A review of the global proliferation of toxic cyanobacterial blooms in the face of excess nutrient enrichment and rapid climate change

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Cyanobacterial Harmful Blooms (CyanoHABs): Symptomatic of human and climatic alteration of aquatic environments

Urban, agricultural and industrial expansion

↓

Increasing nutrient (Nitrogen & Phosphorus) inputs

↓

Water use and hydrologic modification play roles

↓

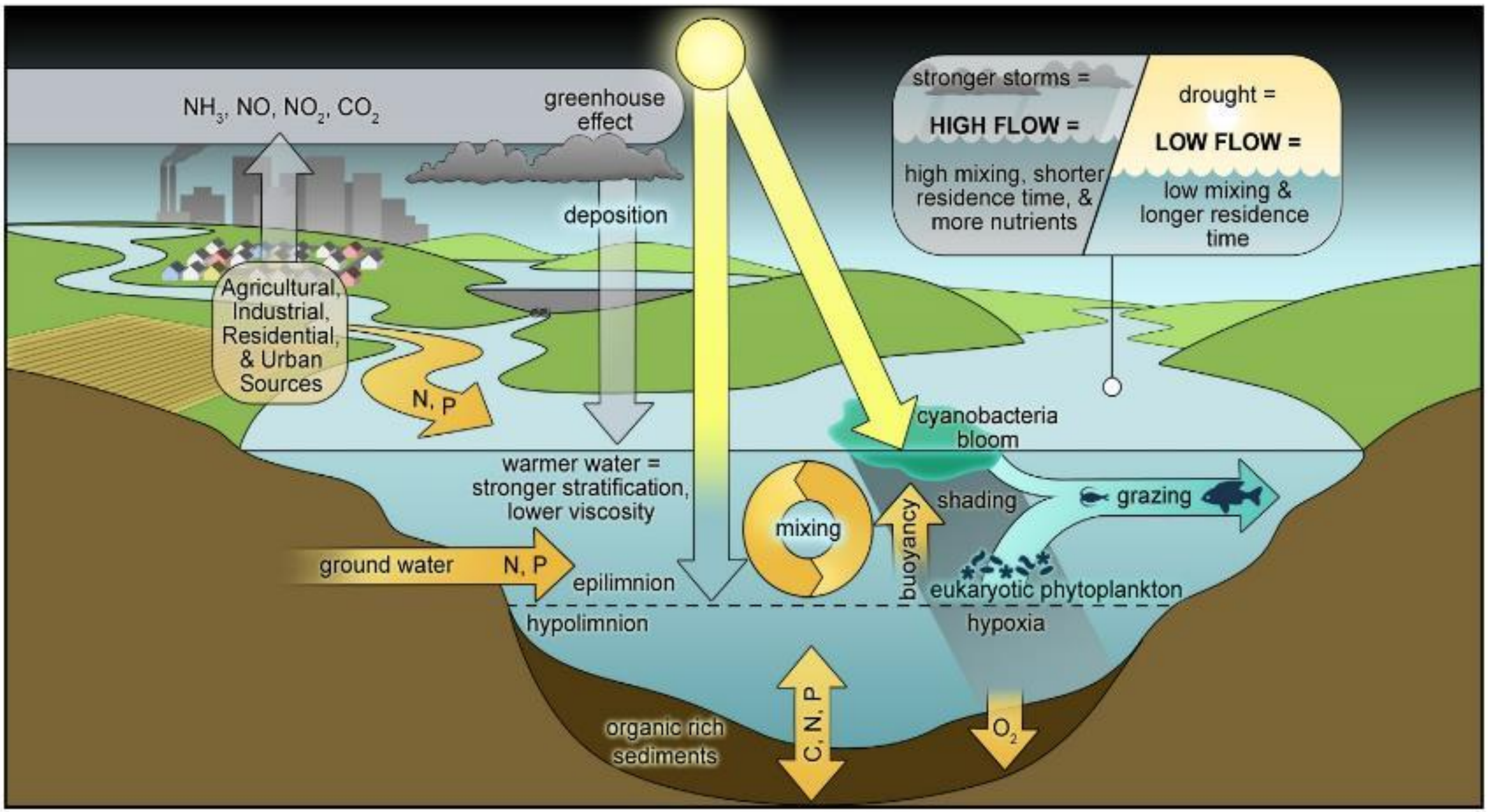
Climate (change) plays a key interactive role

Blooms are intensifying and spreading

↙ ↓ ↘

What drives CyanoHABs? Interactive physical, chemical and biotic factors

The “nutrient knob” is the one we can tweek most effectively



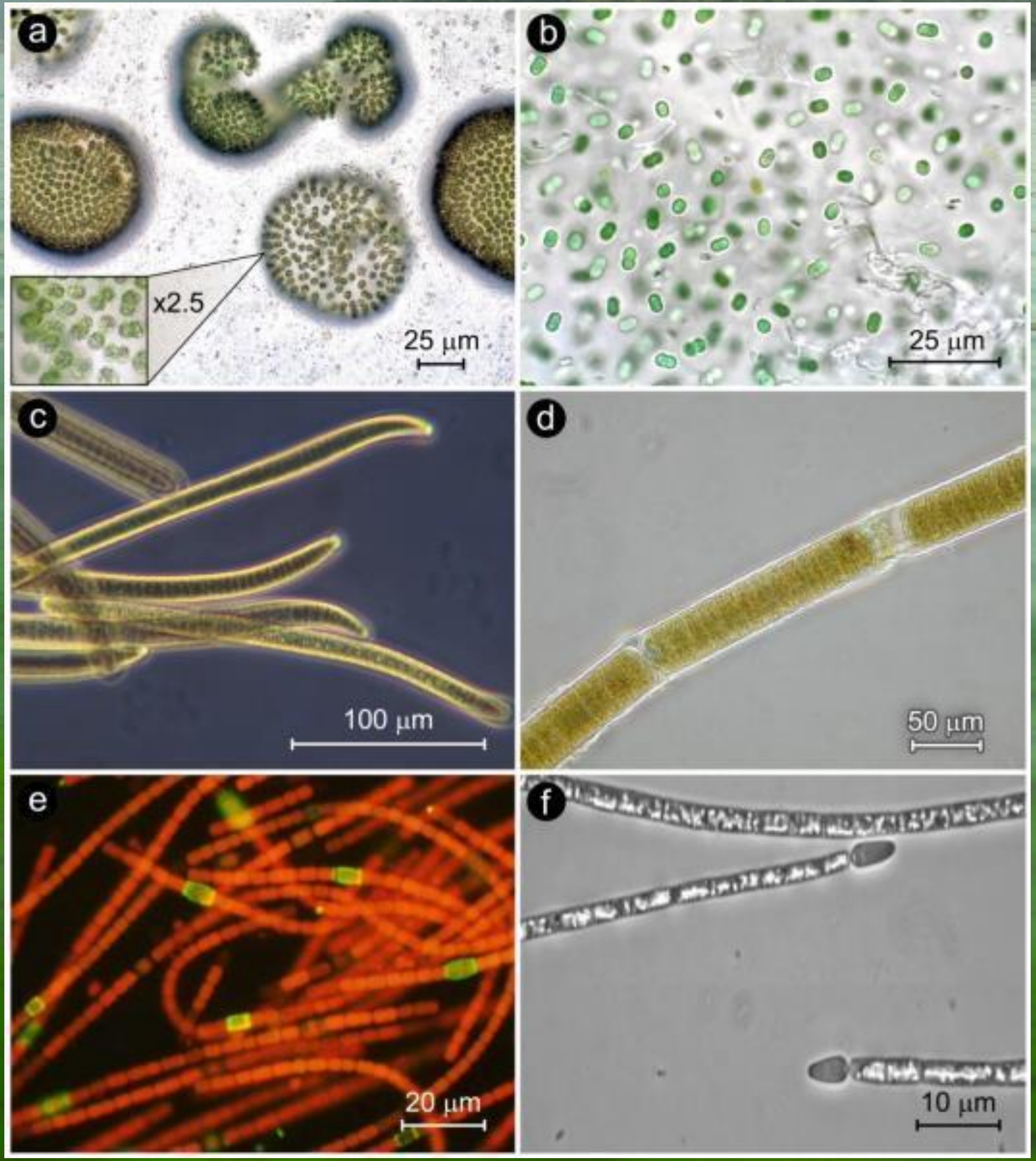
Paerl et al., 2016

The Planktonic CyanoHAB "Players"

Coccoid, solitary/colonial
(e.g. *Microcystis* & picocyanos).
Most do not fix N_2

Filamentous, non-heterocystous
(e.g. *Lyngbya, Oscillatoria*).
Some species fix N_2

Filamentous, heterocystous
(e.g. *Dolichospermum, Nodularia, Cylindrospermopsis*).
All fix N_2



Geographical background of Taihu

Surface: 2338 km^2

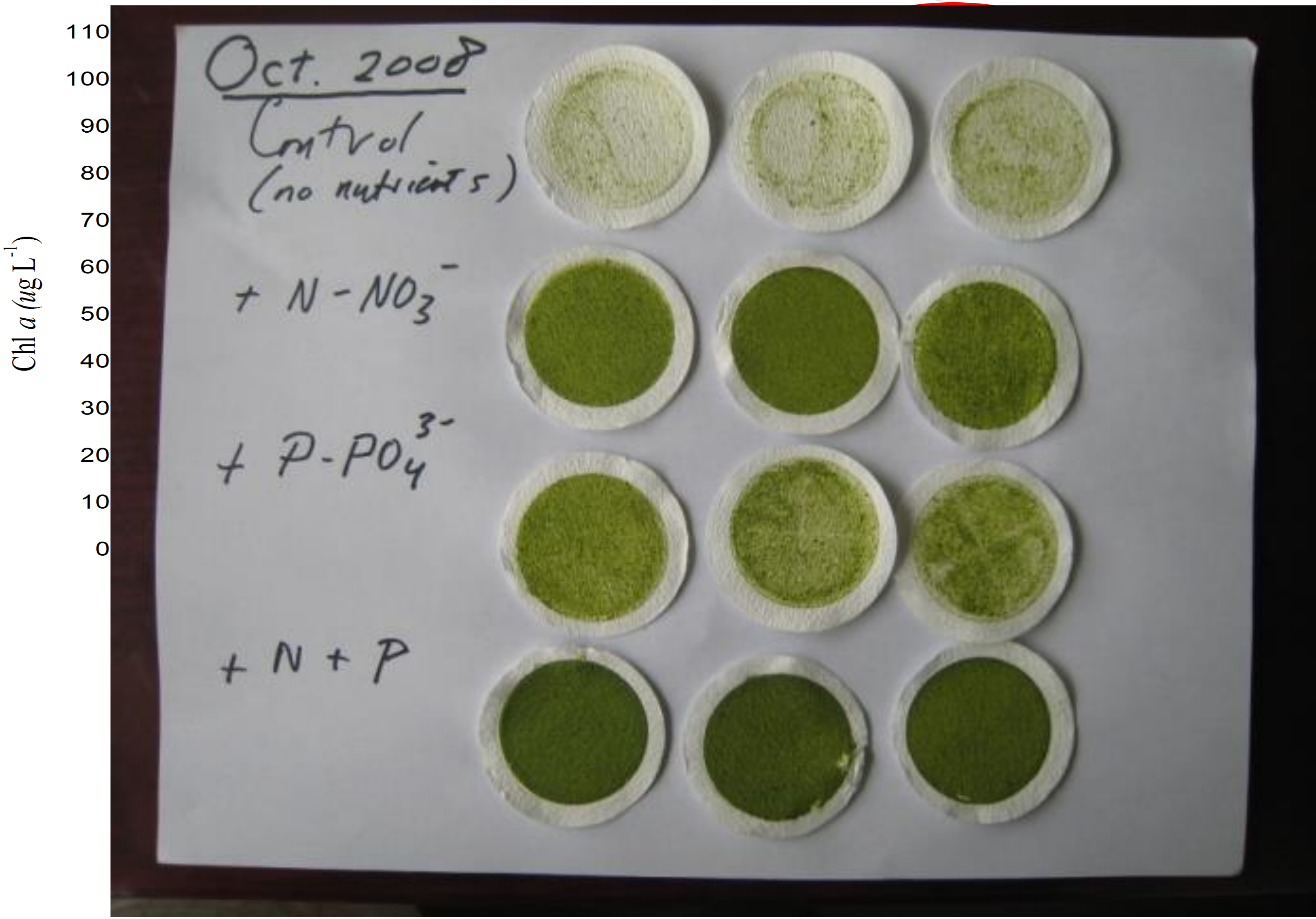
Average Depth: 2 m

Maximum Depth: 3 m

Catchment: 36900 km^2

Population: >1200 person/km^2

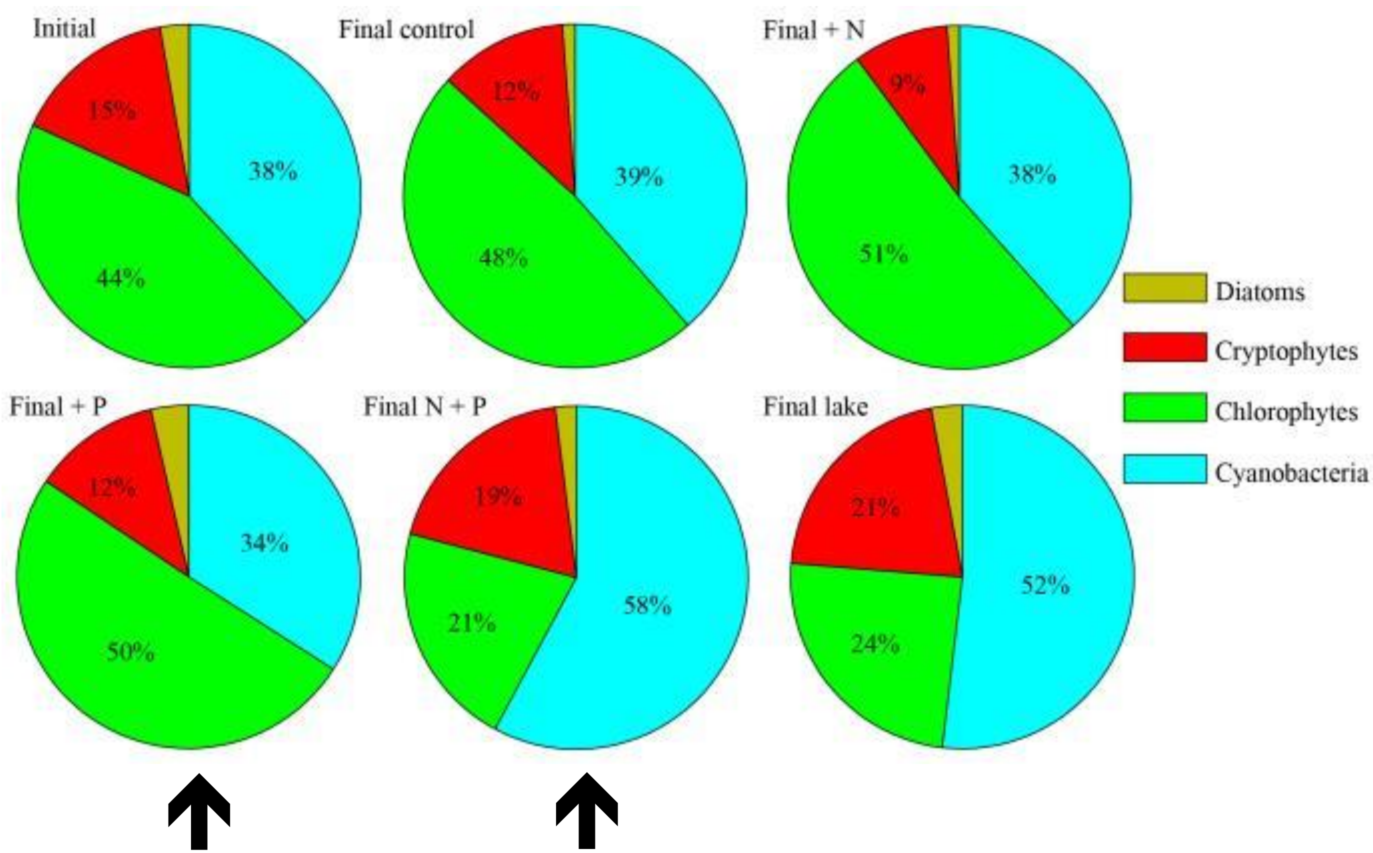
Effects of nutrient (N & P) additions on phytoplankton production (Chl *a*) in Lake Taihu, China: **Both N & P inputs matter!!**



Xu et al. 2010; Paerl et al. 2011

Bioassays: Increased P loading alone doesn't necessarily lead to ↑% Cyanos, but N+P does

This challenges the paradigm that low N:P ratios favor cyanos and argues for a dual nutrient (N&P) reduction strategy

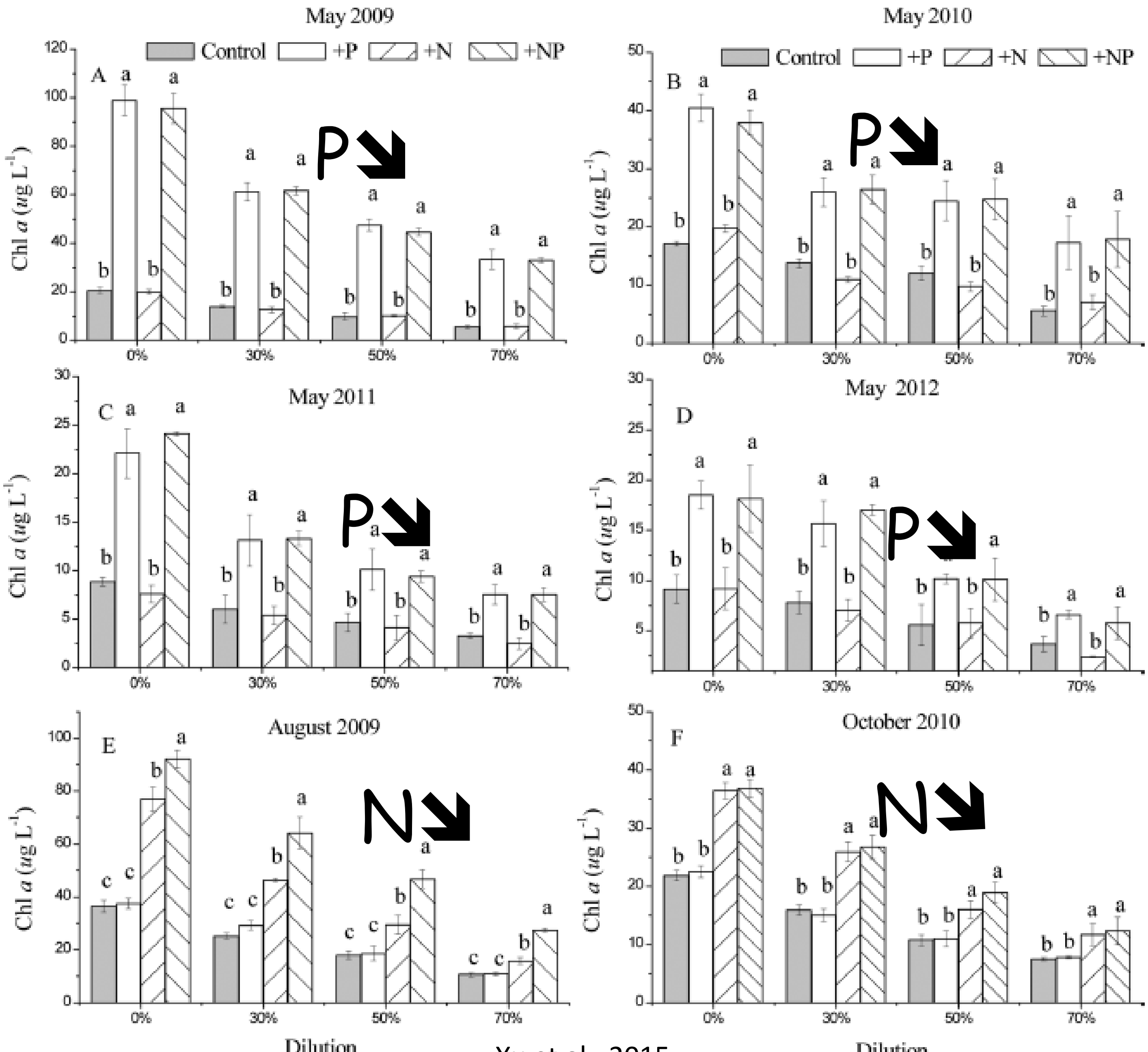


Paerl et al., 2014

Nutrient Dilution Bioassays: How much N & P reduction is needed to control blooms?

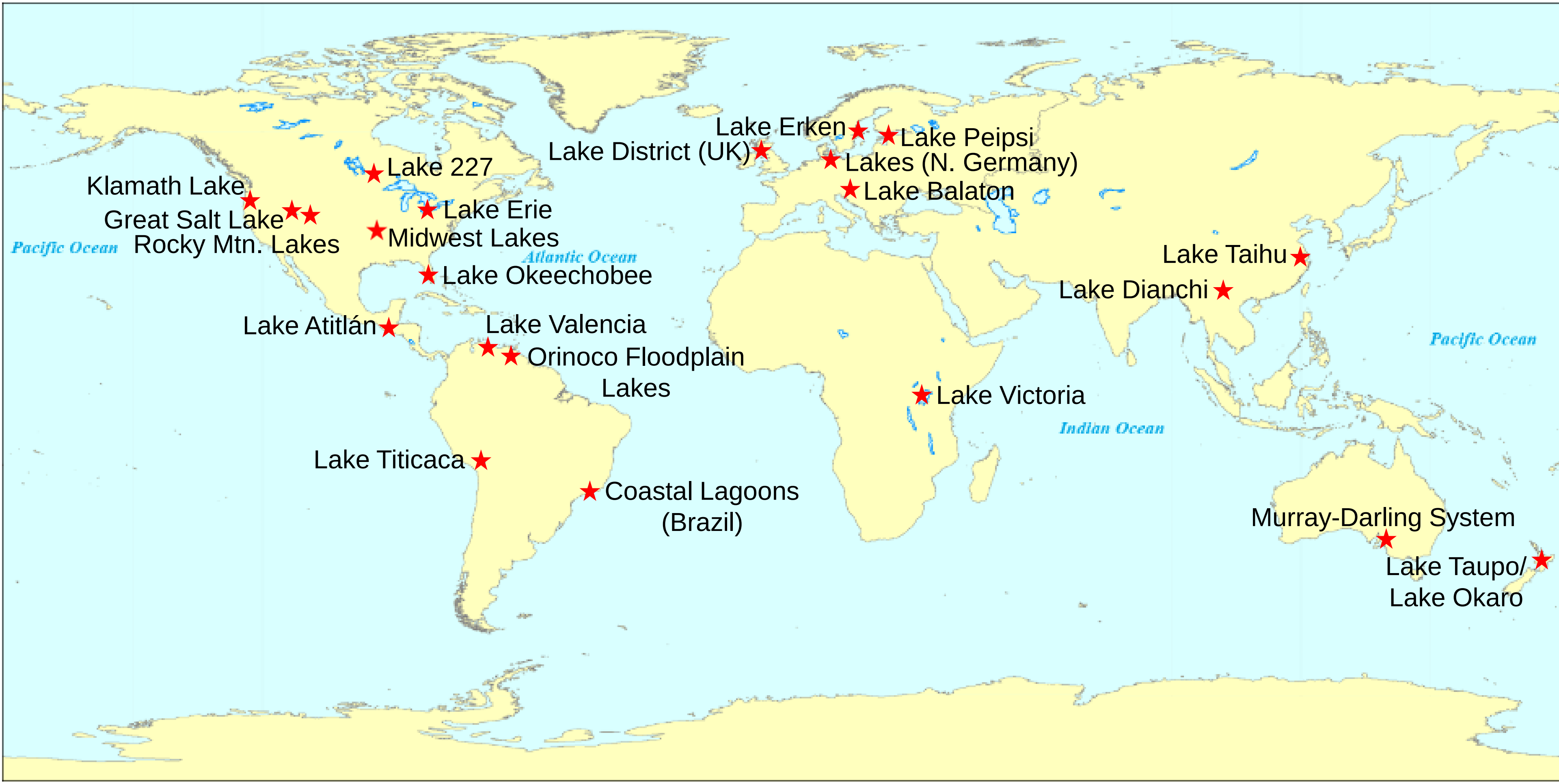
30-50% for P

50-70% for N

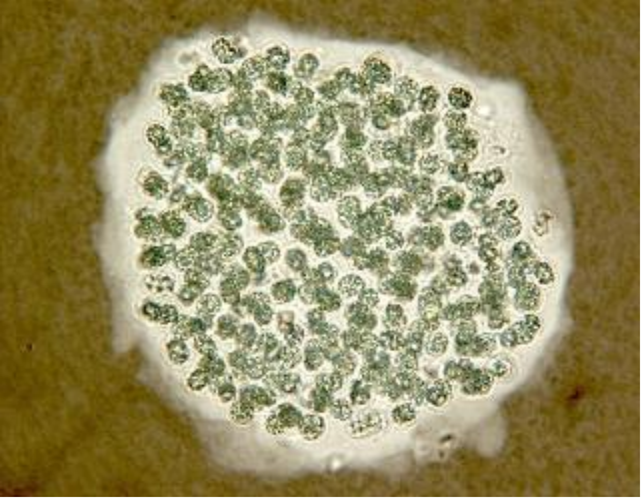


Xu et al., 2015

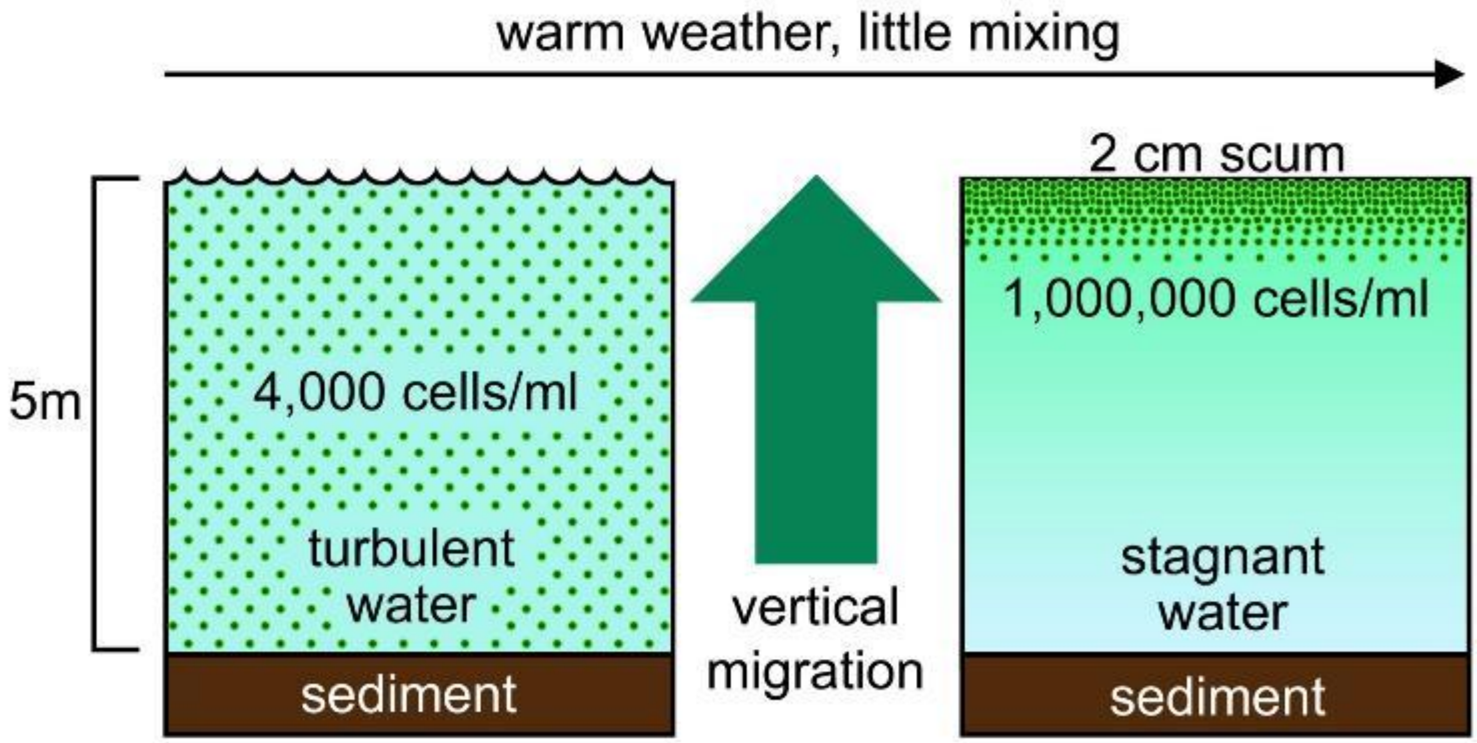
Large lakes and reservoirs in which algal blooms (mostly cyanobacteria) have been shown to be N & P stimulated



Sources: Havens et al., 2003; Elser et al. 2007; North et al., 2007; Lewis & Wurtsbaugh 2008; Conley et al., 2009; Moisander et al., 2009; Lewis et al. 2011; Abell et al., 2011; Özkundakci et al., 2011; Paerl et al., 2014; and many others.



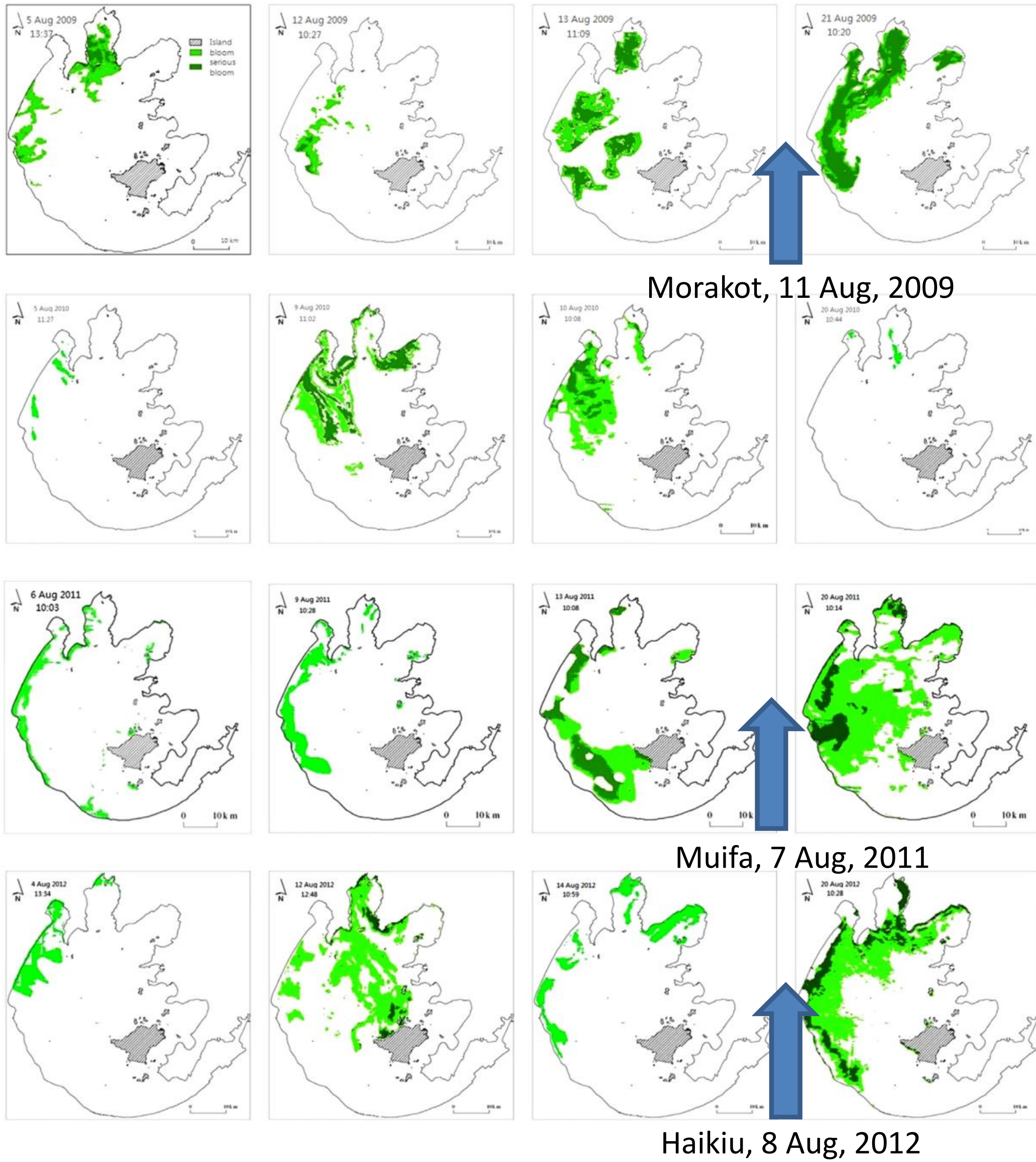
Warming leads to stronger vertical stratification…….
Buoyant cyanobacteria favored by stronger stratification



Paerl and Huisman 2009

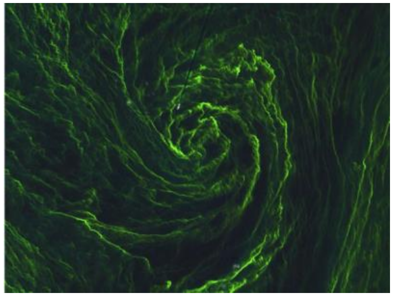
Impacts of Typhoon Passages on Cyano blooms in Lake Taihu, China, based on MODIS data

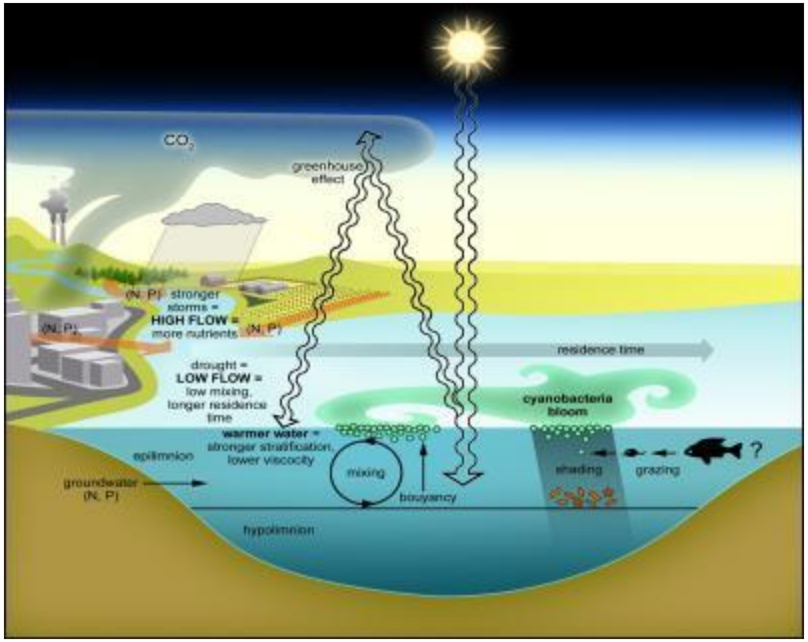
(Zhu et al. 2014)

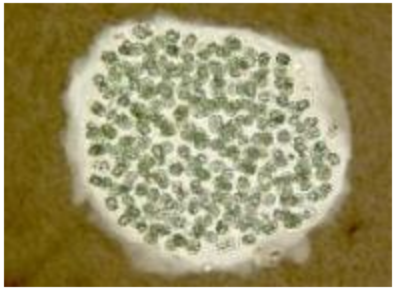


Conclusions/Recommendations for today and the future

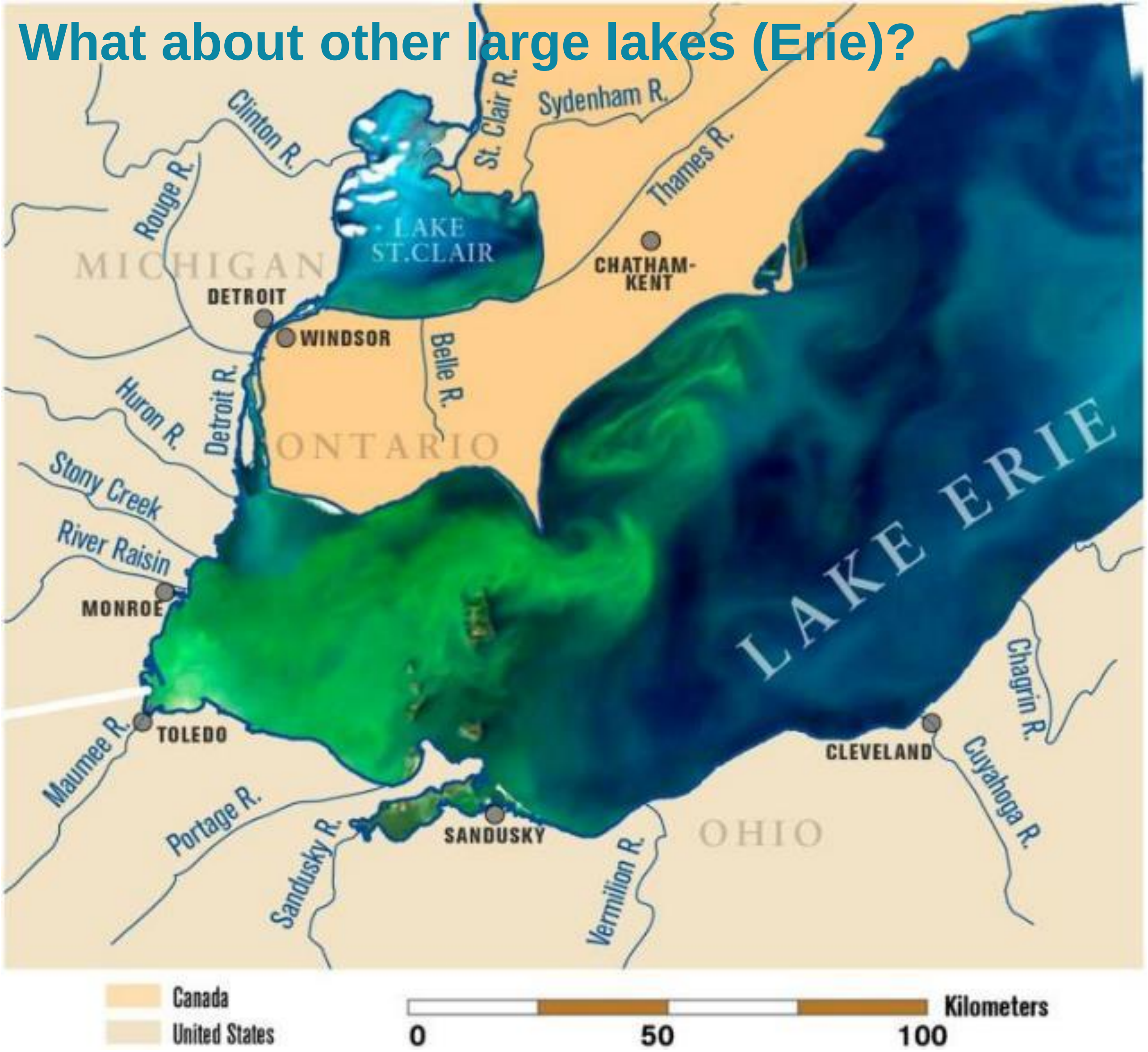
- Reduce both N & P inputs in most cases (P legacy a serious issue)
  - Nutrient-bloom threshold are system-specific
    - However, in many cases >30% reductions should be targeted
  - May need to reduce N and P inputs even more in a warmer, stormier world
    - Blooms “like it hot”
    - Episodic events favor CyanoHABs
- Impose nutrient input restrictions year-round
  - Residence time is long in many lakes (usually > 6 months)
  - Warmer, longer growing seasons (earlier ice off, later ice on)



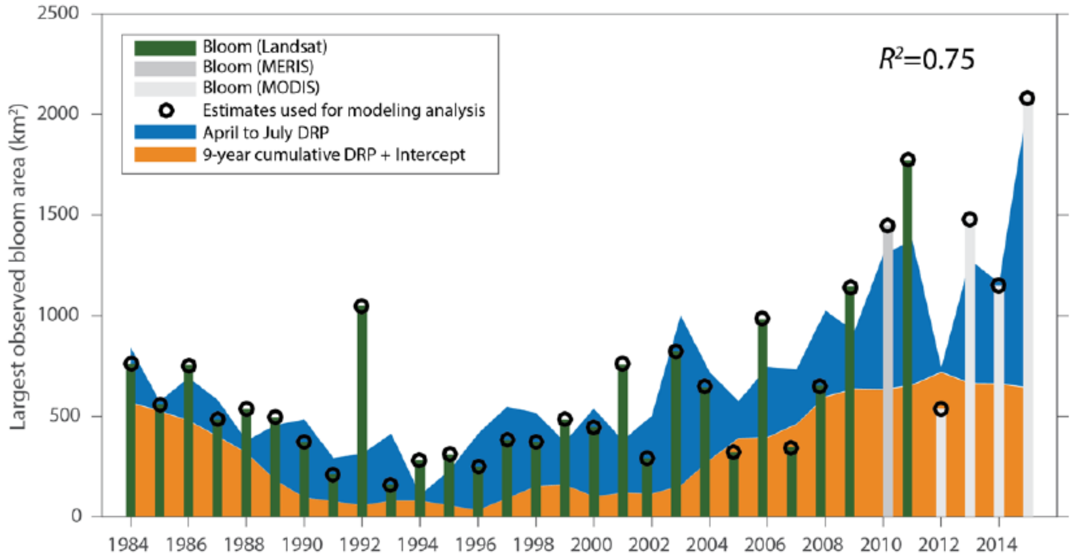




What about other large lakes (Erie)?



Dual role of dissolved reactive phosphorus



Springtime and decadal dissolved reactive phosphorus loading explain 30-years of phytoplankton blooms in Lake Erie (across changing phytoplankton populations)

Ho & Michalak (JGLR 2017)

Lake Erie cyano HABs

- >80% of TP load occurs through NPS (primarily agriculture); majority of load occurs in Maumee River
- 90% of the load occurs during 20% of the rainfall period– runoff events
- Wind direction and speed mobilizes bloom to other parts of lake
- Due to these investigations, mitigation strategies have been targeted for specific activities in specific areas

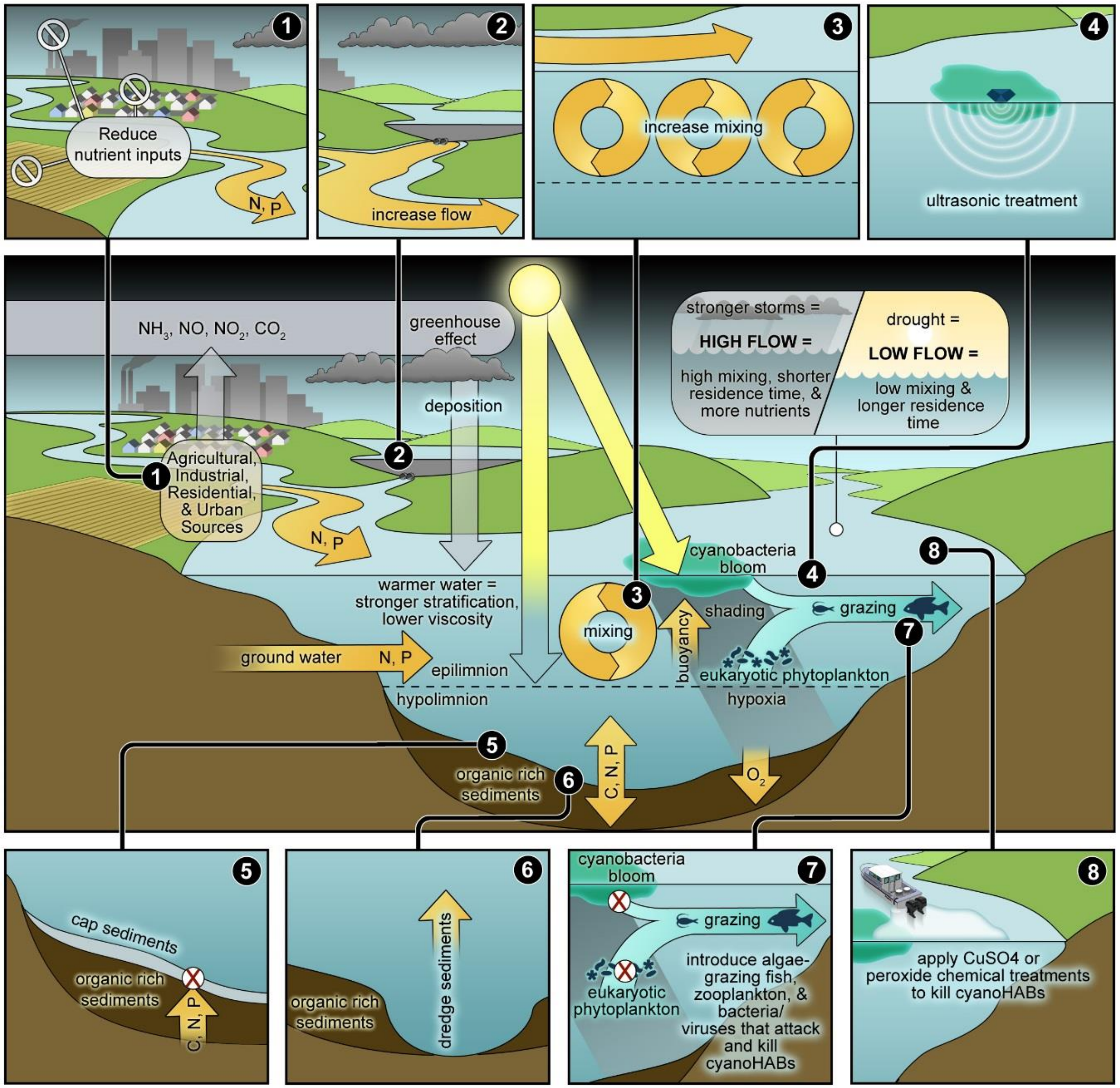
Fighting battles vs Winning the war

Management of Harmful Algal Blooms

- Prevention
  - Alteration of nutrient inputs
  - Alteration of water management
- Mitigation
  - Monitoring for cells and toxins
  - Forecasting and public notification
- Control
  - Biological –viruses, bacteria, parasites, grazers
  - Chemical– barley straw, copper sulfate
  - Ultrasonic
  - Ozonation
  - Chemical flocculation
  - Clay flocculation

Mario Sengco- US EPA

Commonly-used prevention/mitigation strategies



HAB Management Conclusions

1. Preventative strategies should be pursued to prevent/limit HAB occurrence– implementation will take decades

2. Bloom control research is relatively immature

3. Biological control options are possible in theory, but application is also likely decades away.

4. Chemical control options are possible but limited due to scope of application, broad lethality to non-targets and other environmental concerns.

5. Clay flocculation may be useful in specific instances but is prohibitively expensive and has environmental consequences.

Taking Action

What can we do?

New Harvest Innovations

Dr. Ron Sims

USU Water Research Lab

Developing cyanobacteria harvesting technologies and market processes for natural systems

May include aerial imagery through Aggie Air; particularly for smaller waterbodies

New Preventative Innovations

South Davis Sewer District Wastewater Tertiary Treatment (Nutrient Polishing)

Pilot Plant- Photobioreactor

Nutrient Reduction Success: Deer Creek Reservoir

Deer Creek Reservoir Algal Blooms (1970s)

Deer Creek Reservoir Algal Blooms (1990s)

QUESTIONS

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