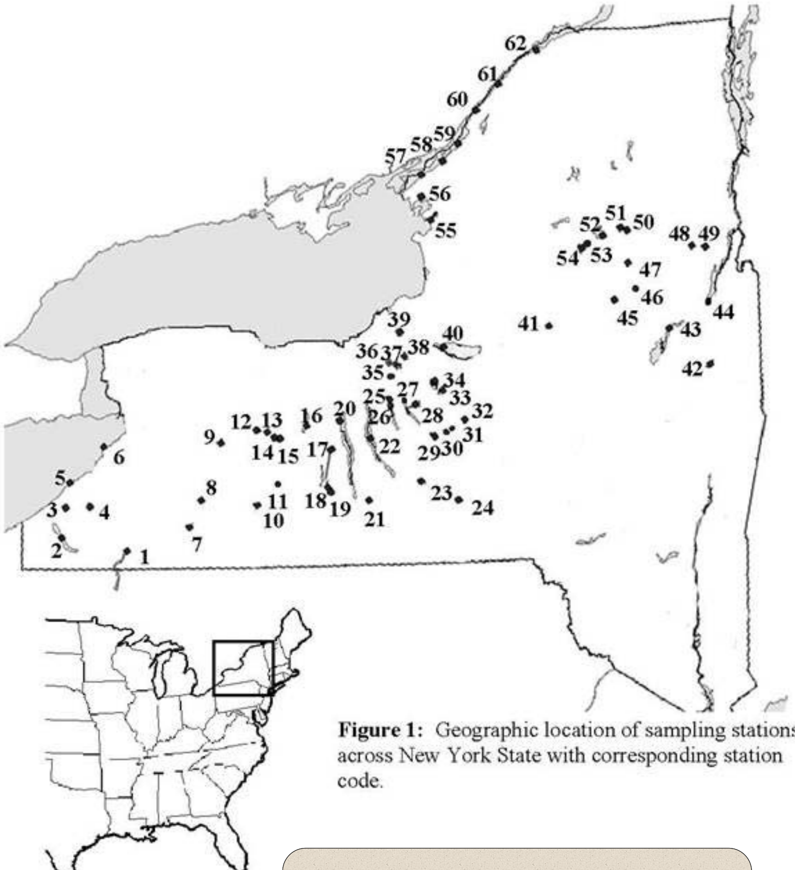


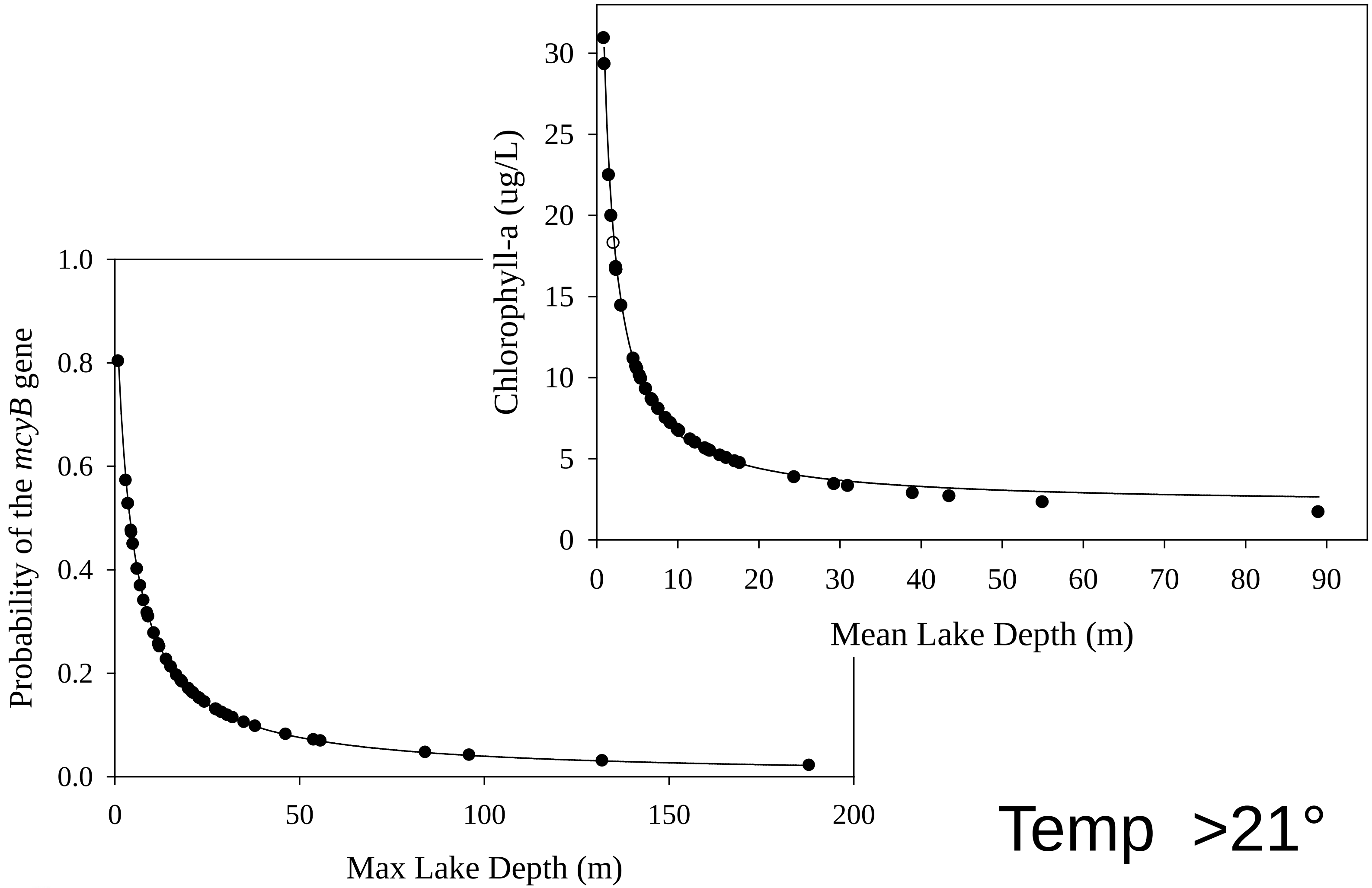
Figure 1: Geographic location of sampling stations across New York State with corresponding station code.

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
  - Non-toxic
  - Potentially toxic (Toxigenic)
- Correlate this with easily-to-measure parameters.

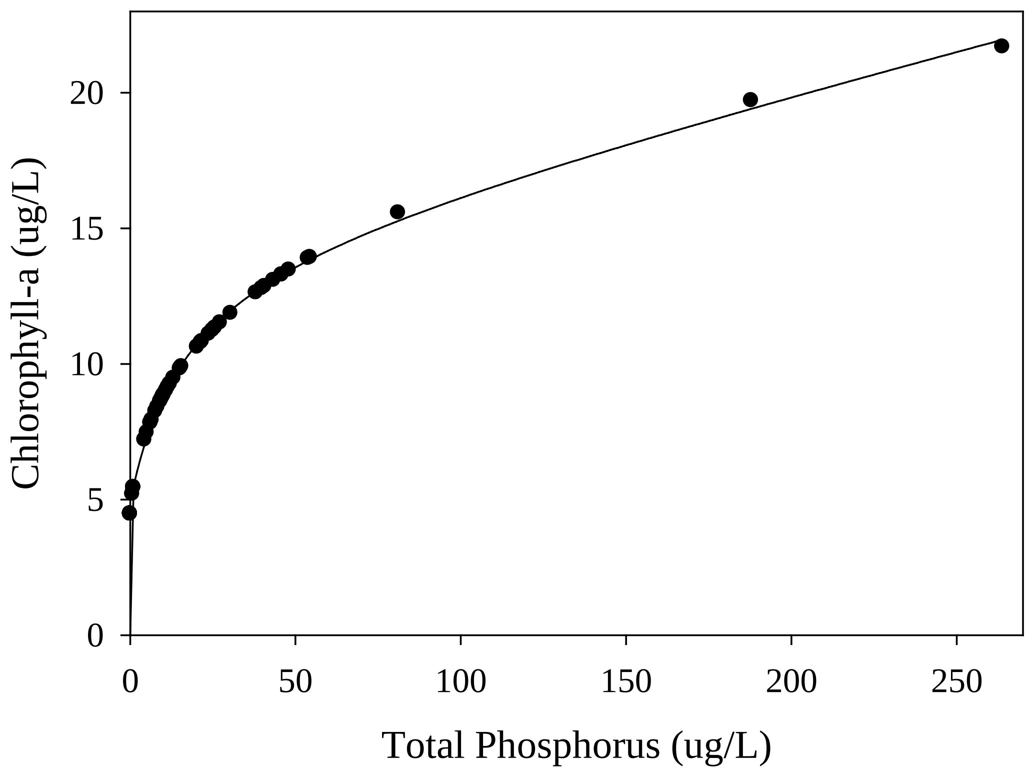
Hotto et al., 2007

Most blooms were associated with shallower waters



Temp >21°

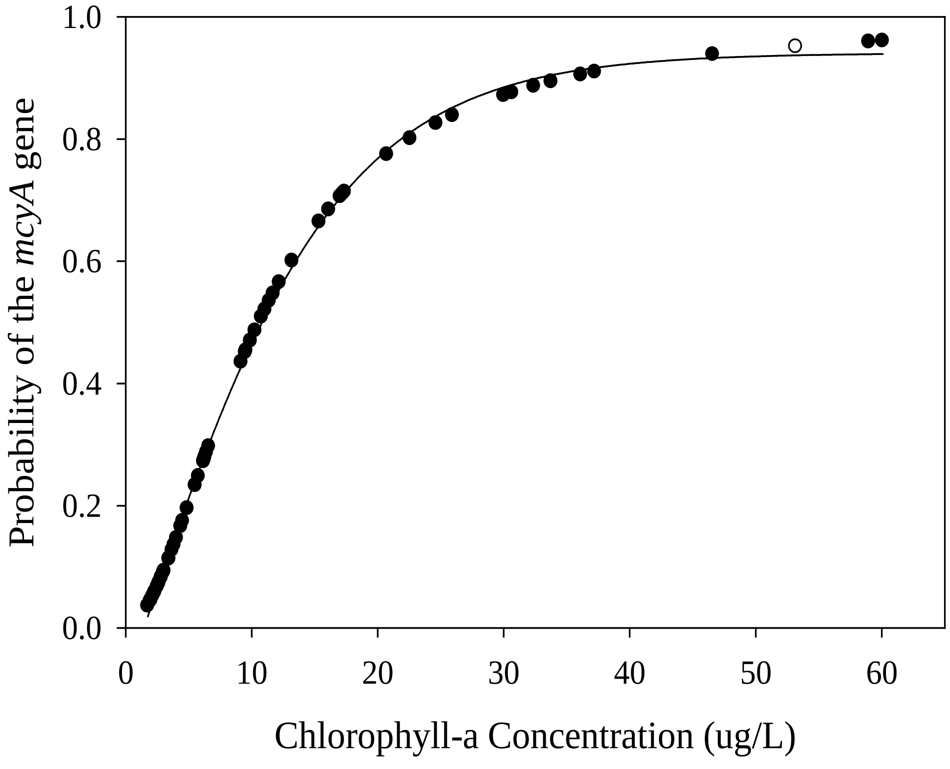
Good correlation between nutrients and algal biomass



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

Toxin ≠ growth

Increased biomass increased the chance of a toxigenic bloom



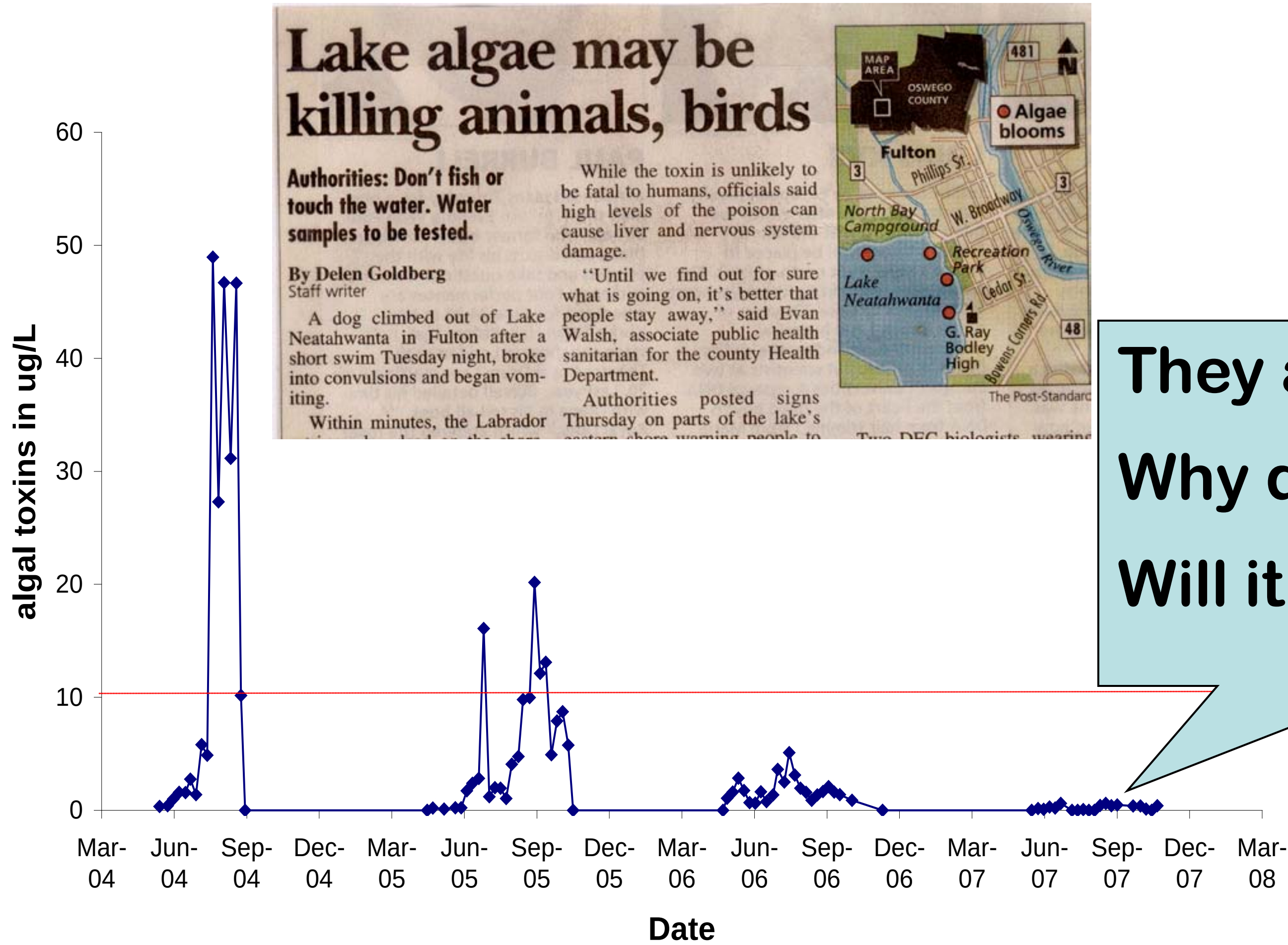
Oligrotrophic waters <5%

Mesotrophic waters ~20-40%

Hypereutrophic waters >90%

Source water protection works!

Lake Neatahwanta



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.

"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.

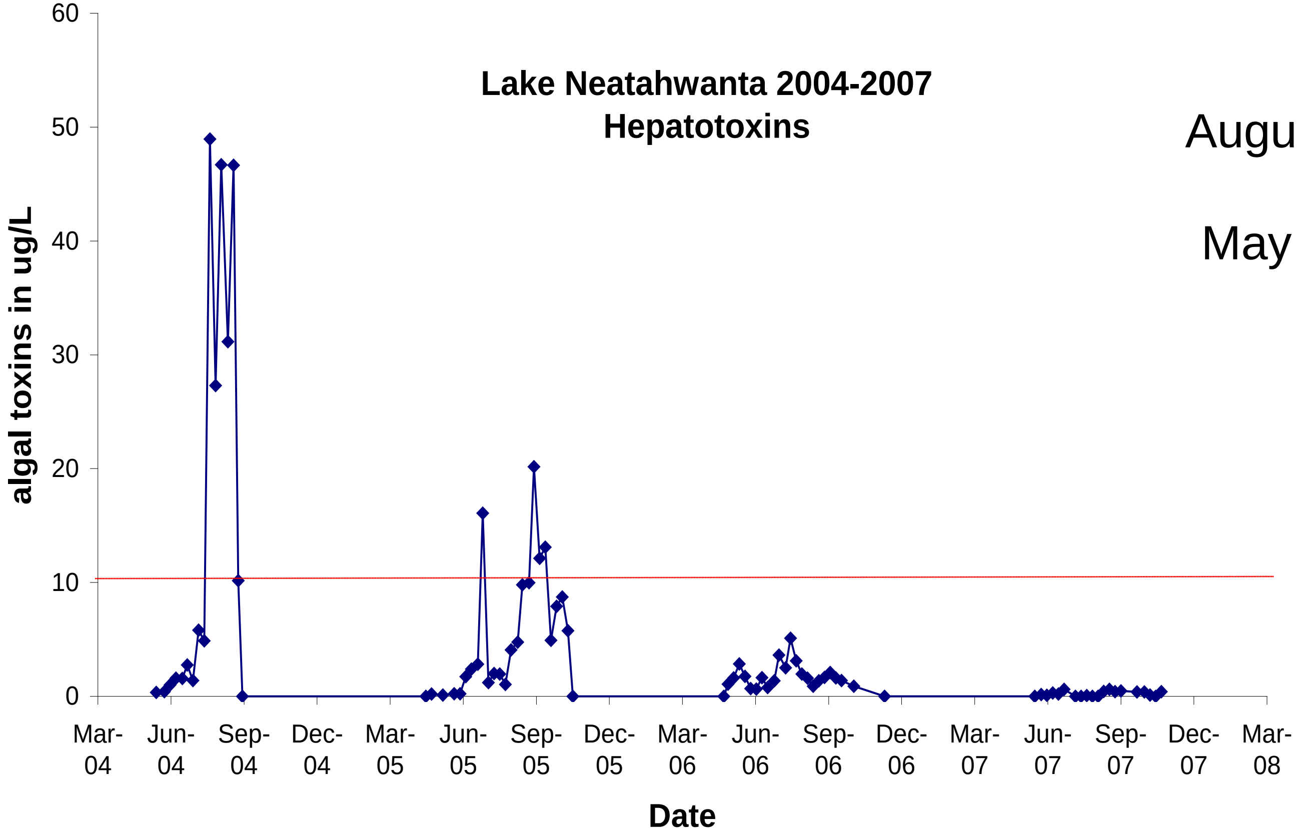
Authorities posted signs Thursday on parts of the lake's

They are gone!

Why did it go away?

Will it come back?

Lake Neatahwanta



August 2010: 3 ug/L

May 2010 600 ug/L

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.
- These 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*