



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-379

Proposal Title: Understanding and Fixing Excess Lake Oxygen Depletion

Project Manager Information

Name: John Downing

Organization: U of MN - Duluth

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Project Basic Information

Project Summary: The purpose of this project is to find out why important Minnesota lakes are losing their cisco-trout-friendly waters so that remedial measures can be selected to sustain cold water fisheries.

Funds Requested: \$171,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

Secondary 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?

Statewide

When will the work impact occur?

In the Future

Narrative

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

Coldwater cisco-trout lakes are an important and iconic resource in Minnesota but lakes are becoming uninhabitable by these fish species due to the combination of low oxygen and warming waters. Coldwater fish are being squeezed between warm water at the surface and deoxygenated water at the bottom (see figure). Background research shows that oxygen loss rates in some of these lakes are 2-5-times that expected based on nutrient levels. Oxygen is depleted in lakes by decomposition of algae and other organic matter which is one reason managers try to keep nutrient and algae levels low. In these clear, coldwater lakes, however, oxygen may be being depleted by other mechanisms including chemical oxygen demand from ammonia and other chemicals or by catalytic uptake from reduced iron and dissolved organic matter. We will diagnose the mechanism for a group of coldwater lakes to identify the most efficient and cost-effective ways to fix the problem. Choosing a method for remediation depends 100% on the reason oxygen is depleted. Hypolimnetic aeration could be useful in some cases but diversion of organic matter or iron inactivation may be necessary in others. After all, one can't cure a disease until we identify the cause.

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

Our proposed solution is to find out why important Minnesota lakes are losing their cisco-trout-friendly waters and recommend remedial measures that can sustain coldwater fisheries for Minnesotans. We will find out the mechanism of oxygen loss so that we can design cost-effective measures to save this important and disappearing fishery. Remediation could include deep-water reoxygenation, iron oxidation, or other approaches that work only for specific mechanisms of oxygen loss. Already, some lakes have a few ciscoes and trout but the squeeze between warming surface waters and increasing loss of deep-water oxygen is isolating cold-water fish in a thin layer during crucial times of year. There are 176 cisco lakes in Minnesota (see Figure). The purposes of this project are (1) to determine how much oxygen is removed from a subset of Tier 1 cisco-trout lakes by different mechanisms, (2) to find how cisco-trout lakes are different from those where trout and cisco have been lost, and (3) recommend means of remediating excess oxygen loss. Nearly all aspects of this work are pandemic-proof. Activity 1 can be accomplished by a single individual working alone in a boat. Activity 2 can be performed remotely. Activity 3 will communicate all outcomes virtually.

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?

Analyses of the Tier 1 lakes will show remedial measures that will enhance the quality of cisco-trout lakes in the state and reinvigorate the sport-fishing opportunities in lakes experiencing similar changes. Analyses of MNDNR data will indicate the differences between lakes where cisco and trout have been lost and those where they still exist. This will indicate how to protect the remaining coldwater fishery lakes as well as showing ways to fix those where cisco and trout have been lost. Recommendations for specific lakes will lead lake associations and others toward seeking funding for remedial measures to restore vigorous fisheries.

Activities and Milestones

Activity 1: Field measurements of oxygen demand, temperature, and chemistry in Tier 1 cisco lakes

Activity Budget: \$110,050

Activity Description:

We will measure oxygen and temperature profiles every second week from ice-out to ice cover in 12 Tier 1 cisco-trout lakes (see map) over one full year. Two under-ice profiles will also be measured in each lake. Chemical measurements of nutrients, chlorophyll, iron, and dissolved organic carbon, as well as titration with acidic potassium permanganate will allow us to distinguish decompositional, catalytic, chemical and biochemical oxygen demand. Oxygen and temperature profiles will be determined using existing equipment in the Downing laboratory. Chemical measurements will be made in the Filstrup laboratory using standard methods. We feel certain that we can complete this work in a single year (calendar year 2022).

Activity Milestones:

Description	Completion Date
Measure oxygen demand and partition among mechanisms	2022-04-30
Complete seasonal lake profiles and water chemistry	2022-12-31

Activity 2: Determine difference between lakes that have lost ciscoes and trout and those where they still are found

Activity Budget: \$51,170

Activity Description:

We will search Minnesota DNR fisheries files to find moderate-large lakes where ciscoes or trout have disappeared over recorded time. Also, we will search MN Lake Finder for data on characteristics of these lakes and use Geographical Information Systems to characterize current landscape and land use information. We will then perform a multi-dimensional analysis to find how lakes retaining ciscoes and trout differ from those from which they have been lost. This will tell us how many coldwater fishery lakes there once were and where and why they have been lost. This information will also lead to determining how to remediate these lakes.

Activity Milestones:

Description	Completion Date
Analyze characteristics of lakes that distinguish cisco-trout lakes that have lost vs retained populations	2022-06-30
Augment lake data with chemical, physical, and GIS data on lakes with and without ciscoes or trout	2022-06-30
Student builds database of lakes where ciscoes or trout have disappeared historically	2022-06-30

Activity 3: Report on remedial measures to fix the problem and bring back ciscoes-trout in other lakes

Activity Budget: \$9,780

Activity Description:

Based on the partitioning of oxygen demand among mechanisms of oxygen uptake, we will compile the best and most cost-effective approaches to remediation to use in these valuable lakes. These recommendations will be supplied for each of the study lakes. Depending upon the chemical and geographical characteristics of lakes showing diverse oxygen loss mechanisms, we will calculate the likelihood of lakes other than our 12 study lakes showing one deoxygenation

mechanism or another. This information will be communicated to concerned environmental and fishing groups along with a list of potential lake management methods that could return healthy oxygen concentrations to the temperature strata where ciscoes and trout live. We will also provide estimates of the cost of diverse oxygen remediation pathways. Outcomes will include showing practical means of diagnosis of mechanisms of oxygen loss and creation of a key for deciding what remediation measures would be most effective and economical.

Activity Milestones:

Description	Completion Date
Make recommendations of lake-specific approaches to enhancing cisco-trout habitat and reproductive success	2023-06-30
Determine costs of diverse approaches of re-oxygenation that will sustain cold water habitat	2023-06-30
Compile compendium of proven re-oxygenation approaches that work with different causes	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
John R. Jones	Retired from University of Missouri, Columbia	Volunteer collaborator - summer resident of Itasca County, MN	No
Christopher T. Filstrup	Natural Resources Research Institute	Co-PI	Yes

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 be funded?

The results of this study will inform future management of the cisco-trout lakes of Minnesota. One of the principal outcomes will be to define management strategies for retaining cold water fisheries in Minnesota. Execution of management actions, in some cases, will require funding to treat low oxygen conditions as well as operation of this infrastructure. We will work with lake associations and other environmental groups to design, fund, and operate remedial measures. If innovative methods to inactivate specific processes are needed, funding proposals to USGS, the National Science Foundation, and NOAA will be submitted to supply those innovations.

Project Manager and Organization Qualifications

Project Manager Name: John Downing

Job Title: Director and Professor

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

John A. Downing has 40 years of experience in aquatic research and community outreach. He is currently the Director of the Minnesota Sea Grant College Program, a research scientist at the Large Lakes Observatory, and a tenured Professor in the Department of Biology at the University of Minnesota Duluth. Although he has life-long roots in Minnesota, he was formerly a Regent's Professor of Ecology, Evolution, & Organismal Biology and Agricultural & Biosystems Engineering at Iowa State University and ran one of the best-funded and long-standing research operations at that institution. His 150+ peer-reviewed books and journal articles cover diverse topics in limnology, marine science, environmental economics, and terrestrial ecology. His leadership has been as the Director of the Laurentian Biological Station (Montreal), the co-founder of the Inter-University Limnological Research Group (Montreal), Director of the Iowa State University Limnology Laboratory, Chair of the Environmental Science Graduate Program (Iowa State), President of the Association for the Sciences of Limnology and Oceanography, and Chair of the Council of Scientific Society Presidents. Recent outreach has assisted in agricultural regions to understand and mitigate nutrient pollution and helped citizens and industries in northern citizens Minnesota combat eutrophication and avoid lake degradation from aquatic invasive species.

Organization: U of MN - Duluth

Organization Description:

Minnesota Sea Grant is part of the National Oceanic and Atmospheric Administration's (NOAA) Sea Grant Program, which supports 34 similar programs in coastal states throughout the United States and Puerto Rico. Our mission is to facilitate interaction among the public and scientists to enhance communities, the environment and economies along

Lake Superior and Minnesota's inland waters by identifying information needs, fostering research and communicating results. Minnesota Sea Grant concentrates on research, outreach, and education in four focus areas: Healthy coastal ecosystems, sustainable fisheries and aquaculture, resilient communities and economies, environmental literacy and workforce development. This research will be performed using the facilities of the Large Lakes Observatory (LLO) and the Natural Resources Research Institute (NRRI), both in Duluth, Minnesota. LLO has a unique mission: to perform scientific study of the largest lakes of Earth. It is one of the largest water-centered research units at the university and its impact has been felt all over the world. NRRI's mission is to deliver research solutions to balance our economy, resources and environment for resilient communities.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
John A. Downing		Principle investigator			26.7%	0.1		\$29,339
Christopher T. Filstrup		Co-PI			26.7%	0.1		\$9,615
MS Student		Graduate student			48%	1		\$79,940
Undergraduate field and lab assistant		Assist graduate student and Co-PIs with lab and field research			0%	0.42		\$6,720
							Sub Total	\$125,614
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Chemicals and field collection bottles	to ensure that water samples are properly collected and conserved until analysis					\$1,062
							Sub Total	\$1,062
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	14 sampling trips x 600 miles x \$0.575 + 1485 miles for data mining	To access lakes and data sources					\$5,684

5/18/2020

							Sub Total	\$5,684
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
							Sub Total	-
Other Expenses								
		Chemical analysis: 12 lakes, 2 samples/lake/event, 14 sampling events TN+TP @\$28, chlorophyll @\$32, DOC@\$25 & Fe panel @\$30 - at limnology lab at the Natural Resources Research	To determine the characteristics of lakes sampled to give us evidence of causes of oxygen depletion					\$38,640
							Sub Total	\$38,640
							Grand Total	\$171,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
In-Kind	University of Minnesota Sea Grant unrecovered indirect cost @55% MTDC; base = \$138,146	Ensure office and lab space, computing equipment and other university services	Secured	\$75,822
			Non State Sub Total	\$75,822
			Funds Total	\$75,822

Attachments

Required Attachments

Visual Component

File: [49ca5603-b4e.pdf](#)

Alternate Text for Visual Component

Panel 1. Results of a pilot study on Bluewater Lake, Itasca County, showing the top-to-bottom distribution of oxygen across the 2018 ice-free season. Bluewater Lake is a Tier 1 cisco lake that is hoped to be a refuge for cold water fish. The cool colors at the top show depths and dates at which there was sufficient oxygen for cold water fish while the hotter colors at the bottom show where oxygen was insufficient. The top solid line shows the depth/date limit of 10 C water (50 F) above which ciscoes and trout have trouble living. The bottom solid line shows the depth/date limit of water with 5 mg per liter of oxygen, below which ciscoes and trout have trouble living. Depth in the lake is shown in meters (m), approximately equal to yards. We will find out what mechanisms are making low oxygen water rise so far from the bottom so we can find ways of fixing it.

Panel 2. Locations of Minnesota's Tier-1 cisco lakes. These are lakes where ciscoes are present but landscapes are undeveloped enough to potentially provide a refuge for ciscoes – assuming that landscape changes are the principal mechanism leading to loss of oxygen in deep, cold waters. We will select study lakes from Tier-1 lakes. There are 176 cisco-trout lakes in Minnesota according to Mr. Peter Jacobson of the Minnesota Department of Natural Resources and we will choose 12 to study that cover the range of important lake configurations and conditions.

Optional Attachments

Support Letter or Other

Title	File
Transmittal letter from University of Minnesota Duluth approving submission	b98306b9-a6d.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

No

Does your project include research?

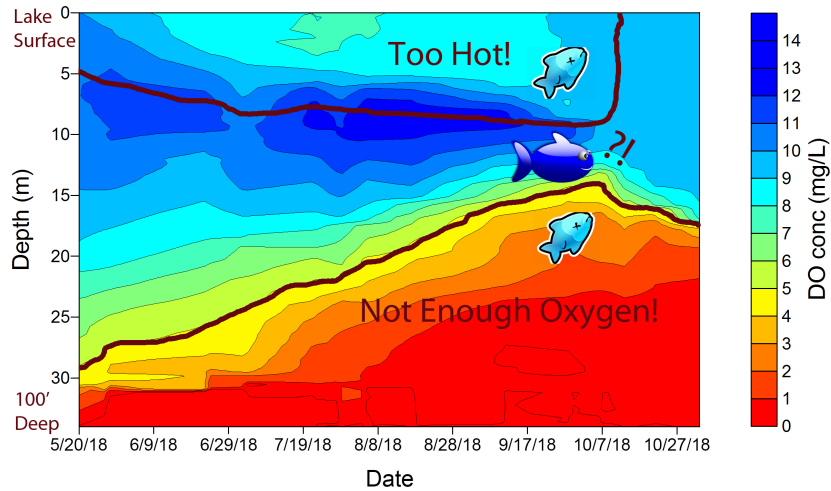
Yes

Does the organization have a fiscal agent for this project?

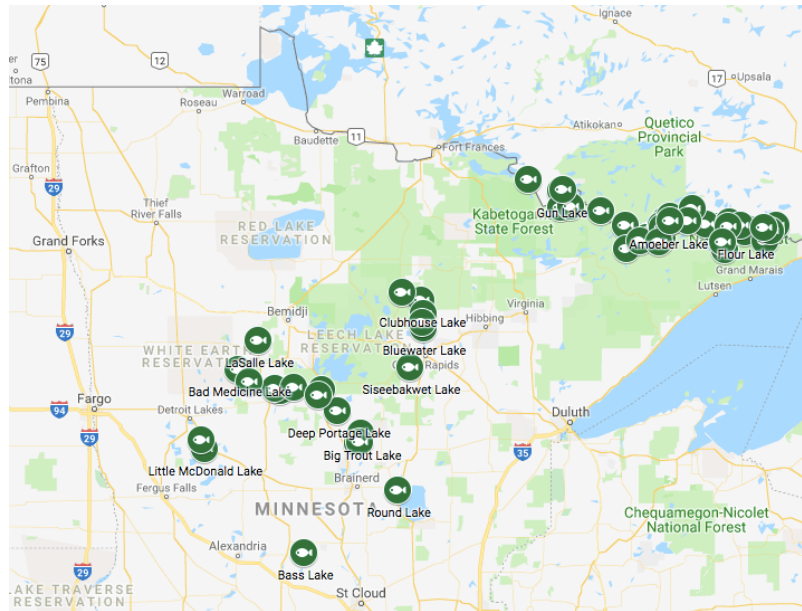
No



Environment and Natural Resources Trust Fund (ENRTF)
2021 Visual or Map
Project Title: Understanding and fixing excess lake oxygen depletion



Results of a pilot study on Bluewater Lake, Itasca County, showing the top-to-bottom distribution of oxygen across the 2018 ice-free season. Bluewater Lake is a Tier 1 cisco lake that is hoped to be a refuge for cold water fish. The cool colors at the top show depths and dates at which there was sufficient oxygen for cold water fish while the hotter colors at the bottom show where oxygen was insufficient. The top solid line shows the depth/date limit of 10° C water (50° F) above which ciscoes and trout have trouble living. The bottom solid line shows the depth/date limit of water with 5 mg per liter of oxygen, below which ciscoes and trout have trouble living. Depth in the lake is shown in meters (m), approximately equal to yards. We will find out what mechanisms are making low oxygen water rise so far from the bottom so we can find ways of fixing it.



Locations of Minnesota’s Tier-1 cisco lakes. These are lakes where ciscoes are present but landscapes are undeveloped enough to potentially provide a refuge for ciscoes – assuming that landscape changes are the principal mechanism leading to loss of oxygen in deep, cold waters. We will select study lakes from Tier-1 lakes. There are 176 cisco-trout lakes in Minnesota according to Mr. Peter Jacobson of the Minnesota Department of Natural Resources and we will choose 12 to study that cover the range of important lake configurations and conditions.