

# Toxic Cyanobacteria and Harmful Algal Blooms in Lake Ontario:

Greg Boyer, SUNY-ESF,  
Syracuse NY

*With help from:*

Joe Makarewicz, SUNY – Brockport

Susan Watson, CCIW, Environment Canada



# Isolation and Characterization of Microcystins, Cyclic Heptapeptide Hepatotoxins from a Lake Erie Strain of *Microcystis aeruginosa*

Scott M. Brittain<sup>1</sup>, Jim Wang<sup>3</sup>, Lisa Babcock-Jackson<sup>2</sup>, Wayne W. Carmichael<sup>1\*</sup>,  
Kenneth L. Rinehart<sup>3</sup>, and David A. Culver<sup>2</sup>

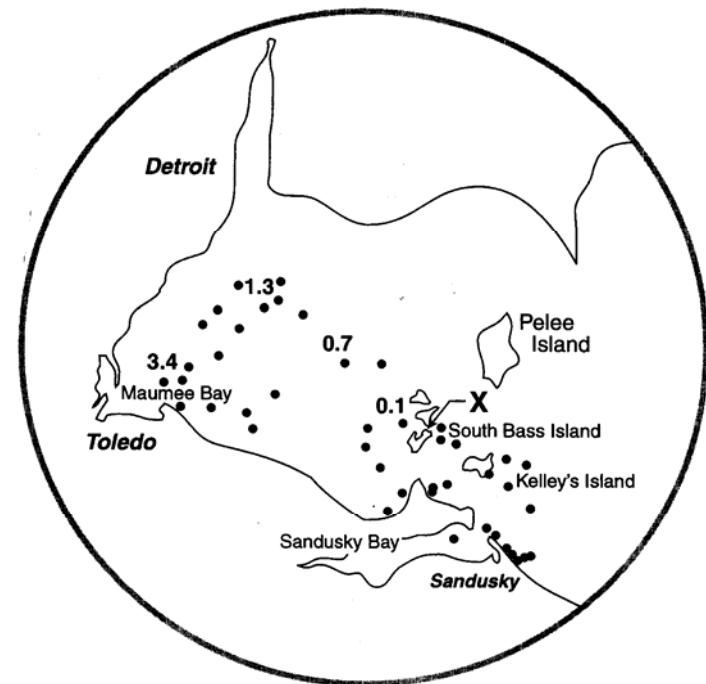
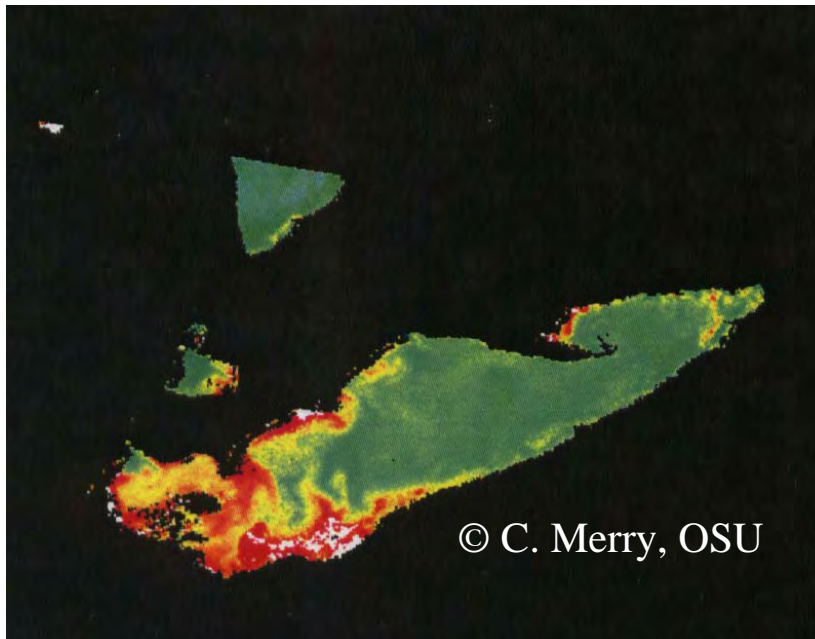
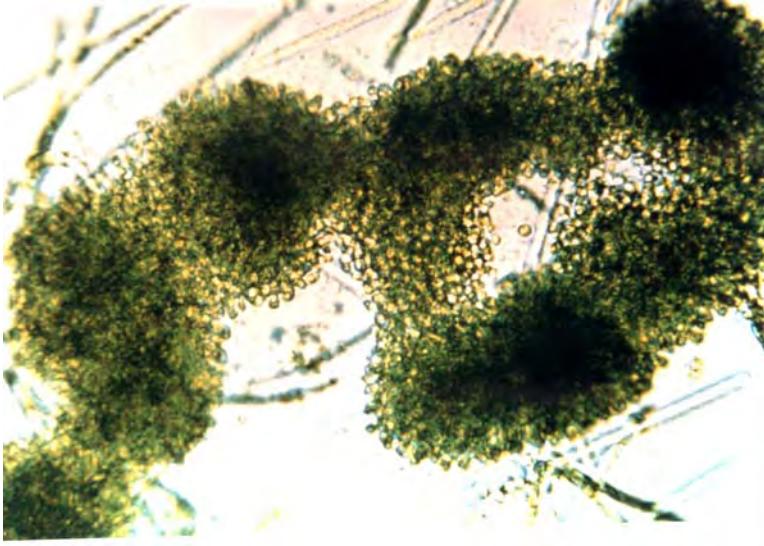
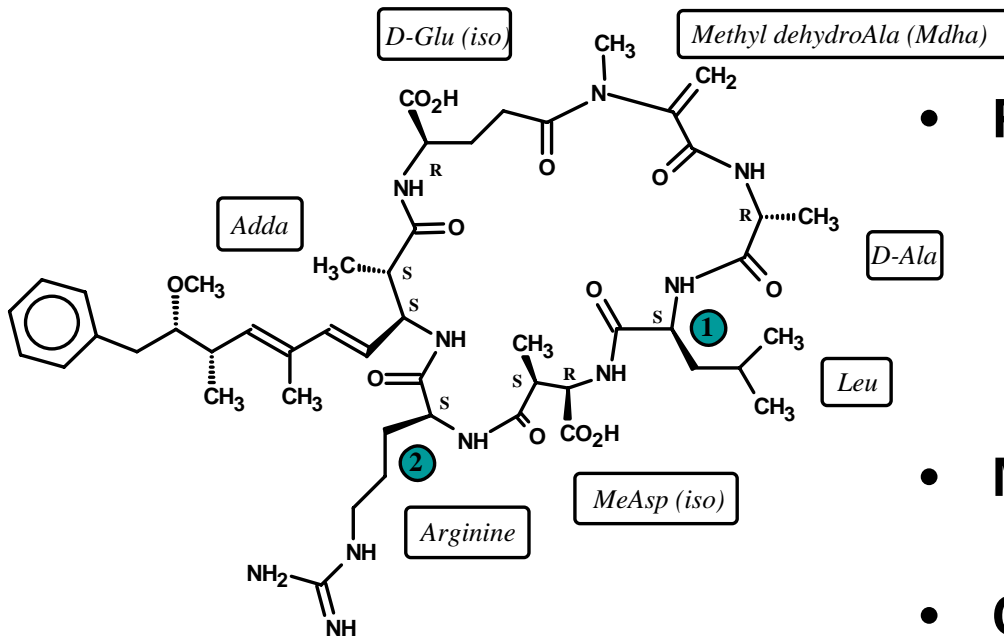


FIG. 2. *Microcystis aeruginosa* field collection sites: Put-In-Bay, Lake Erie, Ohio. "X" marks Hatchery Bay where  $> 1 \mu\text{g/L}$  microcystin was detected in October 1995.



# Microcystins

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



- Peptide Toxins:
  - 90+ structural variants
  - + 200 others related compounds: nodularins, anabaenapeptins, etc.
- Microcystins are hepatotoxic  
LD-50: 25-60  $\mu\text{g kg}^{-1}$
- Called “fast death factor”  
Potent tumor promotor

# Never trust a name!

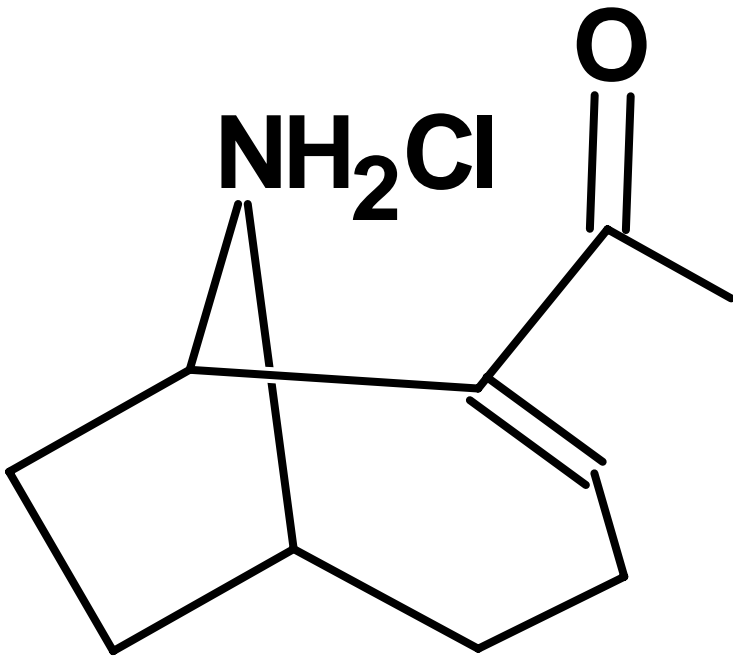
Microcystin-producing strains include:

- *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 hibernicus*
- *Gleotrichia sp.*



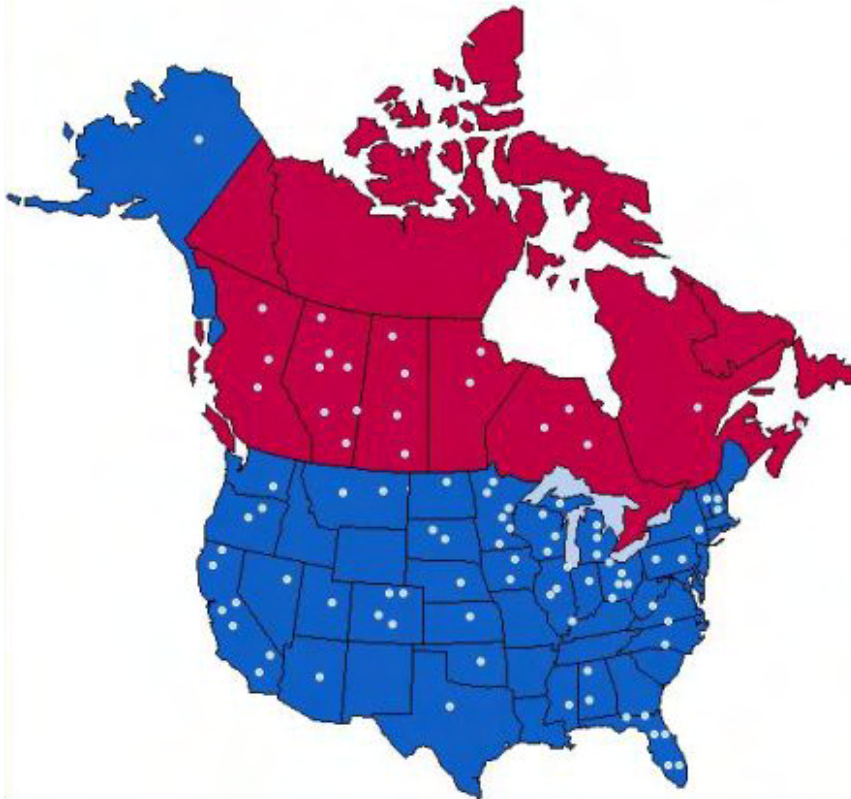
# Anatoxin-a

- Potent Neurotoxin.
  - (very fast Death Factor)
  - Several variants
- LD-50: 200  $\mu\text{g kg}^{-1}$
- Causative organisms include:
  - *Anabaena species (many)*
  - *Oscillatoria sp.*
  - *Aphanizomenon sp.*
  - *Planktothrix sp.*
- Toxin not particularly stable in the water column
- Responsible for a number of animal fatalities.



# So how common are toxic blooms?

Documented HAB Outbreaks  
in North America



- Toxic blooms are very common and have been reported almost every state of the nation.
- Many reports end up in the “grey” literature and do not get counted.

# Problem extends way beyond the western basin of Lake Erie



# How Commonplace are Toxic Blooms in Lake Ontario?

Cruise date	# sta	Toxin ? (%)	Highest values	Notes
2000 (Aug)	2	0%	MC: < 0.02 $\mu\text{g l}^{-1}$	Eastern end
2001 (late July)	52	2% (MC) 4% (ATX)	MC: 0.15 $\mu\text{g l}^{-1}$ ATX: 0.05 $\mu\text{g l}^{-1}$	Whole lake
2003 (July, August)	80 63 17	>25% (MC) 0.5% (ATX)	MC: 1.06 $\mu\text{g l}^{-1}$ ATX: 0.01 $\mu\text{g l}^{-1}$	Whole lake + Eastern shore
2004 (Aug-Sept)	81	17% (MC) 16% (ATX)	MC: 0.85 $\mu\text{g l}^{-1}$ ATX: 0.02 $\mu\text{g l}^{-1}$	Whole lake
2005 (Aug-Sept)	81	10% (MC) 4% (ATX)	MC: 0.19 $\mu\text{g l}^{-1}$ ATX: 0.07 $\mu\text{g l}^{-1}$	Whole lake

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

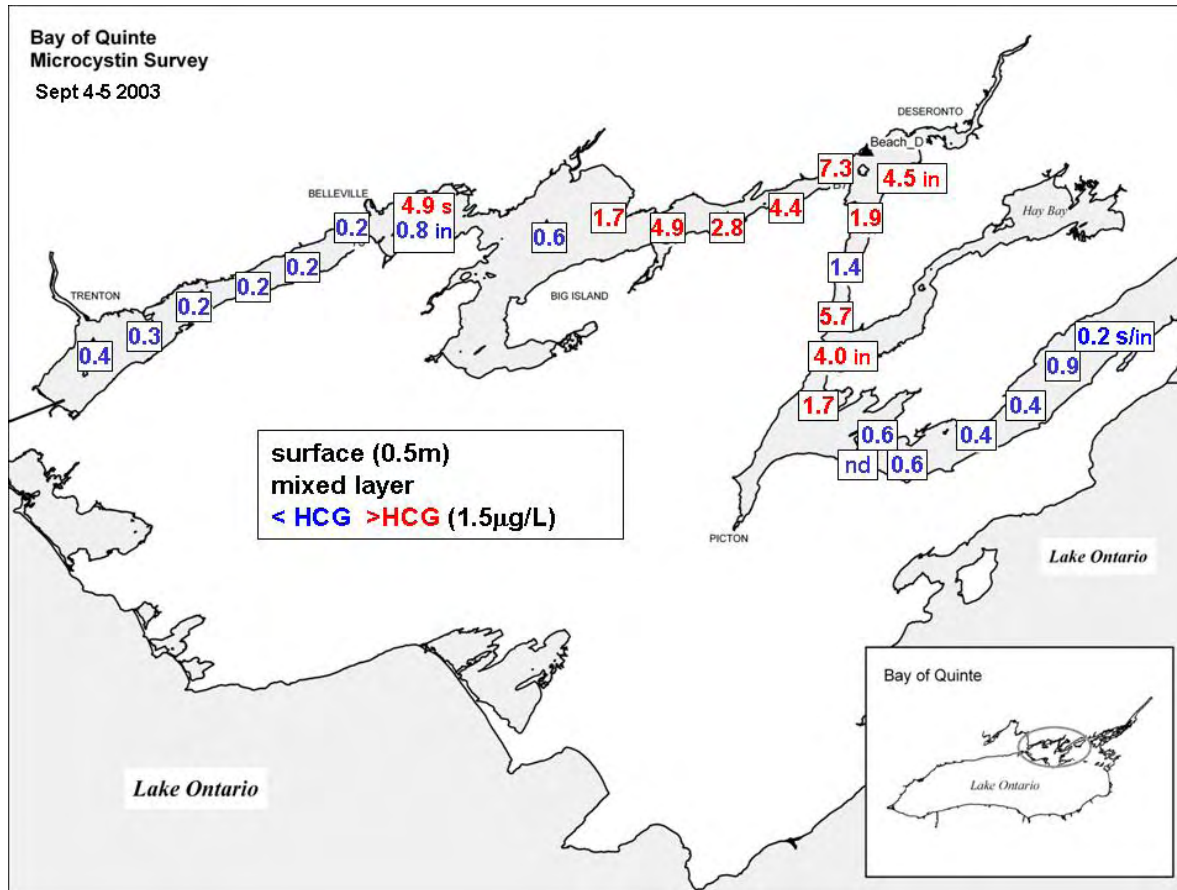
Disclaimer: Numbers would be much higher if we included Environment Canada's data!

from Boyer, 2006

# Open questions

- What is the origin of these blooms:
  - Embayments or offshore waters?
- Are they being carried by the Lake-wide circulation patterns?
- Are toxins other than microcystins involved?

# What is the role of the embayments in the total toxin budget of Lake Ontario?

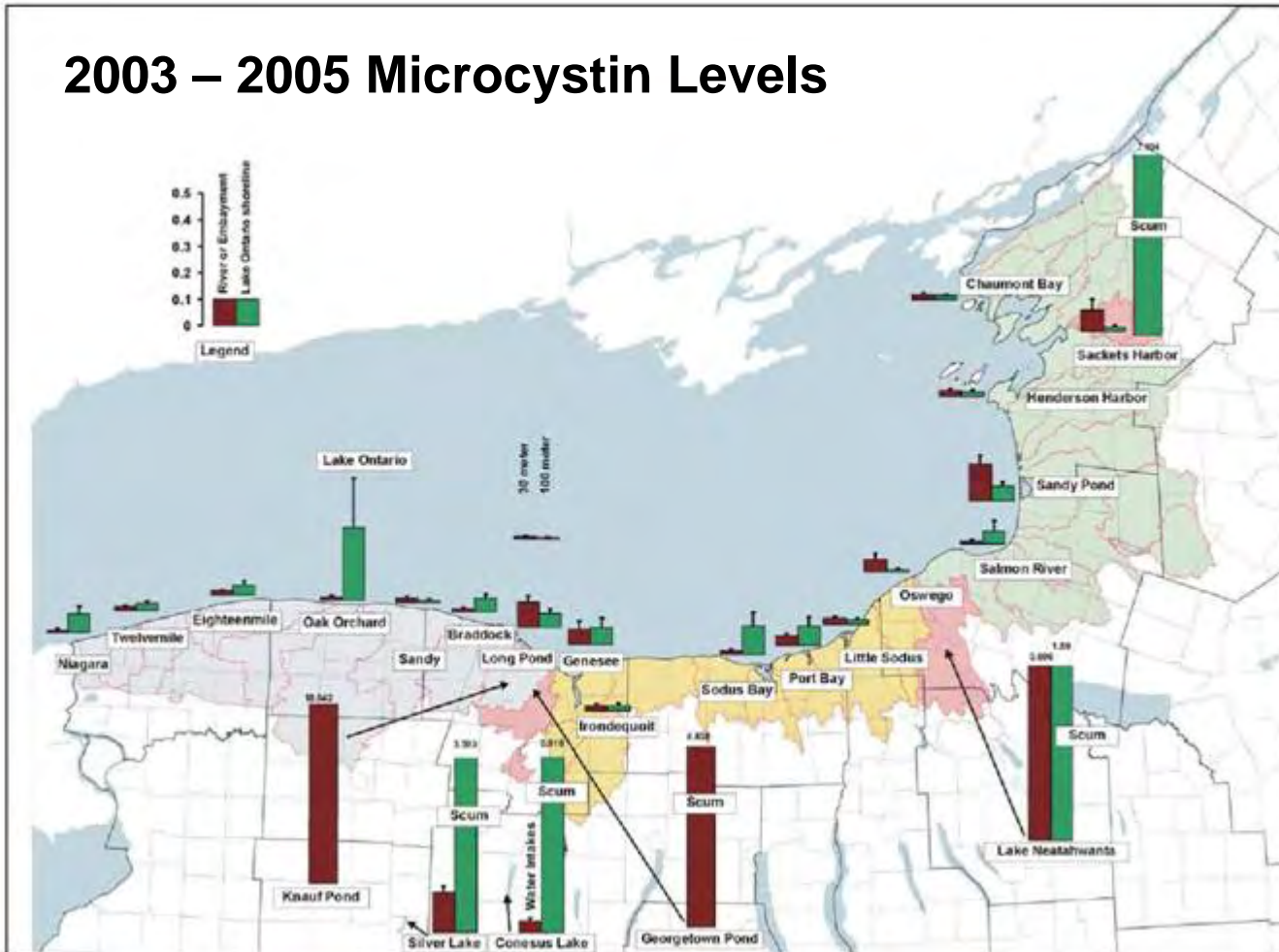


Bay of Quinte Survey  
Environment Canada  
Sue Watson

In these eutrophic embayments, microcystin levels can routinely exceed the WHO guideline for drinking water of  $1 \mu\text{g L}^{-1}$ .

# Role of Embayments - NY side

2003 – 2005 Microcystin Levels

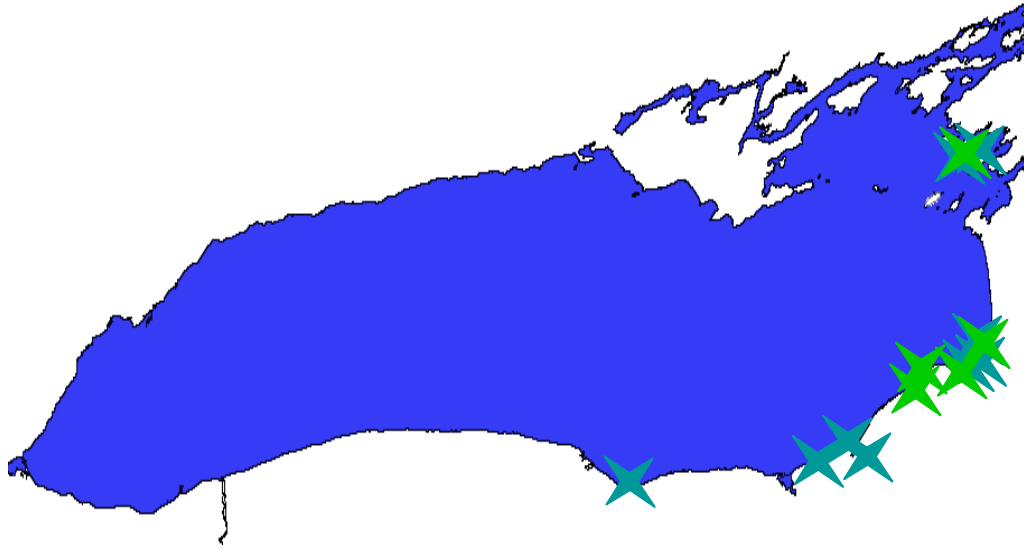


NY embayments also have higher phosphate levels, but much lower toxicity

Brown: embayment  
Green: lake-side

Picture from  
Joe Makarewicz,  
SUNY Brockport

# Genetic potential for microcystin production is widespread in NY embayments



Microcystin gene amplicons cloned and sequenced.

data from Amber Hotto, submitted

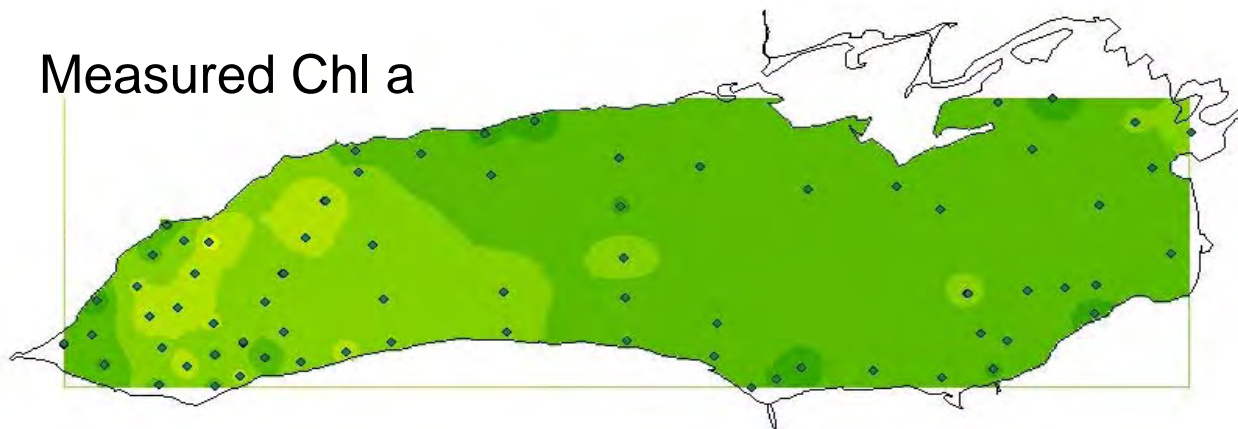
## Take home messages:

- Genes for microcystin were found in most embayments.
  - Separate from toxin concentrations.
- Primary toxin signature is for *Microcystis* species.
- Embayments in 2001 showed different signatures than open water samples. These were mixed in 2003, suggest influx or mixing of embayments with the lake.

CCGS Limnos  
July 15-18, 2003  
81 stations

# Are they being carried by the Lake-wide circulation patterns?

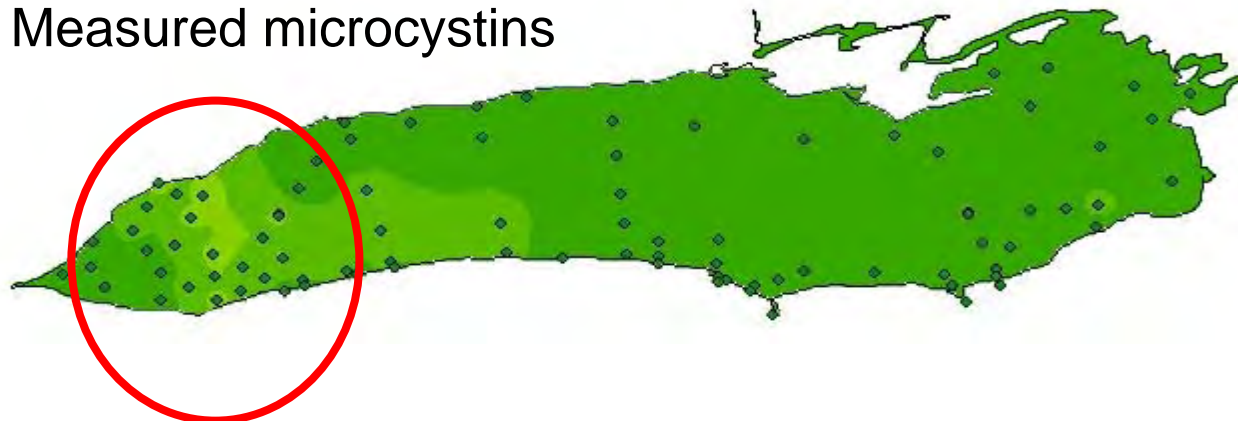
Measured Chl a



Microcystin  
toxic: 18 (22%)

Range:  
0–0.26  $\mu\text{g L}^{-1}$   
by PPIA

Measured microcystins

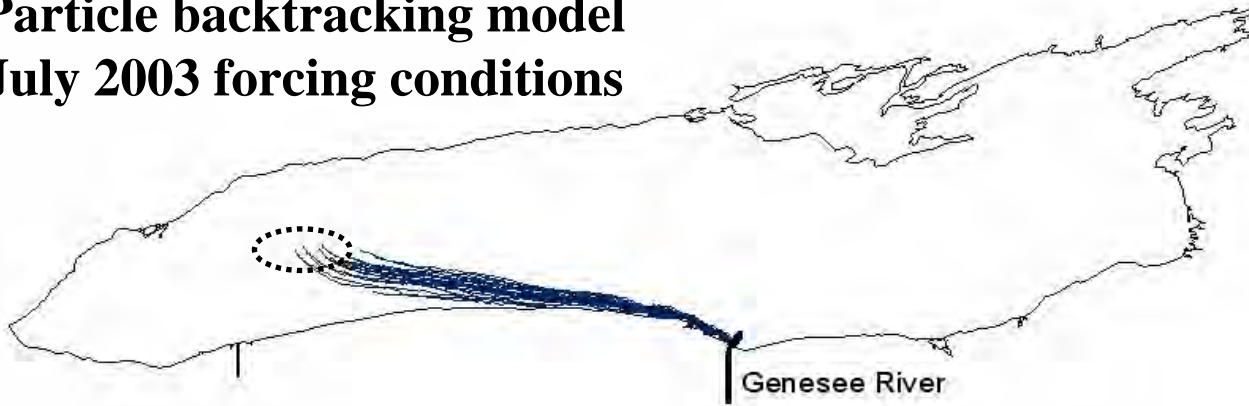


No visible  
blooms

Limnos LOLA / Taste and odor  
August 10<sup>th</sup> – 21<sup>st</sup> 31 stations  
August 25<sup>th</sup> – 28<sup>th</sup> 36 stations  
Oswego shore: 18 stations

# August 2003 Toxin levels

**Particle backtracking model  
July 2003 forcing conditions**

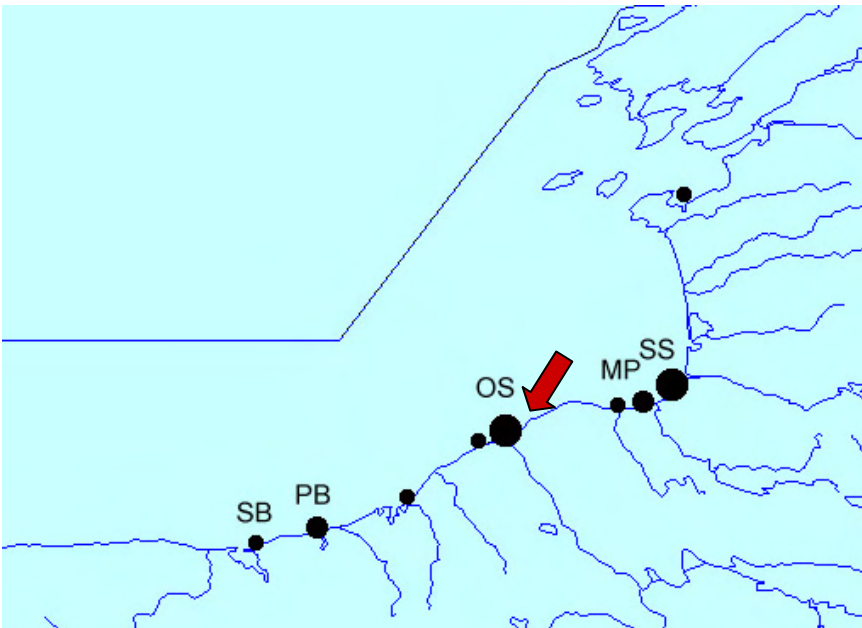


Measured microcystins



# Why do we care?

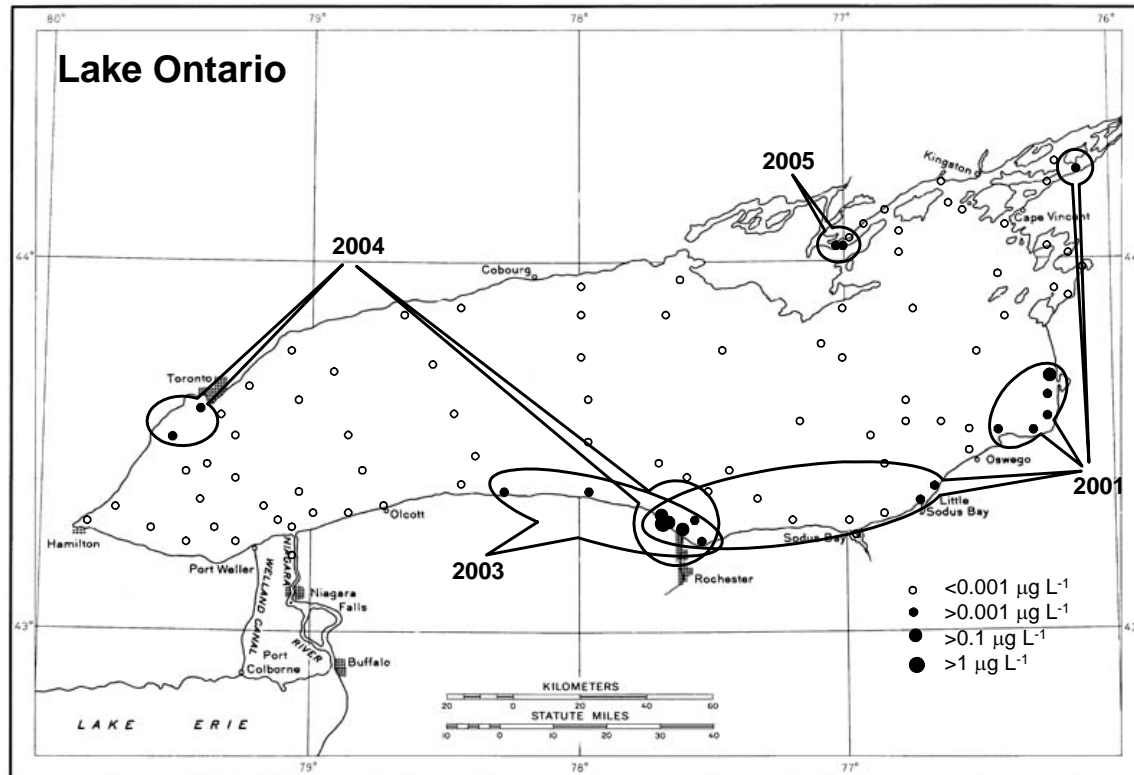
- The August 20th bloom was positioned nicely over the top of the Syracuse water supply intakes:



## *Eastern Lake Ontario August 20, 2003*

<u>Sample site</u>	<u>PPIA (<math>\mu\text{g l}^{-1}</math>)</u>
Sodus Bay	0.21
Port Bay	0.34
Oswego	0.93
Selkirk Shores	1.06
Mexico Point	0.21

# What about other toxins?



Distribution of Anatoxin-a  
in Lake Ontario

From: Xingye Yang

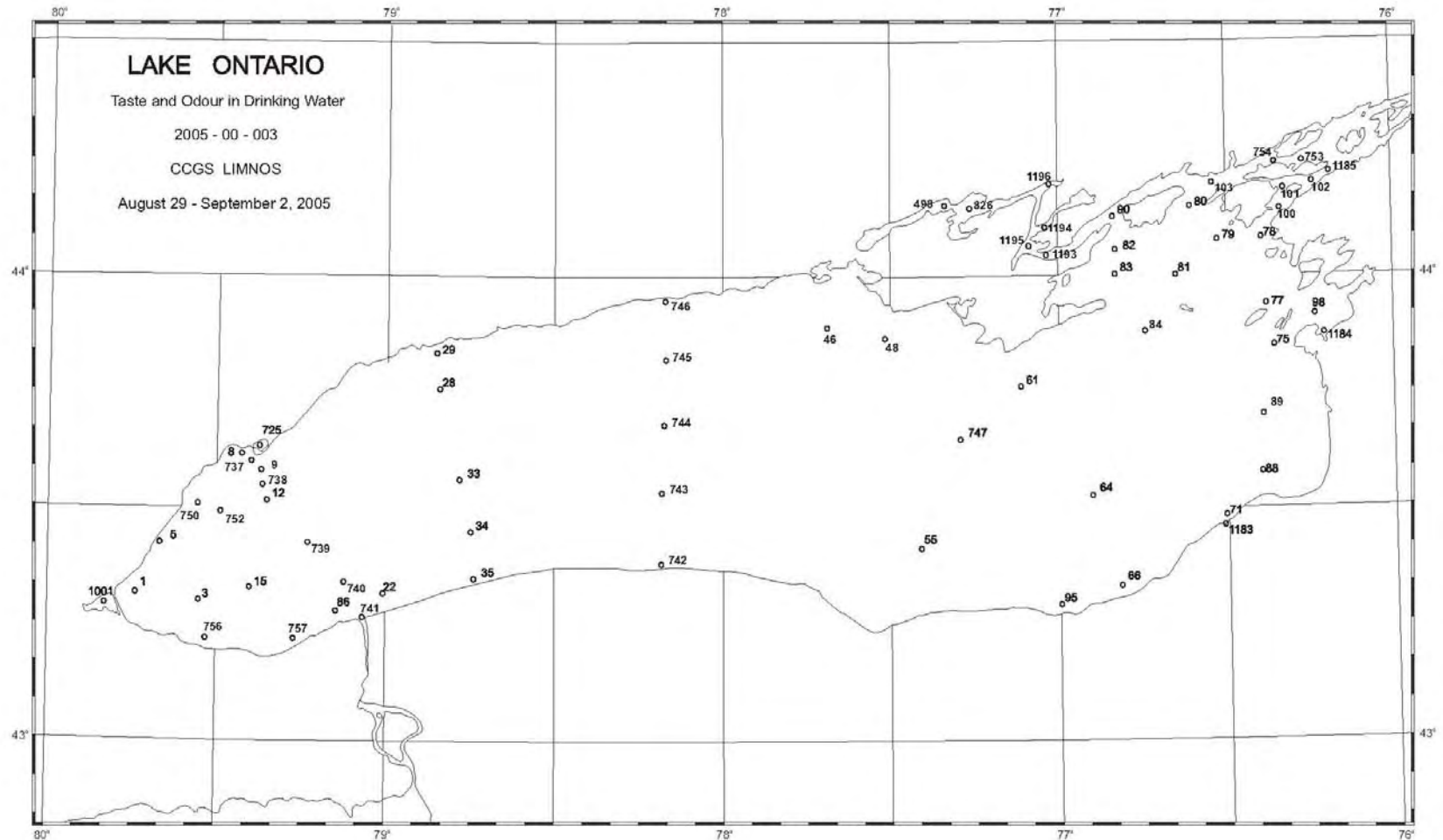
- Different Toxin
- Different Organisms
- Different Ecology

ATX often shows up  
earlier in the season  
than microcystin.

# Assessment: Resources

- Current monitoring for cyanobacterial toxins and cHABs is through:
  - Environment Canada (CCIW)
    - Fall taste and odor cruise on CCGS Limnos.
    - Separate monitoring for Bay of Quinte and Hamilton Harbor.
  - NOAA MERHAB-LGL project
    - 5-year project ending in 2007 (no ship)
    - Near shore sampling (Brockport, ESF, Oswego)
  - Others ?

# Taste and Odor stations for Environment Canada



# Assessment: Information Needs

- Need to know the **temporal and spatial distribution** of toxic species and toxins.
- Need to improve our understanding on the **role of embayments** in promoting these blooms (important management issue).
- Need better understanding of those **factors limiting toxin production** and growth.
- Need a better understanding of the **movement of toxins through the foodweb**.
- Need to expand the focus from *Microcystis* /microcystins to **include other toxins** as EPA guidelines are unlikely to be limited to one toxin.

# Summary

- Cyanobacteria produce a number of toxins but not all species are toxic.
- Hepatotoxic microcystins are probably the toxin of most concern for human health.
- These toxins can be produced by a number of different species making visual monitoring difficult.
- We have a poor understanding of the spatial, temporal and environmental factors affecting cyanobacterial toxin production in Lake Ontario.

**Your Questions?**