Whole Lake Experiments to Control Harmful Algal Blooms in Multi-use Watersheds

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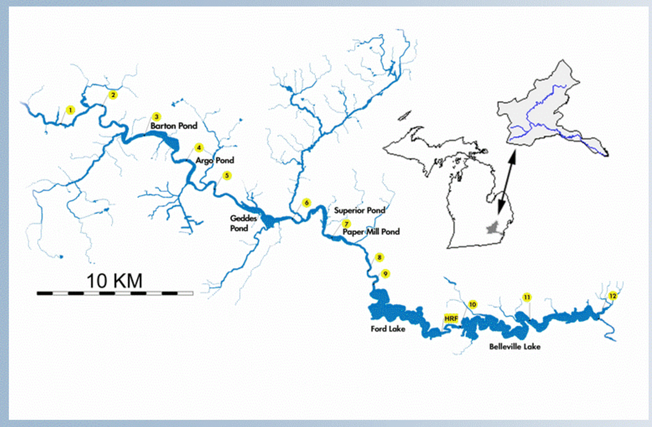
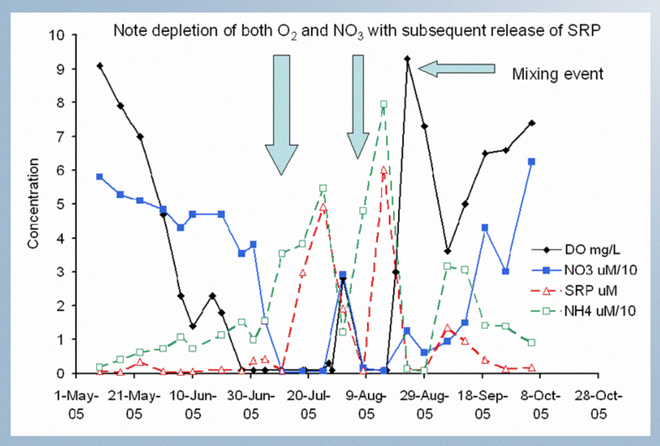
BACKGROUND

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.

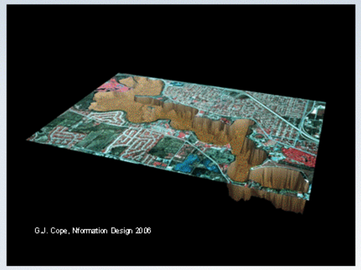


Below: Hypolimnion chemistry of Ford Lake, summer 2004. Severe blooms such as depicted above are inevitably triggered by storm driven destratification after prolonged hypolimnetic anoxia.

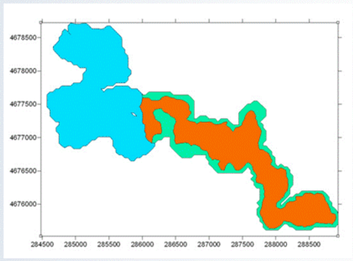


METHODS AND HYPOTHESES

Ford Lake bathymetry and color IR imagery. Outlet dam at lower right.



Ford Lake upstream unstratified (blue), downstream epilimnion (green), and hypolimnion (orange). Scales are UTM coordinates in meters.



Key Features of Outlet Dam

- Dam operates as "run of river" constant stage height; outflow = inflow
- Turbines draw water from epilimnion
- Dam has bottom sluice gates to bypass water at peak flows

Numerical Model

- Whole lake experiments were designed based on a model that characterizes the lake as a thermally stratified two-layer system at its deeper, downstream end, and as an isothermal well-mixed system at its shallower end.
- Each of the three regions was divided into 10 longitudinal sections of equal volume.
- Advective fluxes between compartments was unidirectional downstream and controlled by river discharge.
- Outlet water can be discharged from epilimnion at turbines or from hypolimnion via sluice gates.
- Oxygen consumption at sediment-water interface was based on experiments with sediment cores.
- Vertical diffusion between epilimnion and hypolimnion was modeled as "piston velocities" calibrated against summer 2005 data.
- Simulation results predicted that hypolimnetic discharge at 300,000 m^3 d^{-1} could prevent anoxia.

Hypotheses

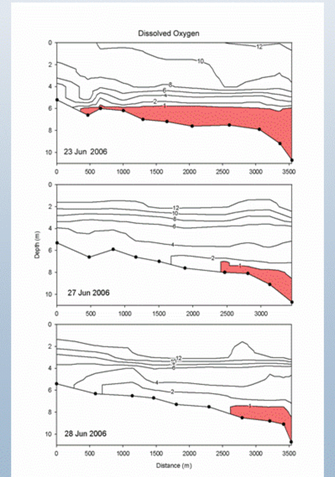
- Ford Lake will not export P if deep water remains oxic.
- Ford Lake will grow diatoms during summer if deep mixing can be achieved.
- If diatoms consume lake nutrients (N and P), bluegreens will have less resource and will be less abundant.

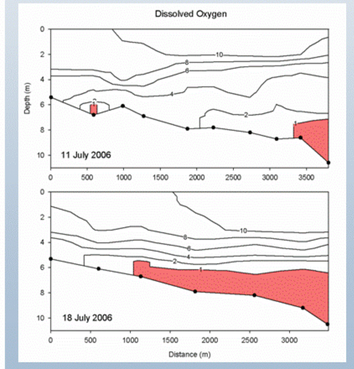
RESULTS: MODEL TESTING

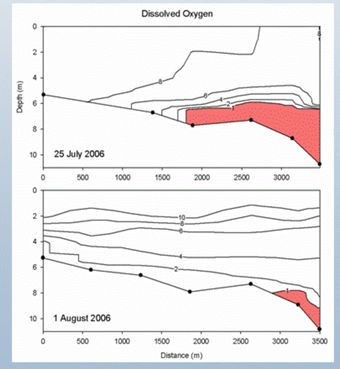
Experiment 2006-1: Calibration. Longitudinal transect. Outlet dam is at right margin of figure. Release 300,000 m^3/d from 22 to 30 June 2006. Note contraction of hypoxic region (red), consistent with model prediction.

Experiment 2006-2: Calibration. Test whether a lower rate of discharge can produce beneficial effects with less loss of hydroelectric capacity. Release half as much water as in 2006-1 (150,000 m^3/d) from 14 to 21 July 2006. Note expansion of hypoxic region (red), also consistent with model prediction.

Experiment 2006-3: Repeat Experiment 2006-1. Release 300,000 m^3/d from 28 July to 4 August 2006. Hypoxic region contracts, consistent with model prediction.

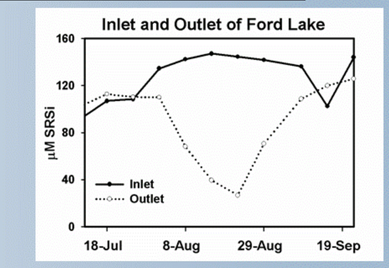




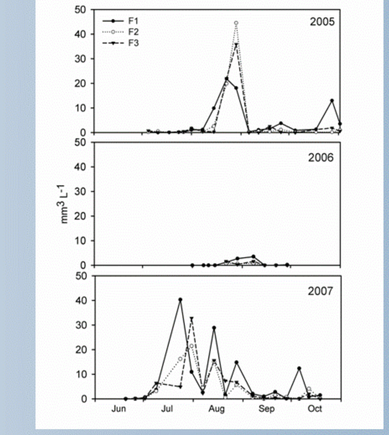


RESULTS: COMMUNITY TRANSFORMATION

- Deeper lake mixing
- Summer diatom bloom
- Severe reduction in cyanobacteria biovolume



Right: *Aphanizomenon* biovolume. Note reduction in 2006 (experimental treatment) compared with 2005 and 2007 (control years). Sample sites identified below.



SUMMER 2007: OXYGEN INJECTION

- We experimented with a novel method of hypolimnetic oxygen injection with the trade name DynamOx. Hypolimnetic water is pumped to shore, where it is supersaturated with pure oxygen at elevated pressure and then returned to depth. The supersaturated water is discharged through capillary tubes, maintaining laminar flow long enough for the oxygen to dissipate into bulk solution before forming gas bubbles.
- Please view the accompanying digital video account of the experiments.

ACKNOWLEDGEMENTS

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