Final Abstract

Final Report Approved on November 14, 2025

M.L. 2022 Project Abstract

For the Period Ending June 30, 2025

Project Title: Changing Winters and Game Fish in Minnesota Lakes

Project Manager: Ted Ozersky

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Funding Source:

Fiscal Year:

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 04d

Appropriation Amount: $238,000

Amount Spent: $236,376

Amount Remaining: $1,624

Sound bite of Project Outcomes and Results

This project produced the most comprehensive dataset to date on winter conditions in Minnesota lakes, linking temperature, oxygen, and food availability to game fish health. Results reveal strong year-to-year and lake-to-lake variability in winter ecology, providing key insights into how changing winters may affect Minnesota's fish populations.

Overall Project Outcome and Results

This project addressed a major knowledge gap on winter conditions in Minnesota lakes and their effects on fish habitat and food webs. We conducted year-round sampling on four study lakes: Portage Lake (sentinel lake), Carrie (sentinel lake), Madison Lake (sentinel lake), and Pike Lake (non-sentinel lake). These lakes represent different regions, morphologies, and productivity levels, allowing us to evaluate how winter conditions vary across Minnesota.

We collected physical, chemical, and biological data across seasons, including under-ice temperature, oxygen, nutrients, phytoplankton, zooplankton, benthic invertebrates, and fish. Fish were analyzed for body and reproductive condition, diets, and stable isotopes to assess energy flow through winter.

The resulting dataset is the most comprehensive record of winter conditions in Minnesota lakes, spanning under-ice physics to fish feeding ecology. Findings show that winter processes strongly shape lake food webs and game fish habitat. We documented the first recorded case of a zooplankton "winterkill," linking oxygen depletion under thick ice and snow to collapse of key prey species. Seasonal patterns also revealed that zooplankton and benthic invertebrates peak at different times of year, meaning that prey availability for fish can shift dramatically among lakes and winters. Game fish diets varied widely across lakes and years, demonstrating that both species traits and winter habitat conditions influence feeding under ice.

These results matter for fisheries and water-resource management because winter habitat is changing rapidly as ice cover declines and snowpack becomes more variable. The dataset provides a baseline for evaluating winter sensitivity of Minnesota's game fish and their prey, improves predictions of winterkill risk, and helps identify when and where winter habitat bottlenecks occur. Next steps include working with DNR partners to integrate winter metrics into lake assessments and to identify lakes most vulnerable to changing winter conditions.

Project Results Use and Dissemination

Results were shared through 12 conference and workshop presentations, including multiple DNR-hosted events. One peer-reviewed paper from the project has been accepted in Ecology (uploaded as Benedict.etal.2025Accepted), and the underlying dataset has been made publicly available. Public outreach included exhibits at Freshwater Discovery Days and the "Black Box of Winter" installation at the Art Shanty Projects, which engaged hundreds of Minnesotans in under-ice ecology. Three students (undergraduate, M.S., Ph.D.) were trained through the project. A workshop with DNR staff is planned to discuss management implications and how to incorporate winter metrics into fisheries and lake-assessment efforts.

Environment and Natural Resources Trust Fund

M.L. 2022 Approved Final Report

General Information

Date: December 2, 2025

ID Number: 2022-103

Staff Lead: Tiffany Schaufler

Project Title: Changing Winters and Game Fish in Minnesota Lakes

Project Budget: $238,000

Project Manager Information

Name: Ted Ozersky

Organization: U of MN - Duluth - Large Lakes Observatory

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Project Reporting

Final Report Approved: November 14, 2025

Reporting Status: Project Completed

Date of Last Action: November 14, 2025

Project Completion: June 30, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 04d

Appropriation Language: $238,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Large Lakes Observatory in Duluth to determine how changing winter conditions such as ice cover, snowfall patterns, and water quality affect Minnesota's game fish populations.

Appropriation End Date: June 30, 2025

Narrative

Project Summary: Winter is a critical period for game fish recruitment and survival, yet little is known about winter lake ecology. We will determine how changing winter conditions affect Minnesota's fish resources.

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

Winter is the main seasonal bottleneck for the survival and recruitment of Minnesota's game fish because of cold temperatures, oxygen depletion in productive lakes, decreased food availability, and predation. Winter is changing in Minnesota, but very little is known about the biology of Minnesota's lakes in winter and how changing environmental conditions affect the under-ice environment for fish. This knowledge gap represents a significant challenge to resource management.

Ongoing reductions in the duration of ice cover, changing snowfall patterns, and changes in water quality (e.g., eutrophication or its remediation) mean that winter conditions in lakes will continue to change statewide over the coming decades. These changes will impact under-ice abiotic and biotic conditions and the recruitment and survival of juvenile and adult gamefish such as walleye, yellow perch, and panfish. This will result in new patterns of competition, cannibalism, and predation among fish species and long-term change in fish communities.

Managing Minnesota's game fish resources into this uncertain future requires substantially improved understanding of winter in lakes. In collaboration with the Sentinel Lakes Program, this project will determine how winter conditions affect game fish in Minnesota lakes that vary in water quality and winter climate.

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.

Bottom-up (temperature, oxygen, food) and top-down (predation) forces control fish survival and recruitment. Researchers from UMD and the Sentinel Lakes Program (SLP) will work with citizen scientists to determine how these forces vary over winter in 5 sentinel lakes with different water quality and winter conditions.

UMD researchers will visit each lake 3 times during winter (and 2 times in summer), collecting data on abiotic and biotic conditions. The SLP will provide matching open-water season data for these lakes and continuous winter oxygen data collected on a subset of lakes. Studies of juvenile fish food habits and sizes (collected by SLP) and adult fish stomach contents (collected by researchers and community scientists) will determine how recruitment, feeding, and predation change during winter across lakes.

Findings will be shared with community members, scientists, and resource managers through a workshop in Year 3 of the project. Participants will produce recommendations for management and information needs given ongoing environmental change.

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?

Too little is known about the winter biology of seasonally frozen lakes to predict the response of Minnesota's aquatic resources to ongoing changes in winter conditions. This project will provide information about how abiotic and biotic conditions important for water quality and the survival and recruitment of game fish vary in Minnesota lakes of different trophic status and winter climate setting. This work will contribute to long term, science-based resource management, produce foundational winter data and establish methodologies for future winter work for the Sentinel Lakes Program.

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

Activities and Milestones

Activity 1: Determine how abiotic and biotic winter conditions change across diverse Minnesota lakes.

Activity Budget: $234,037

Activity Description:
Researchers from UMD will sample 5 diverse MN sentinel lakes in Years 1 and 2 of the project (3 visits per lake in winter, 2 visits in summer), collecting physical (light, temperature), chemical (oxygen, water quality), and biological (phytoplankton, zooplankton, benthic communities) metrics relevant to fish survival and recruitment. This information will be combined with available open water season data from the study lakes and year-round continuous oxygen and temperature records maintained by the Sentinel Lakes Program (SLP).

SLP researchers will collect juvenile game fish in a subset of study lakes during fall and spring. These samples will help determine how overwinter size, survival, body condition and feeding patterns of juvenile fish vary across water quality and winter climate gradients. UMD and SLP researchers will work with ice fishers (e.g., lake association members, fishing tournament participants) to collect samples of adult game fish from the study lakes for stomach content and isotopic diet analysis.

Combined, the assembled data will show how bottom-up and top-down forces interact to shape winter conditions for fish in different lakes. Results will provide a benchmark for comparing future conditions in Sentinel Lakes and enable forecasting how changing environmental conditions will affect Minnesota's resources.

Activity Milestones:

Description	Approximate Completion Date
Graduate students hired and preparation for first field season completed	December 31, 2022
UMD sampling of 2 of 5 study lakes completed	November 30, 2023
UMD sampling of all lakes completed	April 30, 2024
Sentinel Lakes Program (SLP) sampling of age-0 fish completed	May 31, 2024
UMD and SLP sample analysis complete	January 31, 2025
UMD and SLP data integrated	March 31, 2025

Activity 2: Communicate study results and management implications to citizens, scientists, resource managers, and other stakeholders.

Activity Budget: $3,963

Activity Description:
We will communicate the results of our research through outreach to the media, a workshop/webinar, presentations at regional meetings (e.g., Minnesota Water Resources Conference), and the scientific literature.

In year 3 of the project, we will convene a 1-day workshop to communicate and discuss the results of our work with stakeholders. Participants will include academic and government scientists, resource managers, and interested members of the public (e.g., lake association members). During the first half of the day, UMD and Sentinel Lake Program (SLP) researchers will present the results of their work. During the second part of the day, participants will engage in a guided discussion of the results. The goal of the discussion will be to summarize the state of knowledge on winter ecology in Minnesota lakes, identify remaining priority questions regarding the role of winter conditions in shaping fish communities, and draft a set of management implications and recommendations based on results. The results of the

workshop will be summarized as a report and distributed to state agencies and LCCMR. The workshop will be held in person with an option to attend remotely to increase public accessibility and participation.

Activity Milestones:

Description	Approximate Completion Date
Presentations at Minnesota Water Resources Conference	October 31, 2024
Workshop with state stakeholders and report to stakeholders	April 30, 2025
Publications in scientific literature	June 30, 2025
Outreach to media	June 30, 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Thomas Hrabik	University of Minnesota Duluth	Dr. Thomas Hrabik is a professor in the department of Biology (University of Minnesota Duluth). He has extensive experience studying freshwater fish and food webs. Dr. Hrabik will lead the fisheries portion of this work.	Yes
Marte Kitson	University of Minnesota Sea Grant Program	Marte Kitson is an Environmental Literacy Extension Educator at Minnesota Sea Grant. She has extensive experience with environmental education and extension activities, including work with the public, media and K-12 educators. She will help coordinate outreach and extension activities associated with this project.	Yes
Casey Schoenebeck	MN DNR Sentinel Lakes Program	The Sentinel Lakes Program will provide year-round dissolved oxygen and temperature data and sample for age-0 fish during fall and spring.	No

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.
Results generated though this project will be shared with researchers, resource managers, and other stakeholders through several mechanisms. The PIs and students working on the project will publish the results of their research in the scientific, peer-reviewed literature, disseminating their findings to the scientific and resource management community. We will also communicate the results of this work at the Minnesota Water Resources conference. In year 3 of the project, we plan a workshop with Minnesota natural resource managers and other interested stakeholders to share the results of our work and discuss management implications and remaining open questions and next steps for winter fisheries research in Minnesota. The discussions from the workshop will be summarized in a report. We will discuss our work with members of the public through our citizen-scientists efforts.

The data generated through this work will be shared through open-access data repositories such as DRUM (Data Repository of the University of Minnesota). Data will be made publicly available at the time of publication of manuscripts based on these data. Data generated through this work will be regularly backed up and stored on computers at the LLO as well as on the cloud storage service 'Google Drive' to ensure the longevity and integrity of the data.

Acknowledgement of ENRTF funding will be included in all project communication. Funding will be acknowledged in accordance with ENRTF Acknowledgement Requirements and Guidelines, through the inclusion of the ENRTF logo, ENRTF-specified attribution language, or by tagging the ENRTF on social media.

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?
Aquatic ecologists increasingly recognize that winter conditions play an important role in structuring lake ecosystems. However, too little is currently known about the links between water quality, winter climate, and fish biology to predict how ongoing environmental change will impact Minnesota's game fish. Our project will address this information gap for Minnesota lakes and produce results that will improve management of fish resources. We will use meetings, workshops, and reports to ensure our results are available to state scientists and resource managers and seek their feedback in identifying remaining open questions and management recommendations.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount	$ Amount Spent	$ Amount Remaining
Personnel										
PI - Ozersky		PI. 1 day summer salary for PI Ozersky in Years 1 and 2 of the project to coordinate project and participate in sampling			26.9%	0.02		$566	-	-
Co-I Hrabik		Co-I. 0.35 months summer salary for PI Hrabik in Year 1 and 0.5 months in Year 2 2 of the project to coordinate project and participate in sampling			26.9%	0.06		$10,574	-	-
Co-I Kitson		0.5 months salary in Years 1-3 to help coordinate citizen science component and workshop			26.9%	0.12		$8,432	-	-
MS Grad Student		Full graduate research assistantship (academic + summer) in year 1 ; just summer in year 2. Student will conduct research of fish diets and survival.			44.2%	0.62		$50,851	-	-
PhD Grad student GRA		Full graduate research assistantship (academic + summer) in 1 and 2 ; just summer in year 3. Student will conduct research on lower trophic levels and connections to fish.			45.1%	1.14		$106,358	-	-
LLO Lab tech		1 months of lab technician that will assist with processing of water chemistry and bulk stable isotope sample analysis in year 2			24.2%	0.16		$9,453	-	-
Research Benedict		Temp/Casual researcher November and December, Y1			7.65%	0.13		$6,826	-	-
							Sub Total	**$193,060**	**$193,060**	**-**
Contracts and Services										
Large Lake Observatory	Internal services or fees (uncommon)	Water sample analysis: analysis of duplicate water chemistry samples characterize nutrients and phytoplankton biomass (TP, TN. Chl. a, DOC, POC/PON) in 5 study lakes, with 5 visits per lake and 3 sampling depths				0		$6,300	$6,300	-

		(90 samples for each analysis/year). Analyses will be performed at UMD-LLO.								
Large Lakes Observatory	Internal services or fees (uncommon)	Foodweb C/N stable isotope analyses: stable isotope analysis (C and N) to determine feeding realtionships and food web strucutre in study lakes throughout the year. Triplicate samples to be analyzed will include zooplankton, benthic invertebrates (3 groups) and fish (3 groups). Analyses will be performed at UMD- LLO.				0		$9,533	$8,724	$809
							Sub Total	**$15,833**	**$15,024**	**$809**
Equipment, Tools, and Supplies										
	Tools and Supplies	Winter field gear	Winter field sampling gear, including ice shelter, sleds, auger and ice chisels					$965	$965	-
	Tools and Supplies	Fish sampling gear	Gillnet for collection of adult fish for stomach content and stable isotope composition					$1,000	$1,000	-
	Tools and Supplies	Filters	Various filters for sample collection and processing					$1,500	$1,500	-
	Tools and Supplies	Containers	Containers (bottles, bags) for storage of samples					$1,250	$1,250	-
	Tools and Supplies	EtOH and other chemicals	Ethanol and other chemicals for sample preservation and processing					$750	$750	-
	Tools and Supplies	Misc. supplies	This category includes small field and lab supplies (e.g., tape, pens, etc.), as well as non-capital equipment needed for this research (e.g., chest freezer for sample storage, replacement of a disabled handheld unit for a water quality sonde).					$10,090	$9,467	$623
	Tools and Supplies	Ice fishing gear	Simple ice fishing gear for K-12 environmental education component of the project					$250	$250	-

							Sub Total	**$15,805**	**$15,182**	**$623**
Capital Expenditures										
							Sub Total	**-**	**-**	**-**
Acquisitions and Stewardship										
							Sub Total	**-**	**-**	**-**
Travel In Minnesota										
	Miles/ Meals/ Lodging	Travel to field sites	Car travel to study lakes to perform sampling. Estimate is based on 5 visits to 5 lakes over the duration of the project.					$4,150	$4,150	-
	Miles/ Meals/ Lodging	Accommodations at field sites	Overnight stays during sampling. Assuming 2 rooms needed for each lake visit; 5 lakes x 5 times					$4,000	$4,000	-
	Miles/ Meals/ Lodging	Per diem for field work	Assuming per diem ($30) for 4 people per sampling trip; 2.5 lakes x 5 times/yr					$3,000	$3,000	-
	Miles/ Meals/ Lodging	Travel to citizen-science lakes	Travel to collect samples from citizen scientists; assuming 1 visit to each of the 6 target lakes based on google maps distances, rounded to nearest $1,000					$1,000	$1,000	-
	Conference Registration Miles/ Meals/ Lodging	MN Water Resources conference	Registration and travels expenses for two graduate students to present results of their work at MN Water Resources Conference.					$1,152	$960	$192
							Sub Total	**$13,302**	**$13,110**	**$192**
Travel Outside Minnesota										

							Sub Total	**-**	**-**	**-**
Printing and Publication										
							Sub Total	**-**	**-**	**-**
Other Expenses										
							Sub Total	**-**	**-**	**-**
							Grand Total	**$238,000**	**$236,376**	**$1,624**

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	$ Amount Spent	$ Amount Remaining
State						
In-Kind	MN DNR	240 hours over two years from two staff to collect juvenile fish on 6 Sentinel lakes	Secured	$10,400	-	$10,400
In-Kind	UMN System	Foregone Indirect Costs at 55% Federally Negotiated rate	Secured	$118,757	$104,763	$13,994
			State Sub Total	**$129,157**	**$104,763**	**$24,394**
Non-State						
			Non State Sub Total	**-**	**-**	**-**
			Funds Total	**$129,157**	**$104,763**	**$24,394**

Attachments

Required Attachments

Visual Component

File: 208de673-fca.pdf

Alternate Text for Visual Component

Figure showing overview of project background, approach and outcomes.
> Plots showing long-term decrease of ice cover duration on MN lakes and changing snowfall amounts along with a map showing proposed study sites (Sentinel Lakes) that vary in water quality.
> Diagram summarizing how winter conditions can affect top-down and bottom-up factors affecting health and survival of game fish.
> Summary of research, outreach and educational activities that will be undertaken to address problem...

Supplemental Attachments

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

Title	File
MN DNR Letter of Support	dbfbbc29-412.pdf
Institutional Approval Letter	a2b507d1-047.pdf
Research addendum	b7322ea5-aae.pdf
Background check form	08c51310-e6a.pdf
BURST poster- summer 2023	7981a441-d5b.pdf
AFS conference abstracts	67d4c180-13d.pdf
August poster; UMD undergrad research showcase	dd33804b-9ce.pdf
May poster; Duluth freshwater poster showcase	e34ad926-061.pdf
Feucht fish diet presentation	bfedecc3-531.pptx
Benedict winter pres	8506cd7c-612.pptx
Benedict.etal.2025	328c1f56-9bb.docx
Final report- list of prodcuts	ce214afe-abf.docx
Results summary	b761bcd8-b68.docx
Benedict et al. Ecology publication	98d1f7fa-040.pdf

Media Links

Title	Link
OPENING THE BLACK BOX OF WINTER	https://blackboxofwinter.weebly.com/

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

The appropriation was $29,000 lower than the amount requested. We therefore had to modify our workplan in two key ways:

1. We eliminated Activity 3 from the project. Activity 3 was an educational outreach component to middle school students. We planned to visit two rural Minnesota middle schools (one in each of Y1 and Y2 of the project), deliver classroom lessons on environmental science and take students into the field to participate in hands-on sampling of lakes. This change saves funds by reducing the salary of the outreach coordinator on this project (co-PI Kitson) and the budget for travel to the schools and bussing the students to field activities.

2. We reduced our proposed sampling effort. In the original proposal, we proposed to samples 6 lakes in different parts

of Minnesota 5 times through the year (3 lakes in Y1 and 3 lakes in Y2). The allocated funds are insufficient to support this sampling effort. We therefore eliminated one lake from the study (Madison Lake). In the revised approach we will sample 2 lakes in Y1 and 3 lakes in Y2 of the project. This change saves funds by reducing the funds needed for travel to the field sites, supplies and analyses.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

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?

Yes, I understand the UMN Policy on travel applies.

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?

Yes, 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

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	• Budget - Personnel	We wish to amend the budget (rebudget among categories) to use some personnel support funds to allow a graduate student enrolled in January 2023 to begin working on the project in November 2022 as a temp/casual technician. This will help the student begin her work on the project earlier and ensure we are ready for the winter 2022-2023 field season.	October 20, 2022	Yes	October 21, 2022
2	Amendment Request	• Budget - Capital, Equipment, Tools, and Supplies	We wish to amend the budget by moving funds within the equipment and supplies budget section. Specifically, we wish to move $3,000 from containers, $1,000 from filters, $1,000 and $535 from winter field gear subcategories to the miscellaneous supplies subcategory. We were spending less than expected from the these four categories and more on items that do not neatly fit within those more specific categories. All of these items are critical.	October 3, 2023	Yes	October 4, 2023
3	Amendment Request	• Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Budget - Non-ENRTF Funds Contributed • Attachments	We wish to amend the budget by moving some of the expenses between/within categories. We spent more than expected on the Misc. supplies subcategory on materials necessary to complete field and lab work. To compensate, we wish to move $1,500 from the 'sensor calibration' expense (which turned out to be unnecessary) and $1,000 from the 'citizen science kits' expense- we were able to collect sufficient fish samples without relying on citizen scientists.	April 9, 2025	Yes	May 1, 2025
4	Amendment Request	• Budget - Personnel • Budget - Professional / Technical	We are anticipating a small overage of $1,297 in the personnel category,	August 8, 2025	Yes	August 11, 2025

		Contracts • Budget - Capital, Equipment, Tools, and Supplies	specifically for the temp/casual support where a small amount of additional hours were needed than originally anticipated. We would like to offset that overage using underspent funds needed for lab services ($2,106 available). We also anticipate underspending $623 for supplies and $192 for travel. The net result is projecting to spend 99.3% of the award and returning $1,624.			
5	Completion Date	Previous Completion Date: 06/30/2025 New Completion Date: 12/31/2025	TS changed completion date to 12/31/25 as the PM needed to submit past status updates and amendment request before working on the final status update. Will change the completion date back to 6/30/25 after accepting the Sept. 2024 status update, March 2025 status update, and amendment request.	August 11, 2025	Yes	August 11, 2025
6	Completion Date	Previous Completion Date: 12/31/2025 New Completion Date: 06/30/2025	TS changing the completion date back to original 6/30/25 after approving status updates and amendment request.	August 11, 2025	Yes	August 11, 2025

Status Update Reporting

Final Status Update August 14, 2025

Date Submitted: August 14, 2025

Date Approved: September 30, 2025

Overall Update
The main objective of this project was to address the information gap on winter conditions in Minnesota lakes, especially as they pertain to game fish. To do this, we conducted year-round studies 4 lakes throughout the state. We collected physical, chemical, and biological data on these lakes. Biological parameters included abundance of phytoplankton, zooplankton, benthic invertebrates, and fish, fish body and reproductive condition, as well as fish diets based on gut content and stable isotope analyses.

We have completed all field sampling and, since the last update, all analyses of water chemistry and biological samples. To our knowledge, this project has assembled the most comprehensive dataset of winter conditions in Minnesota lakes, from physics to fish. These results will help understand how habitat quality (temperature, oxygen) and food abundance and quality affect the feeding and health of common game fish in different lake types. The results will be relevant for predicting how changing winter climate and water quality may impact Minnesota's fish resources.
Three students-- 1 undergraduate, 1 MS, and 1 PhD-- worked on this project. The students presented their work at local, regional, and international conferences. Both graduate students are working on their theses and peer-reviewed papers.

Activity 1
We proposed to study five sentinel lakes. Because of logistical challenges, we sampled four lakes (3 sentinel, 1 non-sentinel). The lakes were studied year-round; two lakes were studied for two consecutive years with different winters (one very snowy, long winter, the other a record low snow year). In collaboration with the Sentinel Lakes Program and regional DNR offices, we collected year-round physical, chemical and biological data.

While analysis of data is ongoing, we have made several novel findings about the winter ecology of Minnesota lakes. First, we have documented the first recoded instance of a zooplankton 'winterkill' event in one of our study lakes, showing that the negative effects of low oxygen conditions in severe winters extent beyond fish. Second, we have shown that zooplankton and benthic invertebrates, both important food sources for game fish, have distinct and out-of-phase seasonalities, zooplankton peaking in spring and summer and benthos peaking in fall and under the ice. Finally, gut content analysis of game fish revealed large variability in the winter diets and feeding activity of different species across lakes.

Our results highlight that winter conditions, and winter ecological processes, are highly variable between years and between lakes. See ResultsFinalReport.docx attachment.

Activity 2
Activity 2 focused around dissemination of results to relevant stakeholders, including scientists, resource managers, and members of the public.

We have presented our results through 12 oral and poster presentations. Of these, three were at local undergraduate and graduate research showcases, six at regional to international scientific conferences, and the rest at DNR workshops and webinars. This allowed us to reach a broad mix of researchers and DNR resource managers, communicating our findings and receiving feedback.

So far, we have submitted one paper for publication in the peer-reviewed scientific literature, to the journal Ecology (Benedict et al. 2025, attached). The manuscript describes, what is to our knowledge, the first record of a zooplankton winterkill event linked to a severe winter and underice oxygen depletion. These results come from two years of observations on Portage Lake, a productive lake in north central Minnesota. The findings show that winter conditions can have ecological repercussions beyond fish and that the changes during winter can be seen in following seasons. The paper has undergone review and a revised version is under consideration in the journal.

Additional manuscripts on plankton, benthos, and fish diets in the study lakes are in preparation.

See the ProductsFinalReport.doc

Dissemination

We provided some information on dissemination to scientists under Activity 2; here we provide info on outreach to the public and planned dissemination to resource managers.

Project PIs and students participated in several public outreach efforts, where we described our work and our findings. We created an information booth with winter field gear at two Freshwater Discovery Day events in Duluth, MN (in July 2024 and 2025). These events highlighted freshwater research conducted at UMD and hosted hundreds of people.

In January and February of 2025 we set up an exhibit at the Art Shanty festival on Lake Harriet (https://artshantyprojects.org/) called the Black Box of Winter (https://blackboxofwinter.weebly.com/). The exhibit featured live video and sound from under the ice, allowing visitors to learn about the environment of frozen lakes. We also conducted demos of winter lake sampling and talked to many hundreds of festival visitors about Minnesota's changing winters.

We planned a 1-day workshop with DNR staff to communicate our results and discuss management implications. Because we are still analyzing data, we postponed this workshop until we had more results to share. We are in communication with DNR and hope to host the workshop this winter.

Additional Status Update Reporting

Additional Status Update August 14, 2025

Date Submitted: August 8, 2025

Date Approved: August 11, 2025

Overall Update
Per LCCMR staff guidance, due to system logic, this is a place holder text for final update to be submitted by August 14, 2025

Activity 1
Per LCCMR staff guidance, due to system logic, this is a place holder text for final update to be submitted by August 14, 2025

Activity 2
Per LCCMR staff guidance, due to system logic, this is a place holder text for final update to be submitted by August 14, 2025

Dissemination
Per LCCMR staff guidance, due to system logic, this is a place holder text for final update to be submitted by August 14, 2025

Status Update Reporting

Status Update March 1, 2025

Date Submitted: August 8, 2025

Date Approved: August 11, 2025

Overall Update

The project is nearing completion. We have finished field sampling of all study lakes and are nearing completion of sample analyses. Since last update, 95% of all sample analysis has been completed. Through this project, we have created one of the most extensive datasets on winter conditions in Minnesota lakes that we are aware of. An especially noteworthy element of our dataset is that it covers both abiotic parameters, as well as information on lower trophic levels and fish, providing an unprecedented view into winter food webs and how winter conditions affect Minnesota lake ecosystems. As part of this project we were able to sample some of our lakes in two very different winter, showing how winter severity affects lake ecology. We have continued to communicate our findings to other scientists and lake mangers in Minnesota through presentations and scientific papers. Between now and the official end date of the project, we will finish sample analysis and continue working on data analysis and preparation and dissemination of products.

Activity 1

The objective of this activity was to assess abiotic and biotic winter conditions in diverse MN lakes and determine how winter conditions affect game fish. Since our last report, we focused on sample processing and data analysis. We have completed fish stomach content analysis and the ageing of fish otoliths (both highly time consuming activities). We worked on parametrizing fish bioenergetic models using these data, which allow estimation of fish growth rates in different time of the year. We nearly completed zooplankton and benthic invertebrate sample analysis (to examine variation in their abundance and community composition) and are finishing stable isotope analyses of fish samples (to determine feeding relationships). Work is currently ongoing on data organization and analysis, as well as on preparation and dissemination of results as presentations and manuscripts. Results from our work have shown that winter conditions can have dramatic impact on under-ice (and following open water period) zooplankton communities through impact on oxygen, a new finding in the literature (see the attached Benedict.etal.2025 manuscript draft). Fish feeding information has reveled large differences in overwinter feeding between different lakes and fish species, providing new information on how fish survive over winter (see attached Feucht poster).

Activity 2

The objective of this activity was to communicate the results of this work to citizens, scientists, resource managers, and other stakeholders. Since our last update, we have worked to disseminate results through publications, presentations to managers at a DNR workshop, and a winter outreach event to public.

The first scientific paper from this project is in peer review in the journal Ecology:
Benedict A, Shchoenenbeck C, Hrabik T, Ozersky T. Winter severity shapes zooplankton community in a shallow green lake. Ecology, in Review (draft attached- Benedict.etal.2025).

Graduate students working on this projects have presented an update on their work to a DNR Sentinel Lakes virtual workshop (130 attendees):
Benedict A, Ozersky T. Changing winters and game fish in Minnesota Lakes, Minnesota Department of Natural Resources Sentinel Lakes Webinar, March 2025. Oral presentation

Feucht L, Hrabik T, Stott A, Schoenebeck C, Ozersky T. The feeding ecology and energy budget of fish communities under

winter ice in Minnesota lakes.

Our lab also participated in the Art Shanty Festival on Lake Harriet over 4 weekends in January and February. We talked to thousands of visitors about lakes in winter and our LCCMR-funded research. Project website: https://blackboxofwinter.weebly.com/

Dissemination
Activity 2 centers on dissemination; see information given for Activity 2 update.

Status Update Reporting

Status Update September 1, 2024

Date Submitted: August 8, 2025

Date Approved: August 11, 2025

Overall Update

The goals of this project are to 1) improve understanding of how winter conditions affect Minnesota lakes and fish, and 2) communicate findings to relevant stakeholders. As part of this project, we conducted comprehensive year-round sampling on four Minnesota Sentinel lakes. Since the last update we completed all fieldwork on the study lakes. Since the last update, we continued to process lake water, plankton, and fish samples. Sample processing is approx. 80% complete overall, with almost all water sample analyses completed, 90% of plankton sample analyses completed, 70% of benthic organisms sampling complete, and 80% of all fish sample processed. As part of our dissemination efforts, results of work were presented at the Association for the Sciences of Limnology and Oceanography conference (June 2024), and the University of Minnesota Summer Undergraduate Research Showcase (August 2024). Remaining sample and data analysis, as well as dissemination activities, are on schedule and on track to timely completion.

In the original submission, we proposed to sample five lakes. Due to the unexpectedly high effort required for under-ice fish sampling, we were only able to sample four lakes. This should not have major implications on the conclusions of the research.

Activity 1

The objective of this activity was to assess abiotic and biotic winter conditions in diverse MN lakes and determine how winter conditions affect game fish. This activity involved year-round sampling of diverse MN sentinel lakes, collecting information about temperature, light, nutrient, plankton, bottom animals and fish. In Y1 we completed sampling of two lakes, capturing an unusually snowy winter and a subsequent fish-kill event in one of the lakes. These results provide new information about how lower-trophic levels and fish respond to winter deoxygenation events. We continued monitoring the Y1 lakes into this year (Y2) to provide a contrast with a very different year. Since the last update we finished monitoring Y1 lakes and completed all sampling on two additional (Y2) lakes. This marks the completion of all field sampling under this project. We continued processing water, lower trophic level, and fish samples. Sample processing in nearly complete, and should be finished by the end of 2024. Data analysis if ongoing, as is preparation of dissemination products (see A2 update).

Activity 2

Activity 2 centers around communicating study results to relevant stakeholders, including academics, resource managers, and members of the public. Since the last report, researchers working on this project presented results at 2 scientific conferences, an environmental seminar series and a undergraduate research showcase:

1. A. Benedict and T. Ozersky. Loss of winter and changing food webs, Midwest Climate Adaptation Center Annual Meeting, East Lansing, Michigan, August 2023. Poster.

2. A. Benedict, L. Feucht, C. Schoenebeck, T. Hrabik, and T. Ozersky. Seasonal community dynamics in lakes of contrasting trophic status and winter severity, Association for the Science of Limnology and Oceanography annual meeting, Madison, Wisconsin, June 2024. Oral presentation.

3. A. Benedict, C. Schonebeck, T. Hrabik, and T. Ozersky. Winter anoxia in shallow eutrophic lake, Twin Ports Freshwater Folk May Symposium, Duluth, Minnesota, May 2024. Poster.

4. A. Stott, L. Feucht, T. Hrabik, T. Ozersky. Evaluation of Yellow Perch Gonadosomatic Indices Across Various Minnesota Populations. UMD undergrad research showcase. Duluth, Minnesota, August 2024. Poster

We have also engaged in public outreach through events at the Large Lakes Observatory.

We are working toward a workshop with stakeholders in 2025, once sample and data analyses are complete.

Dissemination
Activity 2 centers on dissemination; see information given for Activity 2 update.

Status Update Reporting

Status Update March 1, 2024

Date Submitted: April 2, 2024

Date Approved: May 31, 2024

Overall Update

The goal of this project is to improve understanding of how winter conditions affect Minnesota lakes and fish and communicate findings to relevant stakeholders. As part of this goal we are conducting year-round sampling on four Minnesota Sentinel lakes. Since the start of the project we completed all work on two of those lakes. Since the last update we completed all winter work on the remaining two lakes and are starting open water sampling. Overall, the lake sampling phase is 75% complete. We continued to process lake water, plankton, and fish samples. Sample processing is 40% complete. As part of our dissemination efforts, results of work were presented at the Minnesota chapter of the American Fisheries Society conference in Brainerd in Feb. 2024. Field operations, sample and data analysis, and dissemination activities are on schedule and on track to timely completion.

Activity 1

The objective of this activity was to assess abiotic and biotic winter conditions in diverse MN lakes and determine how winter conditions affect game fish. This activity involved year-round sampling of diverse MN sentinel lakes, collecting information about temperature, light, nutrient, plankton, bottom animals and fish. In Y1 we completed sampling of two lakes, capturing an unusually snowy winter and a subsequent fish-kill event in one of the lakes. These results provide new information about how lower-trophic levels and fish respond to winter deoxygenation events. We continued monitoring the Y1 lakes into this year to provide a contrast with a very different year. Since the last update we also initialed and completed 50% of our sampling on two other lakes. We processed water, lower trophic level, and fish samples, collecting new data on lake fish diets in winter. Some of these results were presented at the Minnesota chapter of the American Fisheries Society conference in Brainerd in Feb. 2024. We expect to complete all field sampling by October 2024. Sample processing will be mostly completed early in 2025.

Activity 2

Activity 2 centers around communicating study results to relevant stakeholders, including academics, resource managers, and members of the public. In February 2024 two graduate students and one undergraduate student working on the project presented their results at the Minnesota chapter of the American Fisheries Society conference in Brainerd. This conference was attended by lake scientists and resource managers, contributing to dissemination of findings. The conference abstracts for the three talks are highlighted in the attached file (AFStalks.pdf). We anticipate continuing to present the results at meetings and preparing research papers. We are also working toward a workshop with stakeholders in 2025, once sampling and data analysis are complete. Some of our work was featured in a CBS news story on climate change and winter (https://www.cbsnews.com/minnesota/news/lake-superior-known-for-icy-waters-one-of-the-fastest-warming-lakes-in-the-world/).

Dissemination

Activity 2 centers on dissemination; see information given for Activity 2 update.

Status Update Reporting

Status Update September 1, 2023

Date Submitted: September 15, 2023

Date Approved: October 4, 2023

Overall Update

The overall goal of this project is to provide information about the effect of winter conditions on water quality and game fish in Minnesota lakes of different trophic status and winter climate setting. During the past year we completed approximately 50% of the proposed fieldwork, sampling two of our study lakes in detail across a full annual cycle. We collected water quality samples, samples of invertebrates and samples of game fish and are in the process of analyzing these samples. Throughout the past year, we collaborated closely with the MN DNR Sentinel Lakes program and regional DNR offices to collect data and ensure we are collecting information that will be of value to resource managers in the sate. We also interacted with members of the public to tell them about our work and share preliminary results. During the upcoming year we will sample the remaining study lakes, with the goal of completing field work by August 2024. We will continue sample and data analysis, and the communication of results to stakeholders, including the MN DNR, lake associations and members of the public.

Activity 1

Activity 1 (Determine how abiotic and biotic winter conditions change across diverse Minnesota lakes) is currently in progress and is approximately 40% complete. In the past year we collected detailed, year-round information on 2 MN lakes: Portage and Pike Lakes. We visited each lake 6 times during the year (3 visits during ice cover), collecting physical information about the lakes, and samples of water, lower trophic level organisms, and of fish. Samples are currently in the process of being analyzed, with approximately half of the sample analyses complete. We have begun data analyses and reporting of results (see activity 2 update and attachment). We are gearing up for year 2 of fieldwork.

Activity 2

While sample and data analyses are ongoing, we have made progress on Activity 2 (Communicate study results and management implications to citizens, scientists, resource managers, and other stakeholders). Data about the seasonal dynamics of benthic invertebrates in Pike and Portage have been analyzed and were presented to the public as part of UMD's Biology Undergraduate Research in Science and Technology program, but an undergraduate fellow who worked with us on this project (see attachment). We have also maintained regular communication with the MN DNR Sentinel Lakes program (one of our main stakeholders), with updates on progress and to coordinate sampling. We have engaged in informal outreach to the general public (including members of lake associations) while doing fieldwork, explaining what we are doing and why. Our team has also participated in a documentary produced by Hamline University (https://www.youtube.com/watch?v=9GTUsfTXfcM), on climate change in the Great Lakes. In addition, students working on this project participated in outreach through the STARBASE program (a summer school program which exposes Duluth-area kids to people in STEM careers), where they spoke about what an average field sampling day is like and why winter research is important.

Dissemination

While sample and data analyses are ongoing, we have made progress on Activity 2 (Communicate study results and management implications to citizens, scientists, resource managers, and other stakeholders). Data about the seasonal dynamics of benthic invertebrates in Pike and Portage have been analyzed and were presented to the public as part of UMD's Biology Undergraduate Research in Science and Technology program, but an undergraduate fellow who worked with us on this project (see attachment). We have also maintained regular communication with the MN DNR Sentinel Lakes program (one of our main stakeholders), with updates on progress and to coordinate sampling. We have engaged in informal outreach to the general public (including members of lake associations) while doing fieldwork, explaining

what we are doing and why. Our team has also participated in a documentary produced by Hamline University (https://www.youtube.com/watch?v=9GTUsfTXfcM), on climate change in the Great Lakes. In addition, students working on this project participated in outreach through the STARBASE program (a summer school program which exposes Duluth-area kids to people in STEM careers), where they spoke about what an average field sampling day is like and why winter research is important.

Status Update Reporting

Status Update March 1, 2023

Date Submitted: March 14, 2023

Date Approved: March 17, 2023

Overall Update
Field sampling for this project has started this winter (January 2023) to characterize abiotic, lower trophic level, and fish biology in 2 of the 5 study lakes. Sampling is on schedule and each lake has been sampled twice. We have been closely collaborating with the MN DNR Sentinel Lakes program during this research.

Activity 1
Since the start of the project, we recruited 2 graduate students to work on the project, acquired the necessary lab and field gear, and started the field research that we proposed under activity 1. As part of activity 1 we proposed to study 5 MN Sentinel lakes through the full year during the first 2 years of the project. Since the start of the project, we sampled two lakes (Portage Lake and Pike Lake) two times (once in January, once in February), collecting measurements and samples for abiotic parameters, lower trophic level organisms (phytoplankton, zooplankton, benthic animals), and fish. We also started processing some of the samples. In addition, UMD students collaborated with MN Sentinel Lakes researchers to collect fall samples of juveniles fish. Progress is currently on track with our proposed timeline and we expect to complete sampling of the two Year 1 lakes this fall (Sept 2023), moving on to sampling the three Year 2 lakes in October.

In our proposal, we planned to sample Portage Lake and South Twin Lake in Y1. However, due to permitting issues involving gillnetting, we could not sample South Twin Lake. We pivoted to studying an ecologically similar lake (Pike Lake).

Activity 2
Since work is currently in progress, there have not been results ready for communication. However, we did have informal interactions with members of the public during our field sampling, where we explained what we are doing and the objectives of the research. We have also kept in regular contact with the MN DNR Sentinel Lakes program and the local DNR fisheries offices near our study lakes.

Dissemination
As mentioned above, no sharable results have been generated yet.