Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-059

Proposal Title: Pristine to Green: Toxic Blooms Threaten Northern Lakes

Project Manager Information

Name: Lienne Sethna

Organization: Science Museum of Minnesota - St. Croix Watershed Research Station

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Project Basic Information

Project Summary: We will uncover drivers beyond watershed nutrient inputs that contribute to the formation of nuisance and toxic algal blooms in relatively pristine and protected lakes across Minnesota.

ENRTF Funds Requested: $1,362,000

Proposed Project Completion: June 30, 2028

LCCMR Funding Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Region(s): NE, NW, Central, Metro,

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Reports of nuisance and toxic blooms of algae have been increasing across the state of Minnesota over the last decade, the most surprising of which have come from relatively pristine waters including lakes within the Superior National Forest, Red Lake Reservation, and 1854 Ceded Territory. Harmful algal blooms by cyanobacteria (cyanoHABs) produce toxins that present the risk of illness and, in some cases, mortality, and are not easily removed from drinking water sources. Increased cyanobacterial abundance is strongly linked to increased anthropogenic nutrient inputs; however, reports of toxic cyanoHABs in protected and minimally impacted waterbodies prompt the exploration of drivers beyond watershed inputs of nutrients that contribute to the formation of blooms. Previous research has identified the internal loading of phosphorus (P) from lake sediments as one potential mechanism in facilitating cyanoHABs, yet critical knowledge gaps remain in constraining the rates and timing of internal P loading in various lake systems, the variation in community composition and functional traits of cyanoHABs, and the drivers of cyanoHAB toxicity. Better understanding the drivers of cyanoHABs will allow for more accurate prediction of bloom formation and can help direct management efforts to prevent and mitigate future blooms.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

We hypothesize that climate warming and lake physical structure are contributing to the increasing abundance and toxicity of cyanobacterial blooms in northern Minnesota lakes. Based on our previous research, we found that shallow lakes experienced cycles of thermal mixing and bottom water anoxia that was linked to increased phosphorus (P) concentrations in their upper layers, creating favorable conditions for cyanobacterial growth. Identifying a potential mechanism for harmful blooms by cyanobacteria has prompted further study of how, and to what extent, internal P loading facilitates these blooms. The research we propose uses a combination of high-resolution lake monitoring, paleolimnological techniques, and laboratory experiments to uncover drivers of cyanoHABs in relatively pristine and low-nutrient lakes. Analyses will focus on three primary objectives: (1) understand linkages between lake physical structure and internal nutrient loading, both contemporarily and through time; (2) quantify cyanobacterial community abundance and the variability in cyanobacteria species diversity and function over time and space; and (3) characterize the drivers of cyanobacterial toxin concentrations.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Our research aims to:

- Identify lake morphometric characteristics that increase the sensitivity to cyanoHAB formation using high resolution monitoring of lake thermal structure, nutrient concentrations, and algal community composition
- Quantify rates of internal nutrient loading in lakes experiencing cyanoHABs using laboratory experiments with lake sediment cores
- Reconstruct historic phosphorus concentrations and algal communities using paleolimnological and genomic techniques
- Monitor cyanobacterial toxins and relate their concentrations to environmental variables to better understand the factors contributing to the concentration and composition of toxins
- Calibrate existing models that predict the severity of cyanoHABs using meteorological and climate data

Activities and Milestones

Activity 1: High-resolution monitoring of lake thermal structure, nutrient concentrations, and algal community composition in protected Minnesota lakes

Activity Budget: $617,147

Activity Description:
Limited monitoring in remote lakes has contributed to the knowledge gaps in our understanding of low-nutrient algal blooms. We have worked to fill these gaps using water quality sampling and high-resolution monitoring buoys which has allowed us to characterize dynamic lake mixing regimes, cyanobacterial community and abundance, and nutrient concentrations. Our previous research in northern MN lakes has revealed harmful blooms by cyanobacteria occur within the Superior National Forest, Boundary Waters Canoe Area Wilderness, and Isle Royale National Park; however, understanding the frequency, intensity, and toxicity of these blooms requires high-resolution monitoring over longer time periods sufficient to establish relationships between blooms and environmental conditions. In this activity, we will monitor 16 lakes in northern Minnesota that are representative of various lake geometries (basin shape, area, and depth). We will collect water quality and algal samples twice monthly during the summer growing season for two years and install monitoring buoys that will collect temperature and dissolved oxygen data at 30-minute intervals continuously for two years. Additionally, these data will supplement existing data from remote lakes in northern Minnesota and will be used to improve models to predict lake sensitivity to cyanobacterial blooms based on lake geometry, water temperature, and climate.

Activity Milestones:

Description	Approximate Completion Date
Leverage U.S. Forest Service monitoring data to establish study sites and water quality	November 30, 2025
Measure nutrients and algae biweekly for two years from 16 remote and wilderness lakes	October 31, 2027
Install buoys in 16 lakes that collect temperature and oxygen data at sub-hourly intervals	October 31, 2027
Organize data into a “Pristine Lakes” database that will support future synthesis studies	January 31, 2028
Use monitoring data to enhance model predictions of cyanHABs in remote lakes	May 31, 2028

Activity 2: Reconstructing historical nutrient conditions and cyanobacterial community using paleolimnological and genomic techniques

Activity Budget: $475,837

Activity Description:
Effective management plans rely on a baseline understanding of natural fluctuations and stable states within an ecosystem. Establishing these baselines requires long-term (>30 years) measurements of ecological conditions that are not typically available for aquatic systems, much less in remote lakes. To reconstruct lake histories, we use paleolimnological techniques, or the study of lake sediments, and determine when, how much, and why lakes have changed. We will collect sediment cores from each of the sample lakes to understand historical changes in environmental conditions and cyanobacterial community dynamics. Analyses will focus on two primary objectives: (1) reconstruct the ecological history of each lake using geochemistry and sediment accumulation, and (2) characterize the abundance and community composition of cyanobacteria using sedimentary DNA techniques. Sediment cores will be cut into discrete increments, which will then be analyzed for geochemical composition (organic and inorganic matter, nutrient concentrations), and cyanobacterial abundance and diversity. Organic and inorganic matter concentrations in cores help characterize the sediment composition and the availability of nutrients such as phosphorus and silicon. Analysis of fossil algal pigments will help us understand potential changes in trophic status (e.g., becoming eutrophic). We will use genomic techniques to reconstruct the changes in cyanobacterial community.

Activity Milestones:

Description	Approximate Completion Date
Collect sediment cores from each of the 16 sample lakes	March 31, 2027
Radiometrically date each sediment core and analyze geochemical and ecological parameters	August 31, 2027
Extract DNA from sediments and conduct genomic analyses to quantify changes in cyanobacterial communities	January 31, 2028
Relate changes in cyanobacterial community with ecological changes in the lakes	May 31, 2028

Activity 3: Quantify rates of internal nutrient loading using laboratory experiments to simulate conditions within Minnesota's pristine lakes

Activity Budget: $269,016

Activity Description:

We hypothesize that the internal loading of nutrients is the primary driver of toxic cyanobacterial blooms in pristine, northern lakes. To test this hypothesis, we will perform laboratory experiments to understand the effects of lake stratification and anoxia on the rates of internal nutrient loading. Incubating sediment cores under oxygenated and anoxic conditions will allow us to directly relate the effects of lake mixing and bottom water anoxia on internal nutrient loading as well as quantify the rates of nutrient loading in each study lake. We will use short sediment cores collected from our study lakes and incubate cores at two levels of oxygen treatments to simulate oxygen conditions experienced in lake bottom waters. Incubation treatments will expose sediment cores to oxic (with oxygen) or anoxic (without oxygen) conditions by bubbling oxygen or nitrogen into the overlying water. The water will be sampled every 1-3 days for 24 days and analyzed for phosphorus and nitrogen concentrations. The rates of nutrient flux from the sediment cores can then be calculated based on the change in nutrient concentrations in the overlying water over time.

Activity Milestones:

Description	Approximate Completion Date
Collect 6 short sediment cores from each of the 16 study lakes	March 31, 2027
Perform incubation experiments with sampled cores with two oxygen treatments	April 30, 2027
Calculate nutrient loading rates from analyzed water chemistry data	June 30, 2027
Share out results of monitoring, paleo-reconstructions, and experiments through conference presentations and published reports	June 30, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Matthew Santo	1854 Treaty Authority	Assisting in the field collection of water samples, data analysis, and reporting.	Yes
Steve Shier	1854 Treaty Authority	Assisting in the field collection of water samples, data analysis, and reporting.	Yes
Tyler Kaspar	1854 Treaty Authority	Assisting in the field collection of water samples, data analysis, and reporting.	Yes
Brenna Pemberton	Red Lake Department of Natural Resources	Managing field collection of water samples within Red Lake. Assisting with data analysis and reporting. Conducting algal identification analysis.	Yes
Shane Bowe	Red Lake Department of Natural Resources	Assisting with the management of field data collection, analysis, and reporting.	No

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

We will work closely with 1854 Treaty Authority, Red Lake DNR, and the U.S. Forest Service to implement our research methods and use our results to inform cyanoHAB monitoring, prevention, and mitigation strategies. We will engage with stakeholders by presenting results and offering programming in collaboration with our project partners. Programming will include public education on recognizing harmful algal blooms and the corresponding effects on public health and the environment. We will also prepare reports detailing our results and work to calibrate existing models that could predict lake sensitivity to cyanoHAB formation under future climate scenarios.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Unprecedented Change Threatens Minnesota's Pristine Lakes	M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 20a1	$482,000

Project Manager and Organization Qualifications

Project Manager Name: Lienne Sethna

Job Title: Assistant Scientist

Provide description of the project manager's qualifications to manage the proposed project.

Lienne Sethna has many years of experience in water quality monitoring and has led several field projects to monitor ecosystem health and function in streams and lakes. Sethna is an aquatic biogeochemist and ecologist with a specific focus on nutrient management, organic matter processing, and community-driven science.

Organization: Science Museum of Minnesota - St. Croix Watershed Research Station

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. The St. Croix Watershed Research Station (SCWRS) is the

environmental research center of the SMM with the mission “we do the science that helps make our rivers and lakes clean” through research and outreach. 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.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lienne Sethna		Project manager, requesting 0.5 FTE/year to lead overall project design, field sampling, data analysis, synthesis, outreach, and reporting			26%	1.5		$164,300
Hailey Sauer		Responsible for conducting genomics analysis of the sediment cores and managing sediment incubation experiments			26%	1.26		$107,780
Jason Ulrich		Responsible for calibrating existing models to predict lake sensitivity to blooms			26%	0.24		$27,360
Mark Edlund		Assisting with project management, field work, data analysis, and result dissemination			26%	0.3		$48,252
Adam Heathcote		Assisting with project management and result dissemination			26%	0.06	X	$8,197
Environmental research technician		Support for a full time technician, contributing 0.5 FTE/year over two years for assistance with sample collection and laboratory analyses			26%	1		$72,428
Summer research intern		Assisting with summer field work and laboratory analyses			26%	0.5		$36,214
							Sub Total	**$464,531**
Contracts and Services								
Red Lake Department of Natural Resources	Sub award	Supporting the time of Red Lake DNR staff, including Brenna Pemberton and RLDNR technicians, who will be conducting field work and sample collection for a subset of lakes within Red Lake Nation. Brenna will also conduct algal identification for surface water samples. This amount includes a 40% fringe benefit.				3		$185,000
SCWRS	Internal services or fees (uncommon)	Analysis of surface water samples including nitrogen, phosphorus, silicon, carbon, and chlorophyll. ($210/sample, 320 samples total including bi-weekly measurements from 16 lakes during a 5-month monitoring period)				0		$67,200
SCWRS	Internal services or	Analyzing the cyanobacterial toxin concentration, including microcystin, anatoxin, and				0		$19,200

	fees (uncommon)	cylindrospermopsin, of surface waters ($60/sample, 320 samples)						
SCWRS	Internal services or fees (uncommon)	Radioisotope dating of sediment cores from study lakes ($2400/core for 13 cores)				0		$31,200
SCWRS	Professional or Technical Service Contract	Loss-on-ignition analysis of sediment cores from 13 study lakes ($950/core for 13 cores)				-		$12,350
SCWRS	Internal services or fees (uncommon)	Analysis of sediment total phosphorus and phosphorus fractions ($2925/core for 13 cores)				-		$38,025
SCWRS	Internal services or fees (uncommon)	Analysis of fossil diatoms for reconstructing historic ecological and physical lake conditions ($9000/core for 13 cores)				-		$117,000
University of Regina or competitive bid	Professional or Technical Service Contract	Fossil pigment analysis to reconstruct historical algal community composition ($150/sample, 15 samples per core for 13 cores)				-		$29,250
SCWRS	Internal services or fees (uncommon)	Analysis of sediment biogenic silica ($825/core for 13 cores)				-		$10,725
SCWRS	Internal services or fees (uncommon)	Genomic analysis of preserved cyanobacterial community including 16S amplicon sequencing and qPCR analysis ($300/sample, 15 samples/core for 13 cores)				-		$58,500
SCWRS	Internal services or fees (uncommon)	Analysis of dissolved nitrogen and phosphorus from core incubation experiments ($55/sample, 1800 samples)				-		$99,000
Red Lake Department of Natural Resources	Sub award	Supplies and analytical costs associated with algal identification ($15/sample, 320 samples)				0		$4,800
							Sub Total	**$672,250**

Equipment, Tools, and Supplies								
	Tools and Supplies	Lab and field supplies	Bottles, reagents, preservatives, consumables for the collection and analysis of water and sediment samples. For example, bottles for water sample, filtration kits, sediment core tubes, and sediment specimen cups)					$7,000
	Equipment	Monitoring buoy supplies	Includes component sensors, rope, and anchors to construct and install 16 monitoring buoys on lakes					$54,000
	Equipment	Subaward to Red Lake DNR: sampling equipment for water quality monitoring	Sample bottles, filtering kits, calibration solutions, and replacement sensors for YSI sonde.					$9,000
							Sub Total	**$70,000**
Capital Expenditures								
		YSI EXO 2 sonde with total algae sensor	Part of the subaward to 1854 Treaty Authority, this sonde will enable advanced water quality monitoring and allow the 1854 TA to monitor a subset of sampling lakes.	X				$25,500
		bbe Fluoroprobe	Used to analyze the algal community composition (at a group level) via fluorescent techniques. The sonde will be used for biweekly field monitoring to provide real time information about the algal community, including density of cyanobacteria, and can be used to analyze grab sample measurements sent to SCWRS from our project collaborators.	X				$47,632
							Sub Total	**$73,132**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel for water quality monitoring of 16 lakes in northern Minnesota. Includes cost of vehicle mileage ($0.67/mile for 900 miles), gas ($180 for 900 miles), lodging (5 nights for 3 people at $98/night), and per diem ($36/day for 3 people for 6 days) for 20 total trips	Water quality monitoring for Activity 1					$58,020
	Miles/ Meals/ Lodging	Travel for sediment core collection, both for paleolimnological reconstructions and incubation experiments. Includes cost of vehicle mileage ($0.67/mile for 700 miles), gas ($180 for 700 miles), lodging (3 nights for 3 people at $98/night), and per diem ($36/day for 3 people for 4 days) for 7 total trips	Sediment core collection for Activities 2 and 3					$13,461
	Conference Registration Miles/ Meals/ Lodging	Cost to register and attend the Rainy-Lake of the Woods Watershed Forum in International Falls, MN. includes mileage ($0.67/mile for 600 miles), gas ($120 for 600 miles), lodging ($98/night for 3 nights for 3 people), per diem ($36/day for 4 days for 3 people), and meeting registration ($500/person for 3 people)	Presenting results of this project at the Rainy-Lake of the Woods Watershed Forum,					$3,336
	Miles/ Meals/ Lodging	Subaward to Red Lake DNR: travel to conduct water quality monitoring as part of Activity 1. Includes mileage ($0.67/mile for 50 miles), gas for boats and vehicles ($30/trip) for 20 trips.	Water quality monitoring for Activity 1					$1,270
							Sub Total	**$76,087**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Two peer-reviewed scientific papers published in open-access journals	To communicate our findings with researchers					$6,000
							Sub Total	**$6,000**
Other Expenses								

							Sub Total	**-**
							Grand Total	**$1,362,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Personnel - Adam Heathcote		Assisting with project management and result dissemination	**Classified :** This funding would be only for research conducted specific to this proposed project. This is a partially grant-funded position.
Capital Expenditures		YSI EXO 2 sonde with total algae sensor	This capital expenditure will be purchased by the 1854 Treaty Authority and will be used for the biweekly monitoring of lakes within the 1854 Ceded Territory as a part of this study. **Additional Explanation :** This sonde will be used for biweekly water quality monitoring as a part of this project.
Capital Expenditures		bbe Fluoroprobe	This capital expenditure will be used for the biweekly monitoring of lakes, both in the field and to analyze grab samples collected by project partners. **Additional Explanation :** The sonde will be used for biweekly monitoring as part of Activity 1. It will also be able to provide real time data for the assessment of algal boom dynamics and the density of cyanobacteria without the delay of additional laboratory analyses.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	1854 Treaty Authority	Funds to support the time of project co-PIs Matt Santo, Steve Shier, and Tyler Kaspar who will be monitoring lakes as part of Activity 1, assisting in the data analysis, and presenting and disseminating project results.	Secured	$23,296
In-Kind	Red Lake DNR	Sensors for buoys within Red Lake	Secured	$7,200
			Non State Sub Total	**$30,496**
			Funds Total	**$30,496**

Total Project Cost: $1,392,496

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 1f5064cd-528.pdf

Alternate Text for Visual Component

Pristine, northern lakes in Minnesota are experiencing toxic cyanobacterial blooms and we don't know why! Our research will use monitoring, paleo-reconstructions, experiments, and modeling to understand what drives blooms in sensitive lakes and how we can adapt our lake management strategies to protect these lakes under future climate change....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Letter Authorizing Proposal Submission	879ec850-ebf.pdf
Letter of support - 1854 Treaty Authority	4aa44380-ae9.docx
Letter of support - Red Lake Department of Natural Resources	d8871cad-c2c.pdf
Letter of support - U.S. Forest Service	583e689d-f98.pdf
Letter of support - MN Pollution Control Agency	5c279716-bac.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Hailey Sauer, Jason Ulrich, Mark Edlund, Adam Heathcote: St. Croix Watershed Research Station
Matt Santo, Tyler Kaspar, Steve Shier: 1854 Treaty Authority
Brenna Pemberton, Shane Bowe: Red Lake Department of Natural Resources