Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 074-B**

Minnesota's Coldwater Fish Decline: Causes and Solutions

Category: B. Water Resources

Total Project Budget: $ 789,021

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

Determine long-term causes of fish loss and develop management recommendations for rehabilitation of coldwater fisheries in hundreds of lakes. A collaboration with the MNDNR to enhance the sentinel lakes program.

Name: Euan Reavie

Sponsoring Organization: U of MN - Duluth NRRI

Address: 5013 Miller Trunk Highway

Duluth MN 55811

Telephone Number: (218) 788-2692

Email ereavie@d.umn.edu

Web Address www.nrri.umn.edu

Location

Region: Southeast

County Name: Aitkin, Beltrami, Benton, Carlton, Cass, Clearwater, Cook, Crow Wing, Hubbard, Itasca, Kanabec, Koochiching, Lake, Lake of the Woods, Mille Lacs, Morrison, Roseau, St. Louis, Wadena

City / Township:

Alternate Text for Visual:

Coldwater fish such as tullibee are declining in Minnesota lakes (top). We will use fossil remains in lake sediment cores (middle) to explain the timing and causes of detrimental shifts in fish habitat. This will inform on past nutrient and deep-water oxygen conditions and allow us to relate changes to human stressors such as excess nutrient inputs and atmospheric warming. Outcomes (bottom) will include projections of future fish conditions in lakes and management recommendations for maintenance of coldwater fish populations.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Minnesota's Coldwater fish decline: causes and solutions

I. PROJECT STATEMENT

- Iconic **coldwater fish** such as tullibee (cisco), lake trout and lake whitefish **have been declining in Minnesota lakes** since the 1970s. This trend is particularly alarming because cisco are important food for walleye, pike, muskellunge and lake trout. These declines have been attributed to increased algae due to nutrient inputs (which reduces oxygen concentrations in the bottom waters of lakes), increasing water temperatures (which heat surface waters beyond what fish can tolerate), longer ice-free seasons (which also reduces oxygen in deep waters) and the combined effects of nutrient stress and warming, which collectively "squeeze" fish between habitats that are too warm and those with too little oxygen.
- We will **identify the causes and timing of coldwater fish habitat loss** in Minnesota lakes by determining how nutrients and other stressors have affected fish over the last two centuries. The sentinel lakes program (funded through ENRTF) includes fish monitoring and some historic reconstructions, but historical relationships between oxygen stress and fish, and accurate predictions of future fish habitat, are now possible using innovative methods to predict deep-water oxygen levels. We will use a combination of sediment core data (to infer nutrient and oxygen levels), water quality data and models to quantify coldwater fish habitat from pre-European settlement to the present. Then, **future persistence of fish habitat in lakes will be predicted using projections of future environmental conditions**.
- The major outcome will be a set of urgently needed **management recommendations for water quality** tailored to sustain these important fish populations in Minnesota's northern lakes. With the addition of longer-term information this project will build upon the knowledge base of sentinel lakes data to diagnose water temperature and deep-water oxygen levels that can explain the causes of declines in coldwater fish.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Determine past water quality conditions for 10 coldwater lakes. **Budget: $307,461**

Ten coldwater lakes will be selected for study, ranging from oligotrophic (very low nutrient) with healthy coldwater fish populations to higher nutrient lakes whose coldwater fish populations are in decline or have been lost. Sediment cores will be processed to identify the fossil remains of algae (which are indicators of past nutrient loads) and midges (the remains of aquatic insects, which are indicators of deep-water oxygen levels; i.e. fish habitat). Data will be used to reconstruct historic nutrient and oxygen levels since pre-European settlement.

Outcome: Understand past water quality in lakes important for coldwater fish	Completion Date
1. Collect 20 sediment cores from 10 coldwater lakes; analyze fossil remains; total 1,200 sample analyses.	December 2019
2. Use algae remains to infer historic nutrients and other environmental conditions.	June 2020
3. Use aquatic insect remains to infer historic oxygen levels.	June 2020

Activity 2: Establish relationships between stressors and coldwater fish habitat. **Budget: $271,500**

Past lake nutrient concentrations and deep-water dissolved oxygen levels reconstructed in Activity 1 will be related to historic atmospheric temperatures and land use data. Models relating temperature and dissolved oxygen to habitat availability will be derived based on the historical records from the study lakes. These models will reconstruct lake temperature and deep-water oxygen levels through time in our study lakes, and extrapolate habitat in the past and future for a larger set of 200+ coldwater lakes.

Outcome: Understand factors creating good coldwater fish habitat	Completion Date
1. Revise existing models of relationships between atmospheric temperature, water quality, and fish habitat for coldwater lakes in Minnesota; validate for study lakes.	December 2020
2. Create statewide maps of historical coldwater fish habitat in 200+ coldwater lakes.	December 2020
3. Quantify historical impacts of human stressors on coldwater lake habitat	December 2020

Activity 3: Predict extent of coldwater fish habitat under future environmental scenarios. **Budget: $210,060**

We will make projections of future coldwater fish habitat in coldwater lakes across northern and central Minnesota, based on historical causes and extent of fish loss and atmospheric temperature projections. Future land management scenarios will be developed and applied to the models to quantify the benefits of management (e.g., local land acquisitions and nutrient management strategies). The outcome will be a set of management actions that are suited to different lake types to ensure the persistence or recovery of coldwater fish communities.

Outcome: Management recommendations to preserve coldwater fish habitat	Completion Date
1. Refine future stressor – fish habitat scenarios.	December 2020
2. Map future lake conditions in 200+ lakes under varying land management scenarios.	December 2020
3. Create tailored management recommendations for different lake types (ranging from oligotrophic lakes with healthy coldwater fish populations to mesotrophic lakes whose coldwater fish populations are in decline or have been lost).	June 2021

III. PROJECT STRATEGY

A. Project Team/Partners

Funded via ENRTF: Dr. **Euan Reavie** (NRRI-UMD, algae/nutrient specialist), Dr. **Valerie Brady** (NRRI-UMD, aquatic insect specialist), Dr. **Lucinda Johnson** (NRRI-UMD, freshwater ecologist), Dr. **William Herb** (SAFL-UM, modeling specialist) and **Josh Dumke** (NRRI-UMD, fisheries expert). Drs. Reavie and Brady will lead the project. NRRI staff will perform the lake coring, data collection and compilation, data analysis and report writing. Dr. Herb will assist in data analysis and will perform the hydrologic, nutrient, temperature and oxygen modeling tasks. (These staff are largely supported by grant funds and are not professors.) Collaboration with St. Croix Watershed Research Station personnel (**Daniel Engstrom**, Mark Edlund) will maximize data exchange from past projects from the ENRTF. All qualified personnel required to complete this work are currently in place.

Funded via cost share, in-kind: **Peter Jacobson** (Fisheries Habitat Research Supervisor, MNDNR) will provide advice on lake selection and existing temperature and fish data and will participate in model development and in developing management recommendations to protect coldwater fish habitat. This collaboration will ensure we will complement ongoing work under the Sentinel Lakes program (funded through ENRTF). Other local user sectors (e.g. fishing groups, lake societies) will be consulted to assist with development of management recommendations.

B. Project Impact and Long-Term Strategy

We are losing fish habitat and populations, a trend that will have long-term impacts on angling and tourism in the state. This problem **should be correctable with management options**. With clear linkages among atmospheric temperature, nutrient stress, low oxygen and fish declines we will create management recommendations for improving water quality in northern Minnesota lakes. The data and results produced by this project **will inform existing and future coldwater lake conservation efforts**, and could be extended to other regions. Major long-term benefits will include an expanded knowledge base of the problem, **improved water quality and fish habitat** and **greater stability in angling and tourism**. Training future researchers: We have secured additional in-kind funding to provide training for young scientists and a student in the techniques we will use to complete this work.

C. Timeline Requirements: Three years, starting July 1, 2018 and ending June 30, 2021.

2018 Detailed Project Budget

Project Title: Minnesota's Coldwater fish decline: causes and solutions

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

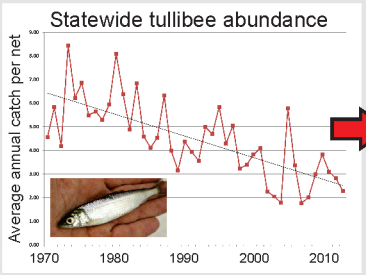
BUDGET ITEM	AMOUNT
PERSONNEL: Euan Reavie, Principal Investigator (66.5% salary, 33.5% benefits); 5% per yr for 3 yrs	$ 45,906
Val Brady, co-Investigator (66.5% salary, 33.5% benefits); 15% oer yr for 3 yrs	$ 47,548
Bill Herb, co-Investigator (66.5% salary, 33.5% benefits); 10% yr 1, 50% years 2-3	$ 115,460
Lucinda Johnson, co-Investigator (66.5% salary, 33.5% benefits); 4% per yr for 3 yrs	$ 25,874
Andrew Bramburger, co-Investigator (66.5% salary, 33.5% benefits); 20% per yr for 3 yrs	$ 62,242
Josh Dumke,Research fellow (66.5% salary, 33.5% benefits); 12% per yr for 3 yrs	$ 25,299
Kristofer Johnson, GIS mapping (72.8% salary, 27.2% benefits); 10% year 1, 15% year 3	$ 20,982
Mei Cai, Statistical analysis (66.6% salary, 33.5% benefits); 1% yr 1, 10% yr 2, 15% yr 3	$ 24,757
Bob Hell, Principal lab technician, 72.8% salary, 27.2% benefits); 50% yrs 1-2, 25% yr 3	$ 78,587
Senior lab technician, 72.8% salary, 27.2% benefits); 100% yrs 1-2, 50% yr 3	$ 115,133
Kitty Kennedy, Lab sediment prep, 72.8% salary, 27.2% benefits); 20% per yr for 3 yrs	$ 35,758
Graduate research assistant (75% salary, 15% benefits); yr 1-50% AY, 30% SUM, yr 2-50% AY, 100% SUM, yr 3-100% SUM	$ 118,327
Temporary lab technician, 72.3% salary, 7.7% benefits); 40% yrs 1-2, 15% yr 3	$ 27,071
Service Contract: St. Croix Wtrshd Research Stn, sediment isotope dating, 10 cores*$2,400 per core	$ 24,000
Supplies: computer and mapping-software/license $500 (statistical package updates, website annual fees, Google Analytics license), hardware $1,000 (server and back up drive), memory/disc storage, ancillaries $300	$ 1,800
Supplies: lab/field needs-sediment containers $600, reagents $1,500, crucibles $100, slides and prep material for $1,200, disposables $600	$ 4,000
Supplies: invertebrate lab-ultrasonic cleaner $500, slides 2,500 @ $0.15 ea = $375, cover slips 20,000 @ $0.07 ea = $1,400, mounting media + vials,sieves,forceps,preservative,gloves $1,320, 4 Bogorov counting troughs $200	$ 3,800
Travel: Project personnel btwn DLH & MSP to confer w/ collaborators & personnel in agencies for water quality data- 325 mi RT*$0.535=$175 + $10 vehicle rent fee*4 trips =$740 per yr * 3 yrs	$ 2,220
Travel: Field work 2 ppl, coring years 1-2; $1,295 vehicle (2,000 mi*$0.535=$1,070 + $225 truck&trailer rent fee@$15/day*15 days), $1530 per diem ($51/day fed meal rate*15 days*2), $2,548 lodging ($91/ni fed rate*14 ni*2), snowmobile support incl fuel $600 ($40/day*15)	$ 5,973
Travel: Water Resources Conf (MSP) year 3; lodg $1,160 (3 days for 4 ppl-lodg: $145 fed rate*2 ni* 4 rooms), meals $640 ($64 full day+$48 for 2 partial days*4 ppl), transp $184 (325 mi RT*$0.535=$174+$10 vehicle rent fee), registration $1,200 ($300 ea*4 ppl)	$ 3,184
Additional Budget Items: NRRI/UMD ISO: analytical lab analysis fees	$ 500
Additional Budget Items: FedEx-expedited mailing / rapid mail of subsamples for analysis	$ 600
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 789,021

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period: $18,000 – Peter Jacobson (MN DNR) effort: 100 hours at $60/hr each year for 3 years $409,796 – Unrecovered indirect: 54% MTDC, $758,883 base (total direct costs minus graduate student tuition reimbursement)	$ 427,796	Secured
Past and Current ENRTF Appropriation:	N/A	
Other Funding History:	N/A	

Minnesota's Coldwater fish decline: causes and solutions

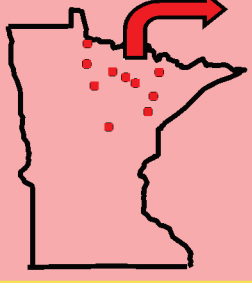
THE PROBLEM: COLDWATER FISH ARE DECLINING

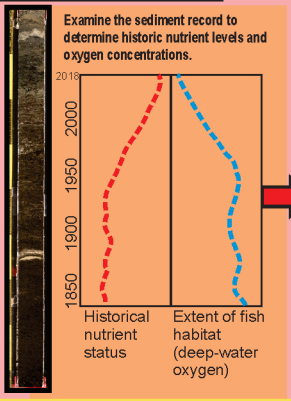


These are important food for walleye, northern pike, muskellunge, lake trout

WHAT ARE WE GOING TO DO?

Collect sediment cores



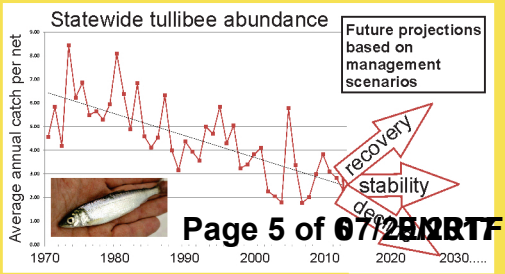


Reconstruct past, current and future fish habitat.

Compare with land-use and temperature data.

Develop maps of future fish habitat quality (100s of lakes).

WHAT ARE THE OUTCOMES OF THIS WORK?



Management recommendations (e.g. for the DNR)

- recommendations for water quality conservation
- quantified impacts on anglers

LCCMR 2018 Project Manager Qualifications and Organization Description

Euan D. Reavie, Natural Resources Research Institute, University of Minnesota Duluth

Key Qualifications

Dr. Reavie is a Senior Research Associate with specialties in the aquatic sciences at the Natural Resources Research Institute. He is an aquatic ecologist with particular expertise in paleoecology, describing the environmental histories of lakes to help define management and remedial protocols. His research focuses on the use of modern and historical biological indicators that inform on the effects of stressors such as nutrient loads, harmful algal blooms and atmospheric warming. Reavie will be supported by Dr. Lucinda Johnson, an expert in forecasting fish habitat conditions due to stressors; Dr. Valerie Brady, an expert in the use of aquatic insects to indicate aquatic habitat condition; Dr. Bill Herb, an expert in aquatic habitat modeling and forecasting; and Mr. Peter Jacobson, MN DNR Fisheries Research, who has worked extensively with coldwater fish and stressor impacts in Minnesota.

Reavie Education

Dec. 1998 – Oct. 2000: Postdoctoral (Geology), University of Toronto
Nov. 1994 – Oct. 1997: PhD (Biology), Queen's University

Reavie Selected Grants as Principal Investigator

USEPA Great Lakes National Program Office, $2,500,000, 2016-21, Great Lakes monitoring: phytoplankton

MPCA + MN Sea Grant (two grants supporting a project), $404,983, 2014-16, Paleolimnology and delisting of the St. Louis River Area of Concern

Northeast-Midwest Institute, NOAA and others, $1,141,000 (to date), 2006-17, Development of ballast water treatment technologies

Reavie Selected Recent Publications:

Reavie, E.D., M.B. Edlund, N.A. Andresen, D.R. Engstrom, P.R. Leavitt, S. Schottler, M. Cai 2017. Paleolimnology of the Lake of the Woods southern basin: continued water quality degradation despite lower nutrient influx. *Lake and Reservoir Management* (in press).

Reavie, E.D., G.V. Sgro, L.R. Estepp, A.J. Bramburger, R.W. Pillsbury, V.L. Shaw Chraïbi, M. Cai, C.A. Stow, A. Dove 2017. Climate warming and changes in *Cyclotella sensu lato* in the Laurentian Great Lakes. *Limnology and Oceanography* 62: 768-783.

Reavie, E.D., M. Cai, M.R. Twiss, H.J. Carrick, T.W. Davis, T.H. Johengen, D. Gossiaux, D.E. Smith, D. Palladino, A. Burtner, G.V. Sgro 2016. Winter-spring diatom production in Lake Erie is an important driver of summer hypoxia. *Journal of Great Lakes Research* 42: 608-618.

Kovalenko, K.E., E.D. Reavie, J.D. Allan, M. Cai, S.D.P. Smith, L.B. Johnson 2017. Pelagic phytoplankton community change-points across nutrient gradients and in response to invasive mussels. *Freshwater Biology* 62(2): 366-381.

The Natural Resources Research Institute is a part of the University of Minnesota Duluth. Its mission is *to deliver research solutions to balance our economy, resources and environment for resilient communities*. NRRI scientists have extensive experience in managing large, interdisciplinary projects. Major objectives include the development of tools for environmental assessment and resource management. NRRI's role is as a non-partial, science-based resource that develops and translates knowledge by characterizing and defining value-resource opportunities, minimizing waste and environmental impact, maximizing value from natural resource utilization and maintaining/restoring ecosystem function. Major outcomes include informing environmental management and policy and assisting industry and communities in defining and maintaining the social license to operate in natural systems.