



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2013 Work Plan

Date of Status Update Report:

Date of Next Status Update Report: February 2014

Date of Work Plan Approval: June 11, 2013

Project Completion Date: June 30, 2016

Is this an amendment request? No

PROJECT TITLE: Evaluation of Lake Superior Water Quality Health

Project Manager: Erik T. Brown

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Location: St. Louis, Lake, and Cook Counties

Total ENRTF Project Budget:

ENRTF Appropriation: \$600,000

Amount Spent: \$0

Balance: \$600,000

Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 05f

Appropriation Language:

\$600,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to evaluate impacts to Lake Superior from a changing thermal structure and invasive species in order to implement lake water quality management strategies. This appropriation is available until June 30, 2016, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Evaluating Lake Superior's Health in a Changing World

II. PROJECT STATEMENT: Lake Superior is among Minnesota's greatest natural resources. Shipping, recreation and tourism on the lake stimulate Minnesota's economy. It provides drinking water to thousands, and it symbolizes our natural heritage. The lake seems timeless, but recently it has been changing dramatically. For example:

- Surface summer water temperatures have increased by 5°F over the past 30 years, some of the most rapid change observed on the planet;
- Average ice cover on the lake over the past 15 years is 2-fold lower than the long-term average;
- Major storm events are becoming more frequent (the Duluth floods of June 2012 are an extreme example);
- The lake's nutrient content is changing markedly, with nitrate increasing 5-fold since 1900;
- The lake is increasingly affected by invasive species (spiny water flea, zebra mussels; etc);
- The lake's biological productivity is decreasing, providing less food for fish;
- While lake trout and herring have recovered from mid-20th Century decimation, lake herring populations rise and fall dramatically from year to year.

We do not fully understand the reasons for these changes, or complex interactions among them. Yet we need such an understanding to protect and foster this resource during a time of unprecedented change.

A team from the U of MN and the DNR will use state-of-the-art techniques to evaluate the lake's behavior in this rapidly changing temperature regime. Ship-based observations (using the research vessel *Blue Heron*) will focus on two transects across the western arm of Lake Superior. These results will be complemented with data obtained using an autonomous underwater glider and moored profiling instruments (purchased with National Science Foundation—NSF—grant support). These new unmanned technologies provide cost-effective measurements at more places and times than possible with labor-intensive ship operations. Our plan (see graphic) includes:

- a. Shipboard sampling (from 5 to 10 depths at 12 locations along two transects occupied four times in 2014 and 2015) to measure nutrients, pH, carbon, oxygen, temperature, particle abundances and composition, activity of photosynthetic and other pigments. We will also measure primary productivity, carbon and nutrient cycling using sediment traps and species abundances of algae, zooplankton, and fish.
- b. Use of an autonomous underwater glider for measurements of temperature, chlorophyll and other pigments, oxygen and water clarity. This unmanned device, which can be released and recovered from small boats, is programmed to "swim" repeatedly from surface to bottom as it navigates across the lake, and can provide results in near-real time via satellite telephone. This work during 2014 and 2015 field seasons will provide a detailed context for interpretation of the ship-based sampling efforts.
- c. Moored profilers to be deployed from Fall 2013 to Spring 2016. These instrument packages are "parked" about ~100 feet below the lake's surface. Several times daily they unspool and float upward to record profiles of temperature, oxygen, nitrate, currents, chlorophyll and other biologically important pigments, and water clarity, providing real time data via satellite telephone. They can provide year-round observations, including under ice measurements never previously made in Lake Superior.
- d. Biological and chemical analyses of archived samples collected over the past decades to identify historic trends—such as changes in fish feeding habits or timing of arrival of invasive species. We will use newly developed analytical techniques to examine samples collected in the past and stored at U of MN or the DNR.
- e. Education and research opportunities for graduate and undergraduate students. Summer stipends will be provided for 5 graduate and 4 undergraduate students during the major field season, along with partial support for one graduate student during the academic year. Other graduate students involved with the project will receive academic year support through other funds such as U of MN teaching assistantships.
- f. Public outreach through a partnership with existing programs and expertise at MN Sea Grant.

This work builds on projects that were initiated with support from MN SeaGrant, the US National Science Foundation (NSF) and from LCCMR. The U of MN's research ship, *Blue Heron*, was purchased with LCCMR

support in 1998 and is directly tied to projects that have brought some \$14 million in competitive external research funding to Minnesota. Research supported by MN Sea Grant has demonstrated the critical role that daily fish migration patterns play in the lake. With SeaGrant and NSF support, U of MN scientists have also made significant progress in understanding overall productivity and nutrient cycling. Recently, NSF provided funds for equipment purchases (glider and moored profiling system) that allow us to make cost-effective measurements to evaluate effects of lake circulation processes (currents/mixing) at far more places and more times than possible with ship-based operations. The work proposed here will merge these avenues of research, using measurements of lake circulation and mixing to improve our understanding of biological processes, including fish and plankton behavior. No prior large lake study has included the breadth of measurements, the geographic range, and the span of seasons we propose.

III. PROJECT STATUS UPDATES:

Project Status as of February 2014:

Project Status as of October 2014:

Project Status as of February 2015:

Project Status as of October 2015:

Project Status as of February 2016:

IV. PROJECT ACTIVITIES AND OUTCOMES:

Activity 1: Abundance and distribution of native and invasive species

Biological sampling (phytoplankton, zooplankton, and fish) along our transects will provide the most detailed analysis yet of the distribution and abundance of both native and invasive plankton and fish and their relation to water quality. This work will be undertaken four times along the two transects during the 2014 and 2015 summer seasons. We will use acoustic techniques (more complex versions of “fish finders”) to evaluate fish populations; these will be calibrated as needed with fish trawls. Plankton will be sampled with net tows at approximately 20 stations on each cruise. Samples of both fish and plankton are processed and preserved on shipboard for subsequent laboratory evaluation. Resulting data will allow evaluation of invasive and native species response to changing lake conditions. Observed warming may affect growth of invasive and native species. For example, lake herring often reproduce more efficiently in warm years, but the mechanism for this is unknown. Undergraduate and Graduate students will participate in this research. As a side benefit, this work will contribute to training the next generation of scientists and research technicians.

Summary Budget Information for Activity 1:

ENRTF Budget: \$186,860

Amount Spent: \$ 0

Balance: \$186,860

Activity 1 Completion Date:

Outcome	Completion Date	Budget
1. Reports on newly identified invasive species	February 2015 & 2016	\$115,000
2. Distribution maps of known invasive species	February 2016	\$35,000
3. Report on status of native species	February 2016	\$36,860

Activity Status as of February 2014:

Activity Status as of October 2014:

Activity Status as of February 2015:

Activity Status as of October 2015:

Activity Status as of February 2016:

Final Report Summary:

Activity 2: Snapshots of current ecosystem health

Physical, chemical and biological results from shipboard sampling, the autonomous glider, and profiling moored instruments will be used to create a comprehensive assessment of the western Lake Superior ecosystem needed to understand responses to ongoing change. The proposed work will use measurements of lake circulation and mixing to improve our understanding of distributions of fish and plankton, building on knowledge acquired through previous work supported by MN Sea Grant and the National Science Foundation.

Shipboard sampling will occur on four cruises each year during the ice-free seasons of 2014 and 2015. The cruises will occupy 12 stations along two transects across the lake, providing some 400 water samples to be analyzed for a suite of chemical and biological parameters. We will undertake measurements of primary biological production at a subset of stations. These results will be complemented by autonomous glider deployments and will be evaluated in the contexts of the data provided by the moored profilers (which will be deployed from fall 2013 to spring 2016). Undergraduate and Graduate students will participate in this research. We also will make this data available to the public through a web-site that will show real-time predictions of lake circulation conditions (e.g. winds, currents, mixing) that are important to fisherman and boaters. The National Weather Office in Duluth already uses results from LLO-operated instruments in making decisions on issuing Small Craft Advisories and Surf Zone Forecasts (issued to alert swimmers to potential rip currents); we expect to build on this ongoing collaboration.

Summary Budget Information for Activity 2:

ENRTF Budget: \$355,435
Amount Spent: \$ 0
Balance: \$355,435

Activity 2 Completion Date: June 2016

Outcome	Completion Date	Budget
1. Reports on seasonal changes in the lake ecosystem	February 2015 & 2016	\$175,000
2. Maps and data cross sections displaying results—temperatures, chlorophyll, nutrients	February 2015 & 2016	\$165,000
3. Website displaying lake circulation predictions for public use	May 2016	\$15,435

Activity Status as of February 2014:

Activity Status as of October 2014:

Activity Status as of February 2015:

Activity Status as of October 2015:

Activity Status as of February 2016:

Final Report Summary:**Activity 3: Evaluation of previous ecosystem conditions**

Identification of historic ecosystem trends using surface sediment cores and archived samples from sediment traps. These samples were collected in the past for other studies; we will examine them with sophisticated methods (e.g. stable isotope mass spectrometry) now available in U of MN laboratories. This is a cost-effective approach because archived samples require no field costs. Anticipated results: historic arrival of invasive species (spiny water flea); past changes in fish feeding habits; past changes in nutrient and carbon cycling; comparison with meteorological data. Undergraduate and Graduate students will participate in this research. As a side benefit, this work will contribute to training the next generation of scientists and research technicians.

Summary Budget Information for Activity 3:

ENRTF Budget: \$38,248
Amount Spent: \$ 0
Balance: \$38,248

Activity 3 Completion Date: June 2016

Outcome	Completion Date	Budget
1. Reports on recent ecosystem trends relative to historic records	February 2015 & 2016	\$24,000
2. Distribution map of arrival of invasive species	February 2016	\$14,248

Activity Status as of February 2014:

Activity Status as of October 2014:

Activity Status as of February 2015:

Activity Status as of October 2015:

Activity Status as of February 2016:

Final Report Summary:

Activity 4: Public outreach

We will maximize impact of our work by building upon ongoing Minnesota Sea Grant outreach efforts. To publicize the process of conducting science and the results of this project to Minnesotans, as well as to people within the Great Lakes region, the project will provide 4 weeks/year of salary support for a Minnesota Sea Grant outreach specialist. These efforts will include press releases, regular updates through social media outlets, and facilitation of newspaper, TV and radio interviews involving project investigators. Sea Grant will also produce short videos and other new media. Sea Grant will publish two newsletter stories about the work.

Summary Budget Information for Activity 4:

ENRTF Budget: \$19,457

Amount Spent: \$ 0

Balance: \$19,457

Activity 4 Completion Date: June 2016

Outcome	Completion Date	Budget
1. Ongoing outreach and publicity in collaboration with Minnesota Sea Grant	June 2016	\$19,457

Activity Status as of February 2014:

Activity Status as of October 2014:

Activity Status as of February 2015:

Activity Status as of October 2015:

Activity Status as of February 2016:

Final Report Summary:

V. DISSEMINATION:

Description:

As described above, we will coordinate public outreach with ongoing Minnesota Sea Grant efforts. One highlight will be development of a real-time model of lake circulation processes (currents, winds, mixing) that will be available on the Internet. This will be a valuable resource for fishermen, boaters, and the interested public. We also intend to publish significant results in peer-reviewed journals to reach the broader scientific community.

Status as of February 2014:

Status as of October 2014:

Status as of February 2015:

Status as of October 2015:

Status as of February 2016:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	\$ Amount	Explanation
Personnel:		
Research technicians	\$93,034	Skilled field and laboratory technicians are needed to undertake the research program, under the direction of project scientists.
Outreach specialist	\$19,457	MN Sea Grant outreach specialists will aid in providing information on the results of this project to the general public.
Graduate students	\$88,099	Support for 5 graduate students working on this project during summer months and to 1 graduate student for 1 academic year. Teaching assistantships or other research grants will provide academic year salary for students with summer support only from this project. Support from the LCCMR will be critical for their training to become scientists or research technicians.
Undergraduate students	\$21,445	Support for 2 undergraduate students working on this project during summer months. This will provide hands-on educational experiences for the next generation of scientists and technicians.
Equipment/Tools/Supplies:		
Plankton nets and endcaps	\$3500	Needed for plankton surveys
Mooring hardware and expendable supplies	\$3500	Supplies (shackles, batteries, anchors, cable, etc) necessary for deployment of moored profiler
Glider spare parts and supplies	\$5216	Parts and supplies needed for autonomous glider deployment
Laboratory and field supplies	\$20,000	Bottles, filters, plastic ware needed for collecting, processing and storing samples for the full range of proposed analyses.
Chemical reagents	\$4000	Chemical reagents and standards needed for processing and analyzing samples.
Radiocarbon tracer	\$3000	Needed for measurement of biological productivity in the lake
Travel Expenses in MN:	\$1200	Mileage for UMTC employees to travel to Duluth for fieldwork
Other:		
Shiptime 33 days.	\$292,050	Day rate of \$8850 covers costs of fuel, crew salaries, insurance, basic maintenance, meals.
Laboratory analyses	\$30,000	600 water samples analyzed for organic carbon, organic nitrogen, nutrients, pH, photosynthetic pigments, stable isotopes of C and N.
Satellite telephone	\$14,000	Monthly fees and data transfer charges for Iridium Satellite telephone service needed to control (and to transfer data from) unmanned instruments deployed in the open lake from fall

		2013 through spring 2016.
Temperature sensor calibration	\$1500	Needed to assure accurate temperature measurements.
TOTAL ENRTF BUDGET:	\$600,000	

Explanation of Use of Classified Staff:

N/A

Explanation of Capital Expenditures Greater Than \$3,500:

N/A

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation:

Technicians and the outreach specialist: 0.5 FTE per year.

Three-year total: 1.50 FTE.

Graduate student support: 8 weeks of summer support for 5 students (0.77 FTE each year), plus one academic year of support (39 weeks) for 1 student in Year 2 (0.75 FTE).

Three-year total: 3.06 FTE

Undergraduate summer student support: 8 weeks of support for 2 students (0.31 FTE each year).

Three-year total: 0.92 FTE

Ship's crew during LCCMR-paid cruise dates: 33 days x 5 crew x (12 hours/day)/(2080 hours/FTE)

Three-year total: 0.95 FTE

Overall three-year total: 6.43 FTE

Number of Full-time Equivalent (FTE) estimated to be funded through contracts with this ENRTF appropriation:

N/A

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
<i>UMD, Large Lakes Observatory</i>	\$106,200	\$	<i>12 days of Blue Heron shiptime</i>
<i>UMD, Large Lakes Observatory</i>	\$3000	\$	Cost of small boat rentals for glider operations
<i>NSF grant</i>	\$485,000	\$	<i>Purchase of moored profiling instruments</i>
TOTAL OTHER FUNDS:	\$594,200	\$	

U of MN scientists associated with this project are *not* requesting salary support, and are providing their expertise—project design, supervising technicians, and advising students—at *no cost to LCCMR*.

VII. PROJECT STRATEGY:

A. Project Partners:

The following scientists are providing time and expertise in the areas noted, but are *not* requesting Trust Fund support for salaries:

U of M Duluth Large Lakes Observatory:

Erik Brown (project management, carbon & nutrient cycling)

Jay Austin (physical processes, moored and autonomous instruments)

Elizabeth Minor (biochemistry, carbon cycling)

Richard Ricketts (ship operations and logistics)

U of M Duluth Department of Biology:

Donn Branstrator (zooplankton ecology)

Tom Hrabik (fish ecology)

U of M Duluth MN SeaGrant:

Jeff Gunderson (public outreach)

U of M Twin Cities Department of Ecology, Evolution and Behavior:

Robert Sterner (biological productivity; nutrient distributions, data management)

Providing services at no cost:

DNR Duluth Office:

Don Schreiner (fish population dynamics); \$0

B. Project Impact and Long-term Strategy:

The ecosystem of Lake Superior is unquestionably changing, due to human activities, invasive species, and long-term warming, but little is being done to monitor those changes. In particular, no baseline exists from which to measure future changes.

The proposed project will fill a gap left by a spectrum of scientific and regulatory agencies. At the Federal level, EPA participates in the bi-national Lakewide Management Plan (LaMP), but this effort involves little data collection. An interagency initiative called the "Coordinated Science Monitoring Initiative" (CSMI) is also underway, but again this does not involve the level of sampling (in space and time) that is truly needed to understand the lake. On the State side, the Department of Natural Resources (DNR) conducts a Coastal Program on Lake Superior, but this program focuses on the landward side of the coastline. DNR also conducts limited small-boat fish surveys; we continue to have good working relations with the DNR, particularly the Duluth Office, in this regard.

The researchers involved in this project have a strong history of support from the National Science Foundation and MN Sea Grant. These agencies fund work that involves specific scientific hypotheses and questions, along with constrained sampling programs to address those specific questions. NSF does not fund data collection or monitoring efforts that are not intimately tied to such topical scientific questions. Despite this, there are urgent applied and scientific reasons to extend the topical NSF studies to repeated sampling and transects studies. In particular, the spatial and seasonal variation of processes and properties in the lake need to be characterized. It is our expectation that results of this LCCMR sponsored work will be used as seed data for additional external funding.

C. Spending History:

Funding Source	M.L. 2007 or FY08	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13
NSF grant. Equipment (Austin PI)*				485,000	
NSF grant. Radiocarbon (Minor PI)*	160,000	160,000	160,000		
NSF grant. Carbon and Ice (Austin PI)*	200,000	200,000	200,000		
SeaGrant. Fish migration (Hrabik PI)*	50,000	50,000			
NOAA Great Lakes Observing			120,000	120,000	120,000

System (Austin PI)					
GLPA (Colman PI)	86,000 subd. 4(i)				

*These projects also provide for shiptime, not part of these research budgets, totalling approximately 30 days per year.

VIII. ACQUISITION/RESTORATION LIST:

N/A

IX. MAP(S):

See attachment with schematic map of our field strategies.

X. RESEARCH ADDENDUM:

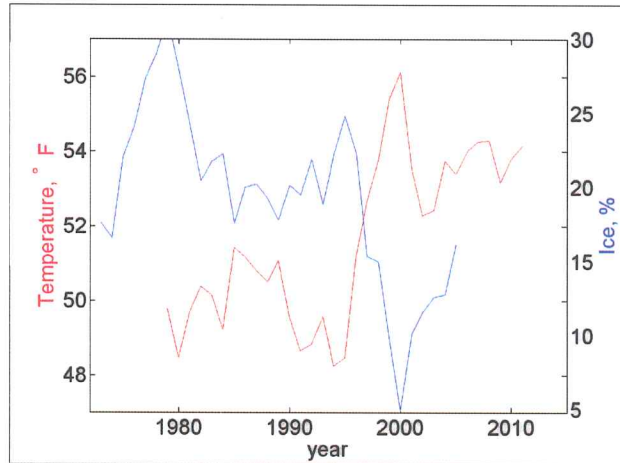
See attachment.

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted not later than February 2014, October 2014, February 2015, October 2015, and February 2016. A final report and associated products will be submitted between June 30 and August 15, 2016 as requested by the LCCMR.

Attachment A: Budget Detail for M.L. 2013 Environment and Natural Resources Trust Fund Projects														
Project Title: Evaluating Lake Superior’s Health in a Changing World														
Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 05f														
Project Manager: Erik Brown														
M.L. 2013 ENRTF Appropriation: \$ 600,000														
Project Length and Completion Date: 1 July 2013 to 30 June 2016														
Date of Update: January 3, 2013														
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Balance	Activity 2 Budget	Amount Spent	Balance	Activity 3 Budget	Amount Spent	Balance	Activity 4 Budget	Amount Spent	Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	Abundance and distribution of native and invasive species			Snapshots of current ecosystem health			Evaluation of previous ecosystem conditions			Public outreach				
Personnel: Total annual compensation (%Wages and %Benefits)	64,540		64,540	115,789		115,789	22,248		22,248	19,457		19,457	222,034	222,034
S. Grossheusch, Chemistry technician: \$60,360 (71.6% salary; 28.4% benefits); 11.5% FTE														
S. Brovold, Biology technician: \$72,229 (71.6% salary; 28.4% benefits); 15.4% FTE														
M. James, Physics technician and programmer: \$76,222 (71.6% salary; 28.4% benefits); 15.4% FTE														
S. Moen, Outreach specialist: \$81,031 (71.6% salary; 28.4% benefits); 7.7% FTE														
Graduate Research Assistant Academic Year: \$36,748 (49.2% salary; 50.8% benefits that include a tuition fellowship of \$13,120); 1 student at 75% FTE in year 2														
Graduate Research Assistant Summer; \$24,167 (80.5% salary, 19.5% benefits); 5 students at 15.4% FTE														
Undergraduate Assistant summer; \$22,329 (93.2% salary, 6.8% benefits); 2 students at 15.4% FTE														
Equipment/Tools/Supplies	5,500		5,500	27,716		27,716	6,000		6,000				39,216	39,216
Puget Sound-style zooplankton net (\$2,500)														
End buckets for plankton net (\$1,000)														
Mooring hardware and expendables (batteries, anchors, cables, shackles, etc) (\$3,500)														
Expendables and supplies for Autonomous Glider (\$5,216)														
Radiocarbon tracer (\$3,000)														
Consumable lab and field supplies and chemical reagents (\$24,000)														
Travel expenses in Minnesota				0										
Mileage for U of M Twin Cities employees to join Duluth-based field programs				1,200		1,200							1,200	1,200
Other														
Shiptime: 33 days. Day rate=\$8850. Covers cost of fuel, crew salaries, insurance, basic maintenance, meals.	116,820		116,820	175,230		175,230							292,050	292,050
Laboratory analyses: 600 water samples analyzed for organic carbon,organic nitrogen, nutrients, pH, photosynthetic pigments, stable isotopes of C and N.				20,000		20,000	10,000		10,000				30,000	30,000
Satellite telephone links for instrument control and data transfer of the autonomous glider and the moored profilers				14,000		14,000							14,000	14,000
Calibration of temperature recorders				1,500		1,500							1,500	1,500
COLUMN TOTAL	\$186,860	\$0	\$186,860	\$355,435	\$0	\$355,435	\$38,248	\$0	\$38,248	\$19,457	\$0	\$19,457	\$600,000	\$600,000

Evaluating Lake Superior's Health in a Changing World

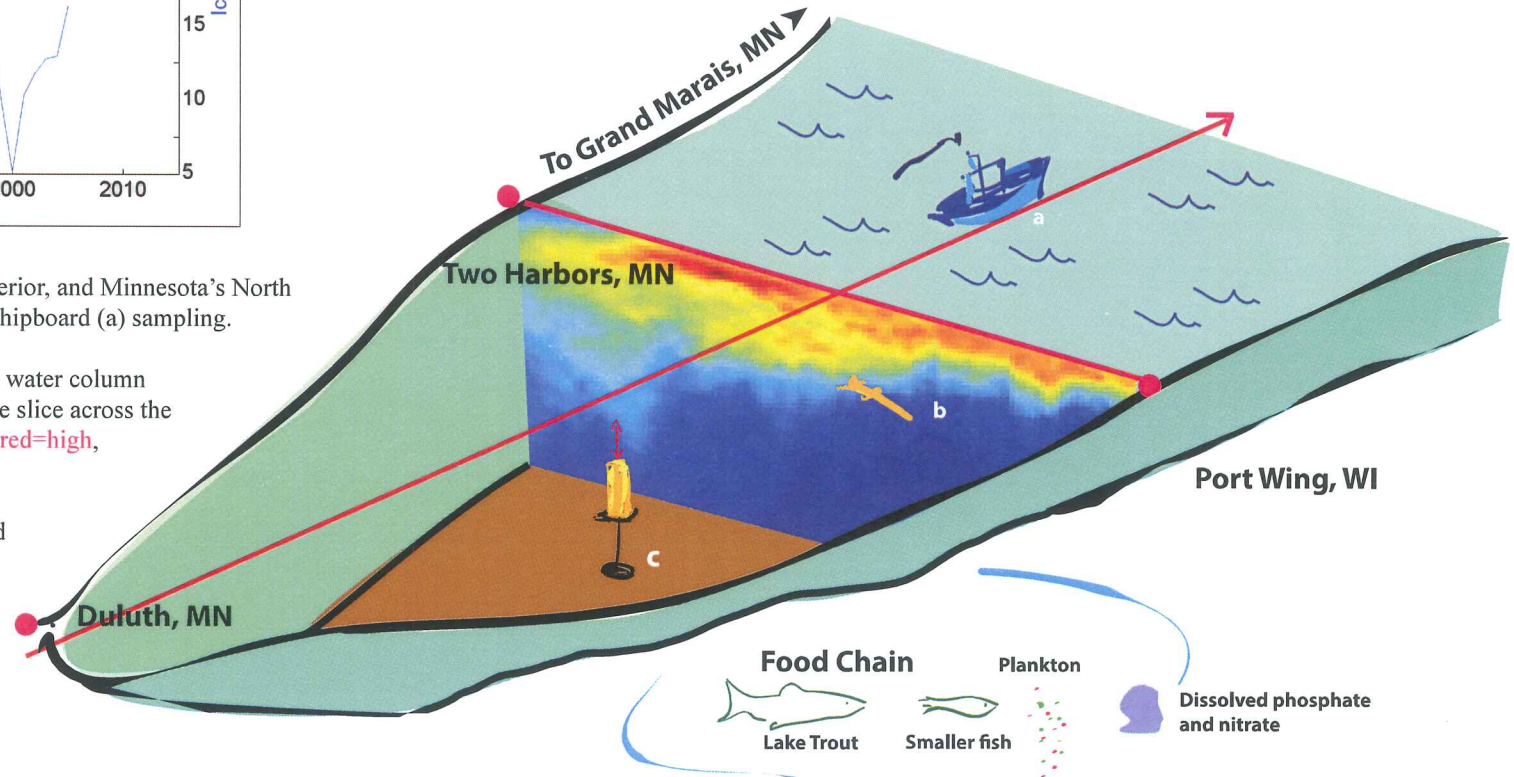


Lake Superior average summer **temperatures (red)** have increased in recent years, in conjunction with declining winter **ice cover (blue)**. Ice reflects the sun's energy in winter setting conditions for more warming during the following summer.

Schematic map of western Lake Superior, and Minnesota's North Shore. **Red lines** show transects for shipboard (a) sampling.

The underwater glider (b) makes full water column measurements of lake conditions. The slice across the lake shows chlorophyll abundances (**red=high**, **blue=low**) on 9/4/11.

Moored profilers (c) will be deployed year-round, including under ice in winter. Several times daily they will record profiles of environmental parameters between the surface and 50 m water depth.



a
Research Vessel Blue Heron. This ship was purchased with LCMR support in 1997, and has support U of M research that has garnered \$14.3 million in external support.



b
UMD's underwater autonomous glider (purchased with NSF support). This device allows our research to cover far more of lake than possible with labor-intensive ship-based studies.



c
UMD's new moored profilers (presently being purchased with NSF support). This system measures and records ecological parameters far more often than possible with ship operations.

