Environment and Natural Resources Trust Fund
2012-2013 Request for Proposals (RFP)

Project Title: **ENRTF ID:** **150-I**

Understanding Recent Ecological Changes in Minnesotas Wilderness Lakes

Topic Area: I. Water Resources

Total Project Budget: $ 326,000

Proposed Project Time Period for the Funding Requested: 3 yrs, July 2013 - June 2016

Other Non-State Funds: $ 0

Summary:

Minnesota's remote northern lakes are experiencing unexpected ecological change, including blooms of noxious blue-green algae. We will explore the root causes and determine which lakes are most at risk.

Name: Daniel Engstrom

Sponsoring Organization: Science Museum of Minnesota

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Marine on St. Croix MN 55047

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Email dre@smm.org

Web Address www.smm.org/scwrs/

Location

Region: NE

County Name: Cook, Lake, St. Louis

City / Township:

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ Employment	_____ TOTAL _____%

PROJECT TITLE: UNDERSTANDING RECENT ECOLOGICAL CHANGES IN MINNESOTA'S WILDERNESS LAKES

I. PROJECT STATEMENT

Ecological changes, including increases in noxious blue-green algae, are occurring in our remote northern lakes (see attached graphic). In most cases local land-use change can be ruled out as a cause, suggesting that other factors such as atmospheric pollution or warmer temperatures may be responsible. Atmospheric deposition of nitrogen has increased worldwide in recent decades, and warmer winters and longer ice-free seasons have been noted in lakes throughout our region. These large-scale changes have the potential to severely disrupt Minnesota's aquatic ecosystems both directly and in concert with other man-made stressors such as invasive species and land-use change. We currently have only a limited scientific grasp of how these forces will interact or how our lakes will respond, yet predicting these effects will be critical to both resource management and public understanding of changes that have already begun.

Recent studies have documented a series of large-scale changes in boreal-region lakes, including:

- stronger thermal stratification
- increased inputs of dissolved organic carbon ("tannins")
- shifts in algal communities,
- and most alarmingly, an increased frequency of blue-green (cyanobacteria) blooms.

These changes have been noted in remote lakes far removed from direct human disturbance, with the strongest evidence coming from analysis of dated sediment cores that record the recent history of the lakes (see attached graphic). However, the scientific picture is currently very incomplete: the observed changes vary considerably among lakes, the physical and biological controls are poorly understood, and the consequences for higher food-chain organisms are virtually unknown. With such incomplete knowledge there is the very distinct possibility that these changes could be attributed to the wrong causes, and resource-management efforts misdirected. What is needed then, is a systematic assessment of recent changes in remote Minnesota lakes where responses to changing meteorological conditions or atmospheric pollution provide a framework for determining which types of lakes are most at risk of undesirable ecological shifts.

II. DESCRIPTION OF PROJECT ACTIVITIES

This project will reconstruct ecological change in remote lakes from northeastern Minnesota using biological fossils and chemical signatures preserved in dated sediment cores. These changes will be compared among contrasting lake types and with physical models of lake thermal conditions. Because of year-to-year variability, the long-term retrospective studies proposed here are far superior to direct observations of short duration. Specifically we will:

- Reconstruct ecological change in a set of 12 carefully-chosen experimental lakes from sediment records spanning the last 150-200 years; these records will place recent lake changes in the context of longer-term ecological conditions.
- Compare these environmental records among four general lake types likely to represent a range of sensitivity to climate warming and nitrogen deposition; specifically shallow and deep lakes and lakes with small and large surface areas.
- Reconstruct the thermal conditions (stratification, ice-free season, temperatures) of the study lakes using physical (hydrodynamic) lake models, and compare these trends with ecological reconstructions from the sediment cores to develop predictive relationships between lake types and ecological risk.

Activity 1: Lake selection, core collection and dating **Budget:** $ 79,300

Sediment cores will be taken from twelve lakes located in undisturbed watersheds of the Boundary Waters Canoe Area Wilderness and surrounding Superior National Forest. Three lakes will be selected from each of four morphometry classes: small and shallow, small and deep, large and shallow, and large and deep. All study lakes will have small watersheds relative to their surface areas so as to minimize effects related to differences in contributing drainage areas and hydrology. A single sediment core will be collected from the central region of each lake by piston corer and dated using lead-210 methods. Lake-surface and watershed areas will be mapped by GIS methods, and depth surveys will be conducted for those sites lacking suitable lake-depth maps.

Outcome	Completion Date
1. Lake selection and coring (provides sediment records from contrasting lake types)	Sept 2013
2. Sediment core dating (provides a time-line of when changes occurred)	Aug 2014
3. Watershed and lake mapping (to quantify physical differences among study sites)	Aug 2014

Activity 2: Environmental reconstructions and interpretation of change **Budget:** $ 246,700

Sediment cores will be analyzed for biotic and chemical indicators of ecological change at roughly decadal intervals over the last 150-200 years of record. The primary indicators will include (a) fossil diatoms – microscopic algae with silica cell walls that are powerful indicators of water quality; (b) fossil algal pigments – chemical signatures for the past abundance of different algal groups, particularly cyanobacteria (blue-green algae); (c) isotopes of nitrogen and carbon – indicators of lake productivity and nitrogen inputs from N-fixing cyanobacteria; (d) biogenic silica – for assessment of total diatom productivity; and (e) sediment phosphorus – to determine past phosphorus loading to the lakes. Historical changes in the thermal structure of the study lakes will be determined from lake hydrodynamic models and local records of air temperature and wind speed. Environmental reconstructions from the sediment cores will be compared with lake thermal modeling to derive predictive relationships between lake types, ecological change, and climate sensitivity.

Outcome	Completion Date
1. Diatom analysis and interpretation (determines changes in biological communities)	Sept 2014
2. Sediment chemical analyses (reveals changes in lake productivity and chemistry)	Mar 2014
3. Hydrodynamic modeling (determines changes in lake temperatures over time)	Dec 2014
4. Data synthesis, reporting, and recommendations (to communicate findings)	Jun 2015

III. PROJECT STRATEGY

A. Project Team/Partners

Dr. Daniel Engstrom (Director, St. Croix Watershed Research Station, SCWRS) will be responsible for coordinating the overall project. Three SCWRS Sr. Scientists will assist with the project: Dr. Shawn Schottler will coordinate core collection, dating, and sediment geochemical analyses, Dr. Mark Edlund will supervise the diatom analyses, and Dr. Jim Almendinger will be responsible for GIS mapping and lake thermal modeling. All four team members are proposed to receive a portion of the requested funds.

B. Timeline Requirements

The project will require 3 years to complete. Sediment sampling will occur in the first year of the project. As sediment cores are collected, they will be dated and analyzed. Geochemical analyses will take 18 months, while diatom analysis will require 24 months. Lake hydrodynamic modeling will commence mid-way through the project and will take 12 months. Six months is allotted for synthesis and final reporting

C. Long-Term Strategy and Future Funding Needs (if applicable)

Provide risk assessment for ecological change in Minnesota's northern lakes. Users of the findings include fish and wildlife managers and natural resource managers; beneficiaries include state water quality, tourism industry, fishermen.

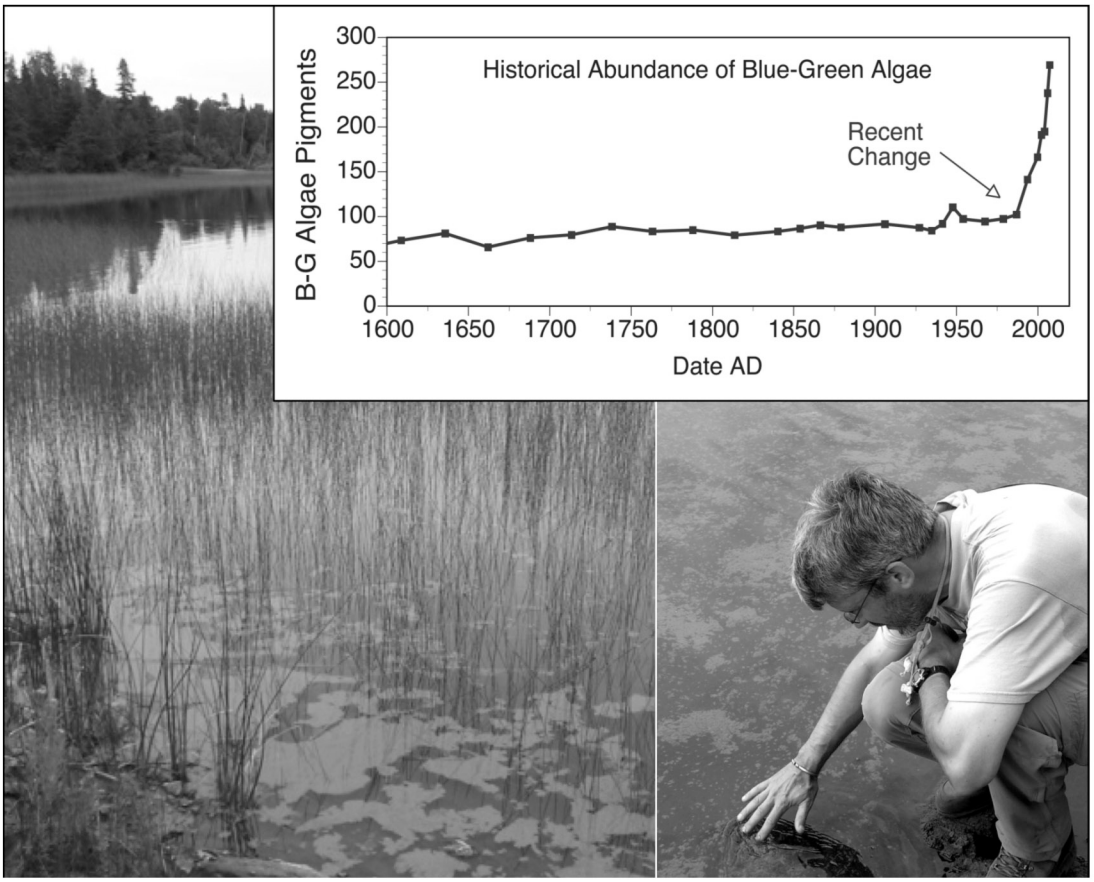
2012-2013 Detailed Project Budget

IV. TOTAL ENRTF REQUEST BUDGET 3 years

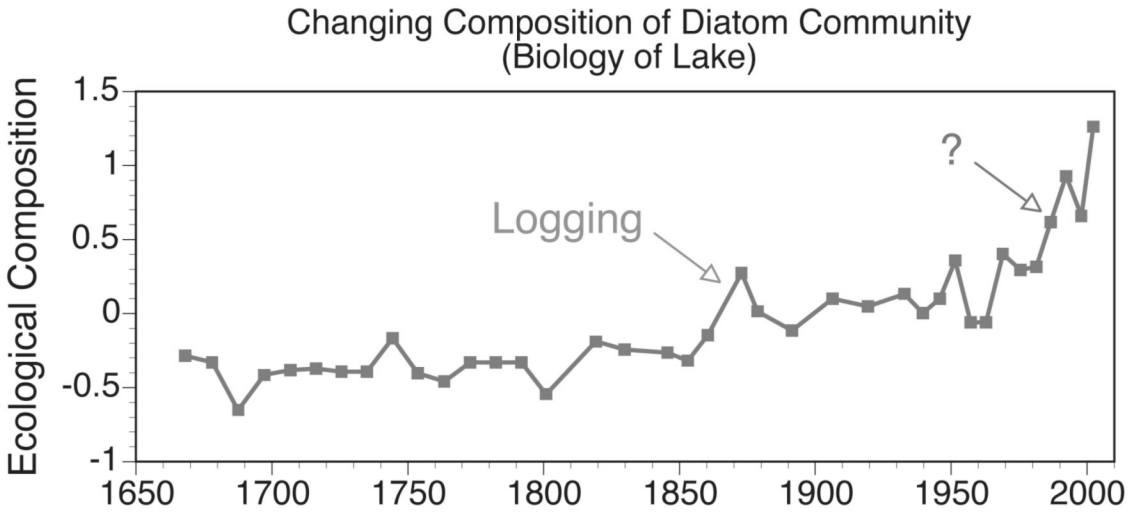
BUDGET ITEM	AMOUNT
Personnel: **SCWRS Staff:** Amounts are Salary + Benefits. Benefits are 30% of Salary. Dan Engstrom Salary + Benefits 10% /yr 3 yrs 36,200 Mark Edlund Salary + Benefits 10% /yr 3 yrs 26,300 Shawn Schottler Salary + Benefits 10% /yr 3 yrs 26,300 Jim Almendinger Salary + Benefits 25% /yr 3 yrs 67,200	$156,000
Contracts: Analytical Services: Analysis of Pigments, C, & N Isotopes: 240 samples @ $100 ea. (Dr. Peter Leavitt, Univ. of Alberta; preferential rates)	$ 24,000
Equipment/Tools/Supplies: Lab supplies and Sediment coring supplies including sample containers, coring tubes, chemical reagents, labware, sample shipping (dry ice, freight)	$ 4,500
Travel: Travel to Collect sediment cores from Lakes. Three coring trips of 3-persons each: mileage ($1050), meals ($2100), lodging ($1350)	$ 4,500
Additional Budget Items: **Analytical Services** at St. Croix Watershed Research Station: Includes Lead-210 dating, gamma spectrometry, sample preparation, diatom counting, analysis for total phosphorus, biogenic silica, and sediment composition: 12 cores @ 20-30 samples each	$ 137,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 326,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period:	NA	
Other State $ Being Applied to Project During Project Period:	NA	
In-kind Services During Project Period:	NA	
Remaining $ from Current ENRTF Appropriation (if applicable):	NA	
Funding History: This project is an outgrowth of monitoring studies in national park units of the Western Great Lakes region funded by the National Park Service	$ 357,000	ongoing



Intense bloom of blue-green algae in Richie Lake, Isle Royale, August 2007. Similar blooms have been observed in lakes at Voyageurs National Park. Sediment records of fossil pigments specific to blue-green algae indicate that these blooms are a recent occurrence in the history of the lake.



Historical changes in the diatom community of Lac La Croix in the heart of the Boundary Waters / Quetico Wilderness. These recent changes in the biology of the lake may signal a response to nitrogen deposition or warming temperatures. Similar changes have been documented in other remote Minnesota lakes.

Project Manager Qualifications

DANIEL R. ENGSTROM

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 Earth Sciences, 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

My research centers on the use of lake sediment records to understand long-term environmental change, particularly the effects of human activities on water quality, atmospheric chemistry, and biogeochemical processes. Areas of current research include: (1) Atmospheric mercury deposition and cycling; (2) Historic nutrient and contaminant loading to the Mississippi River; and (3) Geochemical fingerprinting suspended sediment in agricultural watersheds.

4. Recent Publications (of more than 100)

Drevnick, P.E, D.R. Engstrom, C.T. Driscoll, E.B. Swain, S.J. Balogh, N.C. Kamman, D.T. Long, D.G.C. Muir, M.J. Parsons, K.R. Rolfhus, and R. Rossmann. 2012. Spatial and temporal patterns of mercury accumulation in sediment records from across the Great Lakes Region. *Environmental Pollution* 161:252-260.

Engstrom, D.R., J.E. Almendinger, and J.A. Wolin. 2009. Historical changes in sediment and phosphorus loading to the upper Mississippi River: mass-balance reconstructions from the sediments of Lake Pepin. *Journal of Paleolimnology* 41: 563-588.

Balogh, S.J., D.R. Engstrom, J.E. Almendinger, C. McDermott, J. Hu, Y.H. Nollet, M. L. Meyer, and D. K. Johnson. 2009. A sediment record of trace metal loadings in the upper Mississippi River. *Journal of Paleolimnology* 41: 623-639.

Engstrom, D.R., E.B. Swain, and S.J. Balogh. 2007. History of mercury inputs to Minnesota lakes: influences of watershed disturbance and localized atmospheric deposition. *Limnology and Oceanography* 52: 2467-2483.

Organization Description

The Science Museum of Minnesota (SMM) is a private, non-profit 501(c)3 institution dedicated to encouraging public understanding of science through research and education. Its mission is to invite learners of all ages to experience their changing world through science. The St. Croix Watershed Research Station the environmental research center of the SMM with the mission to foster, through research and outreach, "a better understanding of the ecological systems of the St. Croix River basin and watersheds worldwide." The SCWRS supports an active year-round program in environmental research and graduate-student training, guided by a dedicated in-house research staff with direct ties to area universities and colleges. It collaborates closely with federal, state, and local agencies with responsibility for managing the St. Croix and upper Mississippi rivers and is a full partner with the National Park Service for resource management in parks of the western Great Lakes region. Its research has played a central role in setting management policy for the St. Croix and Mississippi rivers, for establishing water-quality standards for Minnesota lakes and for developing long-term monitoring plans for the National Park Service.