Working Towards a Forecast of Lake Erie Cyanobacterial Bloom Toxicity

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FL SG HABs
Lake Erie cyanobacterial blooms

Roger Knight

July 25 2015
3,144 ppb

Todd Crail
Satellite bloom data since 2002 shows variation in bloom biomass
Maumee River phosphorus load March-July explains the size of the bloom

Stumpf et al., 2016. J Great Lakes Res
Annual bloom biomass is forecasted in early July based on spring-time Maumee River phosphorus load: NOAA HAB Bulletin
Biomass and location can be monitored and forecasted 3 days out with current models

Satellite HAB biomass data + Current models

NOAA Lake Erie HAB bulletin
Fundamental questions remain about the controls and predictability of toxin production.

- A toxin forecast cannot simply rely on cyanobacterial biomass

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Chaffin unpublished
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![Graph showing correlation between cyanobacteria chl a (μg/L) and total microcystins (μg/L).](image)

P < 0.001
R = 0.63
N = 831

Chaffin unpublished
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98% of samples were within these ranges.

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\[
\text{Cyanobacterial biomass} \neq \text{Toxin concentration}
\]

\[
\text{Toxin concentration} \neq \text{Toxicity}
\]

98% of samples were within these ranges.

Chaffin unpublished
The role of nitrogen in bloom growth and toxin production:

• *Microcystis* cannot grow or make microcystins without combined nitrogen.
  • *Microcystis* cannot use atmospheric N₂
  • Some other cyanobacteria can use atmospheric dinitrogen gas by the process called nitrogen fixation
The role of nitrogen in bloom growth and toxin production:

• *Microcystis* cannot grow or make microcystins without combined nitrogen.
  • *Microcystis* cannot use atmospheric $N_2$

• Microcystins are 14% nitrogen by mass.
  • *Microcystis* is only 7% nitrogen by mass (Chaffin et al. 2011).
  • Thus, making microcystins are expensive in terms of nitrogen.
The ratio of microcystins to cyanobacteria biomass decreases with nitrate concentration

- Toxic strains to non-toxic strains as nitrate decreases

Chaffin et al. 2018 ESPR

Davis unpublished
Nitrogen limits HAB biomass and MC production during August and September.


Congeners (and toxicity) differ with nitrate availability: MC-RR decreases, LA increases

MC-RR is much less toxic than MC-LR
MC-LA is as toxic MC-LR
Linking lake data, experiments, models
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- Data from
  - Researchers
  - Water treatment plants
  - Citizen scientists

- Large dataset allows us to:
  - Estimate total toxin mass in the lake daily, weekly, and yearly
  - Determine spatial autocorrelation among samples
Challenges to microcystins concentrations spatial interpolations

N=16

N=2
Challenges to microcystins concentrations spatial interpolations

N=16

N=2
HABs Grab 2019 – Research Team

Funded in part by NOAA ECOHAB:

NCCOS | NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
ECOHAB HABs Grab 9 August 2018

Sampling Locations:
- UT LEC
- OSU Stone Lab
- LimnoTech
- BGSU

NOAA HAB Bulletin 6 August 2018
Toxin Mass =

This is a very scary number. Messaging is critical.
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Change in total microcystins mass from day to day is a rate of change -> a net production rate
Quantifying MC production rates by experiments

Control  P&NO3  P&NH4  P&Urea
Developing (determining if it is feasible) toxicity forecast on multiple scales

• Seasonal forecast – similar to Rick’s seasonal biomass forecast
  • Lake-wide
  • Can total toxin mass be explained by environmental variables?

• Weekly
  • Use biomass data (satellite), current models, and estimated nitrogen and toxic:total ratio to estimate toxins in time and space
    • A concentration value
    • Probably of experience more or less toxins
Key components of a toxin forecast:

1. The ratio of toxic *Microcystis* to total *Microcystis*
   - Affected by nitrogen availability
   - Biomass data

2. Microcystins production rates
   - fg per *mcyE* gene copy
   - Ambient and elevated nutrient concentrations
     - Experiments being conducted during 2018 and 2019
     - Compared to model production rates
Key components of a toxin forecast:

3. Nitrogen concentration model
   • WLEEM (Western Lake Erie Ecosystem Model)
   • LimnoTech Inc.

Verhamme et al. 2016
J Gt Lakes Res
Modelled nitrate concentration from WLEEM

- Model also works for P, Temp, Cyanobacteria biomass

Verhamme et al. 2016 J Gt Lakes Res
Key components of a toxin forecast:

4. Current model to move and dilute toxins and cyanobacteria

• FVCOM is a current model that does not include biology
Key components of a toxin forecast:

5. Microcystin degradation rates
   • Field and experiments
   • Loss rates determine by microcystin biodegradation byproducts.

Schmidt et al. 2014 Toxins
Linking process models and field experiments to forecast microcystin concentrations in Lake Erie

• Current direction is to integrate biological parameters (*Microcystis* biomass, toxic:total) from WLEEM into FVCOM for toxin distribution

• Incorporate model results into NOAA HAB Bulletin and HAB tracker
  • Public awareness
  • Water treatment decisions
Increased readiness to remove toxins at WTP

Safer tap water for consumers

Toxin forecast
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Summer internships/jobs available at Stone Lab for undergrads and recent college grads. Visit stonelab.osu.edu