

**Environment and Natural Resources Trust Fund  
2011-2012 Request for Proposals (RFP)**

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**Subd: 05b**

**Project Title:** Lake Superior Water Quality Monitoring

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**Category:** B. Water Resources

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**Total Project Budget: \$** 500,000

**Proposed Project Time Period for the Funding Requested:** 3 yrs, July 2011 - June 2014

**Other Non-State Funds (secured): \$** 0

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**Summary:**

Integrated and repeated measurements of environmental components along transects in Lake Superior will assess ecosystem health in response to environmental stresses, such as climate change, invasive species, and water quality.

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**Sponsoring Organization:** U of MN

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**Location:**

**Region:** NE

**Ecological Section:** Northern Superior Uplands (212L)

**County Name:** Cook, Lake, St. Louis

**City / Township:**

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## **Project Title: Ecosystem Transects to Monitor Lake Superior's Health**

**I. Project Statement:** A uniquely multi-disciplinary team of scientists from UMD will use state-of-the-art laboratory and ship-board instrumentation deployed from the RV Blue Heron to establish two ecosystem health transects in Lake Superior. The three-year program of two transects across the western arm of Lake Superior will be repeated five times each year during the ice-free season, during which a full range of ecosystem properties will be sampled and measured: physical properties of the water column, aquatic chemistry, and the whole food web from bacteria, through algae, to plankton and fish. The two transects extend from shallow to deep water off Duluth-Superior harbor and off Two Harbors, intersecting near the middle of the western arm of the lake (attachment). When completed, these transects will provide the best monitoring information and most complete baseline data yet available for assessing the ecosystem health of Lake Superior. They will be invaluable for identifying ecosystem shifts as they occur in response to stresses such as climate change, invasive species, and human activities. The key components of this effort are the comprehensiveness of the measurements, the geographic range of the transects, and the span of seasons to be included. To our knowledge, no comparable attempt to characterize and understand the ecosystem of a large lake has ever been made.

Specifically, we will establish a comprehensive, integrative program of measurements of ecosystem health in western Lake Superior that will determine or provide:

- The presence/absence of invasive species and the impacts on coastal and deepwater regions.
- The interaction and exchange between coastal and offshore waters, especially as they respond to seasonal and year-to-year changes in lake circulation, water quality, food web abundance and diversity, and fish community structure
- The first integrated assessment of the ecosystem health of western Lake Superior, using consistent measurements of the entire system, from physical properties to fish populations,
- Integration of our sampling and measurements with those of the 2011 field program of the Lake Superior Coordinated Science Monitoring Initiative

Lake Superior is Minnesota's largest water resource, providing drinking water to many communities in Minnesota, hosting major shipping activity, sustaining a strong and recovering fishery, and providing an attractive focus for recreation and tourism. The lake is enduring multiple stresses that threaten it, including climate change, invasive species, continuing inputs of legacy and present-use contaminants, and long term trends of increasing nitrate and declining phosphorus. Various monitoring efforts are underway, but none operates in an integrated, ecosystem-structured way. Our efforts will avoid duplicating past and ongoing monitoring activities, while greatly enhancing our grasp of ecosystem trends and changes.

## **II. Description of project activities:**

### **Result 1: Invasive species distribution**

**Budget: \$97,000**

Sampling of the lake biology (bacteria, phytoplankton, zooplankton, and fish) at closely spaced intervals along our transects through the whole range of ice-free seasons. Offshore waters currently are very poorly sampled for invasive species. The shallow-to-deep transect information will provide the most detailed analysis yet of the distribution and abundance of invasive plankton and fish and their relation to water quality. It will also allow assessment of how the effects of invasive species change with time. Cruises in 2011 will establish the current status of invasive species in light of new ballast water treatment provisions that will soon become effective.

### **Specific Outcomes:**

Report on newly identified invasive species  
Distribution map of known invasive species

### **Completion Date:**

December each year  
December 2013

**Result 2: Spatial analysis of ecosystem components**

**Budget: \$ 173,000**

Digital mapping of ecosystem components from physical properties to fish abundances (and all of the chemistry and biology in between) along the project transects. Five evenly-spaced, four-day cruises each year will extend from ice-off (April) through early November to examine affects of seasonal and year-to-year variability on spatial distributions. The cross sectional profiles will help with the analysis and visualization of the information. Visualization products for non-specialist audiences will be produced.

**Specific Outcome:**

Digital visualizations of ecosystem component distributions

**Completion Date:**

December 2012 & 2013

**Result 3: Ecosystem health assessment**

**Budget: \$ 100,000**

Create the first comprehensive and integrated assessment of all components of the Lake Superior ecosystem at the same time. This assessment will identify ecosystem trends and progress toward the Lake Superior Lake Management Plan (LaMP).

**Specific Outcomes:**

Report on recent ecosystem trends relative to historic records  
Analysis of progress towards LaMP targets

**Completion Date:**

December 2013  
December 2013

**Result 4: Integrate 2011 measurements into broader monitoring**

**Budget: \$ 130,000**

Multi-agency snap-shot monitoring, structured as part of the Coordinated Science and Monitoring Initiative and the LaMPs, rotate field measurements among the five Great Lakes every five years. We will coordinate the first year of this project (2011) with the Lake Superior LaMP effort. Our measurements are timed and spaced in better alignment with ecosystem functioning than the five-year LaMP cycle, and they will provide essential seasonal perspective.

**Specific Outcomes:**

Standardize sampling and interpretive protocols  
Complete LaMP segment of monitoring program

**Completion Date:**

March 2012  
December 2012

### **III. PROJECT STRATEGY**

#### **A. Project Team/Partners**

The project involves a team that is unique in its breadth and depth of expertise, including, from **UMD Large Lakes Observatory**: Steve Colman (project management, ship logistics, and sediments); Robert Hecky (project management, aquatic ecology, and data integration); Jay Austin (physical limnology); Stephanie Guildford (phytoplankton abundance, productivity); Elizabeth Minor (biochemistry, carbon cycling); **UMD Biology**: Donn Branstrator (zooplankton ecology); Randall Hicks (microbial diversity and ecology, DNA analyses); Tom Hrabik (fish abundance and ecology)

#### **B. Timeline Requirements**

We propose three years of measurements and monitoring along the project transect in Lake Superior. The first year, 2011, is designated by the Coordinated Science and Monitoring Initiative and the bi-national Lake Monitoring Program (LaMP) as the year for field measurements (once every five years), part of its Great Lakes monitoring cycle. This project supports and strengthens these and other monitoring efforts.

#### **C. Long-Term Strategy**

The proposed transects will form a baseline for long-term monitoring and study of ecosystem processes and changes. Many of our current grants and applications for funding from the National Science Foundation, Sea Grant, EPA, and other external sources serve various purposes, but many relate to the ecosystem of Lake Superior and many would benefit from baseline data. Ideally the baseline established in this proposal would be repeated at 5 to 10 year intervals The results of this proposal will be integrated with the **Center for Global Great Lakes Data Analysis, Synthesis and Modeling**, supported by the University of Minnesota Institute on the Environment. The data will be made available both in text and visualizations on the Center's website, and it will be used in ecosystem models developed by the center.

## Project Budget

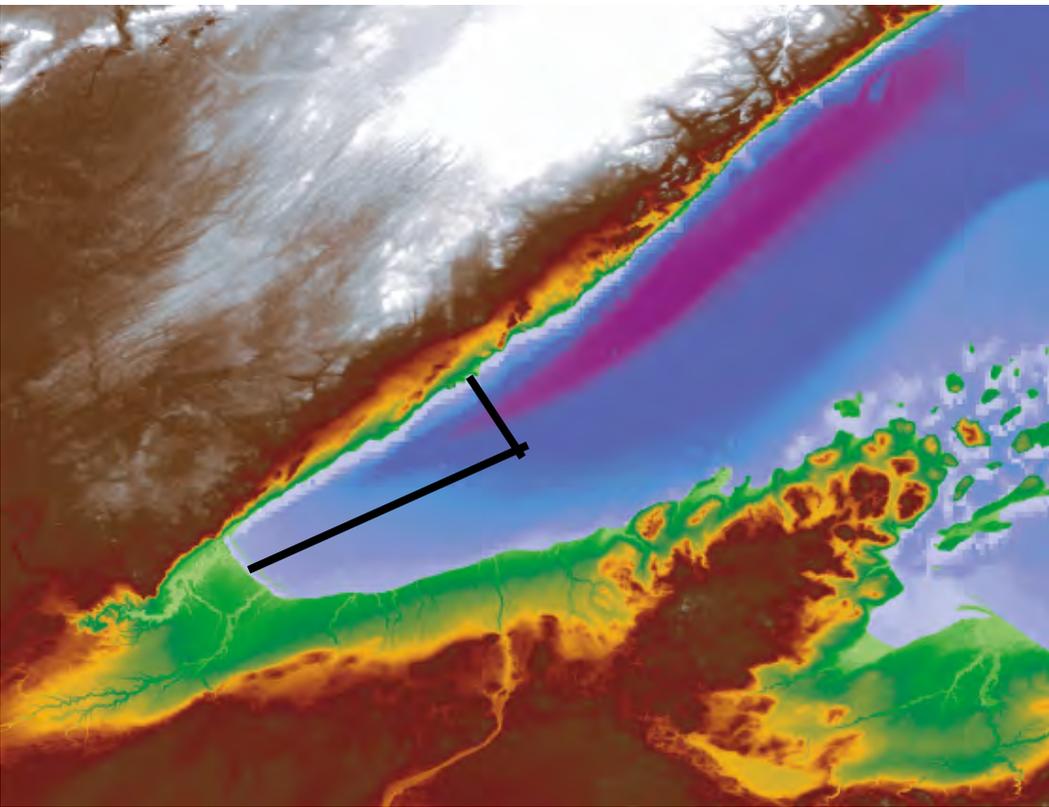
### IV. TOTAL PROJECT REQUEST BUDGET (3 years)

<b>BUDGET ITEM</b>	<b>AMOUNT</b>
<b>Personnel, including fringe benefits (months per year):</b>	
Chemical Laboratory Technician (1,2,2 mo/yr)	\$ 29,000
Biological Lab Technician (upper food web) (1,2,2 mo/yr)	\$ 24,000
Biological Lab Technician (lower food web) (2,3,3 mo/yr)	\$ 44,000
Data and Graphic Analyst (1,2,2 mo/yr)	\$ 27,500
<b>Contracts:</b>	\$ -
<b>Equipment/Tools/Supplies:</b>	\$ -
Instrument calibration (\$1500/yr)	\$ 4,500
<b>Acquisition (Fee Title or Permanent Easements):</b>	
<b>Travel</b>	
To meetings to present results; 6 person-trips @ \$500, yr 2&3	\$ 6,000
<b>Additional Budget Items:</b>	
RV Blue Heron 15 days per year at \$6500/d for 3 yr	\$ 291,000
Laboratory and analytical supplies	\$ 74,000
<b>TOTAL PROJECT BUDGET REQUEST TO LCCMR</b>	<b>\$ 500,000</b>

### V. OTHER FUNDS

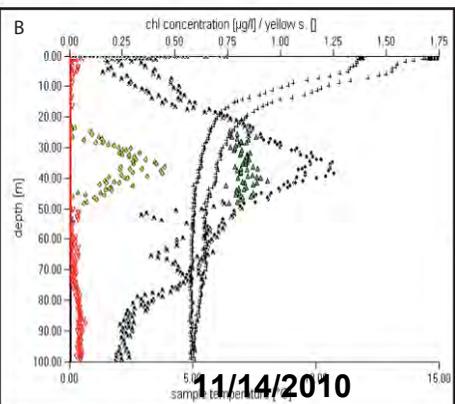
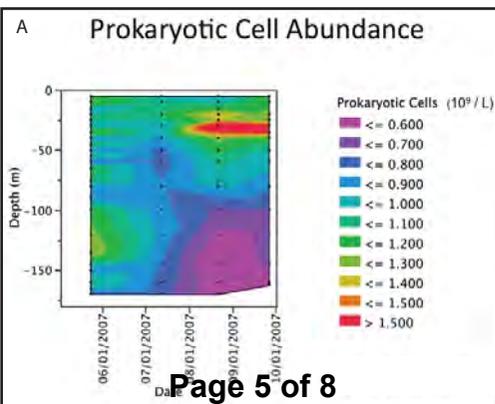
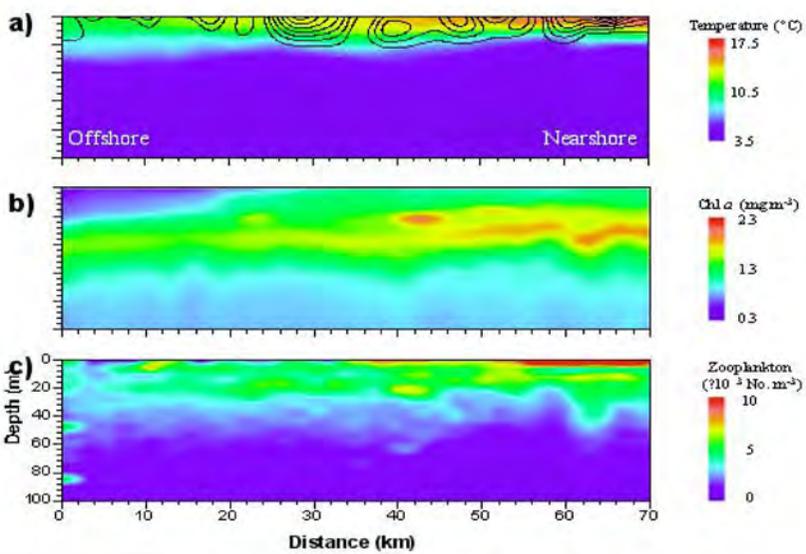
<b>SOURCE OF FUNDS</b>	<b>AMOUNT</b>	<b>Status</b>
<b>Other Non-State \$ Being Applied to Project During Project Period:</b>		
Four National Science Foundation (NSF) grants (J. Austin; E. Minor, S. Katsev, R. Sterner), each 3-4 years, will benefit from and complement LCCMR project activities. Total given: \$2,500,000 (Federal grants, cannot be committed as match.)		<i>Secured</i>
Minnesota Sea Grant (Guildford, Branstrattor, Hrabik, Hecky) \$240,000 (already committed as match for NOAA grant)		<i>Secured</i>
US EPA Great Lakes Restoration (Colman) \$736,000 (Federal dollars, cannot be committed as match)		<i>Pending</i>
<b>Other State \$ Being Applied to Project During Project Period:</b>		
<b>In-kind Services During Project Period:</b>		
Ship time, RV Blue Heron 5 days/year @ \$6500/day	\$ 97,500	<i>Secured</i>
Eight Investigator's time in each of 3 years. Because the investigators are enthusiastic about this project, they are willing to work on it, especially during the summer, without compensation.	\$ -	<i>Secured</i>
<b>Remaining \$ from Current Trust Fund Appropriation (if applicable):</b>		
<b>Funding History:</b> Past year of four NSF grants listed above to Austin, Minor, Katsev, and Sterner; University of Minnesota Institute on Environment Grant (Hecky), 7/09 to start of proposed LCCMR project	\$ 940,000	

Digital elevation model of western Lake Superior (right). Shoreline is at the boundary between green and blue. The two project transects, from Duluth-Superior Harbor and from Two Harbors to the middle of the western arm of the lake. On each cruise of four days (and three nights) duration, the three nights will be devoted to towing or trawling for invertebrates and fish (one night on each of the three transects) to determine community composition, sizing, diets, samples for contaminant analysis, and calibration of bioacoustic equipment for censusing fish populations and their distribution. Two of the days will be devoted to deploying a Triaxus towed vehicle on each of the transects for continuous monitoring of physical water-column structure (CTDO2) and characterization of the phytoplankton (chlorophyll-a fluorescence and FluoroProbe for phytoplankton pigment composition) and zooplankton communities (optical plankton counter) by repeatedly traversing the water column from surface to near bottom (Fig. 2). The other two days will be devoted to high-resolution depth profiles of temperature structure, water chemistry, plankton, and bacterial sampling, and primary productivity measurements at about eight stations on each transect, while continuously estimating abundance and size of fishes using calibrated bioacoustics.



Right: An example of transect data from eastern Lake Superior (M. Zhou, unpublished data). A) Temperature (in color); contour lines are currents into or out of the page; B) Chlorophyll-a, a measure of phytoplankton photosynthesis; C) Density of zooplankton, the middle part of the food chain.

Eastern Lake Superior Transect 7/99



Left: Example data. A. Prokaryote cell abundance through time at one site in western Lake Superior (R. Hicks, unpublished data); peak values occur at about 30 m, near the deep chlorophyll maximum. B. FluoroProbe profiles at Lake Superior station WM taken on July 31, 2008. Temperature (crosses), total chlorophyll (black diamonds), greens (green triangles), diatoms (yellow diamonds); S. Guildford, unpublished data. Subd. 05b

Table 1. Shipboard and laboratory measurements to be made.

Parameter	Method	Investigator
<u>Underway measurements</u>		
Suspended sediment	Transmissometer	Colman
Bathymetry and sediment character	Multibeam sonar and Quester-Tangent software	Colman
Zooplankton density	Hydroacoustics Optical Plankton Counter	Branstrator
Fish density and species	Trawl	Hrabik
Dissolved organic matter fluorescence	DOM fluorometer through underway system	Minor
Algal abundance and group composition	Fluoroprobe	Guildford
Temperature and conductivity	CTD sensors on Triaxus vehicle	Austin
<u>Station or on-board measurement/sampling</u>		
Water collection (for chemical and biological analyses)	Niskin Bottles	Hicks
Microbial DNA (for picoplankton community abundance and diversity)	Membrane filtration and DNA extraction	Hicks
Zooplankton collection	Vertical net tow	Branstrator
UV-Visible absorption (800 to 200 nm)	UV-Visible scanning spectrophotometer	Minor
UV and Spectrally defined irradiance extinction profiles (includes PAR)	Submersible Hyperspectral Radiometer	Hecky
Primary productivity	Fast Repetition Rate Fluorometer	Hecky/Guildford
Algal abundance and composition	Fluoroprobe	Guildford
Temperature and conductivity profiles	CTD instrument on water sampling carousel	Austin
<u>Laboratory Analyses (of samples)</u>		
Prokaryotic Cell Abundance	Flow cytometry	Hicks/Guildford
Picoplankton DNA Abundance	qPCR using 16S rDNA primers for <i>Bacteria</i> , <i>Archaea</i> , and <i>Eukarya</i>	Hicks
Microbial Community Diversity	Analysis of 16S and 18S rDNA clones ( <i>Bacteria</i> , <i>Archaea</i> , <i>Eukarya</i> )	Hicks
Zooplankton taxonomy	Microscope	Branstrator
DOC, DIC	Shimadzu TC analyzer	Minor
POC, PN, particulate $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$	Combustion of acidified samples by CHN analyzer coupled to IR-MS	Minor
Caffeine (sewage tracer)	LC-MS	Minor
TN, TP, nitrate	Lachat Autoanalyzer	Guildford/Hecky
Chlorophyll and active fluorescence	PAM Fluorometry	Guildford/Hecky
Suspended P	Digestion and Lachat Autoanalyzer	Guildford/Hecky

## Co-Project Manager Qualifications

**Steve Colman** is a Professor of Geological Sciences and Director of the Large Lakes Observatory at the University of Minnesota Duluth (UMD), having also had a productive research career with the US Geological Survey in Woods Hole, MA. He has published more than 100 scientific articles in leading journals, including *Science* and *Nature*. He currently holds two large grants from the National Science Foundation. He has won several scientific awards and has served as an officer or on the steering committees for many national and international scientific organizations. He has successfully managed a previous LCCMR-funded project, begun in 2006 and recently completed.

**Robert Hecky** joined UMD and LLO in 2007 as a McKnight Presidential Endowed Professor for Lake Ecology. Previously he served as a research scientist with the Canadian Government for 27 years and then held the United Nations University Research Chair for African Great Lakes at the University of Waterloo (Canada). In 1996 he received the Hutchinson Medal for Outstanding Research Career from the American Society of Limnology and Oceanography and in 2006 received the Rigler Award from the Canadian Society of Limnologists for Outstanding Contributions to Canadian freshwater science. He has nearly 200 scientific publications one of which was recently chosen as one of the top 100 scientific discoveries of 2008 by *Discover* magazine. He currently also serves as a Commissioner for the Great Lakes Fisheries Commission.

## Organization Description

The **Large Lakes Observatory** (LLO) is a research institute at the University of Minnesota Duluth. It is the only institute in the country dedicated to the study of large lakes throughout the world. We focus on the global implications of our investigations in areas such as aquatic chemistry, circulation dynamics, geochemistry, acoustic remote sensing, fish ecology, plankton dynamics, sedimentology, and paleoclimatology. LLO's research ranges from lakes in the East African Rift Valley and Central Asia, to the Great Lakes of North America. Close ties have been formed with institutes in Canada, Uganda, France, Norway, Kyrgyzstan, Kenya, Nicaragua, Malawi, Tanzania and England, as well as with many universities within the United States.

The LLO operates the largest university-owned research vessel in the Great Lakes, the R/V Blue Heron, and is the only member of the University National Oceanographic Laboratory System (UNOLS) on the Great Lakes. The ship is outfitted with state-of-the-art research equipment allowing a unique capacity for observing Lake Superior. This equipment includes a SeaBird 911+ CTD and Carousel sampler for determining temperature, salinity, chlorophyll concentration, transparency, dissolved oxygen content and pH of the water column as well as sampling water at desired depths using Niskin bottles. Acoustic Doppler Current Profiler (ADCP) as well as a Triaxus are invaluable for mapping physical conditions along transects. The ADCP is used to measure current speed and direction in 2 m increments throughout the water column while the ship is underway. The Triaxus is a towed vertically undulating vehicle with an extensive instrument package that can measure temperature, salinity, chlorophyll concentration, transparency, dissolved oxygen content and plankton size and distribution. Biological sampling gear includes plankton nets and a 60' Stauffer midwater trawl with a trawl sonar system. It also supports bioacoustic systems for remote sensing of fish populations. Although LLO is the lead organization on this proposal, researchers from other parts of the University of Minnesota Duluth and the University of Minnesota Twin Cities will be involved in the collaborative research proposed.

