Occurrence of Nuisance and Toxic Cyanobacteria in Ford Lake, Michigan, USA: Results from a Whole Lake Experiment

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RATIONALE

Introduction

- Ford Lake is an impoundment located in the Huron River watershed in southeast Michigan (Figure 1)
- Important resource for the local community
  - Dam provides hydroelectric power to surrounding region
  - Lake used intensively for recreation
- Ford Lake is characterized by spring diatom blooms followed by late summer blooms of *Aphanizomenon* and toxic strains of *Microcystis*
- Our research has demonstrated that internal loading of nutrients is responsible for generating conditions ideally suited for blue-green blooms
- Summer stratification leads to loss of oxygen in hypolimnetic water, resulting in the release of inorganic nutrients from lake sediments
- High concentrations of nutrients are then made available to algae following mixing events
- A successful management plan requires an integrated approach that will couple lake physics, chemistry, and biological processes

Objective

- Test selective withdrawal of hypolimnetic water as a management solution to halt nuisance and toxic blooms without harming lake recreation or water quality of downstream lakes

Hypotheses

- Selective withdrawal of hypolimnetic water will increase volume and duration of diatom blooms
- Selective withdrawal of hypolimnetic water will reduce volume of blue-green algae
- Reduced volume of *Microcystis* will lead to reduced toxicity

METHODS: FIELD SITE

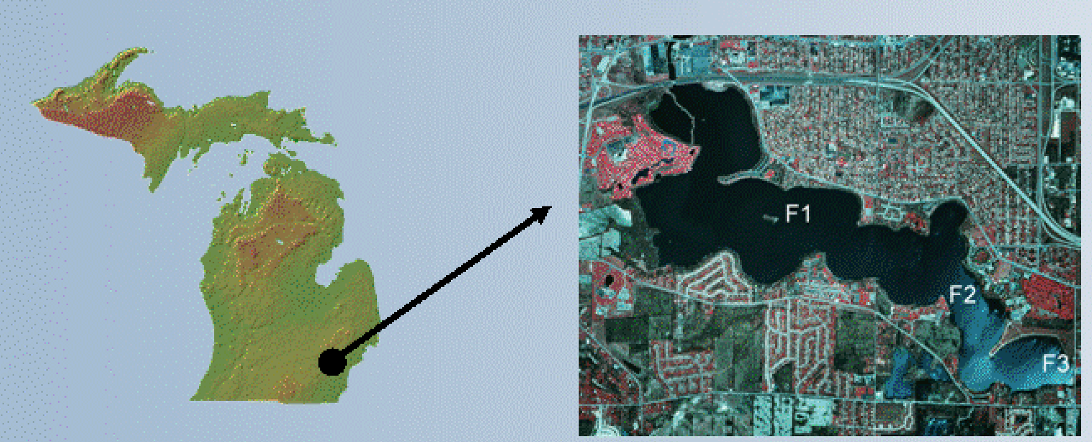

Figure 1. Map of field site with sampling stations F1, F2, and F3 (www.umich.edu/~hrstudy/).

Field Site

- Ford Lake is located in the Huron River watershed in southeastern Michigan (42.221 N, 83.581W; Figure 1)
- Impoundment regulated as "run of river;" i.e. outflow = inflow
- Hydroelectric turbines draw water from topmost 5m of lake depth
- If river discharge exceeds turbine capacity, hydraulic gates are opened at base of dam (11m depth) to expel excess inflow and maintain constant stage height

Selective Water Withdrawal Experiments: 2006

- Objective:
  - Destabilize water column by weakening thermal gradient and deepening the mixed water layer
- Method:
  - Reduce discharge of epilimnetic water to minimum, allowing all available flow to be discharged from the base of the dam
- Selective discharge experiment dates:
  - 22-30 June 2006
  - 14-21 July 2006
  - 28 July – 4 August 2006

METHODS: FIELD OBSERVATIONS

Field Observations

- Timeframe: May - October for years 2005-2007
- Weekly surface water collection from three sites, denoted F1, F2, and F3 (Figure 1)
- Quantitative samples for phytoplankton counts and pigment analyses were collected from 0 to 5m using an integrative tube sampler
- Routine field analyses included: temperature, dissolved oxygen, and Secchi transparency depth
- Chemical analyses included: nitrate, ammonium, dissolved N, particulate N, silicate, soluble reactive P, dissolved P, total P, chlorophyll *a*, phycocyanin, and microcystin by ELISA
- Specific methods for field and chemical analyses have been described in detail elsewhere:
  - EM Lehman, *Water Res* 2007; 41(4):795-802;
  - JA Ferris & JT Lehman, *Water Res* 2007; 41(12):2551-2562.

RESULTS

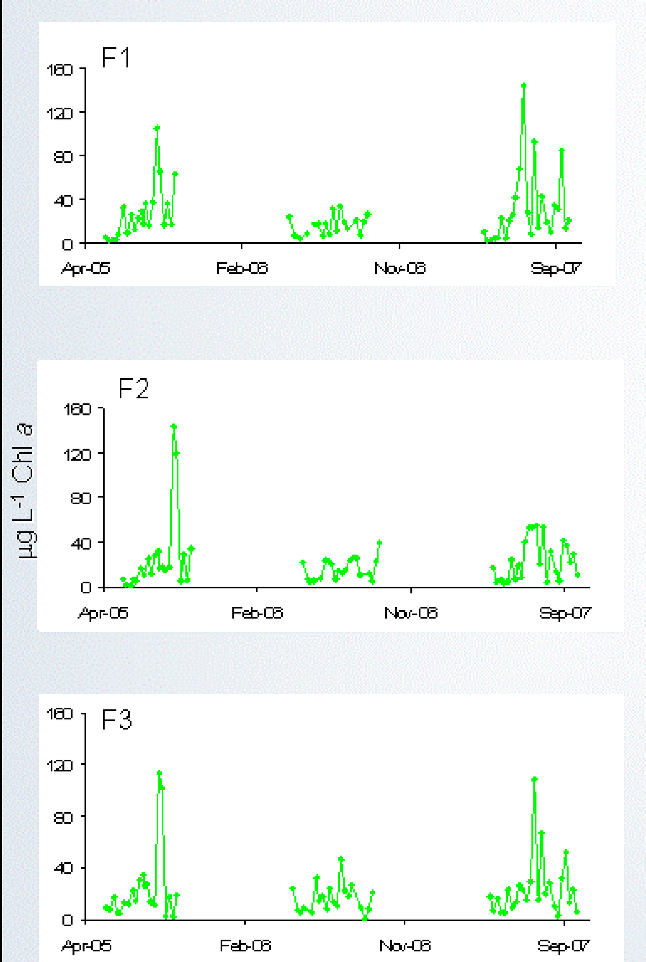

Figure 2. Chlorophyll *a* concentrations (mg L^{-1}) of Ford Lake surface water, June–October 2005-2007, stations F1, F2, and F3.

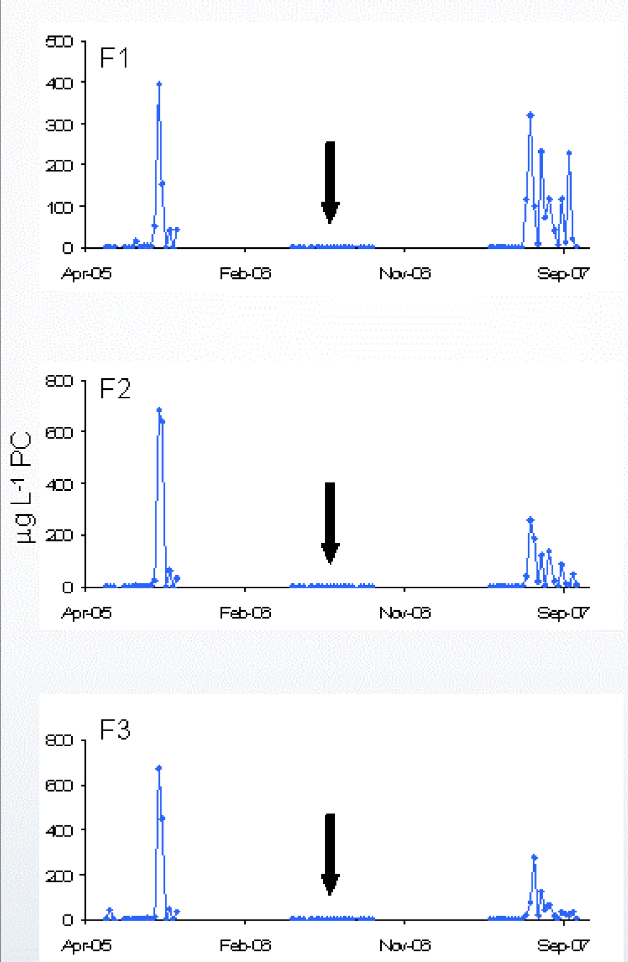

Figure 3. Phycocyanin concentrations (mg L^{-1}) of Ford Lake surface water, June–October 2005-2007, stations F1, F2, and F3.

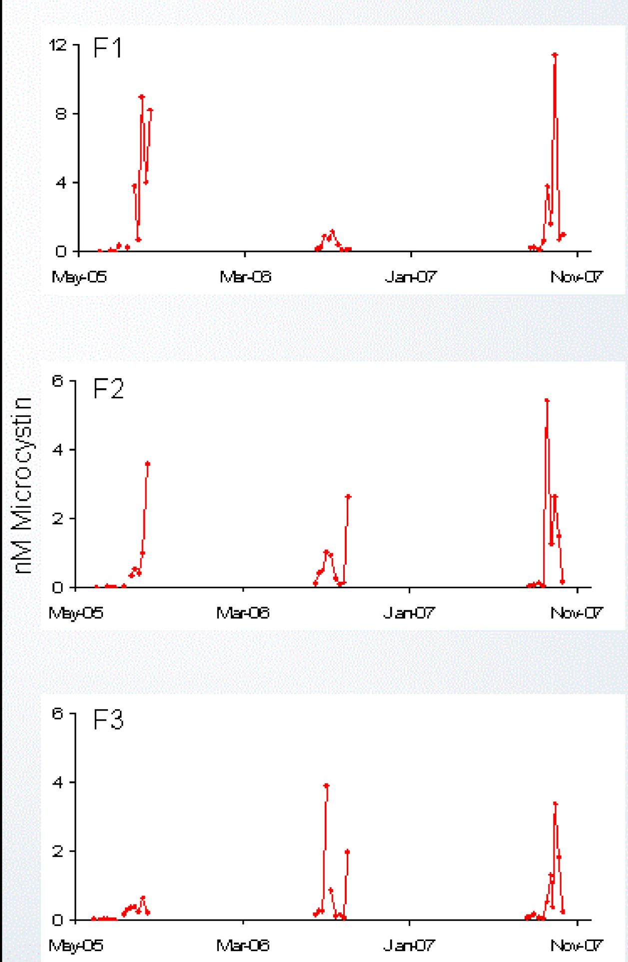

Figure 4. Microcystin concentrations (nM) of Ford Lake surface water, June–October 2005-2007, stations F1, F2, and F3.

Statistical Analysis

- ANOVA tests identified significant variation in PC, SRSi, and NO_3 across the three year study period (Table I)
- Paired T-tests for PC, SRSi, and NO_3 (Table I):
  - 2006 was significantly different from 2005
  - 2006 was significantly different from 2007
  - 2005 was not significantly different from 2007
- 2006 was marked by (Table I):
  - Higher mean levels of NO_3
  - Lower mean levels of SRSi (indicating increased use by diatoms)
  - Near detection limit low levels of PC (indicating decreased biovolume of blue-green algae; Figure 2)
- ANOVA tests indicated no significant variation in Chl *a* across the three year study period (Figure 3)
- Despite differences in ranges of toxin levels observed, ANOVA was unable to detect significant variation in microcystin toxin across the three year study period (Figure 4)
- Peaks in microcystin toxicity appeared to occur approximately one week following a peak in PC, suggesting an association between bloom senescence and toxin expression (not shown)

Table I. Results from ANOVA and paired T-test analyses of NO3, SRSi, and PC. Annual mean values are presented according to sample year.

Analyte	Station	Year	Mean	ANOVA (P-Value)	Years Compared	T-test (P-value)
NO_3	F1	2005	37.15uM	**0.0360**	2005 & 2006	**0.0578**
		2006	46.80 uM		2006 & 2007	**0.0128**
		2007	33.68 uM		2005 & 2007	0.7860
	F2	2005	27.93 uM	**0.0110**	2005 & 2006	**0.0130**
		2006	39.50 uM		2006 & 2007	**0.0104**
		2007	27.80 uM		2005 & 2007	0.7658
	F3	2005	28.09 uM	**0.0030**	2005 & 2006	**0.0242**
		2006	38.12 uM		2006 & 2007	**0.0037**
		2007	23.58 uM		2005 & 2007	0.2947
SRSi	F1	2005	103.43 uM	**0.0027**	2005 & 2006	0.9659
		2006	84.37 uM		2006 & 2007	**0.0087**
		2007	118.77 uM		2005 & 2007	0.1442
	F2	2005	100.37 uM	**0.0027**	2005 & 2006	0.9073
		2006	80.91 uM		2006 & 2007	**0.0106**
		2007	115.10 uM		2005 & 2007	0.1393
	F3	2005	99.78 uM	**0.0010**	2005 & 2006	0.9844
		2006	80.45 uM		2006 & 2007	**0.0074**
		2007	112.66 uM		2005 & 2007	0.1463
PC	F1	2005	45.02 ug L^{-1}	**0.0001**	2005 & 2006	**0.0019**
		2006	0.09 ug L^{-1}		2006 & 2007	**0.0005**
		2007	63.77 ug L^{-1}		2005 & 2007	0.1958
	F2	2005	91.68 ug L^{-1}	**7.88 (0.0023)**	2005 & 2006	**0.0041**
		2006	0.08 ug L^{-1}		2006 & 2007	**0.0002**
		2007	50.14 ug L^{-1}		2005 & 2007	0.3487
	F3	2005	77.34 ug L^{-1}	**12.33 (0.0002)**	2005 & 2006	**0.0032**
		2006	0.34 ug L^{-1}		2006 & 2007	**0.0003**
		2007	38.60 ug L^{-1}		2005 & 2007	0.2806

DISCUSSION

Results of Hypothesis Testing

- Selective withdrawal of hypolimnetic water was associated with reduced biovolume of *Aphanizomenon* and *Microcystis*, as indicated by the dramatic decrease in PC in 2006
- Selective withdrawal of hypolimnetic water increased biovolume of diatoms, as indicated by the absence of variation in Chl *a* and the decrease in SRSi found in 2006
- Reduction of *Microcystis* biovolume did not lead to a comparable reduction in microcystin toxin as measured by ELISA

Ongoing Work

- Currently tabulating cell counts of *Aphanizomenon* and *Microcystis* from the three year study period to confirm biovolume estimates obtained by measuring PC
- Conducting laboratory experiments to isolate which properties select for toxic strains of *Microcystis* and what conditions in addition to bloom senescence increase/decrease the expression of toxin

Conclusions

- Selective withdrawal appears to be a viable management option for improving water quality under certain circumstances
- Environmental sustainability can only be determined by additional experiments and testing of management theory over longer periods of time
- The question of socio-political sustainability exists in a different academic sphere and will require evaluations by the local and municipal governments charged with overseeing such operations in the context of their other commitments and priorities

ACKNOWLEDGEMENTS

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