A framework for cyanobacteria harmful algal bloom (cHAB) monitoring: A case study of China's Lake Taihu

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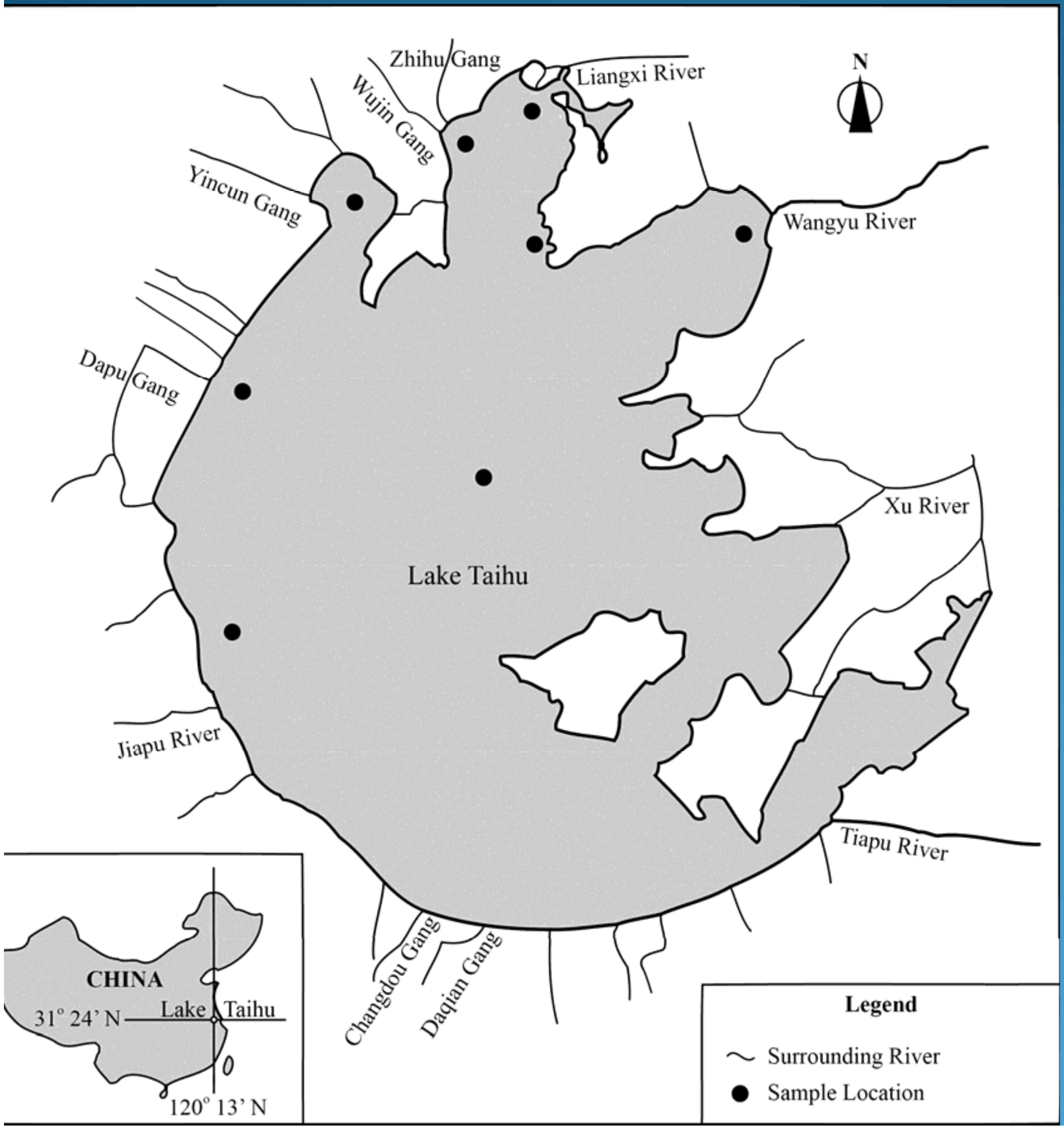
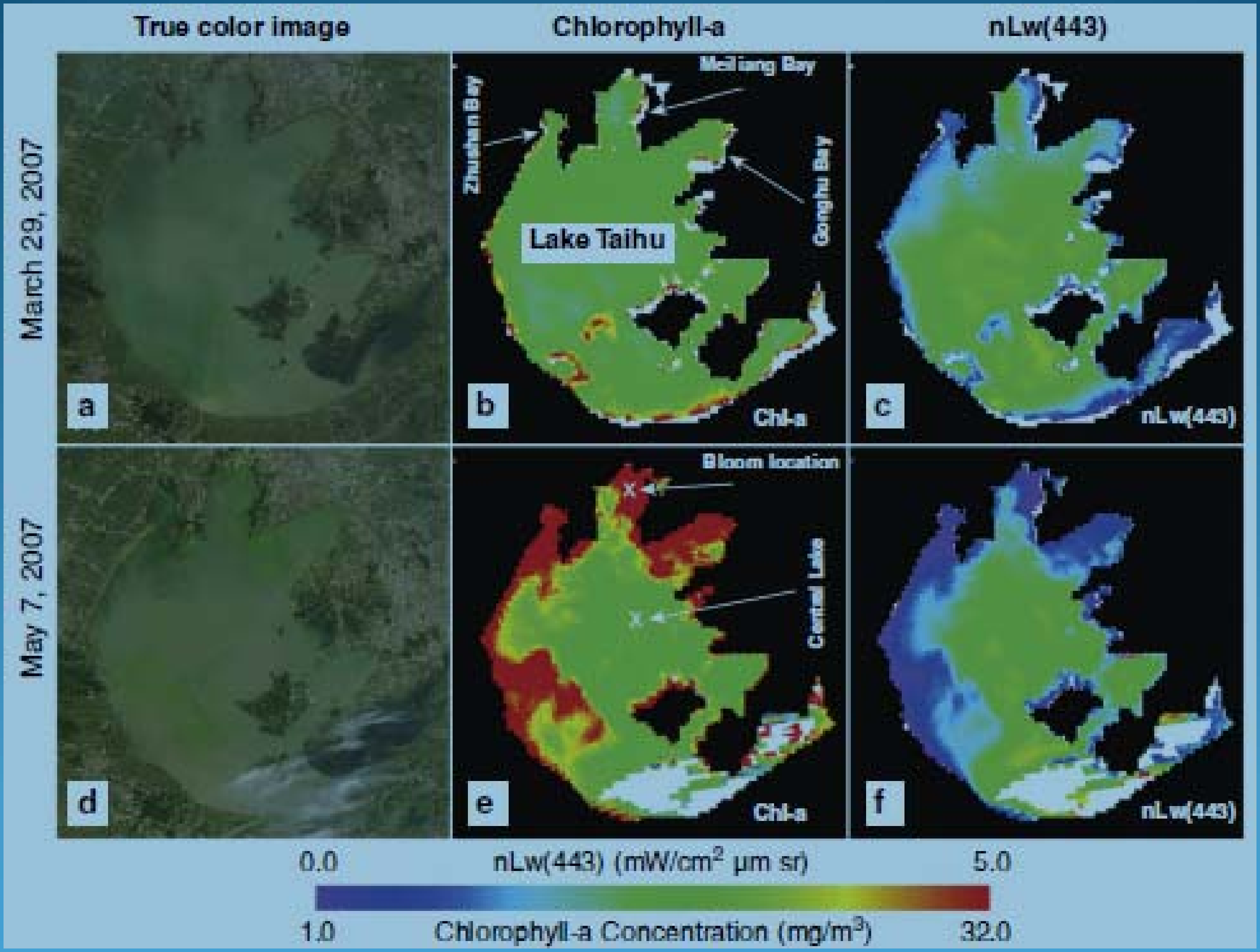
The Lake Taihu Story



- Most populated province
- Pop. Centers to N & E and about 100 km W of Shanghai
- 3rd largest lake (2,338 km²)
  - Shallow (1.9 m)
  - Polymictic
  - HRT ~300 days
  - 200+ water inputs
- Eutrophying since 1980's

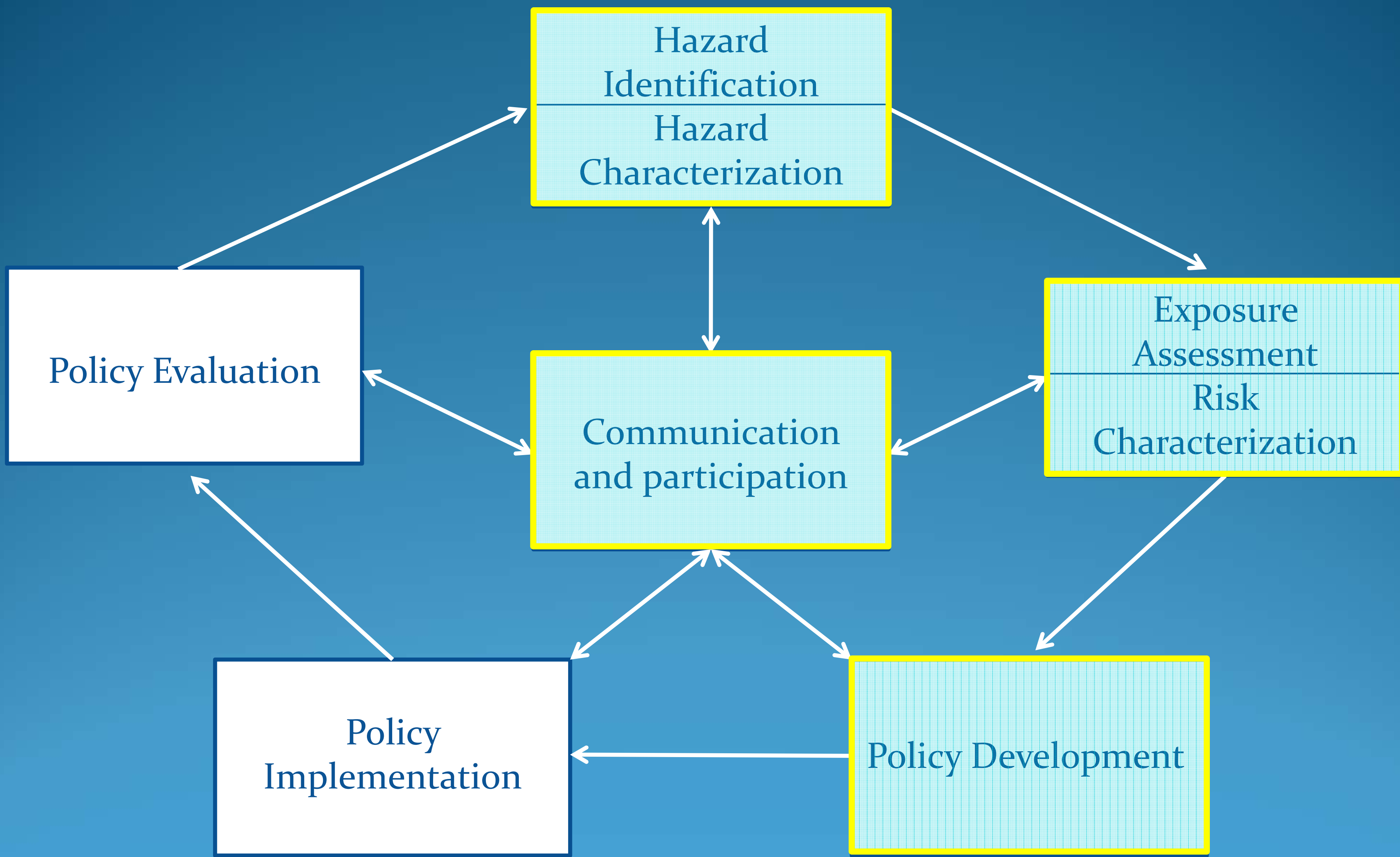
2007 Drinking Water Crisis



Wang and Shi, 2008

2007 Drinking Water Crisis

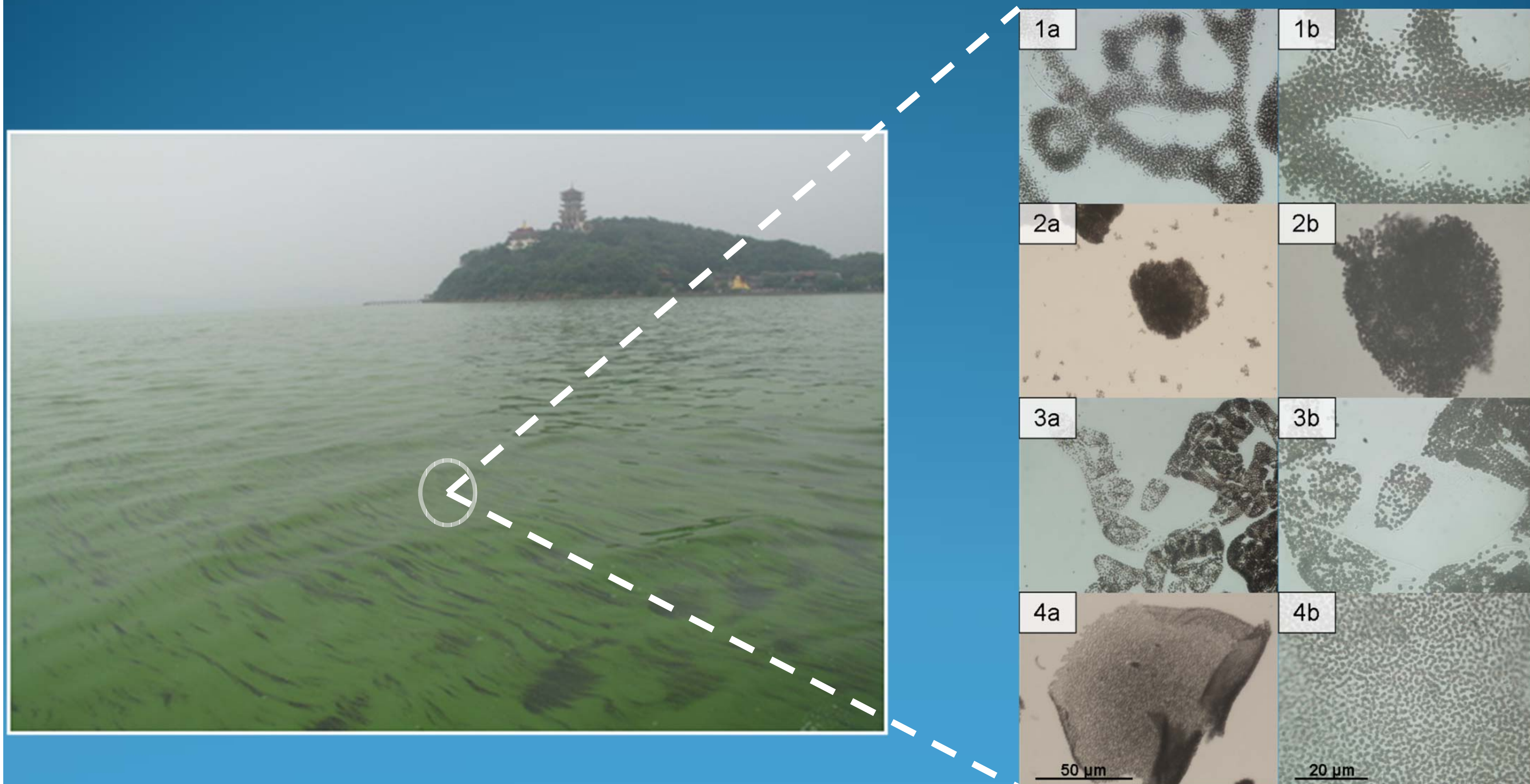
Risk Management



Chorus & Bartram, 1999

Hazard Identification/Characterization

1. Microscopic identification of genera/morphospecies present



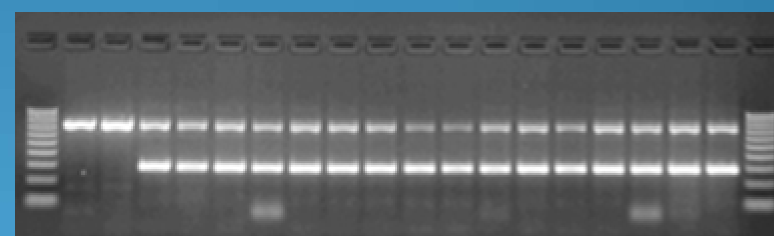
Otten and Paerl, 2011

Hazard Identification/Characterization

2. Are there toxin producers present in *this system*?

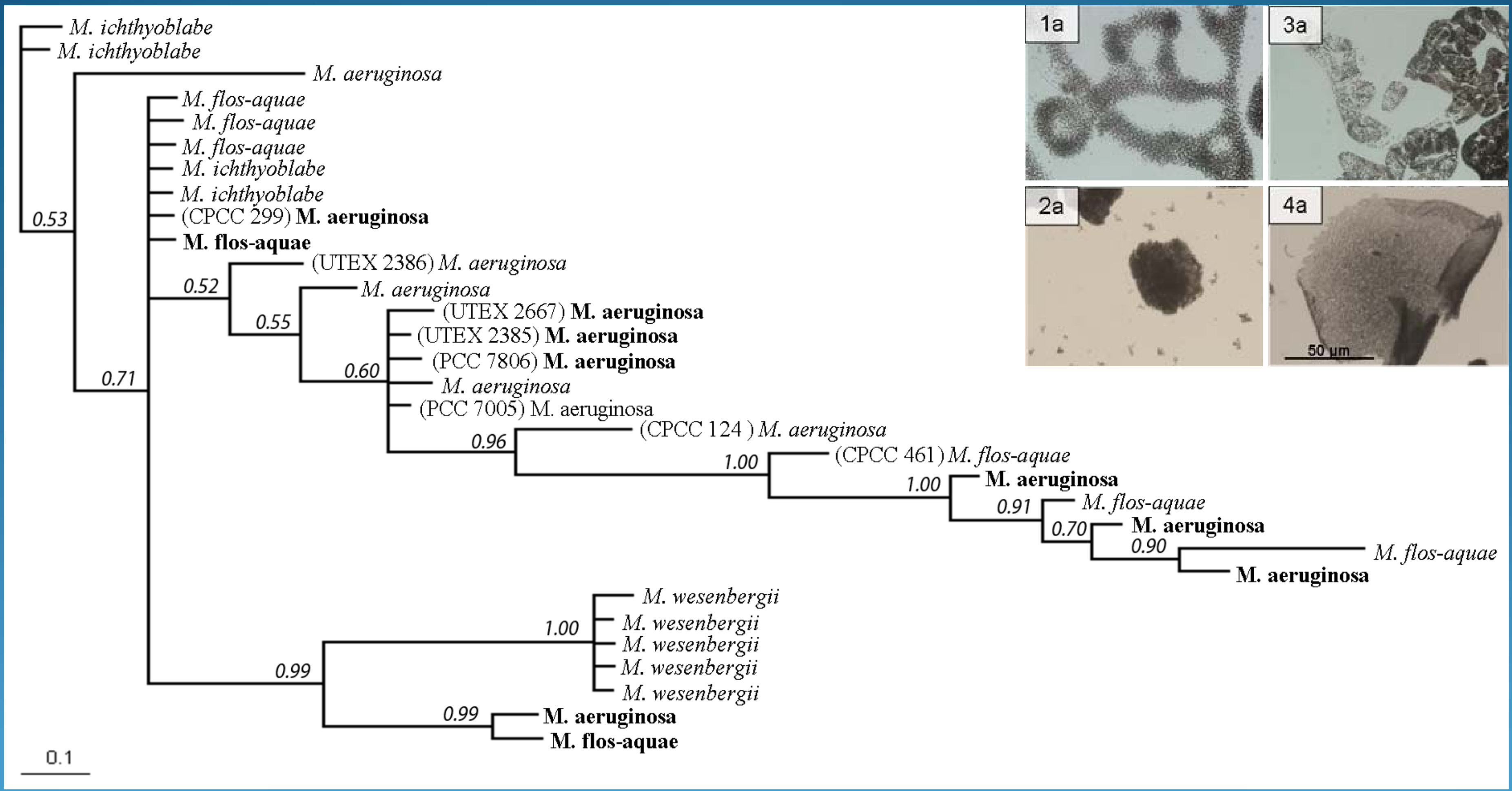
Direct measurements of toxins will indicate if toxin producers are present, but not necessarily which one(s)

Conventional PCR can indicate the presence of potential toxin-producers; false negatives are a concern



Hazard Identification/Characterization

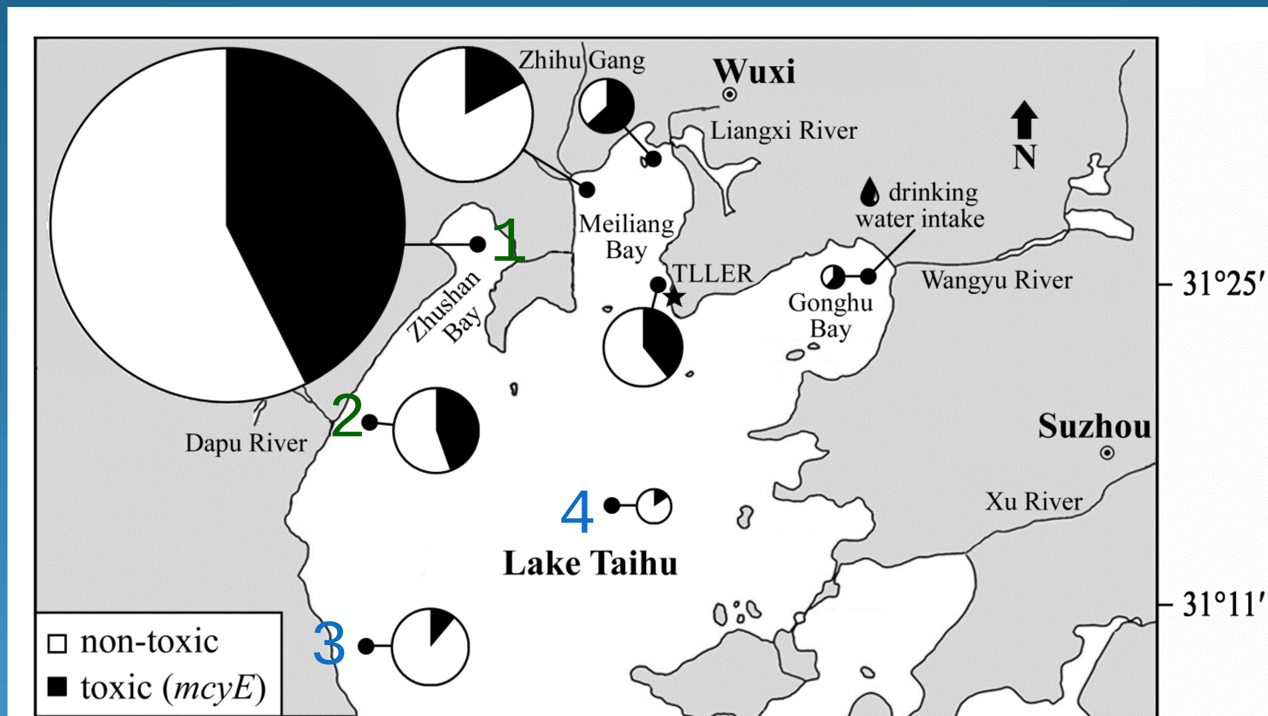
3. Which morphospecies are capable of toxin production?



Otten and Paerl, 2011

Exposure Assessment/Risk Characterization

1. How prevalent is the hazard (e.g., toxigenic *Microcystis*)?

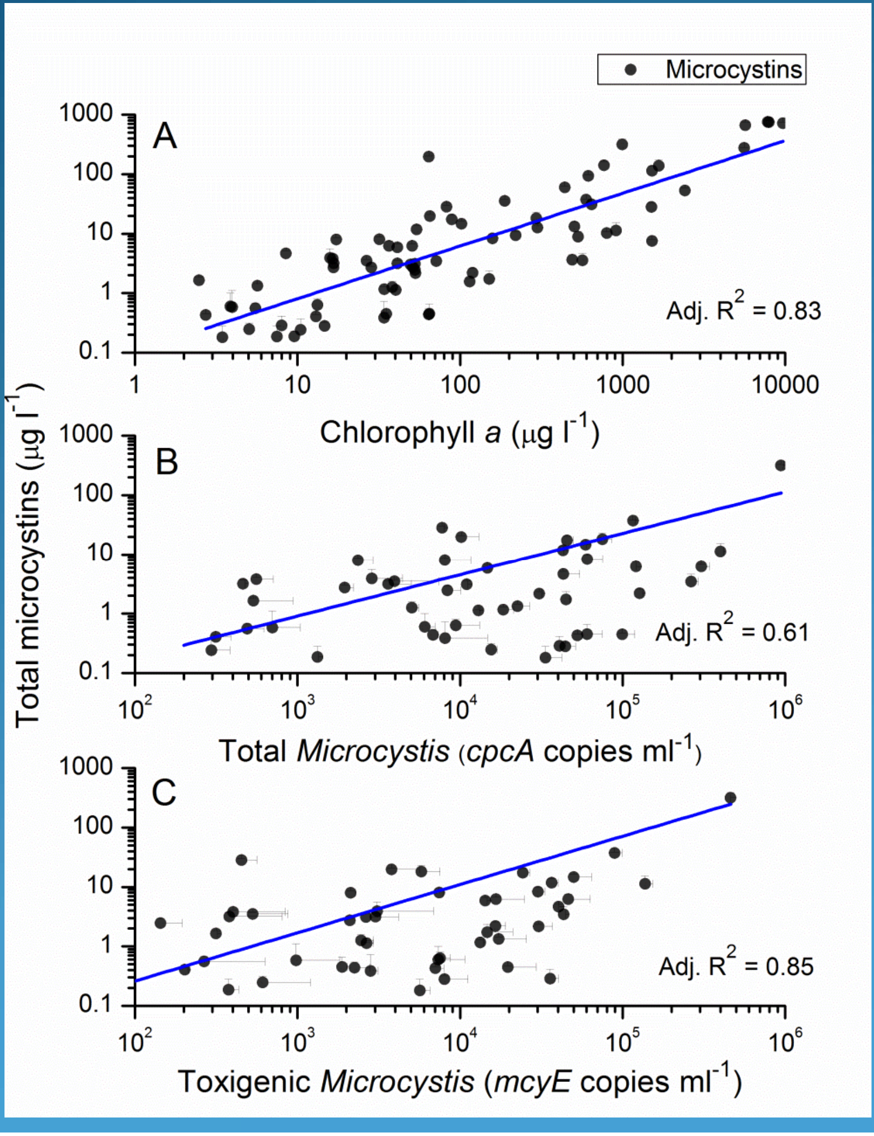


sample site	temperature (°C)	ratio TN:TP	ratio DTN:DTP	avg. DTN (mg l^{-1})	avg. DTP (mg l^{-1})	chl *a* ($\mu g\ l^{-1}$)	avg. MCs ($\mu g\ l^{-1}$)	% toxic (*mcyE*)	turbidity (NTUs)
(1) Northwest (*n* = 12)	26.4 ± 3.1	17:1	29:1	3.62 ± 0.91	0.12 ± 0.10	192.1 ± 359.5	28.7 ± 6.6	42.6	26.4 ± 9.6
(2) West (*n* = 12)	26.8 ± 3.0	18:1	40:1	3.62 ± 0.86	0.09 ± 0.03	97.1 ± 92.3	8.2 ± 0.8	44.6	47.6 ± 23.3
(3) Southwest (*n* = 12)	25.7 ± 3.0	50:1	144:1	2.56 ± 1.00	0.02 ± 0.01	8.6 ± 8.9	1.1 ± 0.1	11.1	34.8 ± 18.0
(4) Lake Center (*n* = 12)	25.1 ± 3.1	58:1	132:1	2.64 ± 0.79	0.02 ± 0.01	7.1 ± 3.9	0.4 ± 0.1	15.5	23.9 ± 12.6
All Sites (*n* = 96)	26.3 ± 3.0	23:1	49:1	3.09 ± 1.06	0.06 ± 0.06	56.1 ± 147.9	6.4 ± 1.2	36.2	32.7 ± 20.3

[a]Sites (1) and (2) = high *Microcystis* biomass and toxigencity (*mcyE* possessing). Sites (3) and (4) = low *Microcystis* biomass and toxigenicity (*mcyE* possessing).

Exposure Assessment/Risk Characterization

2. Can exposure risk be quantified (e.g., MCs in drinking water)?



MCs = 0.07965(chl *a*) + *0.01021*

* Taihu only disinfects with HOCl

Key variables in calculation of water treatment system's specific removal

Effect of treatment

- Concentration
- Time
- Temperature
- pH (lower = greater removal)

Otten et al., 2012

Policy Development

1. Do you treat the symptoms or the causes?
   - Chlorination often assumed ineffective – key lies in removing organic reactants prior to addition

Table 2. Chlorine CT values for reducing microcystin concentration to 1 ugL-1 for a batch reactor.

pH	MCYLR (ug/L)	CT values ($mgL^{-1}min$) 10°C	15°C	20°C	25°C
6	50	46.6	40.2	34.8	30.8
	10	27.4	23.6	20.5	17.8
7	50	67.7	58.4	50.6	44.0
	10	39.8	34.4	29.8	25.9
8	50	187.1	161.3	139.8	121.8
	10	110.3	94.9	82.8	71.7
9	50	617.2	526.0	458.6	399.1
	10	363.3	309.6	269.8	234.9

Westrick, 2005

Policy Development

1. Do you treat the symptoms or the causes?

Remediation of drinking waters

1. Avoid pre-oxidation and cell lysal – toxins are primarily intracellular
2. Most problematic CHABs are positively buoyant – DAF is superior to sedimentation of intact cells but will not remove extracellular toxins
3. Disinfection: O_3 or MnO_4^- > HOCl > NH_2Cl or ClO_2
4. Physical disinfection such as UV can also be effective
5. Auxiliary removal by adsorption (GAC > PAC)

Policy Development

1. Do you treat the symptoms or the causes?

Remediation of source waters

1. Identify major N & P inputs
   - Sewage = 31% TN and 47% TP
   - Industrial point source = 30% TN and 16% TP
   - Ag fertilizer/livestock = 25% TN and 25% TP
   - Can nutrient thresholds be determined (e.g., bioassays)?
2. Effect of hydraulic residence time
   - Can impacted area be flushed out?
3. Stratified systems
   - Will artificial destratification control cyanos?

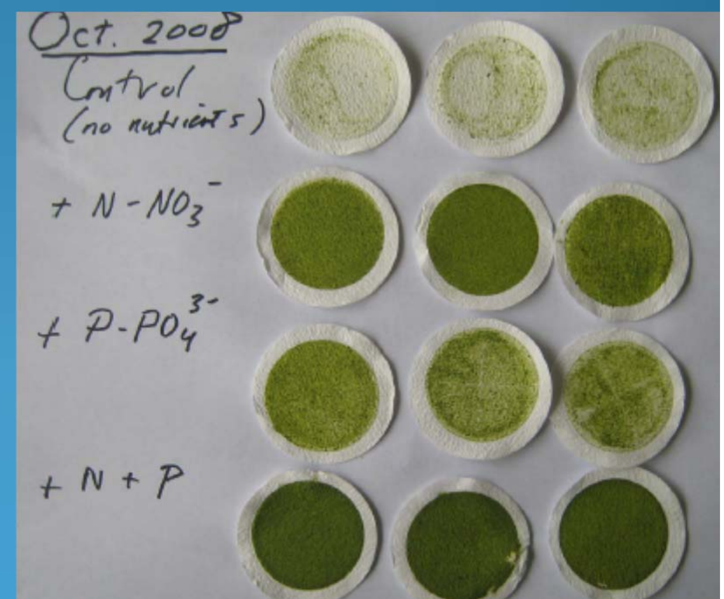
Xu et al., 2010

Policy Development

2. Do you treat the symptoms or the causes?

Remediation of source waters

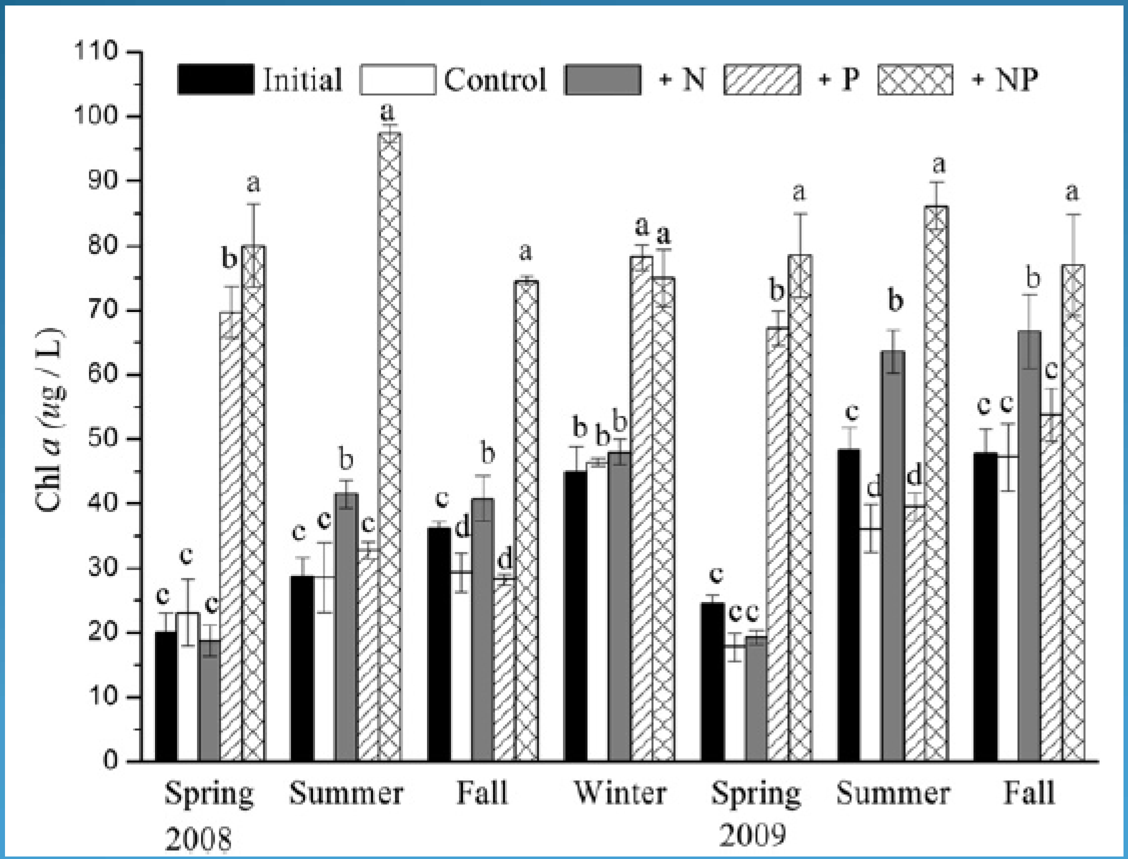
1. Nutrient bioassays

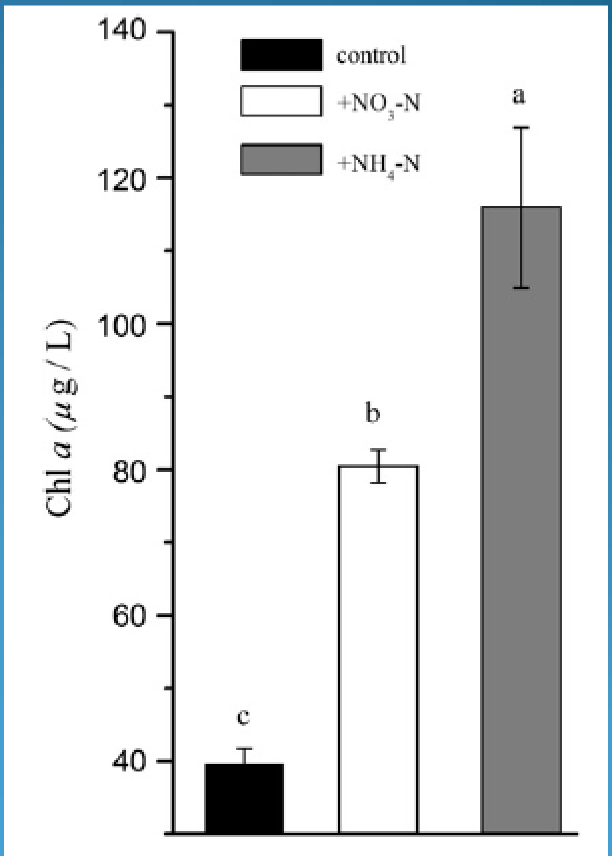


Policy Development

Remediation of source waters

1. Nutrient addition bioassays indicate that N & P are both limiting at different times of the year





Paerl et al., 2011

Policy Implementation

1. Results are ongoing, but a greater than 50% reduction in N & P will likely be needed to mitigate *Microcystis* blooms
2. Potential for community shift to toxin-producing diazotrophs under reduced N scenario currently being investigated
3. Due to highly toxic *Microcystis* populations in the lake, drinking water treatment should account for this
4. Public needs to be educated on cyanotoxin risks

References

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Questions?

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