

## Project ID SN-18:

### Demonstrating Benefits of Conservation Grassland on Water Quality

James E. Almendinger (project manager), Shawn P. Schottler,  
Daniel R. Engstrom, and Mark B. Edlund

*St. Croix Watershed Research Station, Science Museum of Minnesota, Marine on St. Croix, MN 55047*

#### Abstract

Conservation grasslands (set-aside lands in programs such as CRP, CREP, RIM, etc.) not only provide important habitat but also accrue water-quality benefits by reducing nonpoint-source pollutant loads of sediment and nutrients from agricultural lands. To quantify these water-quality benefits, we propose to use lakes as natural, long-term collectors of sediment and nutrients to compare loads from their watersheds before and after such conservation grasslands were established. Ten lakes in watersheds with different acreages of conservation grasslands will be selected for study. Three sediment cores from each lake will be radiometrically dated and analyzed to determine average accumulation rates of sediment and phosphorus; presumably rates will have declined after conservation grasslands were established. The amount of decline will be related to the area and placement of conservation grasslands in the ten watersheds. In addition, analysis of diatoms (a type of algae preserved in the sediments) in cores from five of the lakes will allow reconstruction of past total phosphorus concentrations in the lake water. Any decline in total phosphorus concentrations will likewise be related to area and placement of conservation grasslands in the selected lake watersheds. Results from this study will show the area of conservation grassland needed, and where it should be placed, to result in measurable water-quality improvement, and may help bolster support needed to maintain or expand enrollment in conservation grassland programs .

#### Introduction

##### **Background**

Conservation grasslands, which include lands acquired or enrolled in CRP, CREP, RIM, and WMA (wildlife management areas) programs, provide important habitat for Minnesota wildlife. In addition, these grasslands are known to provide water-quality benefits by reducing sediment and nutrient loads on a field-by-field basis. On a watershed scale, however, these benefits are less clear because they depend not only on how much grassland there is, but also where the grassland is located in the watershed in relation to drainage patterns. Renewal of these conservation programs would be bolstered by quantitative evidence demonstrating their effectiveness in watershed-scale water-quality improvement.

Unfortunately, such quantitative evidence is difficult to obtain. Monitoring the sediment and nutrient load carried by streams is an important approach to quantify watershed-scale erosion. However, to be most effective, such stream-monitoring datasets must be many decades long to show a before-and-after effect of establishing conservation grasslands and to smooth out annual variability in precipitation. Such datasets are expensive and uncommon, and those that exist may not be from optimal locations. In particular, interpreting the sediment load carried by streams is complicated by not knowing the source of the sediment -- how much of the sediment

came from stream bank erosion, and how much came from field erosion in the uplands (where conservation grasslands would provide their benefits)?

An alternative to stream monitoring is to use lakes as natural collectors of sediment and nutrients eroded from the landscape. In effect, lakes constitute a natural "monitoring program" that is already in place and that never fails to record sediment and nutrient loads for each storm event over many years. The landscape sediment load is recorded directly by the accumulating mass of lake sediment; the nutrient load is recorded by the amount of phosphorus in the sediment and by its effect on algae, the remains of which are also preserved in the sediment. Since the lakes have existed for thousands of years, their sediment record can be used to characterize erosion rates under natural prairie conditions, under 20th century agricultural practices, and finally after establishment of conservation grasslands in their watersheds. Furthermore, for carefully selected lakes without perennial stream inlets, the sediment captured by the lakes can be defined as coming only from upland erosion, with no contribution from stream bank erosion.

### **Hypotheses and Questions**

Regarding the relations among landscape erosion, conservation grassland, and lake-sediment accumulation, we put forth the following hypotheses and questions:

- *Hypothesis (1): Lake sediment and phosphorus accumulation rates (and therefore landscape erosion rates) were lowest under natural prairie conditions, increased dramatically from 20th century agriculture practices, and decreased somewhat after the establishment of conservation grasslands.* While the first part of this hypothesis is probably not in question, it still remains to quantify the different rates -- just what were the natural rates of sediment and phosphorus accumulation? How much did things change with the introduction of agriculture? Did establishing conservation grasslands in fact mitigate sediment and phosphorus loading?
- *Hypothesis (2): Reductions in lake sediment and phosphorus accumulation rates accrued by establishment of conservation grasslands can be related primarily (a) to areal extent of these grasslands and other perennial vegetation, and (b) to the location of these vegetation units relative to overland flow paths from the uplands to the lake.* This hypothesis stems from the knowledge that grasslands reduce sediment loads from watersheds for two reasons. First, little erosion is generated from the grasslands themselves. Second, some of the sediment and phosphorus load of runoff from other parts of the watershed can be trapped if it passes through grasslands. While phosphorus loads are often closely related to sediment loads, we recognize that different fertilizer application rates and increases in soil-phosphorus content can influence the dissolved phosphorus loads from watersheds, which would be less directly improved by passing through grasslands. In addition, we recognize that other factors such as difference in soil type, topography, annual runoff, and watershed size will complicate the conclusions. Assuming the data support the hypothesis, we will address the following question: how much acreage of conservation grassland is needed to measurably improve water quality, and where in the watershed should the grassland be placed?
- *Hypothesis (3): The algal community in the lakes has responded over time to phosphorus loading and will therefore be related to phosphorus accumulation rates in the sediment.* Phosphorus is commonly the limiting nutrient in freshwater aquatic ecosystems, and increases in phosphorus loading and concentration are commonly the primary cause of eutrophication. Can we see evidence of eutrophication in the algal community preserved in the lake sediment, and does the community composition shift back in response to reduced phosphorus loads accrued by the establishment of conservation grasslands?

## **Objectives and Scope**

We propose to select ten lakes in small watersheds with different acreages of conservation grasslands. [This is a change from the original proposal, wherein we had proposed only five lakes -- the reason for this change is discussed below.] Sediment and phosphorus accumulation rates will be measured in each lake via the analysis of lake sediment cores, thereby addressing *Hypotheses (1) and (2)*. Five lakes will be selected for analysis of sedimentary diatoms, a type of algae sensitive to phosphorus and well-preserved in lake sediments, thereby addressing *Hypothesis (3)*. Results will help determine the degree to which agriculture has impacted landscape erosion and lake eutrophication, and how much the establishment of conservation grasslands has improved the situation.

## **Approach**

The following sections explain the project tasks and rationale (what we plan to do and why), to build the logical framework for the project. Many details of the analytical methods, most of which are standard, are omitted here but can be provided upon request.

## **Site Selection and Fieldwork**

Lake watershed sites will be selected in south-central Minnesota from existing topographic maps and aerial photographs. We will target relatively small lakes of 5 to 50 ha (2 to 20 acres) in area, with watersheds of 1 to 10 km<sup>2</sup> (0.4 to 4 mi<sup>2</sup>). Ideal lakes will have no inlet and will be hydrologically situated such that they will have had minimal relative water-level changes over the past century. Such lakes would tend to have outlets or otherwise be situated near rivers, where water-table fluctuations would be minimal. Past aerial photographs, especially from the dry 1930s, will help indicate which lakes might fit these criteria. About 20-30 lakes will be selected as possible sites, which will be discussed with local county conservation district personnel, and the 10 sites with the best known history of conservation grassland, and with different areas of grassland, will be selected for initial fieldwork. To the degree possible, placement of grassland in the watersheds will also be considered: we will select some sites with grasslands adjacent to the lake and some with grasslands elsewhere in the uplands.

Three cores will be collected from representative areas of the deeper parts of each lake. Originally we had proposed selecting five lakes and collecting six cores per lake, giving 30 cores to analyze. However, we were concerned that only five sites might be too few to see a general trend, given the many other factors that could cause variability in the data. Hence we decided to double the number of lakes and reduce the number of cores per lake by half down to three, which will still give good relative rates of change. About half the lakes will be cored in the first year of the project, and about half in the second year.

## **Lake Sediment Analyses**

The lake cores will be dated with <sup>210</sup>Pb analysis, which provides reliable core depth-date relationships back to about the mid-1800s. The dating is most precise near the core top (the youngest sediment), when CRP-like programs became established (1986) and afterwards. The

$^{210}\text{Pb}$  dating will be confirmed and adjusted by analyzing for  $^{137}\text{Cs}$ , a bomb product that peaked in 1963. Whole-core magnetics will be determined on all cores as an additional tool for cross-core correlations. Sediment content will be analyzed for total dry matter, organic matter, carbonates, and residual inorganic matter by loss-on-ignition (LOI) analysis. The residual inorganic matter represents the erosional inputs from the landscape, as most of the organic matter and carbonates are likely generated by in-lake processes. As necessary, the inorganic fraction will be further corrected for biogenic silica (bSi) content (originating from in-lake diatom productivity – see below), which would be determined on selected single cores from each lake.

Phosphorus content of the lake sediment, in units of  $\text{mg g}^{-1}$ , will be determined by an extraction procedure that differentiates between bio-relevant forms of phosphorus (phosphorus already incorporated into organic matter plus that which is loosely bound to particles) versus relatively inactive forms of phosphorus (detrital, mineral-bound apatite phosphorus). The bio-relevant fraction of phosphorus, as termed here, is the sedimentary result of phosphorus that originally entered the lake in a bio-reactive form, namely, that which was either dissolved or easily desorbed from particles. This fraction is most directly related to the health, or trophic status, of a lake, and hence it is the fraction of most concern resulting from agricultural runoff. The extraction procedure involves reacting separate aliquots of sediment with various sequences of hydrogen peroxide, sodium citrate, and hydrochloric acid to determine the organic, apatite, and non-apatite mineral (loosely-bound) fractions of phosphorus.

In combination, the  $^{210}\text{Pb}$  and LOI analyses will result in an estimated rate of dry matter accumulation rate ( $\text{g cm}^{-2} \text{yr}^{-1}$ ) for selected points (time slices) in each core. Multiplying these dry-matter accumulation rates by the percentage of residual inorganic matter and bio-relevant phosphorus sediment concentrations gives the accumulation rates due to inputs of eroded sediment and bio-reactive phosphorus. Accumulation rates for the three cores from each lake will be averaged for each time slice to smooth variability among the cores.

Pre-European (and thus pre-agriculture) accumulation rates could be estimated by extrapolation of ca. 1850  $^{210}\text{Pb}$  dates and sedimentation rates. However, obtaining  $^{14}\text{C}$  dates from organic macrofossils or charcoal particles picked from older (deeper) sediment from about the 1500s to 1700s is probably the better method.

### **Diatom Analyses**

Diatoms are a type of microscopic algae that are responsive to lake-water chemistry and that have a glass (biogenic silica) cell wall, unique to each species, that tends to be preserved in lake sediments. Consequently, the analysis of diatom remains in lake sediments can show how the diatom community (the array of species present at any one time) changes over time, which can then be related to past lake-water nutrient conditions, most specifically total phosphorus (TP) concentrations by using quantitative inference models for Minnesota lakes developed at the St. Croix Watershed Research Station. Because of the time-consuming and specialized nature of sedimentary diatom analysis, only single cores from each of five lakes will be analyzed. The five lakes with the most promise of showing a distinctive change in diatom community, based on initial analysis of sediment and phosphorus accumulation rates, will be selected from the full set of ten lakes. The best core in each of these five lakes will be selected primarily on the basis of the precision of the  $^{210}\text{Pb}$  dating. The result will be quantified changes in the diatom community and diatom-inferred total phosphorus concentrations (diTP) in each of the selected five lakes

from the past to the present day. Within each lake, diTP will be compared to the bio-relevant fraction of phosphorus in the sediment.

### ***Spatial Data Acquisition***

Topographic and land-use data sets will be needed for this project. Topographic data will be derived from existing 1:24K quadrangles and either 10-m or 30-m resolution digital elevation models (DEMs) to determine watershed boundaries and flow paths. Areas of closed drainage within delineated watersheds will be excluded. ArcGIS software has a hydrologic toolkit package to facilitate such analyses. Land-use data will be more difficult to obtain. Current land use (particularly acreages in grassland) can be interpreted from recent aerial photographs and delineated within geographical information software (GIS) systems. These areas will be compared with available 30-m resolution National Land Cover Data, derived from satellite imagery from about 1992-93. Earlier sets of aerial photographs can be used to infer coverages of grassland in each watershed during past decades. We expect that local farmers and county personnel will be able to inform us with reasonable accuracy when certain parcels of land were set aside into grassland. We are aware that obtaining enrollment data for CRP-like programs from federal agencies is difficult because of privacy protection policies. However, even if such data were forthcoming, we expect aerial photograph analysis would be necessary anyway because all perennial vegetation will need to be documented, not just that within officially funded programs. For each lake watershed, a chronology of coverage by grassland and other perennial vegetation will be constructed based on available aerial photographic coverage.

### ***Data Synthesis and Analysis***

For each lake, the change over time in sediment and phosphorus accumulation rates and diTP concentrations will be assessed and evaluated on a percentage change basis. In particular, the percentage reduction from peak rates down to lower rates following establishment of conservation grasslands will be established. Ideally, for lakes where we can establish good “natural prairie” (pre-European settlement) rates, we can express changes as disturbance ratios (= modern rate divided by the natural rate). For example, how many times greater was erosion during selected time intervals in the modern era than under natural conditions?

The percent reduction in each sedimentary variable (sediment accumulation rate, phosphorus accumulation rate, and diTP) accrued to establishment of conservation grasslands will then be related to area and placement of these grasslands, probably by multiple or stepwise linear regression. Whereas quantifying the area of grassland (and other perennial vegetation) is fairly straightforward, obtaining a good metric for grassland placement will require some further development with flow-path analysis. Currently we are considering calculating the flow-path length through the grassland divided by the average annual runoff volume delivered to the grassland, which can be estimated by multiplying the contributing sub-watershed area by average annual runoff depths estimated for different parts of the state.

### ***Anticipated Challenges and Future Directions***

In any study that uses accumulating lake sediment as a proxy for upland erosion, any factor that changes the delivery of sediment to the core site can add variability that complicates

interpretation. Both higher and lower lake levels can mobilize near-shore sediment and transport it to the core site, causing an apparent increase in sediment accumulation rate independent of what is being delivered from the uplands. Changes in the extent of aquatic macrophyte beds, both submerged and emergent, can affect the transport of delivered sediment from the lake margin to the core site. Averaging the accumulation rates determined in the cores over selected periods of time, e.g., decadal averages, can help smooth such variability but consequently reduces the resolution of the results.

Factors other than areal extent and placement of grasslands that can affect watershed-scale erosion must be considered. In particular, increases in average precipitation and runoff over the study area has the potential to increase erosion rates over time, independent of changes in land use and coverage. Improvements in tillage practices, from moldboard plowing to conservation tillage, would reduce overall erosion rates even without the establishment of conservation grasslands.

Phosphorus dynamics have probably changed directionally during the period of agriculture. As inorganic phosphorus fertilizer has been added over the past 50 years, the soil phosphorus content has increased. Consequently, not only do mobilized soil particles carry more phosphorus, but a greater fraction of phosphorus likely moves in the dissolved phase which cannot be filtered out effectively by grasslands or other buffer-strip vegetation. Such a change may de-couple phosphorus accumulation rates as measured in lake-sediment cores from the metrics of grassland placement we develop during this study.

While the three cores per lake collected during this study will give good relative rates of change in sediment and phosphorus accumulation rates, it would be better to know actual whole-basin accumulation rates. This would give the total amount of sediment and phosphorus eroded from the watershed, which could then be back-calculated as an absolute yield in terms of eroded mass per unit watershed area ( $\text{kg km}^{-2}$ ). Our experience indicates that even for small lakes, five or six cores per lake would be needed to adequately represent whole-basin accumulation. For this project, we decided that it was better to increase the number of lakes and settle for good relative, rather than absolute, rates of change. However, should additional funding be acquired, we would like to return to the most promising few lakes and obtain the extra cores needed to determine whole-basin accumulations and absolute rates of change.

## **Products**

The final product of this project will be an interpretive report describing (a) the temporal trends in each lake, and (b) the relation between these trends and grassland area and placement. If all goes well, the report will contain regression formulas that will predict the reductions in sediment and phosphorus load resulting from specified areal coverages and placements of grassland in a watershed. To the degree possible, this report will be written as one or more manuscripts to be submitted for publication in peer-reviewed journals.

Intermediate products will be the datasets derived from the sediment core analyses, as identified in the timetable and list of milestones. We expect to invoice based on time expended by Almendinger and Schottler, and on analyses completed based on per-core or per-sample charges.

## Timetable

### Conservation Grasslands Timetable

Task	FY2008				FY2009				FY2010				
	CY2007		CY2008		CY2009		CY2009		CY2010				
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
<b>Site Selection</b>													
4-5 sites/yr, Years 1 and 2	¥	¥		¥	¥								
<b>Fieldwork</b>													
4-5 sites/yr, Years 1 and 2	¥	¥			¥	¥							
<b>Sediment Analyses</b>													
LOI analysis			¥	¥	¥	¥	¥	¥	¥				
Core dating (Pb-210, Cs-137 analysis)		¥	¥	¥	¥	¥	¥	¥					
Phosphorus analysis			¥	¥	¥	¥	¥	¥		¥			
<b>Diatom analyses</b>													
Sample prep and counting				¥	¥	¥	¥	¥		¥	¥		
Inferred TP analysis										¥	¥	¥	
<b>GIS analyses</b>													
Watershed delineation, current land use			¥	¥	¥	¥	¥						
Past aerial photograph interpretation							¥	¥		¥	¥		
Flow-path analysis							¥	¥		¥	¥	¥	
<b>Data Synthesis</b>													
Temporal trend analysis										¥	¥	¥	
Relation to grass area & placement										¥	¥	¥	
<b>Report Preparation</b>												¥	¥

**Timetable Milestones**

Date	Milestone
1-Jul-07	Project begins
31-Dec-07	4-5 sites selected and cored LOI analysis begun on 2007 cores Core chronology begun on 2007 cores
30-Jun-08	LOI complete on 2007 cores Core chronology complete on 2007 cores P analysis on 2007 cores begun Diatom analysis begun GIS: watersheds & current land use, 2007 sites 6-7 sites selected
31-Dec-08	5-6 sites cored LOI analysis begun on 2008 cores Core chronology begun on 2008 cores P analysis on 2007 cores completed Diatom analysis: cores 1-2 completed GIS: watersheds & current land use, 2008 sites
30-Jun-09	LOI complete on all 2008 cores Core chronology complete on 2008 cores P analysis on 2008 cores begun Diatom analysis: cores 3-4 completed GIS: past aerial photo interpretation begun GIS: flow-path analysis begun
31-Dec-09	P analysis on 2008 cores completed Diatom analysis: core 5 completed Diatom-inferred TP analysis begun GIS: past aerial photo interpretation done GIS: flow-path analysis nearly done Data synthesis begun
30-Jun-10	Diatom-inferred TP analysis complete GIS analyses complete Data synthesis complete Final report complete Project ends

## **Budget and Invoicing**

### ***Funds requested from LCCMR:***

#### **Staff: \$156,150**

Almendinger (75% year 1, 67% year 2, 17% year 3)

Schottler (25% year 1, 17% year 2, 8% year 3)

#### **Analytical expenses: \$204,000**

Core dating \$79,000

*Magnetics, LOI, <sup>210</sup>Pb, <sup>137</sup>Cs, and <sup>14</sup>C analyses (alpha and gamma)*

Sediment phosphorus analysis \$25,000

*Plus biogenic silica, as needed*

Diatom analysis \$50,000

GIS analysis \$50,000

#### **Equipment/Other: \$13,850**

Supplies (5% analytical): \$10,200

Travel: \$3,650

#### **TOTAL BUDGET: \$374,000**

### ***Invoicing:***

We expect to invoice based on time expended by Almendinger and Schottler, and on analyses completed based on per-core or per-sample charges.

## **Curricula Vitae**

One-page curricula vitae for the four principal investigators follows.

**JAMES EDWARD ALMENDINGER**

St. Croix Watershed Research Station  
Science Museum of Minnesota  
16910 152nd St. N  
Marine on St. Croix, MN 55047  
651-433-5953 (voice), 651-433-5924 (fax)  
dinger@smm.org (email), www.smm.org/SCWRS/ (internet)

**Education**

- 1978. B.A., Botany. Ohio Wesleyan University, Delaware, OH 43015  
(Valedictorian; Summa Cum Laude; Phi Beta Kappa)
- 1988. Ph.D., Ecology. University of Minnesota, Minneapolis, MN 55455  
(Dissertation: "Lake and groundwater paleohydrology: a groundwater model to explain past lake levels in west-central Minnesota")
- 1988-89. Postdoctoral research, University of Minnesota, Minneapolis MN 55455  
(Landscape evolution and lake ontogeny, Glacier Bay, Alaska)
- 1989-90. Postdoctoral research, University of Lund, Lund, Sweden  
(Lake and groundwater paleohydrology of the Vomb Plain, Sweden)

**Appointments**

- 1995- Associate Scientist, St. Croix Watershed Research Station, Science Museum of Minnesota
- 2001- Adjunct Professor, Dept. of Geology and Geophysics, Univ. of Minn.
- 2000- Adjunct Professor, Water Resources Science Program, Univ. of Minn.
- 1990-95. Hydrologist, U.S. Geological Survey, Mounds View, MN.
- 1989-90. Fellow, American-Scandinavian Foundation, Univ. of Lund, Sweden.
- 1981-89. Research Assistant/Associate, Univ. of Minnesota.
- 1978-81. NSF Predoctoral Fellow, Univ. of Minnesota.

**Selected Publications**

- Clark, J.S., E.C. Grimm, J.J. Donovan, S.C. Fritz, D.R. Engstrom, and **J.E. Almendinger**. 2002. Drought cycles and landscape responses to past aridity on prairies of the northern Great Plains, USA. *Ecology* 83(3): 595-601.
- Engstrom, D.R., S.C. Fritz, **J.E. Almendinger**, and S. Juggins. 2000. Chemical and biological trends during lake evolution in recently deglaciated terrain. *Nature* 408:161-166.
- Almendinger, J.E.** 1999. A method to prioritize and monitor wetland restoration for water-quality improvement. *Wetlands Ecology and Management* 6:241-251.
- Balogh, S.J., D.R. Engstrom, **J.E. Almendinger**, M.L. Meyer, and D.K. Johnston. 1999. A history of mercury loading in the upper Mississippi River reconstructed from the sediments of Lake Pepin. *Environmental Science and Technology* 33: 3297-3302.
- Almendinger, J.E.**, and J.H. Leete. 1998. Peat characteristics and ground-water geochemistry of calcareous fens in the Minnesota River Basin, U.S.A. *Biogeochemistry* 43: 17-41.
- Almendinger, J.E.**, and J.H. Leete. 1998. Regional and local hydrogeology of calcareous fens in the Minnesota River Basin, U.S.A. *Wetlands* 18: 184-202.
- Almendinger, J.E.** 1993. A groundwater model to explain past lake levels at Parkers Prairie, Minnesota, USA. *The Holocene* 3: 105-115.
- Almquist-Jacobson, H., **J.E. Almendinger**, and S. Hobbie. 1992. Influence of terrestrial vegetation on sediment-forming processes in kettle lakes of west-central Minnesota. *Quaternary Research* 38: 103-116.
- Almendinger, J.E.** 1990. Groundwater control of closed-basin lake levels under steady-state conditions. *Journal of Hydrology* 112: 293-318.

**Shawn Schottler, Ph.D.-- Associate Scientist,  
St. Croix Watershed Research Station, Marine, MN  
Curriculum Vitae Summary**

**Education**

**Ph.D. University of Minnesota, Minneapolis, Minnesota**

Environmental Engineering, 1996

**B.S. University of Minnesota, Minneapolis, Minnesota**

Geotechnical Engineering, 1989

**Research**

**Associate Scientist: St. Croix Watershed Research Station, 1997-**

Radioisotopic tracers of sediment sources in agricultural watersheds

New techniques for sampling of suspended sediment, and field erosion

Refine analytical methodology of using radioisotopes as sediment tracers

Quantify the effects of land use-BMP on water quality and hydrology

Coordination and supervision of upland restoration projects

**Post-Doctoral Research: University of Minnesota, 1996- 1997**

Dept. of Health Sciences: Fate and transport of airborne toxins to the Great Lakes

**Research Associate: Gray Freshwater Institute, Navarre MN, 1989-1995**

Sources and transport of pesticides in the Minnesota River, and Great Lakes

Correlation between land use and non-point source inputs to agri-watersheds

**Recent Publications**

Schottler S. P. and Engstrom, D. R. 2006. A chronological assessment of Lake Okeechobee (Florida) sediments using multiple dating markers. *Journal of Paleolimnology*, v. 36, 19-36.

Engstrom, D. R., Schottler, S. P., Leavitt, P. R., and Havens K. E. 2006. A Re-evaluation of the cultural eutrophication of Lake Okeechobee using multiproxy sediment records, *Ecological Applications*, v.16(3), 1194-1206.

Schottler S. P., Port J. and DeGolier, T., 2007, Influence of floristic diversity on pheasant and songbird nesting preferences and small mammal abundance in a suite of adjacent reconstructed grasslands, *Restoration Ecology*, In press.

Peters, M., Schottler S.P. and Buck W. 2006, Evaluation of Dormant Season Basal Bark Spraying with Garlon 4 as an Efficient Method for Controlling Buckthorn (*Rhamnus cathartica* L.), *Natural Areas Journal*, In Review.

Schottler, S.P., Identification of Sediment Sources in an Agricultural Watershed, Final Report to the Legislative Commission on Minnesota's Resources, December 30, 2002

Swackhamer, D.S., Schottler, S.P., and Pearson, R.F. Air-Water Exchange and Mass balance of Toxaphene in the Great Lakes, *Environmental Science and Technology*, v.33, pp. 3864-3872, 1999

Schottler S.P., Heinz N., and Eisenreich S.J., Temporal and Spatial Trends of Atrazine, DEA and DIA in the Great Lakes, In *Triazine Herbicides: A Risk Assessment*, (Cpt. 18) Ballantine, L.; McFarland, J. Hackett, D., (Eds.); ACS Books: Washington D.C., Symp. Series no. 683, 1998

## Daniel R. Engstrom

St. Croix Watershed Research Station  
Science Museum of Minnesota  
Marine on St. Croix, MN 55047

Tel: 651-433-5953  
E-mail: dre@smm.org  
Web page: www.smm.org/scwrs/

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### 1. Education

- Ph.D. 1983 University of Minnesota, Minneapolis (Ecology)  
M.S. 1975 University of Minnesota, Duluth (Zoology, minor: Botany)  
1971-73 University of Wisconsin, Madison (Zoology: Limnology)  
B.A. 1971 University of Minn., Duluth (Zoology, minor: chemistry) Magna cum Laude

### 2. Positions

- 1999- Director, St. Croix Watershed Research Station, Science Museum of Minn.  
1995-99 Sr. Scientist, St. Croix Watershed Research Station, Science Museum of Minn.  
1990- Adjunct Professor, Dept. of Geology and Geophysics, University of Minnesota  
2004- Adjunct Professor, Water Resources Science, Univ. of Minnesota  
1983-95 Research Associate, Limnological Research Center, Univ. of Minnesota

### 3. Research Expertise

General research interests in geological and chemical limnology. Current research projects include: (1) atmospheric mercury deposition and cycling in temperate and Arctic regions; (2) historic nutrient and contaminant loading to the upper Mississippi and St. Croix Rivers; (3) the paleohydrology and paleochemistry of saline lakes in the northern Great Plains; and (4) fingerprinting suspended sediment sources in agricultural watersheds.

### 4. Selected Publications (of more than 80)

- Lindberg, S.E., O.R. Bullock, R. Ebinghaus, D.R. Engstrom, X. Feng, W.F. Fitzgerald, N. Pirrone, E.M. Prestbo, and C. Seigneur. 2007. A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. *Ambio* (in press).
- Wiener, J.G., B.C. Knights, M.B. Sandheinrich, J.D. Jeremiason, M.E. Brigham, D.R. Engstrom, L.G. Woodruff, W.F. Cannon, and S.J. Balogh. 2006. Mercury in soils, lakes, and fish in Voyageurs National Park (Minnesota): importance of atmospheric deposition and ecosystem factors. *Environmental Science and Technology* DOI: 10.1021/es060822h.
- Engstrom, D.R., Schottler, S.P., Leavitt, P.R., and Havens, K.E. 2006. A re-evaluation of the cultural eutrophication of Lake Okeechobee, Florida, using multiproxy sediment records. *Ecological Applications* 16: 1194-1206.
- Engstrom, D.R. and Fritz, S.C. 2006. Coupling between primary terrestrial succession and the trophic development of lakes at Glacier Bay, Alaska. *Journal of Paleolimnology* 35: 873-880.
- Jeremiason, J.D., D.R. Engstrom, E.B. Swain, E.A. Nater, B.M. Johnson, J.E. Almendinger, B.A. Monson, and R.K. Kolka. 2006. Sulfate addition increases methylmercury production in an experimental wetland. *Environmental Science and Technology* 40: 3800-3806.
- Engstrom, D.R. 2005. Long-term changes in iron and phosphorus sedimentation in Vadnais Lake, Minnesota, resulting from ferric chloride addition and hypolimnetic aeration. *Lake and Reservoir Management* 21:96-106.
- Fitzgerald, W.F., D.R. Engstrom, C.H. Lamborg, C.-M. Tseng, P. Balcom, and C.R. Hammerschmidt. 2005. Modern and historic atmospheric mercury fluxes in northern Alaska: global sources and Arctic depletion. *Environmental Science and Technology* 39: 557-568.
- Shapley, M.D., W.C. Johnson, D.R. Engstrom, and W.R. Osterkamp. 2005. Late Holocene flooding and drought in the Northern Great Plains, reconstructed from tree rings, lake sediments and ancient shorelines. *The Holocene* 15: 29-41.
- Ramstack, J.M., S.C. Fritz, and D.R. Engstrom. 2004. Twentieth-century water-quality trends in Minnesota lakes compared with pre-settlement variability. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 561-576.

**MARK B. EDLUND**

Science Museum of Minnesota, St. Croix Watershed Research Station  
16910 152nd St. N., Marine on St. Croix, MN 55047  
TEL: (651) 433-5953, FAX: (651)433-5924  
email: mbedlund@smm.org

**INSTITUTIONS ATTENDED AND ACADEMIC DEGREES**

University of Michigan-Ann Arbor (1993-1998)  
Ph. D., Natural Resources & Environment (1998)  
University of Michigan-Ann Arbor (1987-1992)  
M. S., Natural Resources (1992)  
University of Minnesota-Twin Cities Campus (1981-1987)  
B. S., Biochemistry and Botany (1987)

**PROFESSIONAL EXPERIENCE**

Assistant/Associate Scientist, 2000-present, St. Croix Watershed Research Station,  
Science Museum of Minnesota  
Postdoctoral Research Fellow, 1998-2001, Center for Great Lakes and Aquatic Sciences,  
University of Michigan, St. Croix Watershed Research Station  
International Research Fellow, National Science Foundation, 1998-1999, Mongolian  
State University and University of Michigan

**PROFESSIONAL SOCIETIES**

Phycological Society of America (1987-present), International Phycological Society (1987-present), International Society for Diatom Research (1987-present), International Association for Great Lakes Research (1994-present), Honor Society of Phi Kappa Phi (1985-present)

**PUBLICATIONS AND REPORTS (five relevant to proposal)**

Edlund, M.B. and Ramstack, J. 2006. Diatom-Inferred TP in Minnehaha Creek Watershed District Lakes. Final Report to Minnehaha Creek Watershed District, Work Order #116-04, 33 pp.

Heiskary, S. A., Swain, E. M. and Edlund, M. B. September 2004. Reconstructing Historical Water Quality in Minnesota Lakes from Fossil Diatoms. Minnesota Pollution Control Agency, *Environmental Bulletin* 4:1-8.

Triplett, L. D., Edlund, M. B. and Engstrom, D. R. 2003. A Whole-Basin Reconstruction of Sediment and Phosphorus Loading to Lake St. Croix. Final Project Report to Metropolitan Council Environmental Services, 46 pp. <<http://www.smm.org/scwrs>>

Edlund, M. B. and Stoermer, E. F. 2000. A 200,000-year, high-resolution record of diatom productivity and community makeup from Lake Baikal shows high correspondence to the marine oxygen-isotope record of climate change. *Limnology and Oceanography* 45:948-962.

Edlund, M. B., Taylor, C. M., Schelske, C. L. and Stoermer, E. F. 2000. *Thalassiosira baltica* (Bacillariophyta), a new exotic species in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 57:610-615.