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Introduction

Like many rivers transecting the heartland of America, the Huron River of southeastern Michigan inherits a legacy of rural agriculture, patchwork urbanization, and fragmented management efforts. For more than 150 years, it has generated power for local populations, first for sawmills, then flour mills, woolen mills, and carding mills. The history *Past and Present of Washtenaw County* published in 1906 declared that "the Huron River is believed to be capable of furnishing more power than any other river in the state" and "it is extremely probable that within a short period it will be used more than now for the development of electric power, which it is planned to develop by the building of immense dams."

The Huron River watershed covers 2324 km^2. The main stem extends 218 km from source to its mouth at Lake Erie, with 24 major tributaries adding about 590 km of additional stream length. It is the only state-designated Country-Scenic Natural River in southeast Michigan. However, this watershed is undergoing development-driven transition from rural and agricultural composition to residential and urbanizing conditions.

The main stream was heavily modified during the early 20th Century to generate hydroelectric power. Seven man-made impoundments occupy the heart if the watershed (Figure 1). Six of the dams were built between 1912 and 1932. Detroit Edison developed most of the river valley, starting in 1912 at Barton dam and culminating with French Landing dam in 1924 that created Belleville Lake. Henry Ford meanwhile purchased the river frontage upstream of Belleville Lake and constructed the Ford Lake dam from 1929 to 1932 to supply power to his Motor Company. Dams at 4 of these sites still generate power.

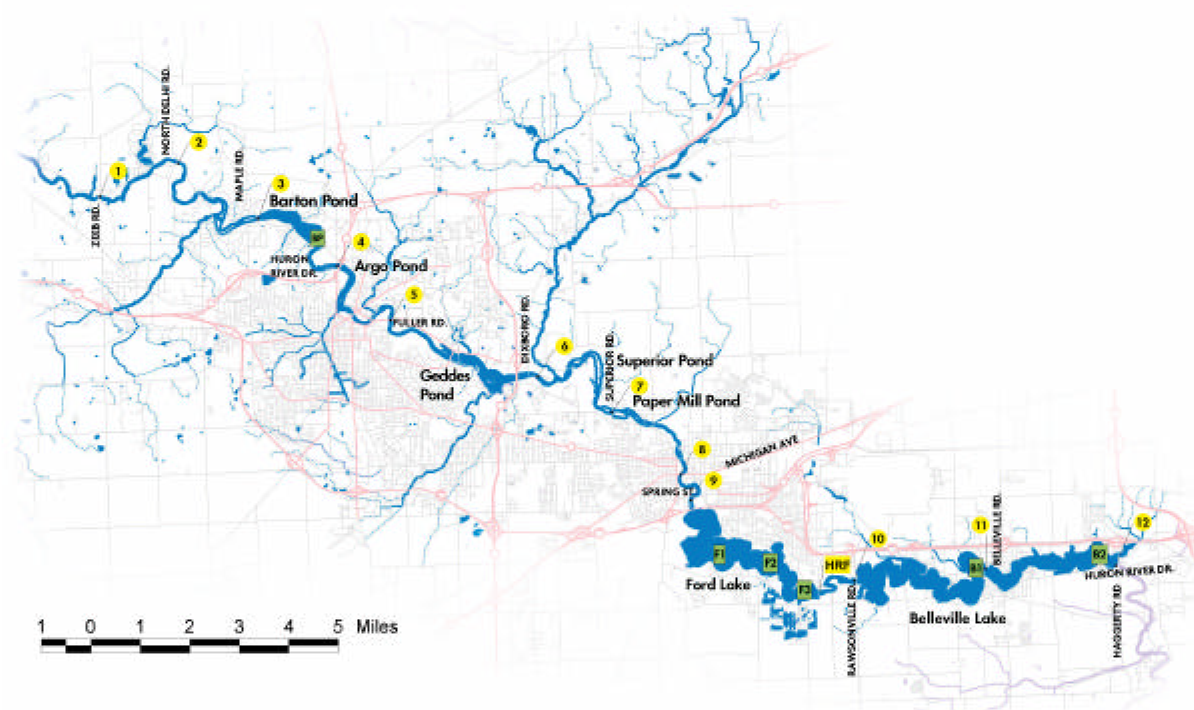


Fig 1. Middle Huron River, SE Michigan; river sampling sites (yellow) and lake sites (green).

Nuisance blooms of *Aphanizomenon flos aquae*, *Microcystis aeruginosa* and other cyanobacteria are regular features during summer. Paleolimnological investigation reveals that Ford Lake has been eutrophic since its creation (Donar et al. 1996).

Efforts to control algal blooms have concentrated on P income. MDEQ (MI Dept of Environmental Quality) officials have been placing ever more restrictive and costly discharge limits on wastewater treatment facilities but there is absolutely no evidence that the strategy, though socially conscious, is working. An unplanned experiment in 2003 revealed quite the contrary. During the Great Blackout of mid-August, Ann Arbor inadvertently discharged more phosphorus in partially treated wastewater into the river and thence to Ford Lake than it had supplied during the previous 2 weeks. Abundant cyanobacteria did not appear in the lake until more than one month later, and then only in response to a weather-related mixing event that stirred up anoxic hypolimnetic water with over 6 μM phosphate (Figure 2).

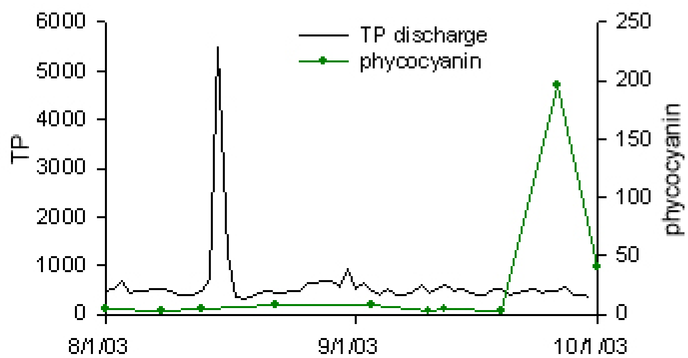


Figure 2. External TP loading (mol/d) to Ford Lake and phycocyanin (μg/L), proxy for cyanobacteria abundance.

During the past 3 years we have been studying nutrient loading and bloom dynamics in the middle Huron River and its lakes with the object of developing an effective management plan in close partnership with municipal governments and state officials. We have demonstrated that during the summer more phosphate and ammonia are released from anoxic lake mud than enters the lake with the river. Severe blooms such as depicted in Fig. 3 are inevitably triggered by storm driven destratification after prolonged hypolimnetic anoxia.

Figure 3 (left) and (right). Water bloom of *Aphanizomenon*, Ford Lake August 2004.

Cyanobacteria bloom lake-wide in spectacular abundance. Conditions during summer 2005 were considered by many lakeshore residents to be the worst in memory. They are all the more striking because the lake exhibits a classic Clear Water Phase in late spring associated with high abundance of *Daphnia mendotae* (Figure 4). Even after the *Daphnia* populations succumb to food limitation and predation, cyanobacteria do not increase until about 2 months later. During 2005 the triggering event was a cold front in mid August with winds approaching 20 knots.

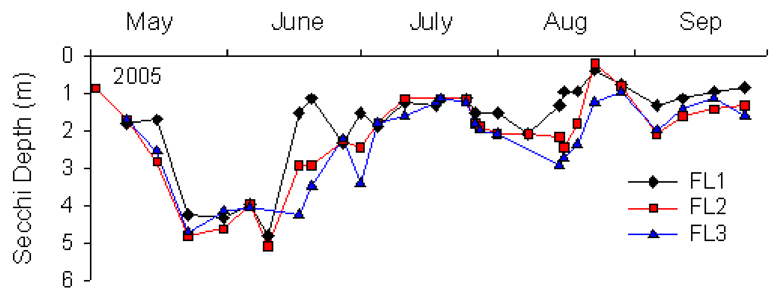
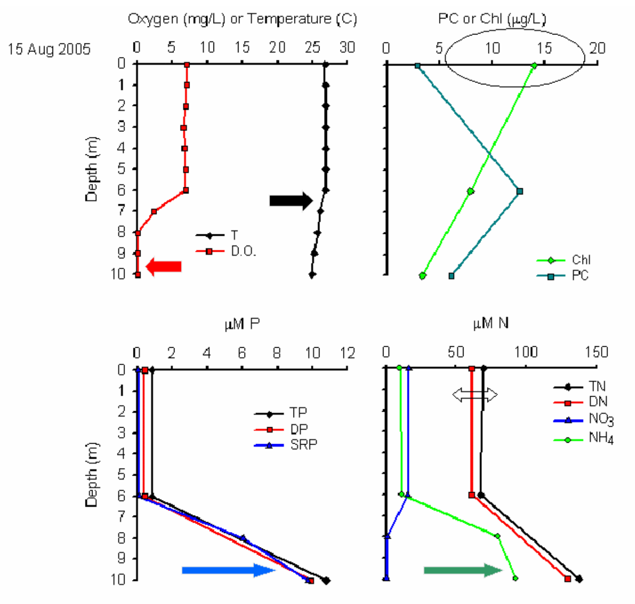


Figure 4. Secchi transparency depth at 3 stations in Ford Lake from west (FL1) to east (FL3).

On 15 August the lake was thermally stratified, the hypolimnion was anoxic and rich in phosphate and ammonium, and both chlorophyll and phycocyanin were low and not indicative of bloom conditions (Figure 5).



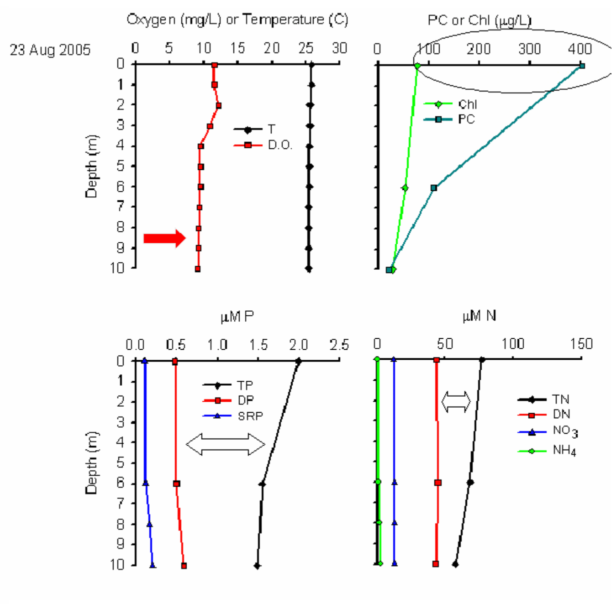
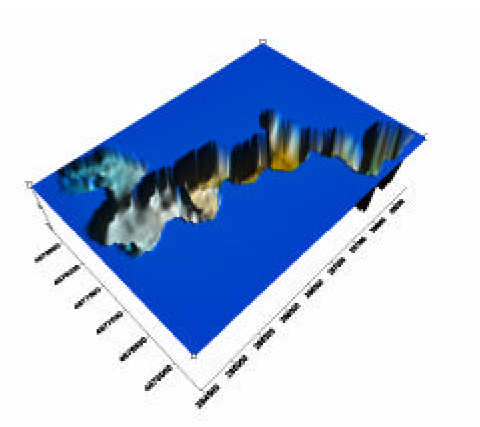


Figure 5 (left): Lake conditions on 15 Aug; Figure 6 (right): conditions a week later.

By 23 August (Figure 6) the lake had mixed, phosphate and ammonium had been consumed and converted into particulate P and N, cyanobacteria increased dramatically and concentrated at the surface, and oxygen became supersaturated. Epilimnion levels of TP doubled. To make matters worse, the initial bloom of *Aphanizomenon* was succeeded by a toxic strain of *Microcystis* that brought microcystin levels above 10 nM (Lehman, ms. in review).

Causes and Adaptive Remedies

Ford Lake is a steep sided basin (Figure 7) protected by surrounding bluffs on both north and south (not shown). Stratification-induced internal loadings are exacerbated by hydroelectric operations. Although hypolimnetic discharge is possible, the hydrostation design is such that power can be generated only if water is drawn from the epilimnion (Fig. 8). As stratification develops, station operators are increasingly reluctant to discharge from the hypolimnion owing to State regulations on the oxygen content of discharge water for protection of downstream fisheries. However, the dam is licensed to operate as "run of the river" so lake stage height must be controlled. If river input exceeds the capacity of the turbines, the excess water is released from the bottom. This occasionally creates problems when excess water forces a release of anoxic, sulfide-rich water contributing to fish kills.



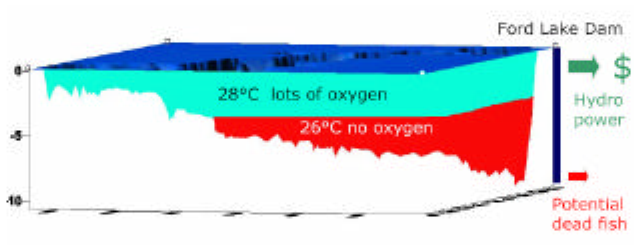


Figure 7 (left) Ford Lake bathymetry. Figure 8 (right) summer conditions.

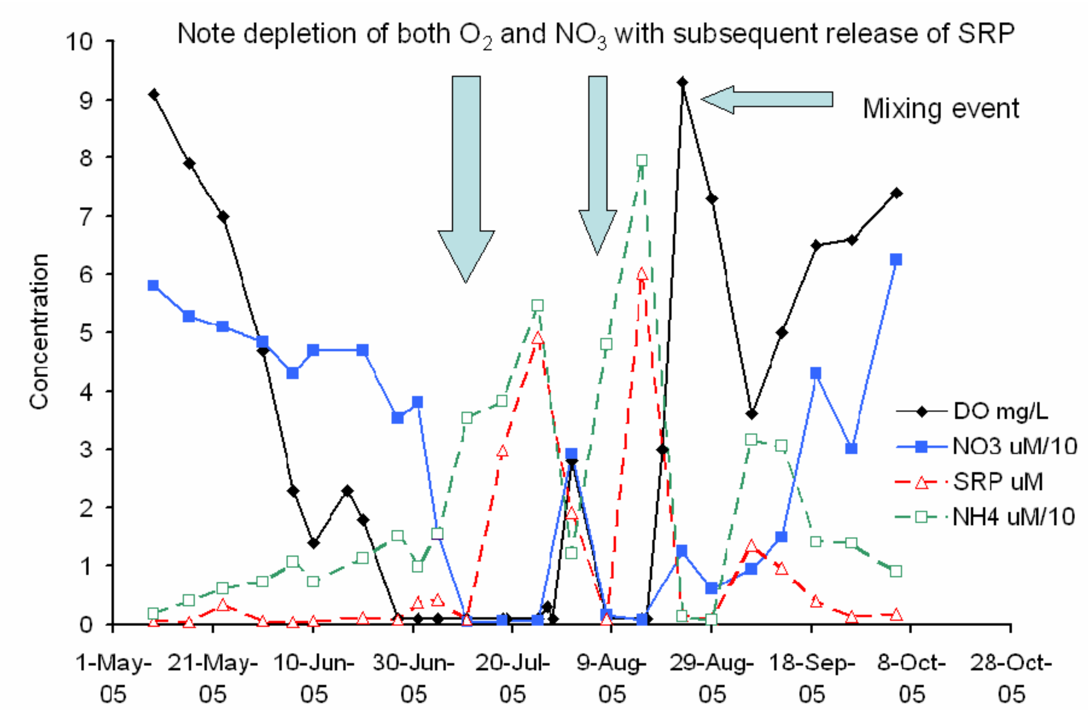


Figure 9. Hypolimnion chemistry of Ford Lake, summer 2005.

For cases like this, where internal nutrient loading from sediment sources are implicated, a range of management options has been proposed (Straškraba 2005):

- Sediment oxidation
- Sediment removal
- Sediment capping
- Chemical additives (algaecides)
- Artificial circulation
- Selective depth withdrawal
- Biomanipulation

The PI has discussed each of these options with the Middle Huron Partners (a coalition of municipal officials), the Ypsilanti Township Water Conservation Advisory Committee, the Township Governing Board, hydropower operators and supervisors, and representatives from MDEQ (water quality) and MDNR (fisheries). Sediment capping, removal, and algaecides are dismissed owing to the logistics (e.g., disposal) and expense for such a large lake (4 km^2). Further, MDNR opposes biomanipulation owing to the existence of a self sustaining walleye population and one of the most productive warmwater sport fishing lakes in Michigan. Besides, to overstock with piscivores it would take the entire hatchery output of the state DNR, and concerns about pathogens in stocks from Wisconsin and Minnesota rule out those states as sources.

Artificial circulation would require up to 25 moored devices of the "Solar Bee" ilk, and the navigation hazards on such a heavily used lake are unthinkable. The remaining options are hypolimnetic oxygen injection and selective depth withdrawal at the dam.

Accordingly, we used our research data to develop a computer simulation model of Ford Lake. The model integrates physics, chemistry, biological processes, and economic factors. We divide the lake into 3 main sections (Figure 10), and divide each section into 10 serial compartments.

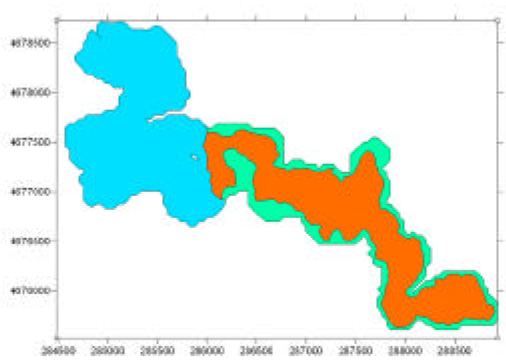


Figure 10. Ford Lake upstream epilimnion (blue), downstream epilimnion (green), and hypolimnion (orange). Scales are Universal Transverse Mercator coordinates in meters.

The model projects two feasible ways to control the cyanobacteria: (1) hypolimnetic discharge commencing before anoxia develops, at discharge rates predicted daily by the computer model; (2) injection of oxygen at a particular site in the hypolimnion, at times predicted adaptively by computer model. The model further includes provisions to optimize generation of electricity (and township revenue) subject to constraints aimed at minimizing algal blooms and fish kills. Township officials have generously shared data logs and personnel resources, and they are eager to test the theory at the whole lake level, even if at some cost to hydroelectricity revenue.

To illustrate feasibility, the model was used to simulate hypolimnetic oxygen during summer 2005, using actual amounts of water logged as drawn from the epilimnion and discharging through the turbines, or released from bottom gates. Figure 11 shows the model projection for the hypolimnetic compartment near the dam compared with actual oxygen measurements near the dam.

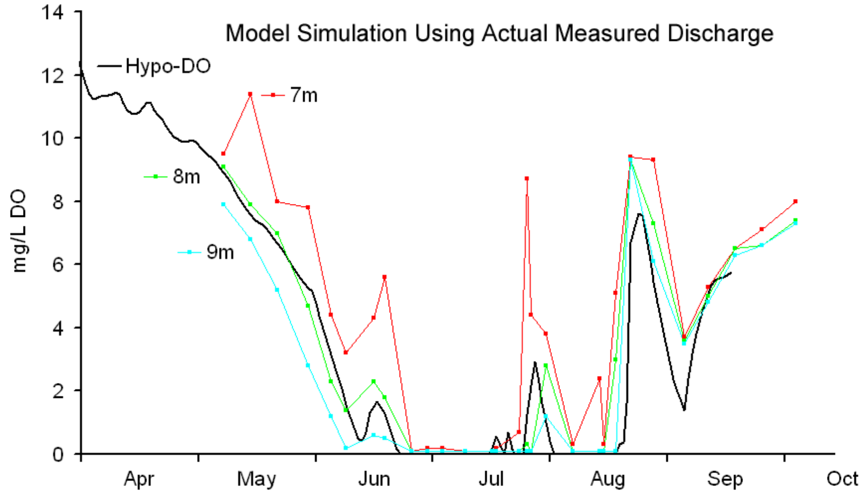
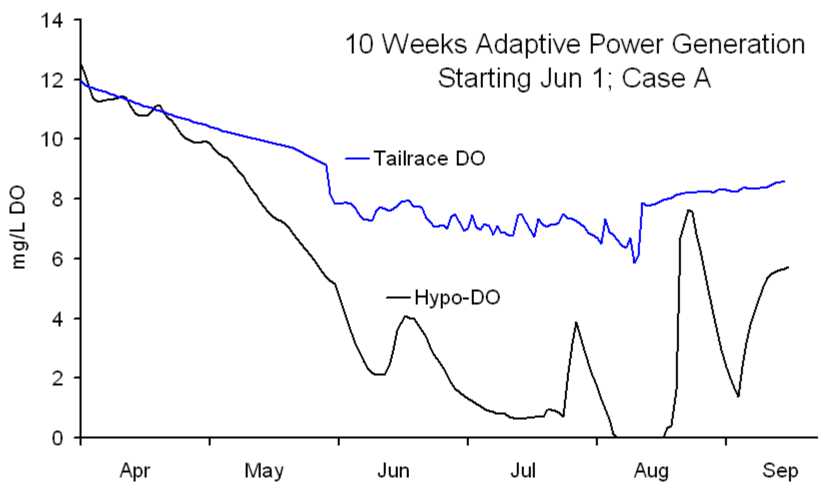
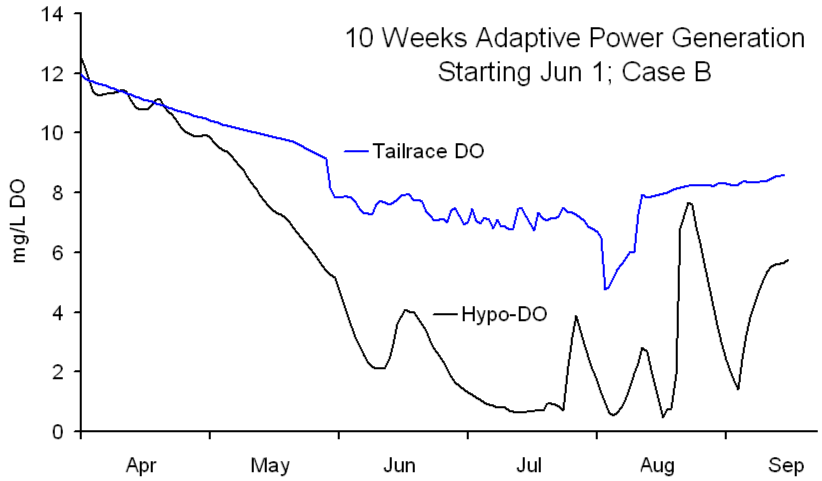


Figure 11. Model (black line) plus measured oxygen at 3 depths in the hypolimnion, 2005.

We then performed two model simulations intended to explore the theoretical effect of selective withdrawal for 10 weeks starting 1 June. In Case A we simulate release of 200,000 m^3 of water from the bottom each day unless that flow would rob the turbines of enough force to generate electricity. In that case, the choice is to generate electricity and throttle the bottom discharge. Both hypolimnion and tailrace oxygen projections are shown. Note that this strategy results in anoxia during early August.



In Case B, bottom discharge was given priority over hydropower. If river flow was insufficient to generate power and also discharge 200,000 m^3 from the hypolimnion, the turbine gates were closed to all but unavoidable leakage of 86,000 m^3 per day. The result was an oxic hypolimnion during the entire period, adequate tailrace oxygen to protect high densities of fish that aggregate there, and expected curtailment of phosphate release from the hypolimnetic sediment. Based on gross revenue from Detroit Edison per KW-h, Case A would have cut revenue by $10403 and Case B would have cost little more: $10892.



Finally, we simulated injection of oxygen. Oxygen demand is about 1000 kg per day based on experiments with sediment cores. For point source oxygen addition we need an advective flow to prevent supersaturation and to aid horizontal dispersion. That means some hypolimnetic discharge is needed. There is a range of possible scenarios (not shown here) but the bottom line seems to be that between lost revenue associated with hypolimnetic discharge and all costs associated with purchase of oxygen, tank rentals, deliveries, and injection the cost is about 10 or 11 thousand dollars, practically the same as Cases A and B.

The preceding research has helped to cement partnership with the community groups and organizations that want to find the best way to clean up their river and its lakes (see supporting letters). We now have theory that needs to be put to the test with blessing and logistical support from a governing board of elected municipal officers. Whole lake experiments are now needed to test whether a fundamentally new approach to environmental management of these ecosystems will produce a desired outcome that has eluded state and local authorities for decades (see Lehman 2000, Nriagu et al. 2001 for historical review).

Magnitude and Relevance of Issues

Survey results obtained from 642 residents in the vicinity of the affected lakes demonstrate that 73.8% consider the algae to be a serious problem, serious enough to affect their recreational activities (83.9% of n= 641), including swimming, fishing, boating, water skiing, and contact recreation in general. Fully 86.1% of 633 respondents reported that they would not eat fish from these lakes. Of 566 respondents, 54.8% believe that current efforts to improve the situation are too little (36.3% say they don't know what is being done). Significantly, 71.7% of 424 respondents said that they would be willing to pay $50 per year or more in additional taxes (37% said $100 or more) if improvements could be made. Complete survey results are posted at www.umich.edu/~hrstudy.

Role of Stakeholders

This is a well-integrated program with engagement by municipal environmental directors, citizen advisory boards, and elected officials. Moreover, the Huron River Watershed Council, an NGO sponsored by all of the jurisdictions in the watershed, is a close partner and subcontractor in this initiative.

Continuing Objectives

The ultimate goal of this project is substantial reduction or complete elimination of cyanobacteria blooms in the impoundments of the Huron River watershed, so as to protect and enhance the region's natural resource base and environment. The watershed is being transformed in patchwork fashion from agriculture to residential and urban use, causing changes in hydrology and water quality. The river is used for drinking water, and toxins have been identified thoughout the treatment process. Moreover, surveys of residents demonstrate that the cyanobacteria affect quality of life issues including access and enjoyment of lake resources, and fish consumption. We have already laid the groundwork by providing scientific evidence and logic that convinces municipalities (Ann Arbor, Ypsilanti Township, Van Buren Township) to try alternative management theory. If the alternative theory is supported by whole lake experiments, the communities probably can be convinced to make capital improvements of a structural nature that would permit sustainable operations without loss of hydropower revenue.

Before a course of expensive retrofitting is encouraged, it is imperative to conduct experiments that demonstrate whether or not it will be worth the economic expense.

1. Use existing mass balance budgets for nutrients and in-lake properties to represent baseline conditions in three lakes: the target lake for experiments, a lake upstream of it, and the lake downstream.
2. Continue to measure inputs, outputs, and in-lake conditions of these 3 lakes during the experimental periods.
3. Generate real time numerical projections of the amount of water that should be discharged from the bottom of the dam, or the amount of oxygen that should be injected into the hypolimnion, to maintain oxic conditions and prevent release of phosphate. Provide these projections to the dam operators and have them implemented.
4. Evaluate changes in the experimental lake with the control lake upstream as well as the lake downstream, and with pre-experiment conditions, to determine whether expected changes occur in the experimental lake, and not in the others.
5. Refine and improve model structure and parameters through feedback from scientific results.
6. Communicate findings and interpretations regularly with our community and municipal partners, incorporate their feedback into continuing measurements and analysis, and formulate recommendations for sustainable environmental improvement.

Theory and Practice

Internal Phosphorus Loading- Before our recent study, knowledge about internal loading and retention of P in Ford and Belleville Lakes was limited by sparse data and poor understanding of storage changes (Brenner and Rentschler 1996; Brenner and Nicita 1997; 1998). Both Owen (1991) and Quets (1991) constructed budgets for Ford Lake that indicated that the lake sometimes exported more P than entered it. Belleville Lake more often than not exhibited negative retention values for TP, indicating major sources of P at or in the lake itself. These internal sources can overwhelm the rates at which P is lost to the sediments.

Ever since Mortimer's (1941) classic experiment with enclosed lake mud, limnologists have recognized that so long as oxygen remains at the sediment surface and redox potential remains high, ferric iron works as an insoluble "trap" for phosphate in the mud (Edmondson 1991). When oxygen is absent, iron is reduced, the "iron trap" for P is defeated, and both Fe^{2+} and P enter the lake water in large quantities. The molar ratio of Fe to P generally needs to be greater than 2 for this mechanism to operate effectively (Manning et al. 1994). At lower ratios a different mechanism can operate with similar outcomes. Gächter et al. (1988) demonstrated that sediment bacteria release intracellular P into the water under anoxia but that they re-assimilate the P when oxygen is supplied.

X-ray fluorescence analysis of Ford Lake sediment cores during summer 2005 established that the molar ratio of Fe to P is 14.9 (SD= 1.7, n= 35). Moreover, P is positively correlated with Fe in cores (R = 0.88) and 96% of the variation in P across sites and along 8 cores can be explained by linear model combination of Fe (positive correlation) and Al (negative effect owing to dilution by clay). Ford Lake is ideal, therefore, for management principles based on the iron trap concept.

These principles have been the basis for numerous remediation efforts through hypolimnetic aeration (reviewed extensively by Pastorok et al. 1980, McQueen and Lean 1984, Prepas and Burke 1997). The efforts have yielded inconsistent results, attributed in part to incomplete data, improper experiment design, or inadequate experiment control. Direct injection of oxygen has been another technique. Prepas et al. (1997) summarized results from Amisk Lake, Alberta, a lake of ca. 5 km^2 surface area, similar to Ford Lake. Hypolimnetic anoxia was prevented, TP concentrations in both epilimnion and hypolimnion declined dramatically, chlorophyll levels were halved, and the phytoplankton community became more diverse. Nonetheless, it must be acknowledged that aeration does not always produce the expected outcome. Typically, stratification and temperature regimes are affected, and these can change metabolism and ecological interactions. Even in Amisk Lake, with less physical disturbance owing to use of pure oxygen, hypolimnetic temperatures became elevated and oxygen demand correspondingly increased.

Anoxic conditions regularly occur during summer near the bottom of both Ford Lake and Belleville Lake, and phosphate concentrations become enriched as phosphate leaves the sediment (Figs. 5 and 9; also Kosek 1993, 1996, 1997a, 1997b). Significantly, anoxia does not affect Barton Pond, upstream of Ford Lake. The City of Ann Arbor draws about 70,000 $m^3\ d^{-1}$ for drinking water from the bottom of the lake. This results in a detention time of only 6 days for hypolimnion water in that basin.

Conditions that favor internal loading of P also favor blooms of cyanobacteria (Schindler 1977). These are (1) little vertical mixing- slack winds, strong sunlight and warm temperatures, and (2) low oxygen levels at the sediment surface during daytime (Hecky et al. 1994). P that leaks from the sediments into bottom waters during daytime stratification may become entrained by convection into upper lake waters during the night, or during cold and windy weather events.

In combination with adequate P concentrations, important bloom-generating factors are (1) ratio of TN to TP, (2) water column stability, or incomplete vertical mixing, and (3) optical depth, the ratio of light penetration depth to mixing depth of the lakes. Cyanobacteria prosper at low ratios of N to P because many species can fix nitrogen from dissolved gas (Carpenter et al. 1998), and because other species seem to outcompete eukaryotes for ammonium in the absence of nitrate (Edmondson et al., 2003). In order to protect lakes from nuisance blooms of cyanobacteria, it is necessary to keep the ratio of TN to TP at about 30:1 or greater by mass (66 by moles). Cyanobacteria are considered to be competitively favored over other species at lower TN:TP ratios (Schindler 1977; Smith 1983; Barica 1990). Eukayotes typically become growth limited by lack of N, and N-fixing cyanobacteria typically appear when the total of nitrate and ammonium nitrogen drops below 50 to 100 mg m^{-3} (3.6 to 7.1 µM; Horne and Commins 1987). The degree to which internal P loading promotes the growth of cyanobacteria rather than other kinds of algae is thus tied to the N dynamics of the sediment-water interface (Gophen et al., 1999). Along with changes in phosphate, there are reactions that eliminate nitrate, and also create or release ammonium into the water. The net result is internal loading of TN to TP at particular ratios. The ratio of these fluxes in Ford Lake is roughly 10:1 by moles, a ratio that strongly favors cyanobacteria.

Next Steps

The results obtained to date have placed our understanding of this system on a solid foundation. Inevitably, they have led to a new series of questions:

Q1. Will rates of selective water withdrawal predicted by a numerical model prove sufficient to prevent anoxia and to reduce accumulation of phosphate and ammonium?

Q2. Will rates of oxygenation predicted by the same model prevent anoxia and reduce accumulation of phosphate and ammonium?

Q3. Will reductions in hypolimnetic concentrations of P and N lead to (a) reduced epilimnetic P, (b) reduced nutrient export to downstream lakes, (c) reduced summertime algal biomass, and (d) reduced occurrence of cyanobacterial blooms?

Q4. Can computer-generated projections be translated into operational decision making fast enough to control water quality?

Q5. Can an algorithm be developed to improve management practices with attention to both environmental quality and economic considerations?

In order to answer these questions and fulfill expectations, we hope to proceed as follows:

(1) Conduct mass balance and in-lake measurements on 3 major lakes in the watershed: an upstream control, an experimental lake, and a lake downstream from the experimental basin. Each of these lakes now have 3 years of pre-manipulation data for reference.

(2) Apply a computer model already developed in Excel™ and Visual Basic to real time available water flow data and lake conditions to guide decisions about water discharge at a hydroelectric dam.

(3) Refine the model to improve the treatment of weather effects on lake stratification and vertical mixing.

(4) Coordinate activities with outreach and stakeholder involvement (see attachments).

(5) Using economic analyses of hydro revenue and expenses, develop a business plan for sustainable operation balancing water quality and financial needs.

(5) Based on experiment results, propose long term sustainable structural or management changes that can be implemented by local governments.

Specifically, we predict:

1. No differences in the upstream lake from past observations;
2. Few differences in the downstream lake, except that nutrient income during late summer to early fall will be reduced;
3. Increased oxygen and nitrate in the Ford Lake hypolimnion during experimentation;
4. Decreased ammonium, SRP, TN, dissolved Fe, and TP in the Ford Lake hypolimnion during experimentation;
5. Increased retention of TP in Ford Lake on an annual basis;
6. Decreased peak concentrations of chlorophyll and phycocyanin in the Ford Lake epilimnion;
7. Increased alkaline phosphatase activity per unit chlorophyll (Ford Lake epilimnion);
8. Decreased microcystin toxin in the Ford Lake epilimnion;
9. Public perception of improved water quality in Ford Lake.

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Charter Township of Van Buren

December 20, 2005

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Ann Arbor, MI 48109-1048

Dear Dr. Lehman:

The initial research you and the University of Michigan have conducted on the Middle Huron River Watershed and Belleville Lake has been tremendously helpful in making local management decisions. As you are aware, the Middle Huron does not meet water quality standards and was the subject of a Total Maximum Daily Load (TMDL) study by the Michigan Department of Environmental Quality (MDEQ). The pollutant of concern in the watershed was found to be the nutrient phosphorous. Unfortunately, the TMDL set phosphorous reduction goals with little or no understanding of where the nutrients were coming from or how they were transported through the system.

In response to the TMDL, several local governments in the watershed formed a partnership, the Middle Huron Initiative (MHI), to address point and non-point nutrient sources. Your research regarding nutrient dynamics and how nutrients are transported in the Middle Huron provides a valuable resource for water quality information, which we have used to craft our phosphorous reduction initiatives. Continued collection and analysis of this type of water quality data would be very useful to the MHI as we continue to struggle to meet the phosphorous reduction goals.

The analysis you have completed is also important in our public education and involvement efforts. The presentations you provided at the MHI meetings as well as other public meetings have helped many of the affected communities relay a complex message to their local elected officials, municipal staff and constituents. In addition, we direct many of our Township residents to the website you maintain with Middle Huron data and analysis. Finally, the information you provide has helped us garner local political and financial support for water quality improvement efforts.

Belleville Lake is the centerpiece of our community and we would like to maintain a complete water quality sampling program to ensure we can understand and address current and future water quality problems. The information you have provided to date has been unbelievably helpful and we strongly support your efforts to obtain resources to continue this work. Without reliable water quality data, our efforts may be misdirected and less effective.

Sincerely,

Cindy C. King
Supervisor

Sincerely,

Daniel E. Swallow
Environmental Director

46425 Tyler Road, Van Buren Twp., MI 48111-5217 Website: *vanburen-mi.org*
Telephone 734.699.8900 Fax 734.699.5213

Charter Township of YPSILANTI
"Placing Residents First"

Human Resources Department
7200 S. Huron River Drive
Ypsilanti, MI 48197
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Fax: (734) 484-5160
www.twp.ypsilanti.mi.us

January 5, 2006

Professor John T. Lehman
Department of Ecology and Evolutionary Biology
Natural Science Building
University of Michigan
Ann Arbor, MI 48109-1048

Dear Professor Lehman:

I am pleased to inform you that on December 19, 2005 the Charter Township of Ypsilanti Board of Trustees voted unanimously to endorse, and to confirm Township cooperation and collaboration with you in your proposed project titled "Whole lake experiments to control harmful algal blooms in multi-use watersheds." Please share this information with potential project sponsors.

This letter also confirms continuing permission for you to moor underwater instruments in Ford Lake as part of your scientific investigations. Furthermore, we will continue to share with you our continuous logs of water flow through turbines and from the base of Ford dam, as well as our monitoring data for temperature and oxygen. As part of your planned experiments, we expect to receive computer-generated predictions from you about the optimal management strategy for discharge in an effort to curtail or eliminate the algal blooms that blanket Ford Lake each summer. Within our operating constraint of maintaining constant stage height at the dam, we will make every effort to apply the guidance from the computer model to real time operation of our discharge structures.

In addition, we will work with you to identify an appropriate site to locate oxygen tanks for your planned oxygenation experiment.

Your project "Adaptive Management for Improved Water Quality in Multi-Use Watersheds" and your presentations to the Water Conservation Advisory Committee have increased public understanding of conditions in our lake, and raise the hope that genuine improvement in water quality is possible. The on-line data archive has been a welcome resource to Township citizens.

The Charter Township of Ypsilanti looks forward to a productive partnership in pursuit of improved water quality in Ford Lake and in effort to resolve an important environmental problem with in our region.

Sincerely,

Joann Brinker

Joann Brinker
Administrative Services/HR Director

CITY OF ANN ARBOR
WATER TREATMENT PLANT

Professor John T. Lehman
Department of Ecology and Evolutionary Biology
Natural Science Building
University of Michigan
Ann Arbor, MI 48109-1048

December 20, 2005

Dear Professor Lehman:

This letter is written to confirm our cooperation and collaboration with you in your proposed project titled "Whole lake experiments to control harmful algal blooms in multi-use watersheds." Please feel free to share this with potential project sponsors.

Our past interactions with you as part of your project "Adaptive Management for Improved Water Quality in Multi-Use Watersheds" have proven beneficial to our office, and we believe, to our citizens, as well. The data and analyses helped inform our long range planning and formulation of the Ann Arbor Water Treatment and Water Resources Master Plan. The on-line data archive represents a much-needed baseline from which we can evaluate future changes in this watershed and our water supply.

We will be pleased to continue our cooperative sampling of Barton Pond using Water Plant personnel and watercraft gratis as part of a control study to complement whole lake experiments on Ford Lake downstream. We will also provide organic carbon analyses to the project for a modest recharge rate.

We are very interested in, and willing to cooperate with, the proposed study of diel vertical changes in the distribution of *Microcystis* and the toxin microcystin in Barton Pond. There may be a public and environmental health benefit resulting from the information.

Sincerely,

Janice Skadsen
Water Quality Manager

Abbreviated Curriculum Vitae

John T. Lehman 30 March 2006
Department of Ecology and Evolutionary Biology, Natural Science Building, University of Michigan, Ann Arbor, Michigan 48l09-1048
Phone: 734-763-4680 FAX: 734-647-2465 E-mail: jtlehman@umich.edu

Education

Yale Univ, 1970-74, B.S./M.S. (Biology); Univ Washington, 1974-78, Ph.D. (Zoology)

Professional Appointments

Assistant Professor (1978-83); Assoc Professor (1983-87); Professor, Univ Michigan 1988-present.

Awards and Fellowships

Phi Beta Kappa; Yale, 1973; Summa Cum Laude, Exceptional Distinction in Biology; Yale, 1974.
NSF Graduate Fellow; University of Washington, l974-l977.
Henry Russel Award, 1982: highest recognition by U-M for achievements of junior faculty
A Tale of Two Lakes, Rotunda Feature Display, Univ Michigan Exhibit Museum, 1992-93
Distinguished Faculty Governance Award 1999, highest recognition through election by U-M faculty elected representatives
Chandler-Misener Award 2004: Most notable paper of 2002 (Internat Assoc for Great Lakes Research)

Teaching Experience

Limnology, Limnology Laboratory, Oceanography, Zooplankton Ecology, Predictive Models in Limnology, Foundations of Limnological Principles, Large Lakes - Ecological Structure and Function, Mathematical Models in Aquatic Science, Ecological Knowledge and Environmental Problem Solving

Professional Service (abbreviated)

Strategic Editor, *Journal of Plankton Research* (current)
Editor**-** *Environmental Change and Response in East African Lakes*. Kluwer. 1998.
NAS NRC committee "Applications of ecological theory to environmental problems": 1983-85.
NAS Ocean Studies Board Review Panel for Office of Naval Research Ocean Biology 1992.
Chair Steering Committee "Basic Issues in Great Lakes Research" 1987-1988.
NSF Advisory Committee on Ocean Sciences: 1987-1991.
President, American Society of Limnology and Oceanography 1992-1994.
Council of Scientific Society Presidents 1992-1995.
Co-Chair Steering Committee, International Decade for the East African Lakes (2000-2001)
Editorial Board, Associate Editor, Special Issue Editor: *Limnology and Oceanography*
Editorial Board, *Oecologia*
Review Panels: NSF Ocean Sciences, EPA STAR, Sea Grant
Huron River Watershed Council (appointed County Representative) 1995-1998

External Advisory Committees

Dean of College of Biological Sciences: Gray Freshwater Institute, Univ. Minnesota
Vice-Chancellor Univ. Minnesota-Duluth: Lake Superior Center
Canada Department of Fisheries and Oceans: Experimental Lakes Area
State of Michigan, Department of Environmental Quality, Office of Attorney General
City of Ann Arbor, Michigan; City of Brighton, Michigan

Doctoral Dissertations Supervised: 6 (10+ additional as committee member)

Masters Degrees Supervised: 4; Undergraduate Research Projects Supervised: 23
Invited Professional Presentations: 60+ North American & International by Invitation
Contributed Papers
30+ North American and International Lectures plus numerous additional poster presentations

Research Grants to John T. Lehman
Previous and Current Research Sponsors: U.S. NSF (Graduate Fellowships, Division of Environmental Biology, Biotic Systems and Resources, Ecology, Biological Oceanography, Climate Dynamics); NOAA (Environmental Research Laboratories, National Undersea Research Program, Michigan Sea Grant); Institute for Water Research; Office of Naval Research; National Geographic Society; EPA STAR

Scientific and Technical Publications (Last 4 years; abbreviated from 100+ total)

JTL, S.E.B. Abella, A.H. Litt, and W.T. Edmondson. 2004. Environmental Fingerprints of Biocomplexity: Taxon-specific Growth of Phytoplankton in Lake Washington. Limnology and Oceanography 49: 150-160.

JTL, A. Bazzi, T. Nosher, and J.O. Nriagu. 2004. Copper inhibition of algal growth in Saginaw Bay – Lake Huron. Canadian Journal of Fisheries and Aquatic Sciences 61: 1871-1880.

Edmondson, W.T., S. E. Abella, and **JTL** 2003. Phytoplankton in Lake Washington: long-term changes 1950-1999. Archiv für Hydrobiologie Suppl. 139/3: 1-52.

JTL 2002. Mixing patterns and plankton biomass of the St. Lawrence Great Lakes under climate change scenarios. Journal of Great Lakes Research 28: 583-596. [recipient of Chandler-Misener Award for most notable paper of 2002]

Jonna, R. and **JTL** 2002. Invasion of Lake Victoria by the large bodied herbivorous cladoceran *Daphnia magna*, p. 321-333. *In* E. Odada and D. Olago [eds.], The East African Great Lakes: Limnology, Palaeolimnology and Biodiversity. Kluwer.

Bazzi, A., **JTL**, J. O. Nriagu, D. Hollandsworth, N. Irish, and T. Nosher. 2002. Chemical speciation of dissolved copper in Saginaw Bay, Lake Huron with Square Wave Anodic Stripping Voltammetry. Journal of Great Lakes Research 28: 466-478.

Hoffman, J.C., M.E. Smith, and **JTL**. 2001. Perch or Plankton: Top-down control of *Daphnia* by yellow perch (*Perca flavescens*) or *Bythotrephes cederstroemi* in an inland lake? Freshwater Biology 46:759-775.

JTL 2001. Application of satellite AVHRR to water balance, mixing dynamics, and the chemistry of Lake Edward, East Africa, *In* E. Odada and D. Olago [eds.], The East African Great Lakes: Limnology, Palaeolimnology and Biodiversity. Kluwer.

Miscellaneous Publications (abbreviated)

JTL 2005. The Lakes Handbook, Volume I. J of Plankton Research 27:297 (book review)

JTL 2005. The Lakes Handbook, Volume II. Journal of Plankton Research 27: (book review)

Harris, R., I. Jenkinson, and **JTL**. 2004. EDITORIAL. The first 25 years of Journal of Plankton Research: looking to the future. Journal of Plankton Research 26: 1-3.

Nriagu, J.O., P.M. Meier, D.L. Pascual, and **JTL** 2001. Nutrients in Ford and Belleville Lakes, Michigan, 1998-2000. University of Michigan School of Public Health Technical Report.

JTL and R. Jonna. 2001. The role of internal nutrient loading in the nuisance algal blooms of 2001 in Ford Lake, Huron River Watershed, Michigan. Technical Report.