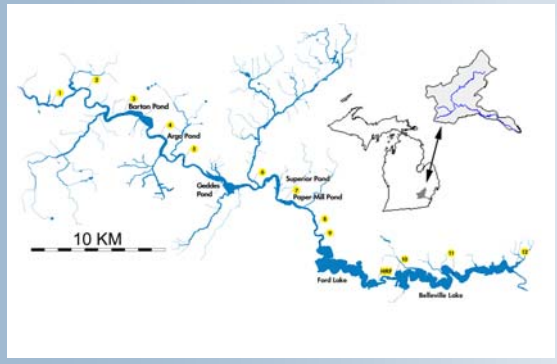
Lake models and lake experiments to control algal species composition

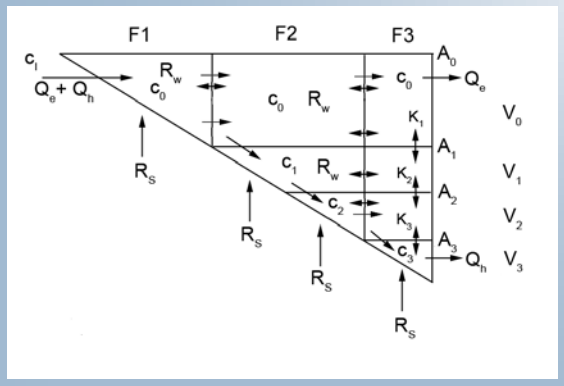
John T. Lehman, Kahli E. McDonald, and Shifra Z. Goldenberg
University of Michigan, Ann Arbor, MI, USA

BACKGROUND

The Huron River of southeastern Michigan includes a series of impoundments, most of which were constructed for hydroelectricity in the early 20th Century. Persistent summer blooms of cyanobacteria, mainly *Aphanizomenon* and *Microcystis*, plague one impoundment in particular: Ford Lake.



Below: 2D box model of Ford Lake, constructed to represent our three sampling sites (F1, F2, F3), and water column vertical profile data. Q_e represents water discharged through turbines; Q_h represents optional discharge through bottom gates. Concentrations (c) are influenced by *in situ* reactions (R_w), sediment-water exchange (R_s), advection, eddy diffusion (K), and air-water exchange in the case of gases. Real-time weather station at F3 provides air temperature, wind speed and direction, humidity, and irradiance.



METHODS AND HYPOTHESES

Enhanced observation program for 2008 field season:

Real time web access to automated sensors at 15 minute intervals-

- **Weather data including irradiance**
- **Temperature at 2, 4, 6, 8 m**
- **D.O./conductance at 6 and 8 m**
- **Chlorophyll and phycocyanin at 3 m**

Automated calculation of turbulence and mixing from KE, PE, temperature and wind stress.

Automated 3D data animation at 1 hour intervals.

Weekly verification of sensor data and collection of plankton by traditional boat sampling.

Spatial resolution by boat weekly at 3 sites.

Experimental Design for 2008

- **Commence experiment at end of June**
- **Discharge 300,000 m³ per day from bottom of dam**
- **Destabilize water column and prolong the spring diatom bloom**
- **Maintain oxic conditions throughout water column and thereby reduce internal nutrient loading**

Numerical Model

- **Custom built to conform to spatial and temporal resolution of data.**
- **Used to guide experiment and to interpret experimental results.**
- **Permitted investigation of relative roles of advection and eddy diffusion in hypolimnetic oxygenation and material fluxes.**
- **Permitted exploration of hypothetical alternative methods for artificial mixing.**

Data Animation

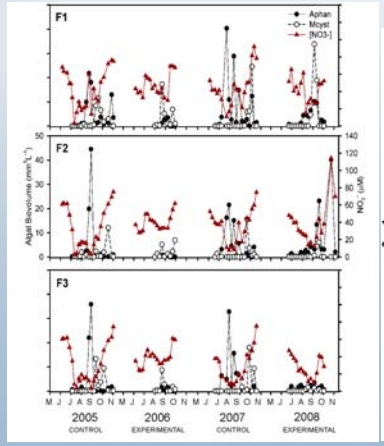
- **Website access to both real-time data and historical data archives**
- **Click and switch between temperature and oxygen profiles**
- **Transparency mask for visualizing spatial Secchi transparency depths; surface masks for spatial distribution of chlorophyll and phycocyanin**
- **Visualize wind speed and direction plus vertical eddy diffusion**

Hypotheses

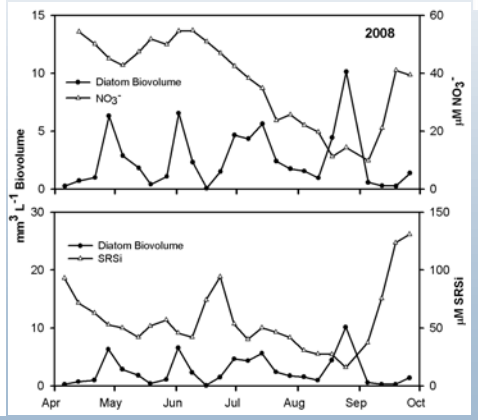
- **The success achieved during pilot experiments in 2006 is reproducible. In particular,**
- **Ford Lake will not export P if deep water remains oxic.**
- **Ford Lake will grow diatoms all summer if deep mixing can be sustained.**
- **Diatoms will consume lake nutrients (N and P), bluegreens will have less resources and will be less abundant than in control years.**

RESULTS: COMMUNITY TRANSFORMATION

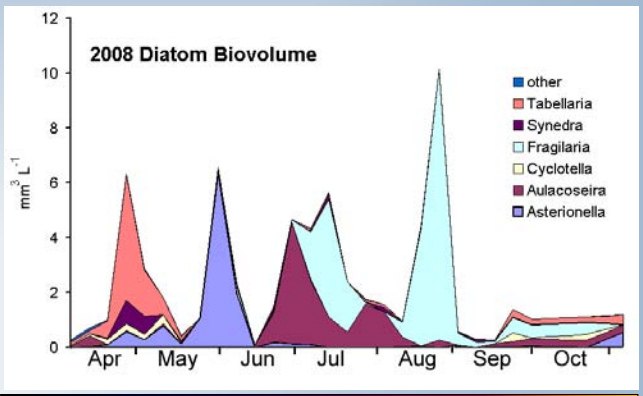
Biovolumes of the nuisance cyanobacteria *Aphanizomenon* and *Microcystis* in control and experimental years. In both experiment years (2006 & 2008), the experiments terminated in August.



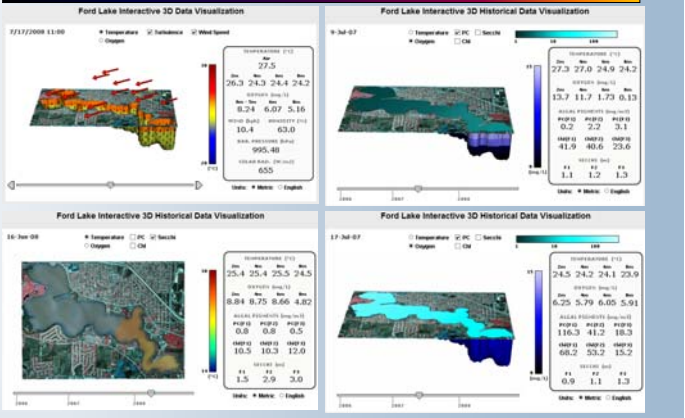
Diatom biovolume during 2008. During control years, diatoms disappear in May and the lake becomes dominated by cyanobacteria by July. Episodes of growth correspond with episodes of accelerated vertical mixing caused by experimental destabilization of the water column.



RESULTS: COMMUNITY COMPOSITION



RESULTS: DATA ANIMATION



Top left: animation of real-time data from *in situ* sensors. Top right: stratified lake with nutrient-rich anoxic hypolimnion on 9 Jul 2007. Bottom right: lake-wide bloom of *Aphanizomenon* following mixing event (compare with top right). Bottom left: visualization of Secchi transparency depth lake-wide. (http://www.umich.edu/~hrstudy)

RELATED PUBLICATIONS

- **Lehman, EM, KE McDonald, and JT Lehman 2009. Whole lake selective withdrawal experiment to control harmful cyanobacteria in an urban impoundment. Water Research (in press) doi:10.1016/j.watres.2008.12.007**
- **Ferris, JA and JT Lehman. 2008. Nutrient budgets and river impoundments: Interannual variation and implications for detecting future changes. *Lake and Reservoir Management* 24: 273-281.**
- **Ferris, JA and JT Lehman. 2007. Interannual variation in diatom bloom dynamics: roles of hydrology, nutrient limitation, sinking, and whole lake manipulation. *Water Research* 41: 2551-2562.**
- **Lehman, JT, JA Ferris, and RA Platte. 2007. Role of hydrology in development of a vernal clear water phase in an urban impoundment. *Freshwater Biology* 52: 1773-1781.**

- **Please view the accompanying digital video examples of data animation.**

ACKNOWLEDGEMENTS

- **This project was part of EPA STAR project R830653-010 and USDA CSREES project 2006-02523**