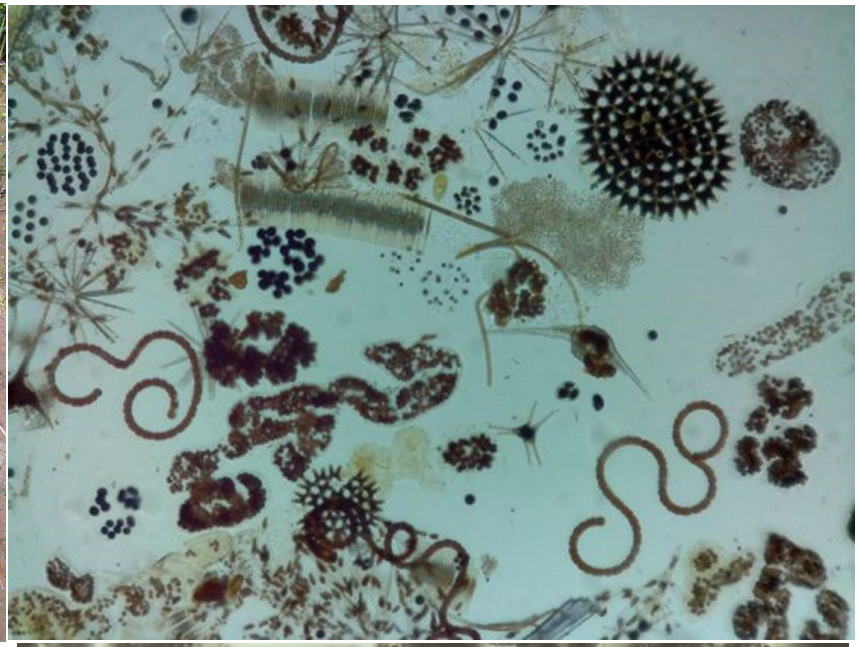
Rapidly Changing Cyanobacteria in a Changing World

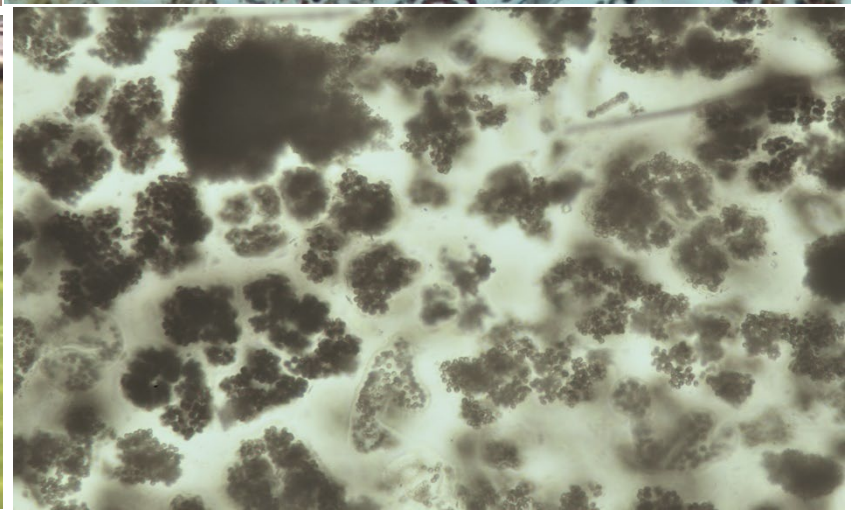
What do we know, what do we think we know, and what do we just make up.

Greg Boyer and Friends

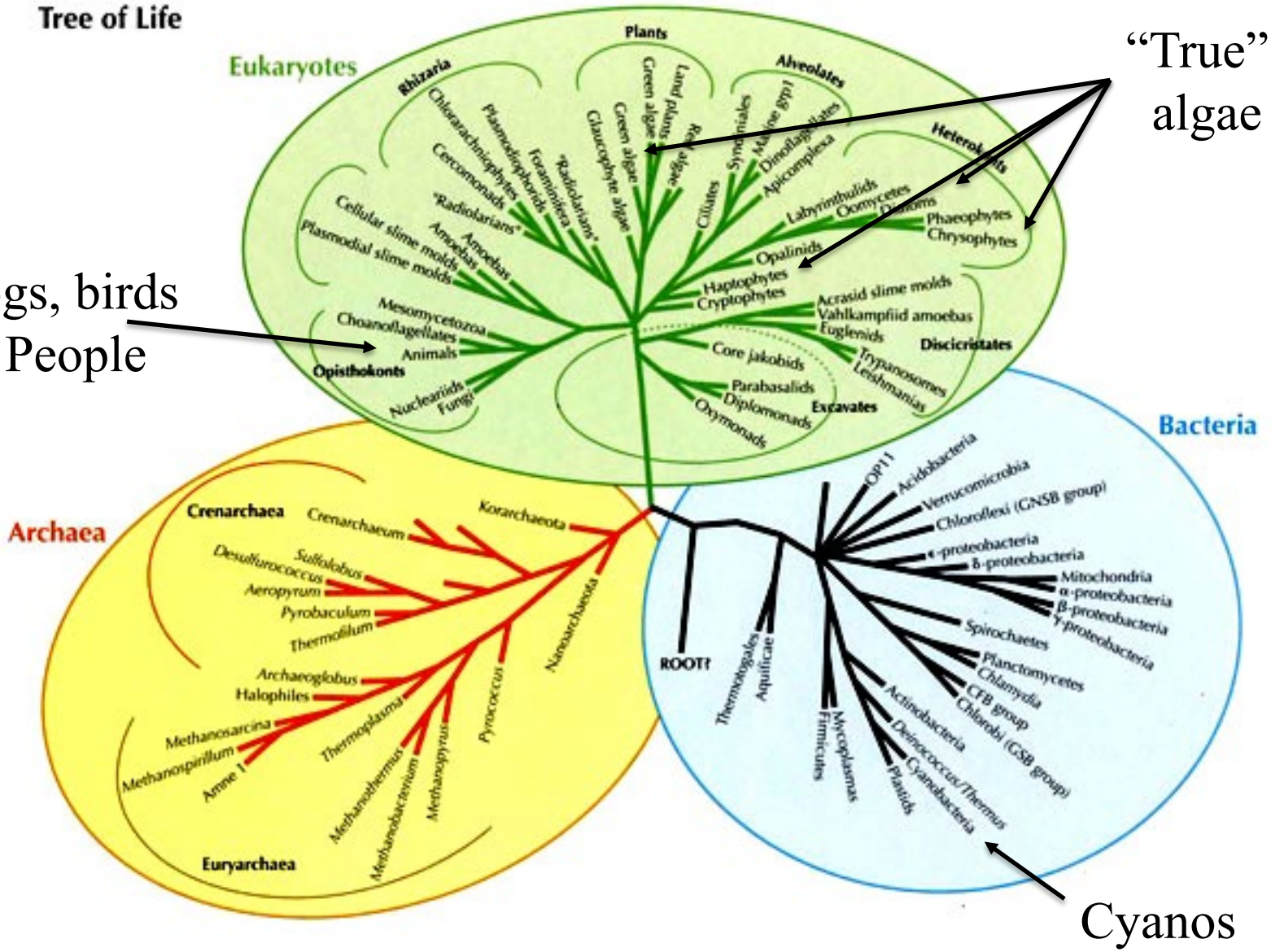
SUNY College of Environmental Science and Forestry, Syracuse, NY

We have all seen images of HABS

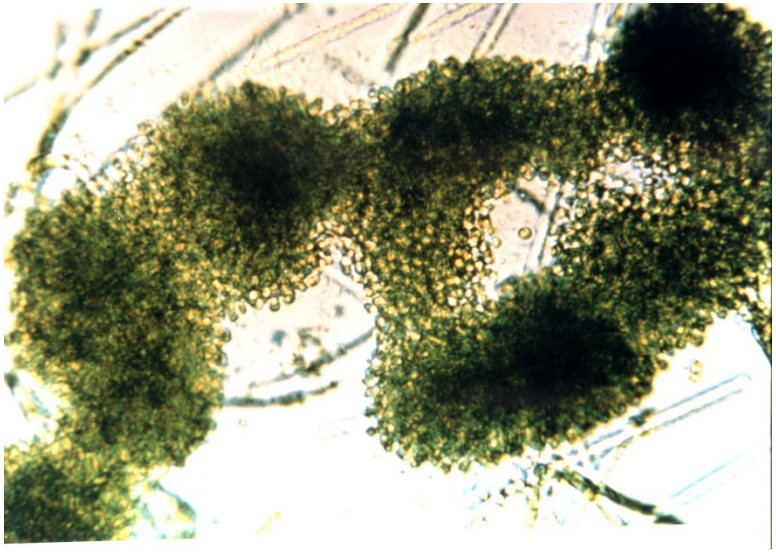




Tree of Life


Tree of Life
Eukaryotes
Plants
Rhizaria
Alveolates
Heterokonts
Opisthokonts
Excavates
Discicristates
Archaea
Crenarchaea
Euryarchaea
Korarchaeota
Nanoarchaeota
Bacteria
ROOT?
Dogs, birds & People
"True" algae
Cyanos

Who is the main culprits? *Microcystis* vs. microcystins



Colonies
100-10,000um

Cells ~7um

- *Microcystis aeruginosa*
  - non-N fixer.
  - Likes organic N
  - forms surface blooms
- Very common genera
  - Found in every water body
  - First reported in the Finger Lakes in 1800s
  - Overwinters in sediments
- Can exist in toxic, non-toxic and potentially toxic.
  - Liver toxin (microcystins)
  - "Fast Death factor"
  - Few blooms get to that level
  - Cell wall may be allergenic to some. Estrogenic cmpd.

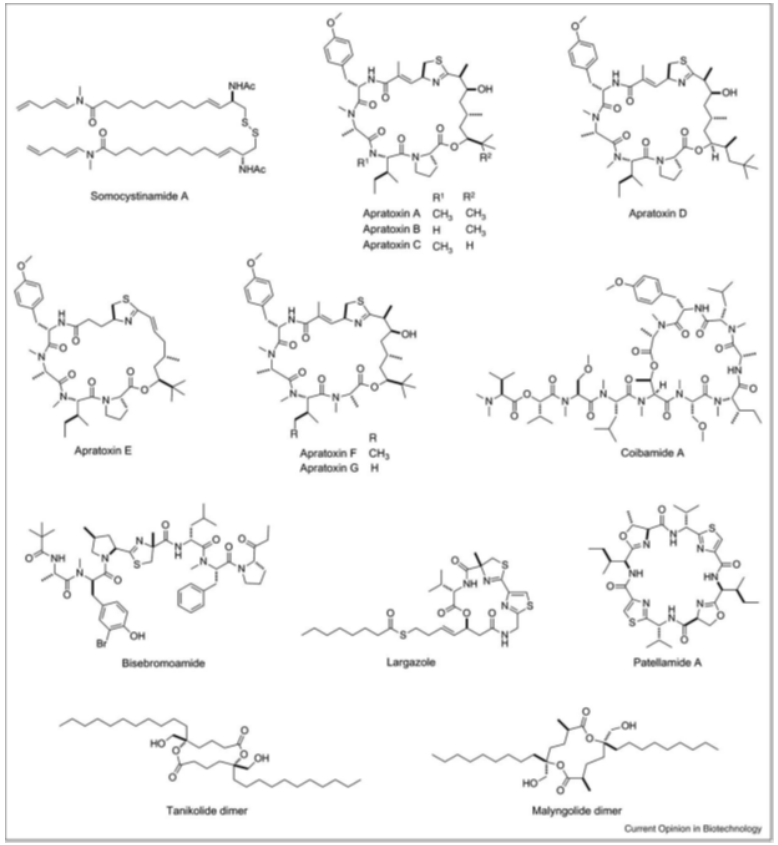
Never trust a name!

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*

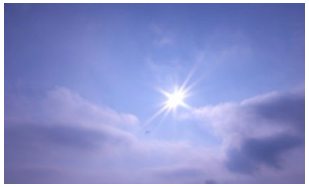
i.e. Biology is a mess!

Many more players and toxins



More toxins than microcystins with more diverse effects…

Why do they bloom?



NUTRIENTS

Nutrients (N,P) usually come from the land as run-off.

LIGHT

WARM TEMPERATURE

Water > 55° F

Algal GROWTH

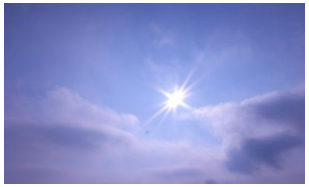
GRAZING ↑↓

CALM WINDS

Seed Population

Many of these factors will increase in current climate change models.

Why do they bloom?



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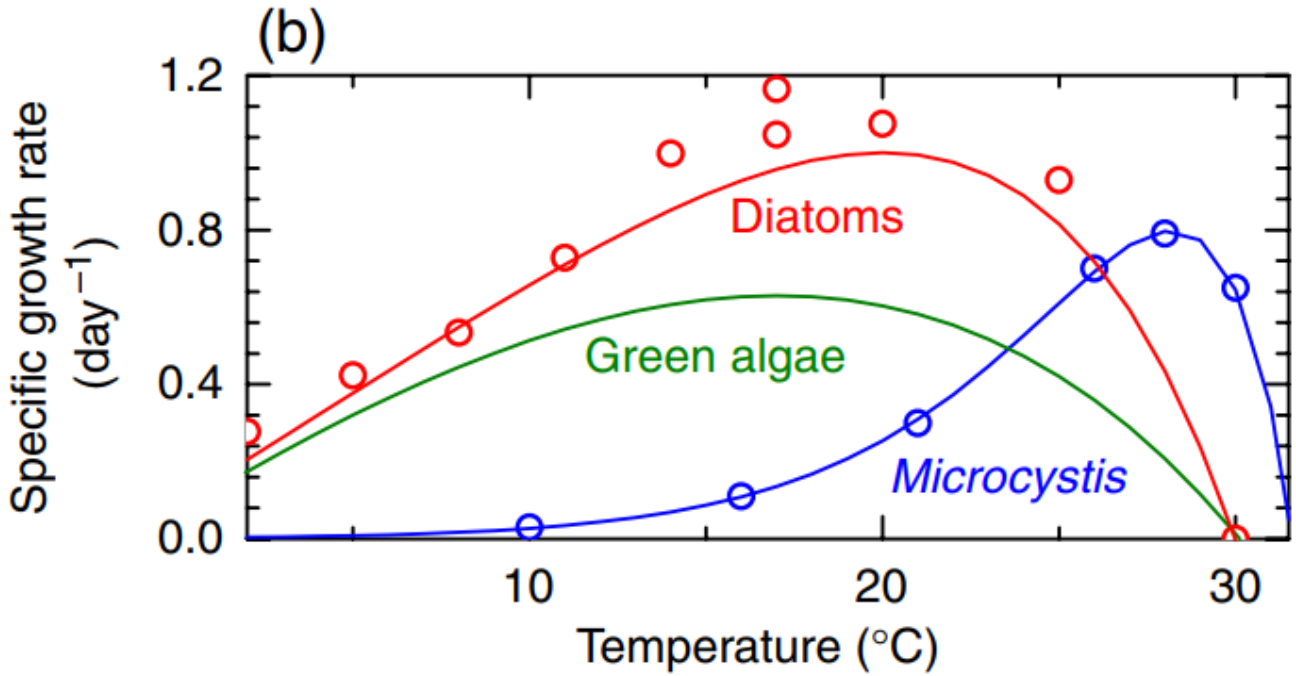
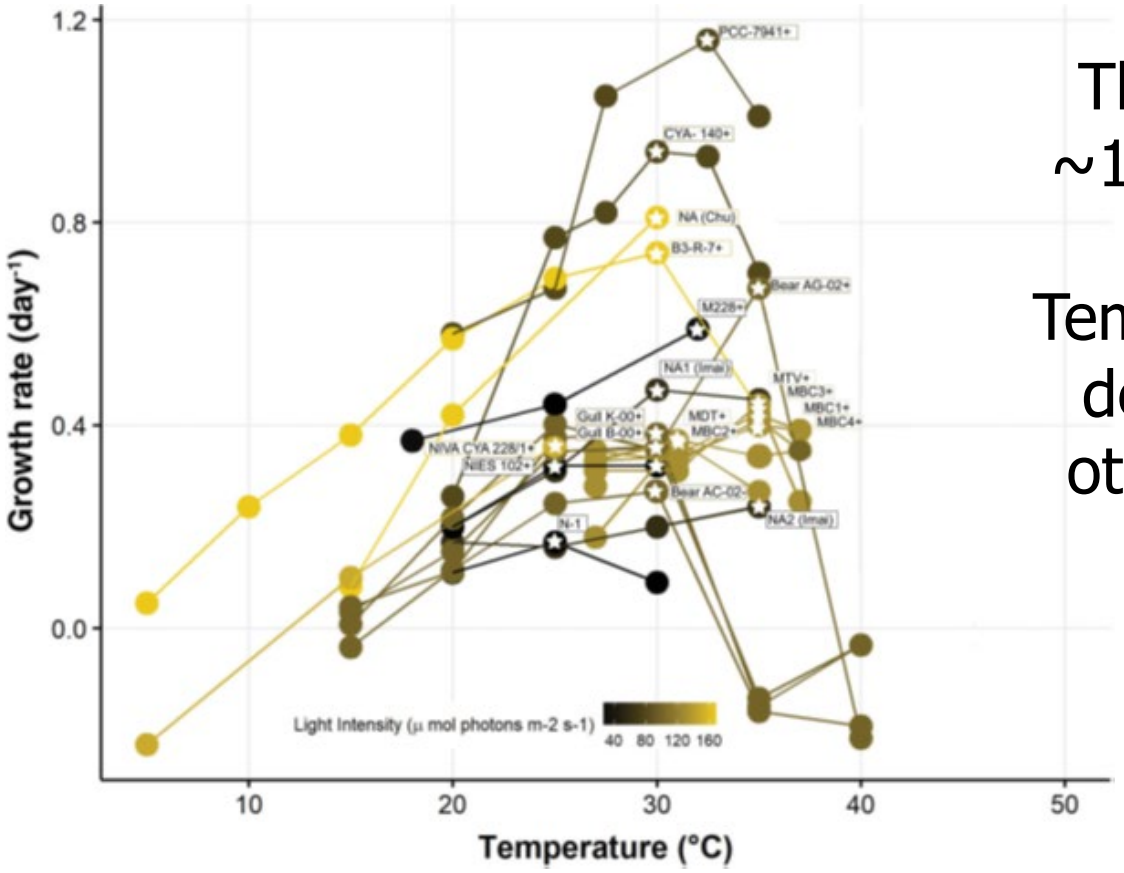
Blooms like it hot (1997 version)



Microcystis will dominate at higher temperatures because of its higher optimal growth rate (Reynolds 1997)

Blooms like any temperature (2021 version)



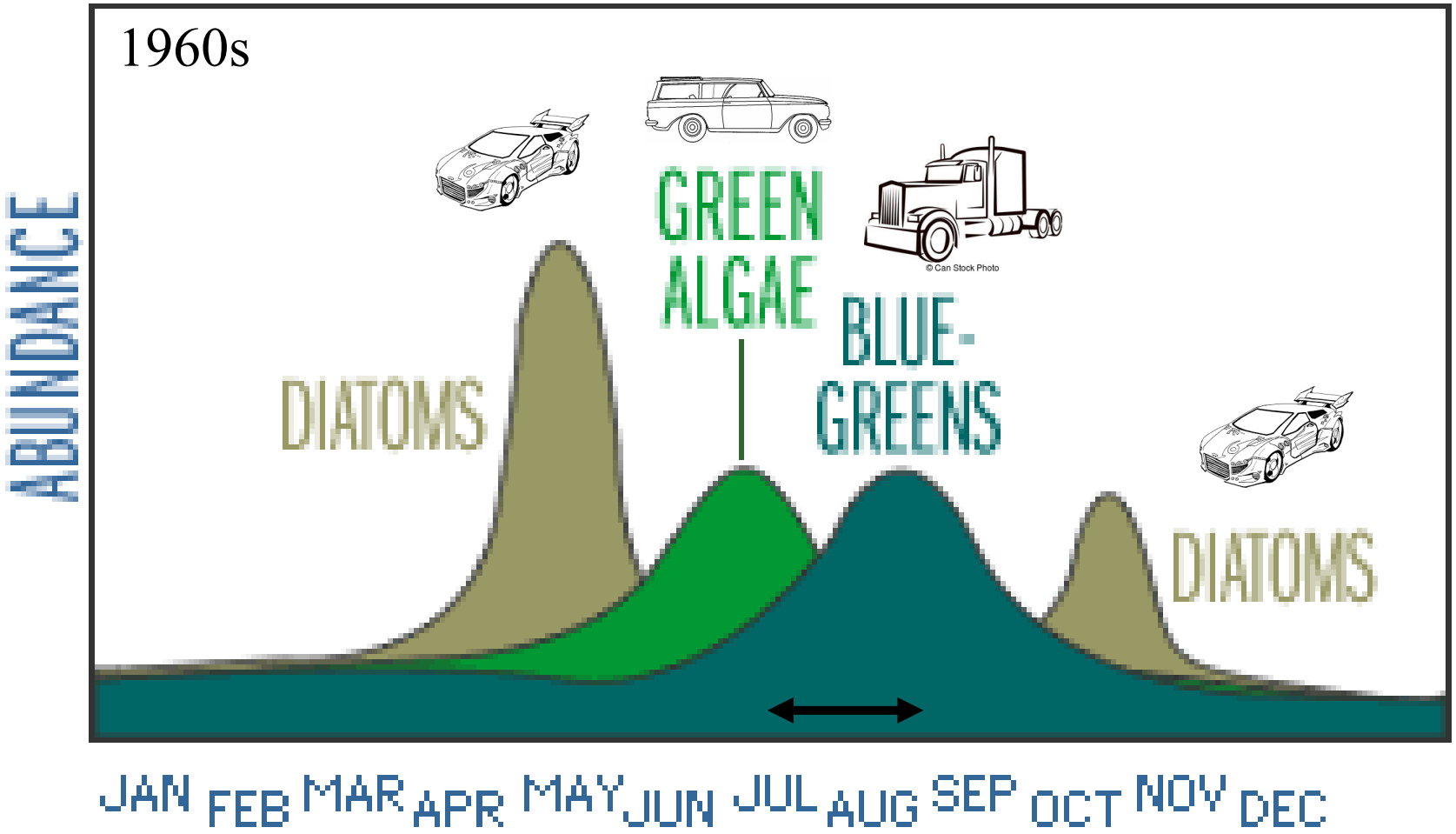
Threshold T ~12ºC (54ºF)

Temp response depends on other factors (light)

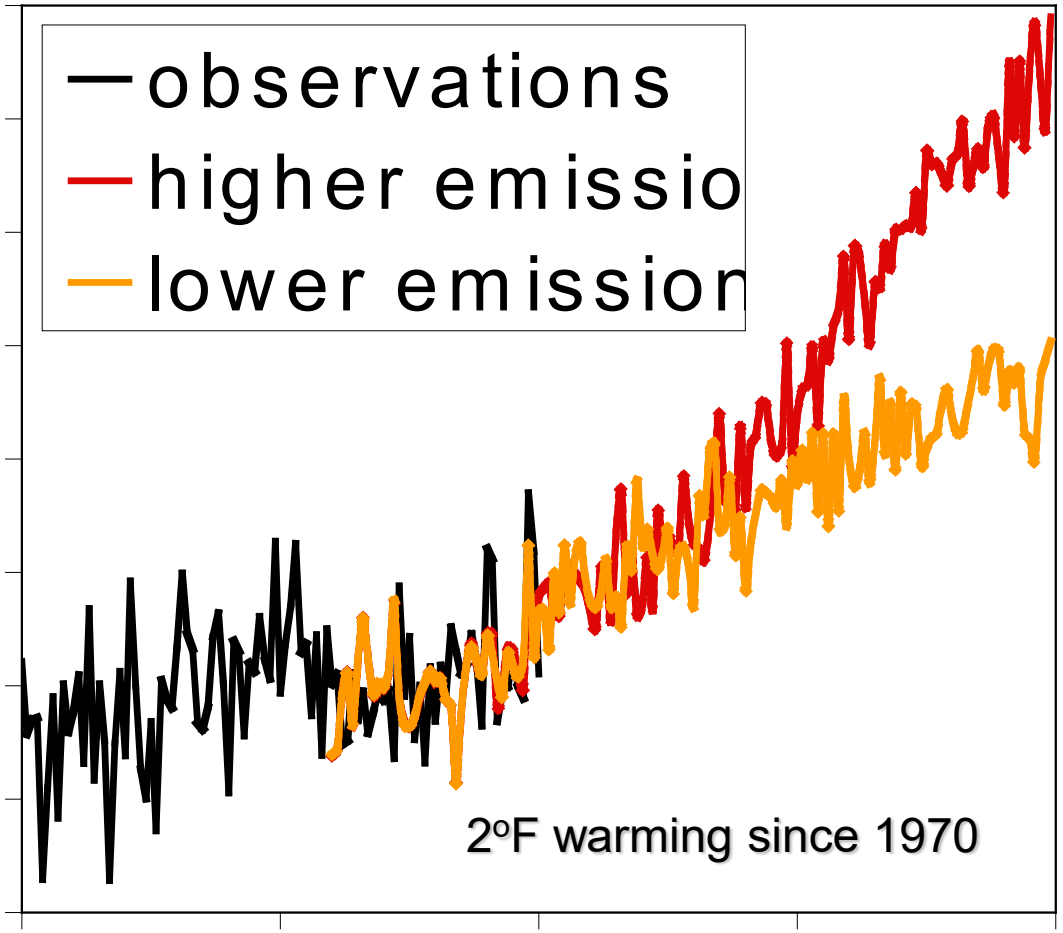
Microcystis has a tremendous variety in how it responds to temperature (Dick et al 2021)

How does climate change fit in?

useful to understand lake ecology

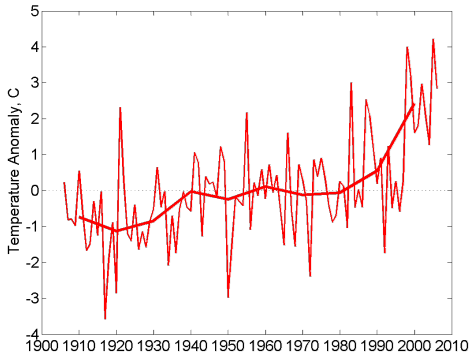


Regardless of Cause – lake temperatures are getting warmer.



Higher: 6.5-12.5°F

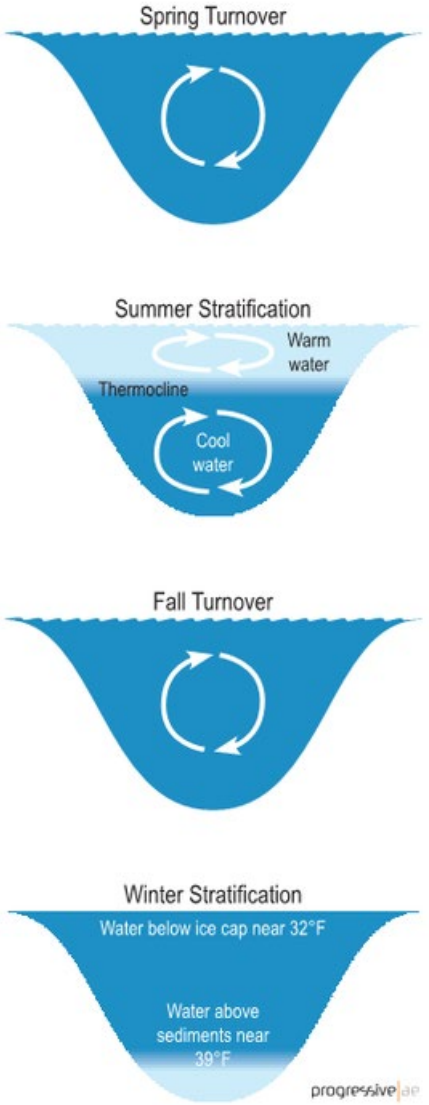
Lower: 3.5-6.5°F



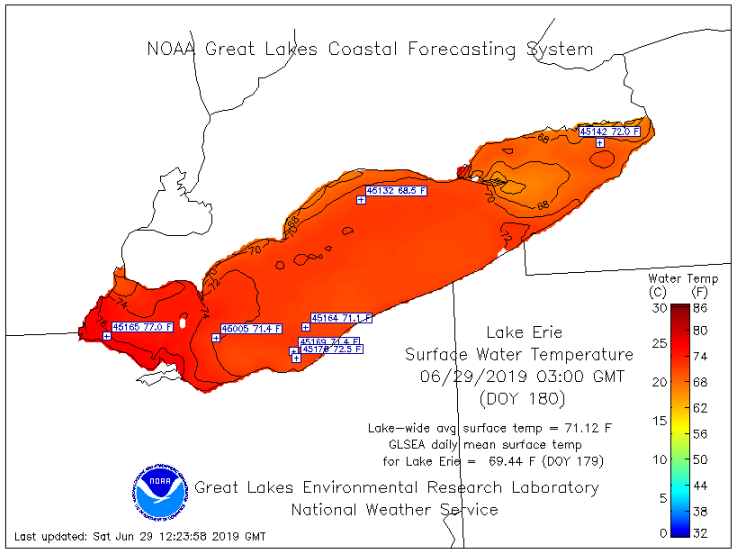
Lake Superior summer surface T

What does this mean for a lake?

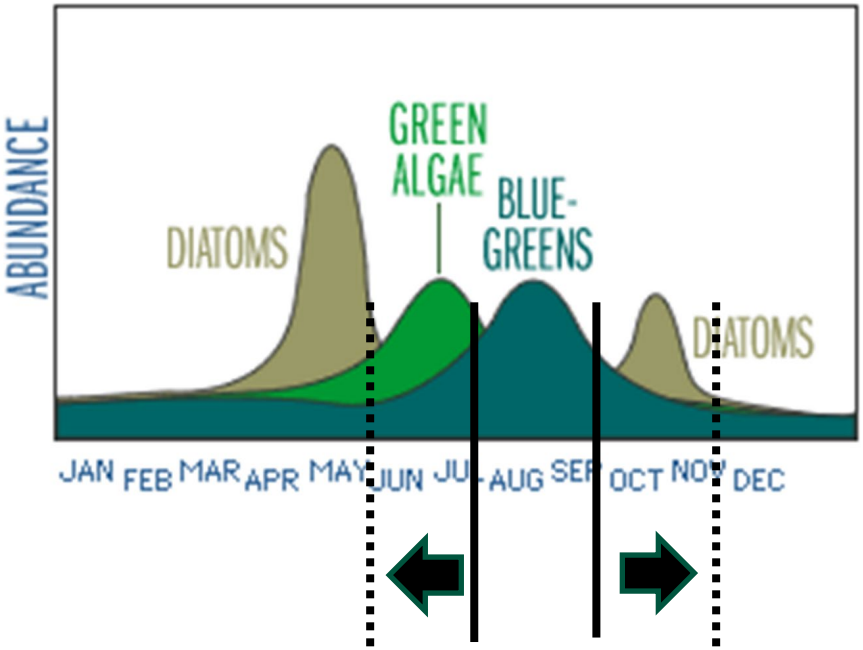
- Our large lakes typically stratify; heavy water on the bottom, light water on top…
- Global warming means:
  - Earlier spring turnover
  - Later fall turnover
  - Longer summer stratification
  - Warmer temperatures means they can start sooner and grow longer.



This shows up as a lengthening of the growing season……

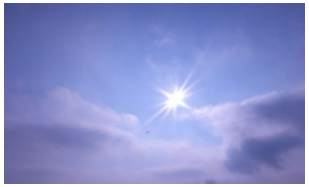


Lake Erie growing season is increasing by 1.9 days per year for the last decade



Blooms start earlier and end later than before

Why do they bloom?



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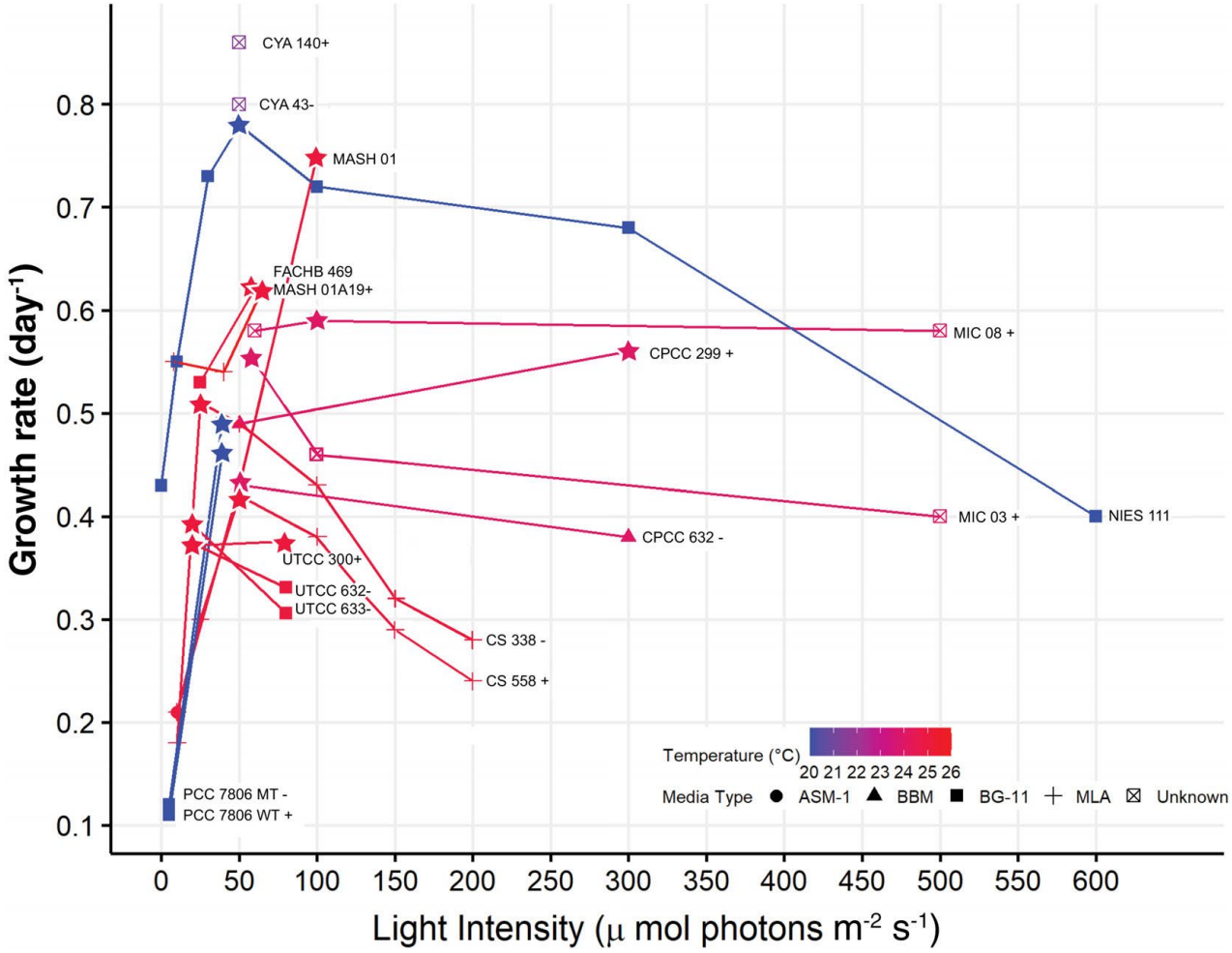
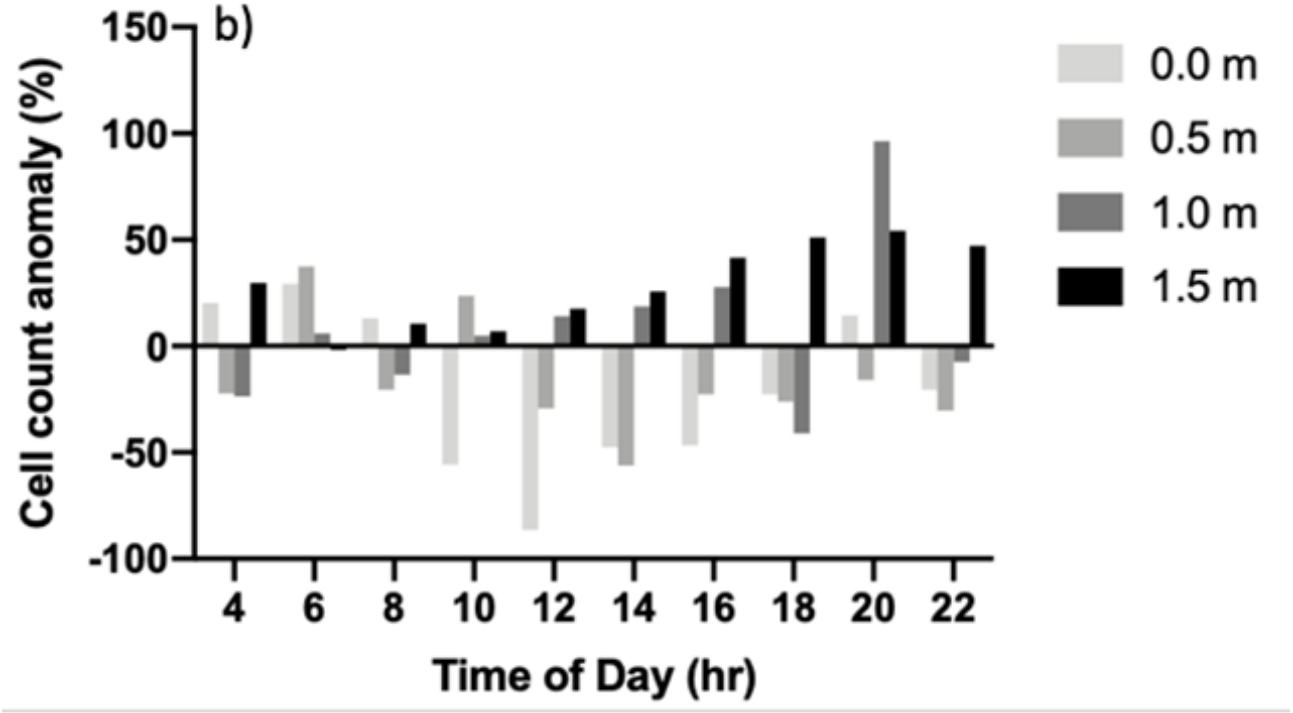
Blooms like bright sunshine



Dick et al 2021

Blooms move to avoid bright sunshine



In well-mixed lakes, *Microcystis* moves down during the day, and to the surface at night (Derminio 2021, 2024)

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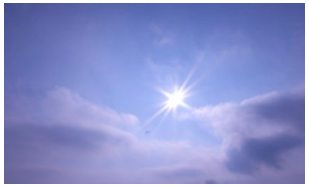

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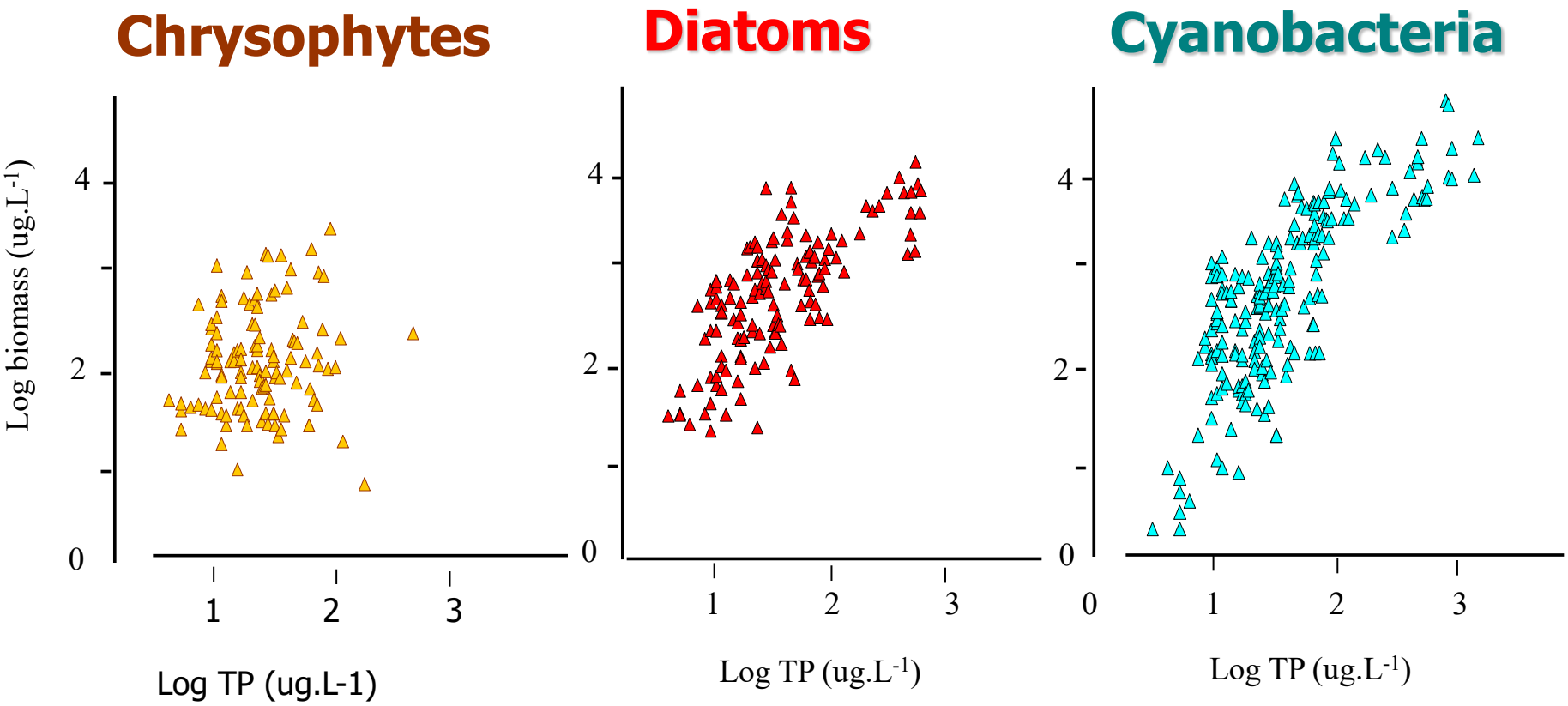
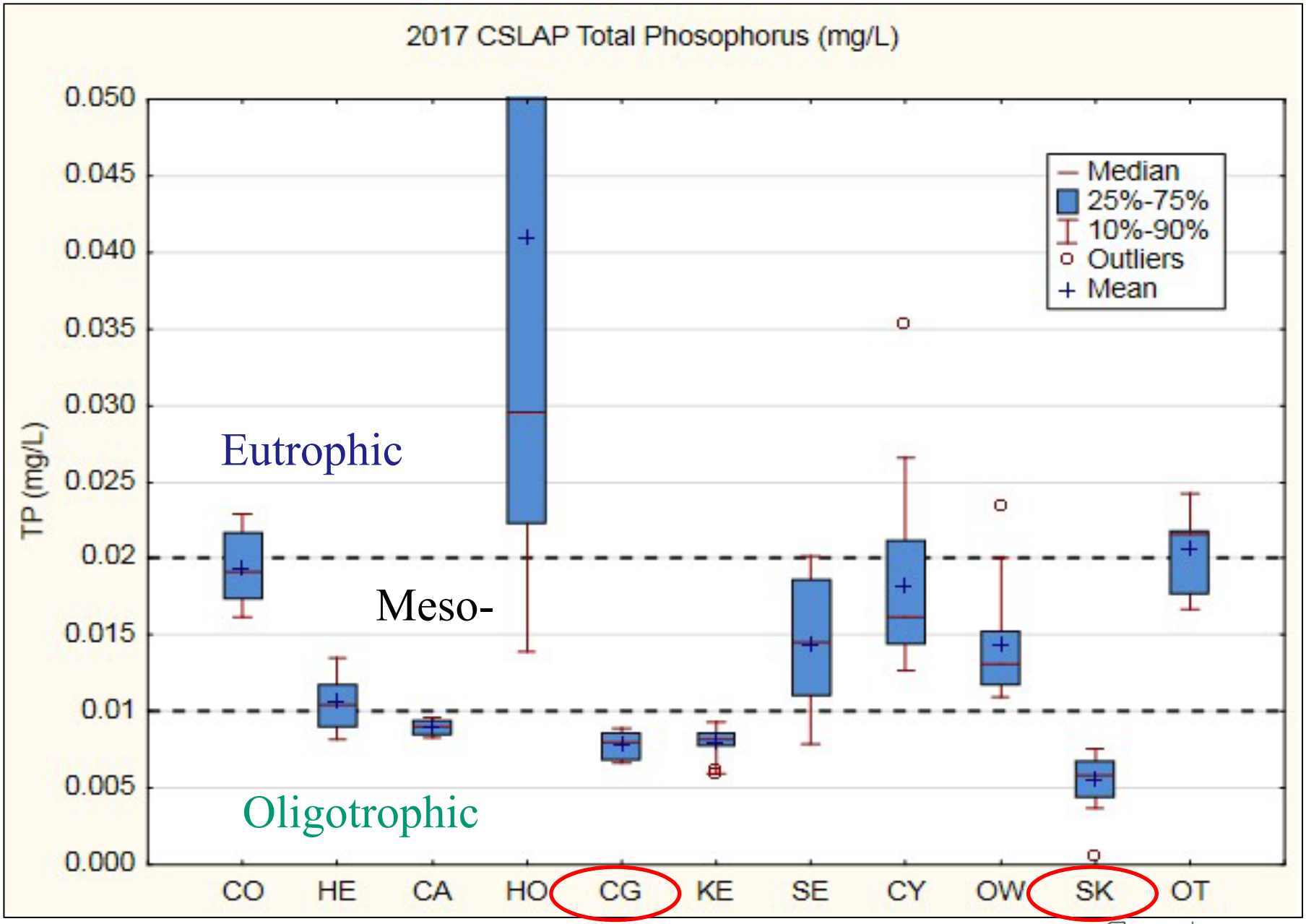
Paradox of the nutrients

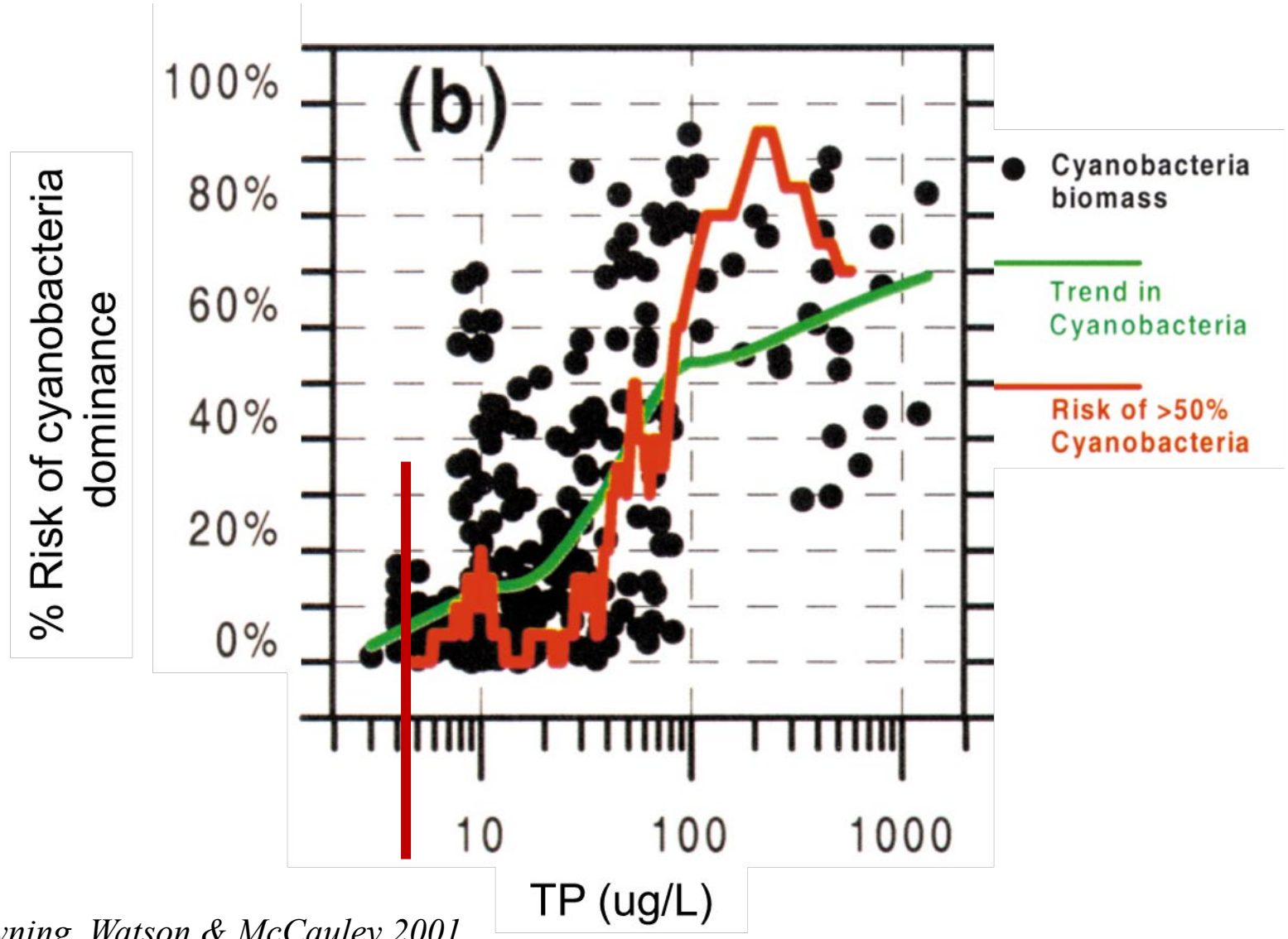


Watson and Boyer, 2007;



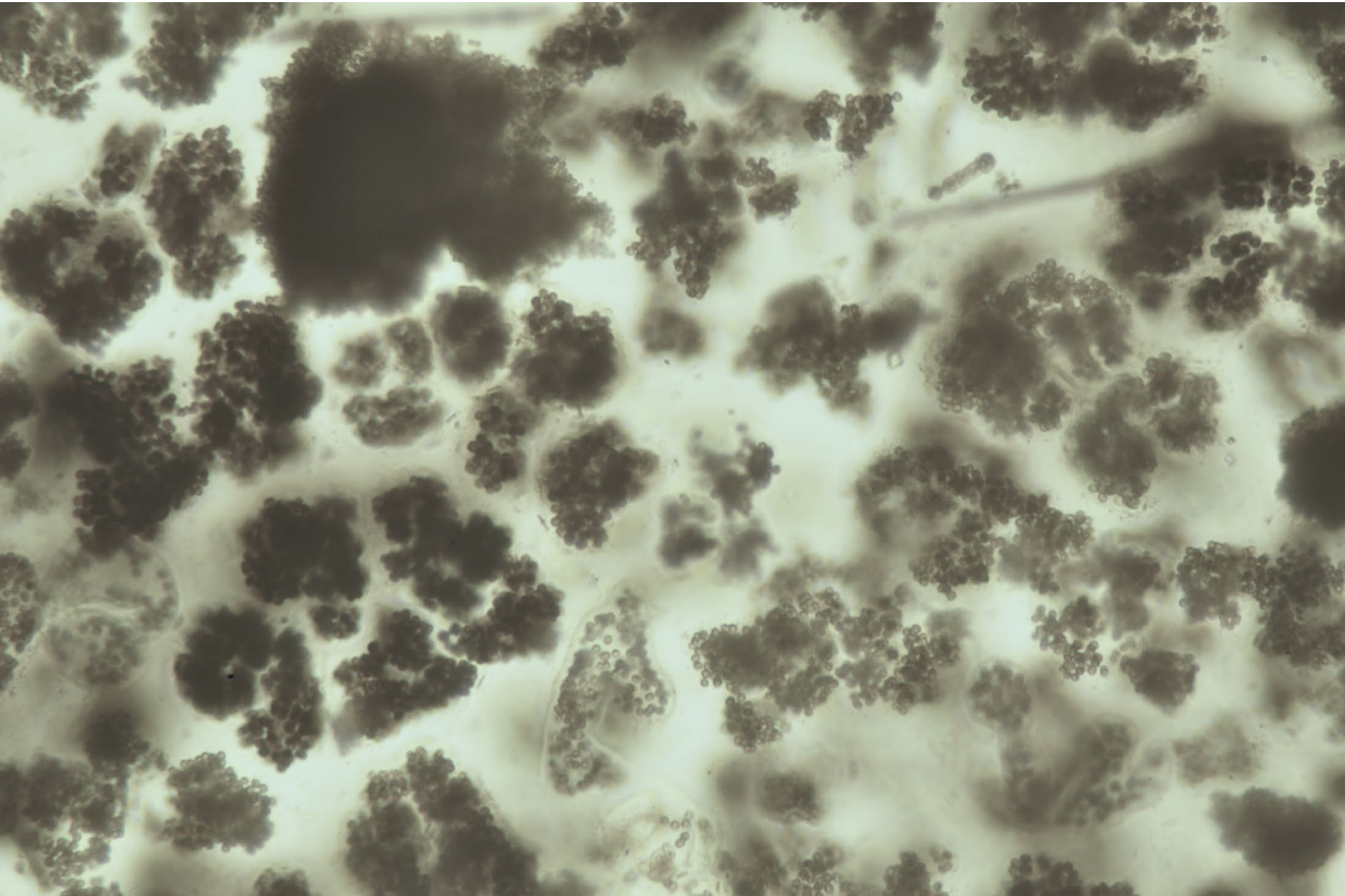
NEW YORK STATE OF OPPORTUNITY
Department of Environmental Conservation

Paradox of Nutrients

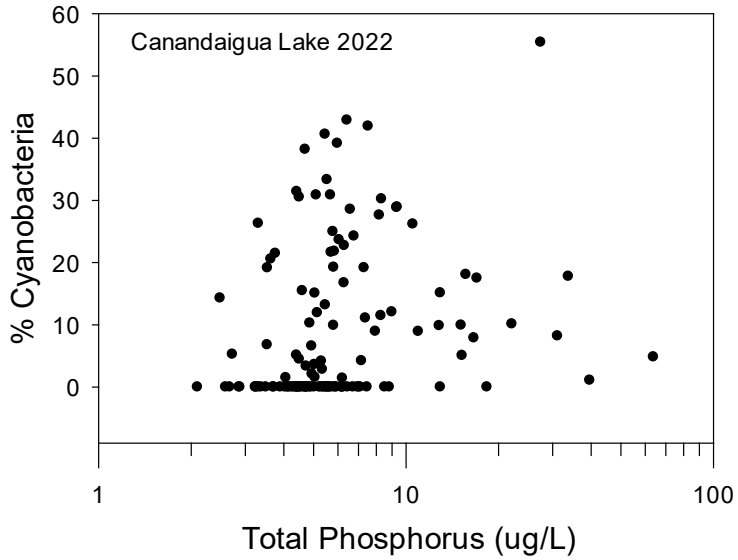


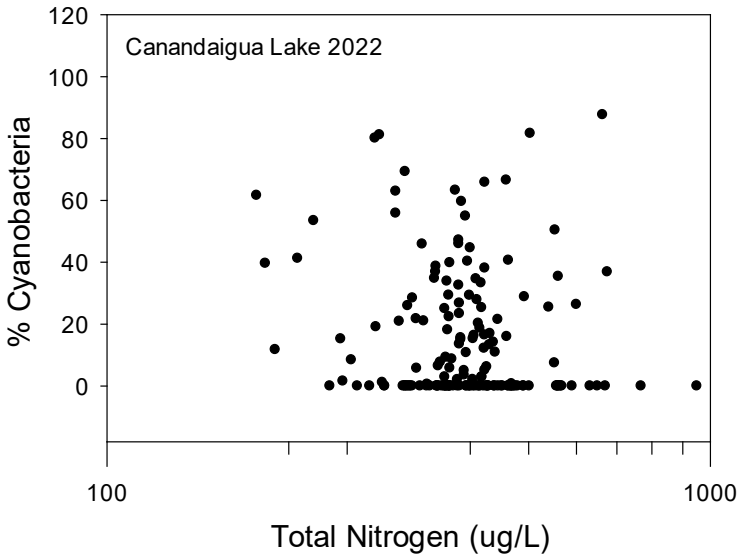
Downing, Watson & McCauley 2001.

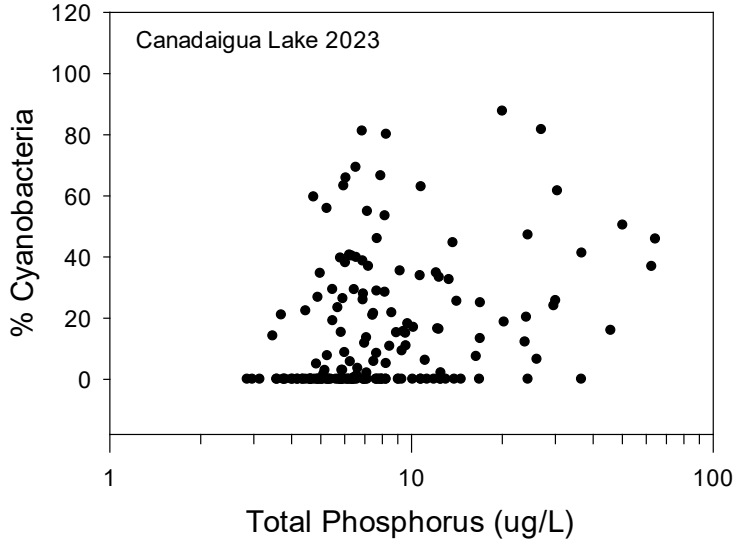
Skaneateles Lake blooms are almost pure *Microcystis*

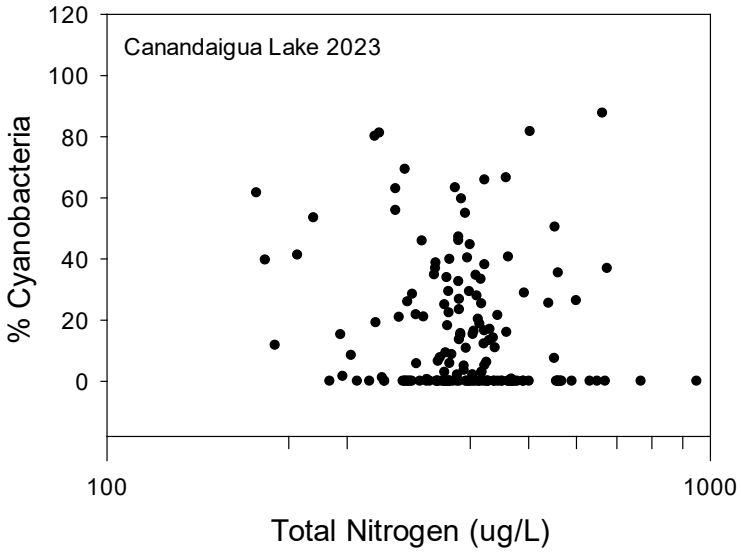


Can N or P explain the increased cyanobacteria abundance?

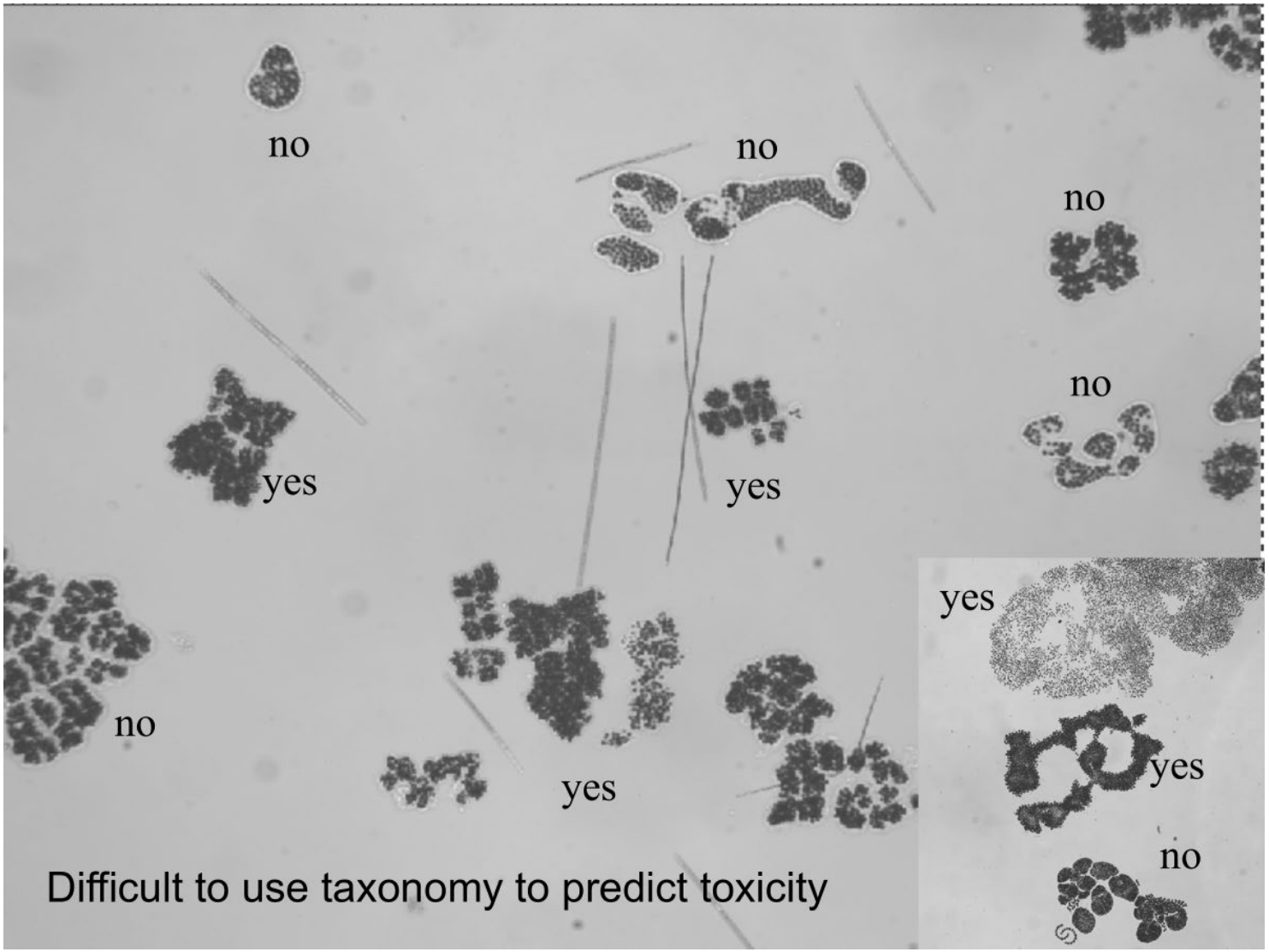




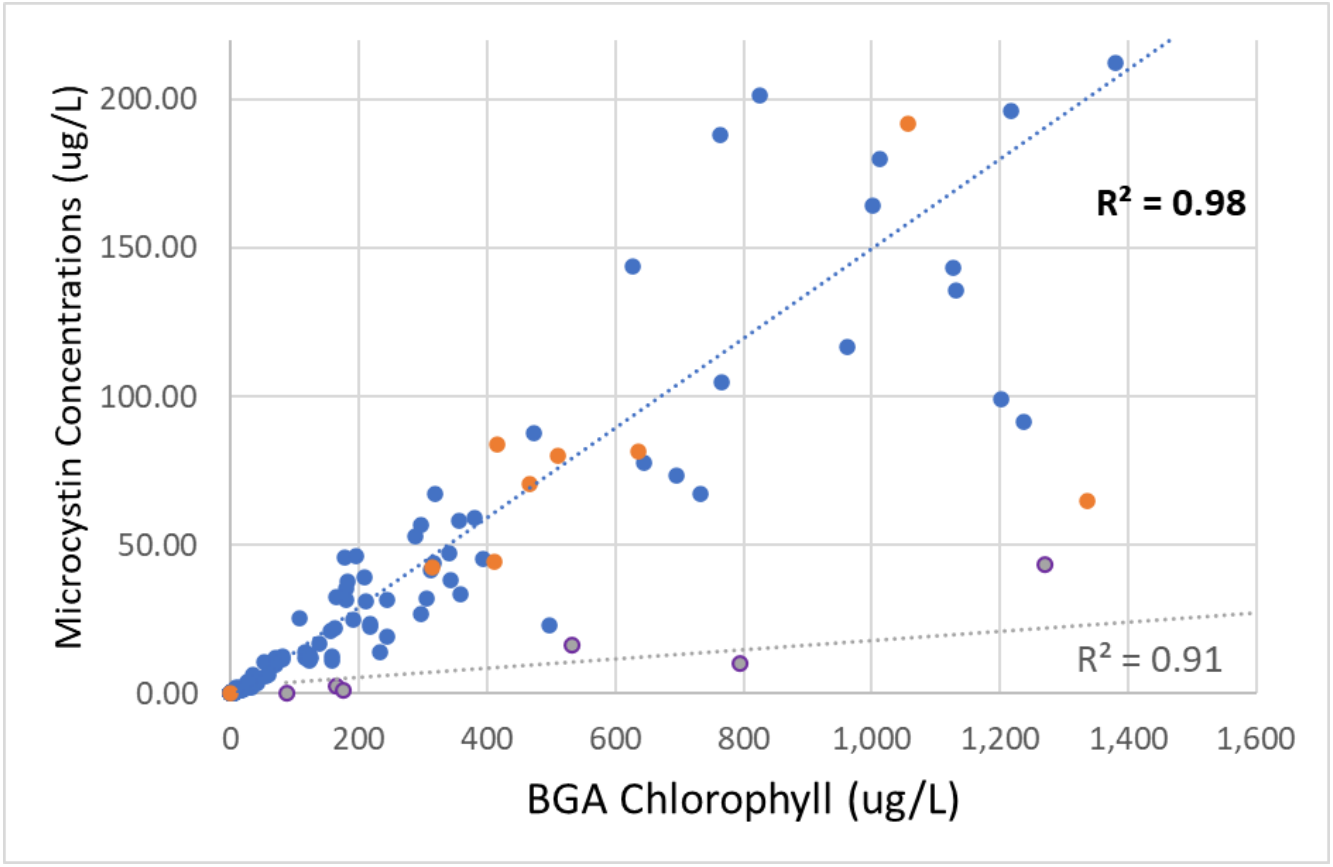




Cyanobacteria are not uniformly toxic



In Canandaigua Lake, the toxicity of the bloom was a function of the biomass.



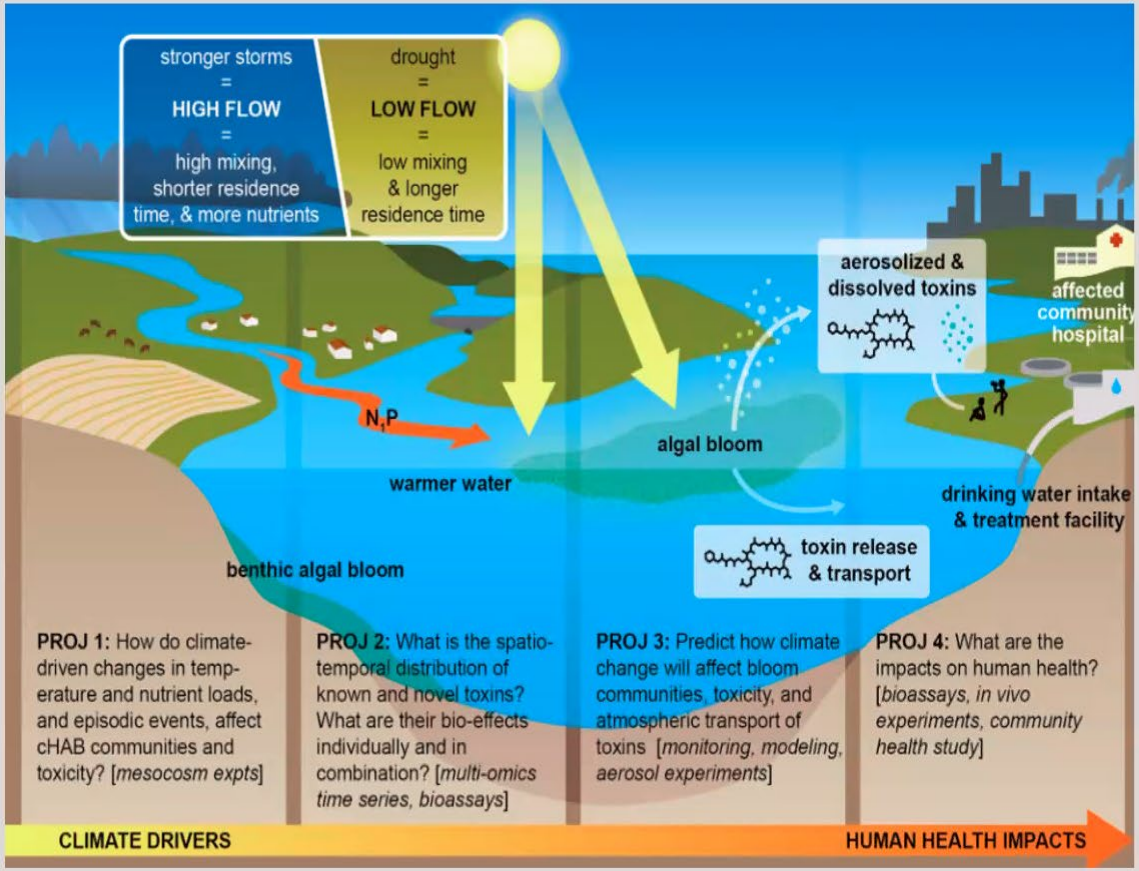
This cyanobacteria chlorophyll – not total chl. (n~210)
Skaneateles Lake (2022-23: orange) follows the same pattern
2024 (purple) is less toxic per BGA chl (?)

Conclusions

- Cyanobacteria blooms are a complex mixture of algae (morphotypes/phenotypes).
  - Differ in temperature optimums
  - Differ in light sensitivity
    - Most are low-light adapted
  - Differ in their sensitivity to some algacides
  - Differ in the ability to take up nutrients
  - Differ in their toxicity
    - More biomass, more chance of toxic members
- Hard to come up with a single explanation for the bloom that applies to all situations.
- Hard to come up with a single prevention that applies to all situations.

The present is not the future – glboyer@esf.edu

CANANDAIGUA LAKE WATERSHED ASSOCIATION



NSF/NIH GREAT LAKES CENTER FOR FRESH WATERS AND HUMAN HEALTH:

How might climate change affect HABs growth, transport of toxins, and public health?

What can we do to more effectively use regional data and other resources?

Who is most in need of current HABs information?

NOAA
WAYNE STATE UNIVERSITY
UNIVERSITY OF MICHIGAN
THE UNIVERSITY OF TOLEDO
THE OHIO STATE UNIVERSITY COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES
SUNY The State University of New York
JMU JAMES MADISON UNIVERSITY
BGSU
THE UNIVERSITY OF TENNESSEE KNOXVILLE
MICHIGAN STATE UNIVERSITY
THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL