# Environment and Natural Resources Trust Fund

2027 Request for Proposal

## General Information

**Proposal ID:** 2027-463

**Proposal Title:** Forecasting Weather-Driven Cold-Water Habitat Risk in Minnesota

## Project Manager Information

**Name:** Anqing Xuan

**Organization:** U of MN - St. Anthony Falls Laboratory

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## Project Basic Information

**Project Summary:** This project will identify the summer weather conditions that trigger cold-water habitat loss in Minnesota lakes and deliver predictive tools for forecasting, targeted monitoring, and conservation planning.

**ENRTF Funds Requested:** $336,000

**Proposed Project Completion:** June 30, 2030

**LCCMR Funding Category:** Resiliency (A)

## 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?**

During the Project and In the Future

## Narrative

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

Minnesota has about 650 lakes that support cisco, but only 176 are considered refuge lakes deep and clear enough to sustain cold, oxygenated habitat as summers warm. A majority of Minnesota's cisco lakes could therefore be vulnerable to habitat loss. Cisco decline is driven by oxythermal squeeze: surface warming deepens the warm layer while deep-water decomposition lowers dissolved oxygen. Because cisco require both cold water and adequate oxygen, the overlap between these conditions can disappear quickly. For the first time since 1956, DNR has proposed reducing the statewide inland walleye possession limit from six fish to four, underscoring the broader management consequences of cisco decline.

The unanswered question is not only which lakes are vulnerable, but which lakes will lose cold-water habitat next and under what weather conditions. DNR collects summer temperature and oxygen profiles in some lakes, but it lacks a framework that links heat waves, calm periods, and wind events to lake-specific habitat collapse. Existing assessments emphasize long-term trends. In practice, habitat can fail when weather events push a lake past its remaining buffer. This project will go beyond broad vulnerability patterns by developing operational forecasts for seasonal decision-making and near-term risk assessment from dynamic trigger conditions.

**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 will build a physics-based lake model that simulates how temperature structure and dissolved oxygen evolve through summer in response to weather. The model will represent the processes that control cisco habitat: surface heating, wind-driven mixing, air-water heat exchange, stratification, and deep-water oxygen consumption. It will calculate weekly oxythermal habitat volume, or the water that is both cold enough and oxygenated enough for cisco. We will calibrate and test the model with DNR monitoring records from lakes with repeated temperature and oxygen profiles. The framework will convert existing vulnerability understanding into quantitative, lake-specific predictions of when habitat shrinks and how much buffer remains under specified near-term weather conditions. The project will deliver a weather trigger catalog, seasonal risk profiles for evaluated cisco lakes, and an interactive forecasting tool for near-term risk assessment. Together, these products will move management from general classification to forecasting: managers will be able to see not only which lakes are vulnerable, but also why, when, and under what weather patterns they are most likely to fail.

**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?**

This project will deliver forecasting and decision-support tools that translate weather data and lake physics into actionable habitat risk information for Minnesota resource managers. Products include:

- Lake model: a thermal-oxygen model that predicts weekly-to-seasonal cisco habitat conditions.
- Weather-trigger catalog: lake-specific documentation of the heat, calm, and wind sequences that drive habitat loss.
- Interactive forecasting tool: a web-accessible tool where managers enter weather conditions and receive habitat risk profiles.
- Public data archive: model code, calibration records, and lake-specific predictions.
- Policy brief: a summary of high-risk lakes, key trigger conditions, and management recommendations for relevant legislative committees.

## Activities and Milestones

### Activity 1: Compile Lake, Habitat, and Weather Datasets Across Minnesota

**Activity Budget:** $78,000

**Activity Description:**
The objective of this activity is to assemble the datasets needed to support modeling of cold-water habitat loss across Minnesota. We will compile temperature and dissolved oxygen profiles from DNR's long-term lake monitoring program, which has collected seasonal profiles for hundreds of Minnesota lakes over several decades. We will gather lake physical characteristics including maximum depth, surface area, mean depth, Secchi depth (water clarity), shoreline development index, and fetch exposure from DNR's lake database and published sources. We will also collect historical weather forcing data, including daily air temperature, wind speed and direction, solar radiation, and humidity, from gridded observational products such as DAYMET and ERA5 reanalysis, which provide spatially continuous records across Minnesota at daily resolution. We will quality control and standardize all records so that each lake has a consistent set of physical, ecological, and atmospheric inputs. This activity establishes the data foundation required for model calibration, habitat reconstruction, and vulnerability analysis in Activities 2 and 3.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Compilation of DNR temperature and dissolved oxygen profiles for cisco lakes with monitoring records | October 31, 2027 |
| Assembly of physical lake characteristics, watershed information, and fisheries survey records | December 31, 2027 |
| Historical weather forcing datasets assembled | March 31, 2028 |

### Activity 2: Build, Calibrate, and Reconstruct Lake Habitat Dynamics

**Activity Budget:** $120,000

**Activity Description:**
The goal of this activity is to develop and calibrate a lake thermal-oxygen model that predicts temperature structure, dissolved oxygen, and oxythermal habitat volume from lake characteristics and weather forcing. The model will represent the key physical processes controlling stratification: solar heating of the surface layer, wind-driven mixing that determines how deep the warm layer extends, heat exchange between the lake surface and the atmosphere, and oxygen consumption in the deep water by decomposition of organic matter. We will calibrate the model against well-monitored reference lakes, adjusting parameters that govern surface-layer deepening, mixing depth, and oxygen depletion rates by reconstructing weekly habitat dynamics (thermal structure, dissolved oxygen, and oxythermal habitat volume) across the past 15 to 20 summers. We will also compare reconstructed habitat compression with historical cisco population change from DNR fisheries surveys to test whether predicted high-stress lakes align with observed declines or disappearance. This activity will establish a credible weekly-to-seasonal forecasting framework before broader vulnerability analysis.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Lake thermal-oxygen model developed | September 30, 2028 |
| Lake model calibrated against well-monitored reference lakes | December 31, 2028 |
| Validation against historical cisco population change completed | March 31, 2029 |

## Activity 3: Predict Lake Vulnerability and Weather-Pattern Risk

**Activity Budget:** $100,000

**Activity Description:**
We will apply the validated model from Activity 2 to assess which cisco lakes are most vulnerable to weather-driven cold-water habitat loss and to identify the specific conditions that trigger collapse. We will select representative lakes spanning DNR's existing cisco lake tiers, from the deepest, clearest refuge lakes to shallower, more vulnerable systems, prioritizing lakes with sufficient historical monitoring data from Activity 1. For each selected lake, we will run the model under a set of forward weather scenarios designed to capture the range of conditions Minnesota lakes may face: typical summers based on historical median conditions, warm summers at the 75th and 90th percentile of heat accumulation, recent extreme summers such as 2012 and 2021, and projected near-term conditions drawn from regional climate projections. We will analyze how heat waves, extended calm periods, and wind events affect each lake's remaining cold-water buffer, quantify each lake's sensitivity to different weather sequences, and identify the threshold conditions under which habitat collapses. These outputs will provide the scientific basis for the weather-trigger catalog and forecasting tool developed in Activity 4.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Representative lake selection and forward weather scenario design completed | August 31, 2029 |
| Forward scenario runs completed for all selected lakes | October 31, 2029 |
| Lake-specific weather-trigger analysis and sensitivity assessment completed | December 31, 2029 |

## Activity 4: Deploy Forecasting Tools, Archive Data, and Brief Stakeholders

**Activity Budget:** $38,000

**Activity Description:**
We will package the model and analysis outputs from Activity 3 into products that managers can use directly. We will compile a weather-trigger catalog to document, for each evaluated cisco lake, the specific heat, calm, and wind sequences that drive cold-water habitat loss. We will also analyze each lake's thermal-oxygen responses and provide monitoring guidance identifying when targeted dissolved-oxygen profiling is most informative. We will implement an interactive forecasting tool as a web application that serves as an accessible interface to the model, where DNR staff can select any evaluated cisco lake, view the weather-trigger catalog, and explore how different summer weather types affect the remaining cold-water buffer. We will deposit all model code, calibration records, lake-by-lake predictions, and model inputs in a publicly accessible University of Minnesota data repository. We will present results to relevant legislative committees and deliver a policy brief summarizing the highest-risk lakes, key trigger conditions, and specific management recommendations for near-term conservation action.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Weather-trigger catalog completed | February 28, 2030 |
| Interactive forecasting tool deployed as a web application | April 30, 2030 |
| Public data archive completed | May 31, 2030 |
| Policy brief delivered and results presented to relevant legislative committees | June 30, 2030 |

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**
We will ensure that data and results generated by this project are communicated broadly and effectively to the stakeholders who can use them to protect Minnesota's cold-water habitat.

Stakeholder engagement and applied communication efforts will include: (1) Agency briefings: we will present results to relevant program managers to support integration of the forecasting tool and trigger catalog into operational monitoring and management workflows. (2) Policy brief and legislative presentation: we will deliver a plain-language policy brief and present findings to relevant legislative committees.

Public communication and education efforts will include: (1) Plain-language summaries and web content describing the project's findings and their implications for Minnesota's cisco lakes and the anglers and communities that depend on them. (2) The interactive forecasting tool will be publicly accessible, allowing Minnesotans to explore cold-water habitat conditions in specific lakes.

Documentation and data management efforts will include: (1) Data archiving: all model code, calibration records, lake-by-lake predictions, and model inputs will be deposited in the University of Minnesota Digital Conservancy for open access and long-term preservation. (2) Data will be documented following open-science best practices to ensure usability by future researchers, agencies, and the public.

Scientific and technical dissemination includes: (1) Peer-reviewed publications: results of lake model development, calibration, and habitat analysis will be submitted to scientific journals for publication. (2) Conference presentations: findings will be presented at professional conferences in limnology, fisheries science, and water resources management to ensure visibility and encourage collaboration. (3) Technical reports: we will produce a technical report documenting model methods, calibration results, and lake-specific findings for use by DNR and other resource agencies.

In all print and electronic media, publications, signage, and other communications produced by this project, we will acknowledge the Environment and Natural Resources Trust Fund through use of the trust fund logo and attribution language per the ENRTF Acknowledgment Guidelines.

## 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?**
Following project completion, the interactive forecasting tool, weather-trigger catalog, and public data archive will remain hosted by the University of Minnesota for continued use by resource managers and the public. The interactive tool will accept new temperature, oxygen, and weather inputs over time, supporting ongoing monitoring and management decisions beyond the grant period. Longer-term maintenance and operational integration will be pursued through Minnesota DNR cooperative agreements and future LCCMR proposals that extend the framework to additional lakes. Federal programs including NSF Hydrological Sciences and NOAA Minnesota Sea Grant will also be pursued to support model development and scientific expansion.

## Project Manager and Organization Qualifications

**Project Manager Name:** Anqing Xuan

**Job Title:** Researcher Pro 5 - Mechanical Eng

**Provide description of the project manager's qualifications to manage the proposed project.**
Dr. Anqing Xuan is a researcher at the University of Minnesota's St. Anthony Falls Laboratory with expertise in environmental fluid dynamics and computational modeling. He obtained a Ph.D. from the University of Minnesota in 2020. He then served as a postdoctoral associate at St. Anthony Falls Laboratory from 2020 to 2023 before continuing there as a researcher. His work examines how water moves and mixes in environmental systems and how computational tools can be used to simulate these processes accurately and efficiently. He has authored 16 peer-reviewed journal articles and 4 peer-reviewed conference papers, including studies in the Journal of Fluid Mechanics, Journal of Computational Physics, and Computers & Mathematics with Applications on water waves and mixing in water. This publication record is directly relevant to the proposed project because it demonstrates experience with the physical processes and numerical tools needed to forecast lake thermal structure, wind-driven mixing, and oxygen conditions. Together, his training, publication record, and experience in environmental flow physics, numerical modeling, and data-driven analysis provide strong qualifications to manage the proposed project. He will lead model development, calibration, validation, data synthesis, and delivery of forecasting products and technical reports.

**Organization:** U of MN - St. Anthony Falls Laboratory

**Organization Description:**
This project will be performed at the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at the University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational center. It has 22 faculty members and 27 research and administrative staff members. Each year, more than 100 postdocs and students conduct research at SAFL. SAFL is a world-renowned research laboratory specializing in environmental, geophysical, and engineering fluid mechanics. SAFL researchers have been performing many innovative environmental studies for Minnesota. Some of the projects were/are funded by the Minnesota Environment and Natural Resources Trust Fund. The proposed research leverages the unique and advanced capabilities of simulating and measuring environmental and geophysical flows at SAFL, which has 16,000 square feet of research space dedicated to research.

## Budget Summary

| Category / Name | Subcategory or Type | Description | Purpose | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | $ Amount |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| Project Manager | | Oversee the project, lead the research and model development, carry out the simulation, and responsible for project reporting | | | 38.5% | 2.25 | | $304,651 |
| Undergraduate Student Assistant | | Assist with data compilation and quality checking | | | 0% | 0.12 | | $4,386 |
| Computer Scientist | | Assist with computational model setup, web tool development, and data archiving | | | 34.9% | 0.24 | | $26,963 |
| | | | | | | | **Sub Total** | **$336,000** |
| **Contracts and Services** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Capital Equipment** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Acquisitions and Stewardship** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel In Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel Outside Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Printing and Publication** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Other Expenses** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| | | | | | | | **Grand Total** | **$336,000** |

## Classified Staff or Generally Ineligible Expenses

| Category/Name | Subcategory or Type | Description | Justification Ineligible Expense or Classified Staff Request |
|---|---|---|---|

## Non ENRTF Funds

| Category | Specific Source | Use | Status | Amount |
|---|---|---|---|---|
| **State** | | | | |
| | | | **State Sub Total** | **-** |
| **Non-State** | | | | |
| In-Kind | Unrecovered F&A | Funds to support SAFL operations where the project will be conducted | Secured | $181,440 |
| | | | **Non State Sub Total** | **$181,440** |
| | | | **Funds Total** | **$181,440** |

**Total Project Cost: $517,440**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

*Visual Component*

File: 15189350-a35.pdf

*Alternate Text for Visual Component*

Conceptual overview of a Minnesota lake habitat forecasting project: a cross-sectional lake illustrates how weather patterns and mixing can compress the cold, oxygen-rich refuge needed by cisco; a map identifies Minnesota lakes at risk; and an interactive tool translates weather inputs into lake-specific habitat risk predictions....

### Supplemental Attachments

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

| Title | File |
|---|---|
| Board authorization letter | 234e6771-cb3.pdf |

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**

N/A

**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?**

No

**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:**

Ben Vargas, Sponsored Projects Administration

**Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements**

N/A