Environment and Natural Resources Trust Fund
2016 Request for Proposals (RFP)

Project Title: **ENRTF ID: 021-A**

Past and Future of Minnesota's Coldwater Fish Habitat

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 670,335

Proposed Project Time Period for the Funding Requested: 3 years, July 2016 to June 2019

Summary:

We will identify the causes of loss of coldwater fish in Minnesotas lakes, predict the future status of lake habitats, and make recommendations for preserving coldwater fish for the future.

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Sponsoring Organization: U of MN - Duluth NRRI

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Flow diagram of the proposed project. Activity 1: sediment cores will be collected and analyzed for fossil material, which are then used to reconstruct quantitative data on long-term lake conditions and oxygen. Activity 2: relate reconstructed data to historical records on land use and climate to develop predictive models. Activity 3: develop ecological trajectories for lakes and provide predictions of future conditions relevant to fish habitat (e.g. cisco habitat suitability).

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

PROJECT TITLE: Past and Future of Minnesota's Coldwater Fish Habitat

I. PROJECT STATEMENT:

This project will identify the causes and timing of loss of coldwater fish habitat in Minnesota lakes to understand how eutrophication and climate change have affected fish since pre-European settlement. Future extrapolations will provide strategies to protect and maintain coldwater fish populations in Minnesota, thereby informing existing and future lake conservation efforts. The outcome will be a set of management recommendations tailored for lake types to help sustain economically important and iconic fish populations in Minnesota's northern lakes. Coldwater fish, such as lake trout, lake whitefish, and cisco, are iconic species representing the pristine nature of Minnesota's deep, northern lakes, but these species have been declining in some lakes since the 1970's. These declines have been attributed to increased productivity due to nutrients inputs (which reduce oxygen concentrations in the cold, bottom waters of lakes), warming water temperatures (which heat surface waters beyond physiological tolerances for coldwater fish), longer durations of lake stratification (which also reduces oxygen concentrations in deep waters), or the combined effects of eutrophication and warming (which collectively "squeeze" fish between habitats that are too warm and those with too little oxygen). Options for protecting and managing the viability of future populations of coldwater fish must be tailored for each lake based on knowledge of the major factors controlling fish habitat. This project will build upon existing data from sentinel lakes (i.e., reconstructions of nutrient levels using fossil diatoms from sediment cores; water chemistry; recent fish surveys), to diagnose water temperature and deep-water oxygen levels that might explain the causes of declines in coldwater fish habitat in Minnesota's lakes. The sentinel lakes program (SLICE, funded through ENRTF) includes fish monitoring and some historic reconstructions, but historical relationships between oxygen stress and fish, and accurate predictions of future coldwater fish habitat, are now possible using new and innovative methods to reconstruct and predict deep-water oxygen levels. We will use a combination of sediment core data (to infer past nutrient and oxygen levels), water quality data, and models to quantify coldwater fish habitat from pre-European settlement to the present. Persistence of coldwater fish habitat will be predicted in other, unsampled lakes using climate projections and findings from this project.

II. PROJECT ACTIVITIES AND OUTCOME

Activity 1: Quantify the past water quality conditions of a set of 10 coldwater lakes. **Budget: $420,000**

A set of 10 coldwater lakes will be selected for study, ranging from oligotrophic lakes with healthy coldwater fish populations to mesotrophic lakes whose coldwater fish populations are in decline or have been lost. Sediment cores will be processed to identify the fossil remains of diatom algae (which are indicators of past nutrient loads) and chironomids (the remains of larval aquatic insects, which are indicators of deep-water oxygen levels; i.e. coldwater fish habitat). Data will be used to reconstruct historic nutrient and oxygen levels since pre-settlement.

Outcome	Completion Date
1. Sediment cores collected and evaluated from 10 coldwater lakes	December 2016
2. Historic nutrient concentrations and environmental conditions inferred from diatoms	June 2018
3. Historic oxygen levels inferred from aquatic insect remains (chironomid head capsules)	June 2018

Activity 2: Establish relationships between climate, water quality, and coldwater fish habitat. **Budget: $125,335**

Past lake nutrient concentrations and deep-water dissolved oxygen levels reconstructed in Activity 1 will be related to historic climate and land use data. Empirical models relating temperature and dissolved oxygen to nutrients, climate and lake depth will be derived based on the historical record from the study lakes. We will use these models to hindcast lake temperature and deep-water oxygen levels through time, and will validate with recent monitoring data. The models will then be used to quantify, , historical water quality conditions in other deep lakes and estimate the relative impacts of climate change and land use change on coldwater fish habitat.

These results will reconstruct the historical timing, causes and extent of changes to lake condition.

Outcome	Completion Date
1. Identified relationships between climate, water quality, and fish habitat for coldwater lakes in Minnesota	December 2018
2. Statewide maps of historical coldwater fish habitat conditions in coldwater lakes.	December 2018
3. Quantification of historical impacts of climate change and land use change impacts on coldwater lake habitat	December 2018

Activity 3: Predict extent of coldwater fish habitat under future climate and land use. **Budget: $125,000**

The models developed in Activity 2 will be used to project future coldwater fish habitat in both study lakes and other deep lakes across northern MN, based on historical interpretations of the causes and extent of fish loss and climate projections. Several future land management scenarios will be developed and applied to the models to quantify the potential benefits of, e.g., local land acquisitions and nutrient management strategies for protecting coldwater fish habitat. The outcome will be a set of management actions that are suited to different lake types to ensure the persistence of coldwater fish under future land use and climate conditions.

Outcome	Completion Date
1. Assembled future climate scenarios	June 2018
2. Map & set of proposed land management scenarios for protecting coldwater lake habitat	June 2018
3. 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 2019

III. PROJECT STRATEGY

A. Project Team/Partners

The project team will comprise: Dr. Euan Reavie (NRRI-UMD, algae/nutrient specialist), Dr. Valerie Brady (NRRI-UMD, invertebrate specialist), Dr. Lucinda Johnson (NRRI-UMD, freshwater ecology), Dr. William Herb (SAFL-UM, modeling specialist), Josh Dumke (NRRI-UMD, fisheries expert), and MNDNR Fisheries. 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. All work by SAFL and NRRI staff will be funded by the ENRTF. (These staff are largely supported by grant funds and are not professors.) MNDNR partners will provide advice on lake selection and existing temperature and fish data, will participate in model development, and developing management recommendations to protect coldwater fish habitat. Other local user sectors (e.g. fishing groups, lake societies) will be consulted to assist with development of management recommendations. We will collaborate with researchers from the St. Croix Watershed Research Station to maximize data exchange from past (and potentially new, e.g. "Tracking and Preventing Harmful Algal Blooms" just submitted) projects from the ENRTF.

B. Project Impact and Long-Term Strategy

With clear linkages among climate, nutrient enrichment, eutrophication, low oxygen and fish declines, we will predict future trends for 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 states in the region or to a regional or national-scale project. We have secured additional funding (cost share) to provide training for young scientists and a student in the paleoecology techniques we will use to complete this work.

C. Timeline Requirements: Three years, starting July 1, 2016 and ending June 30, 2019.

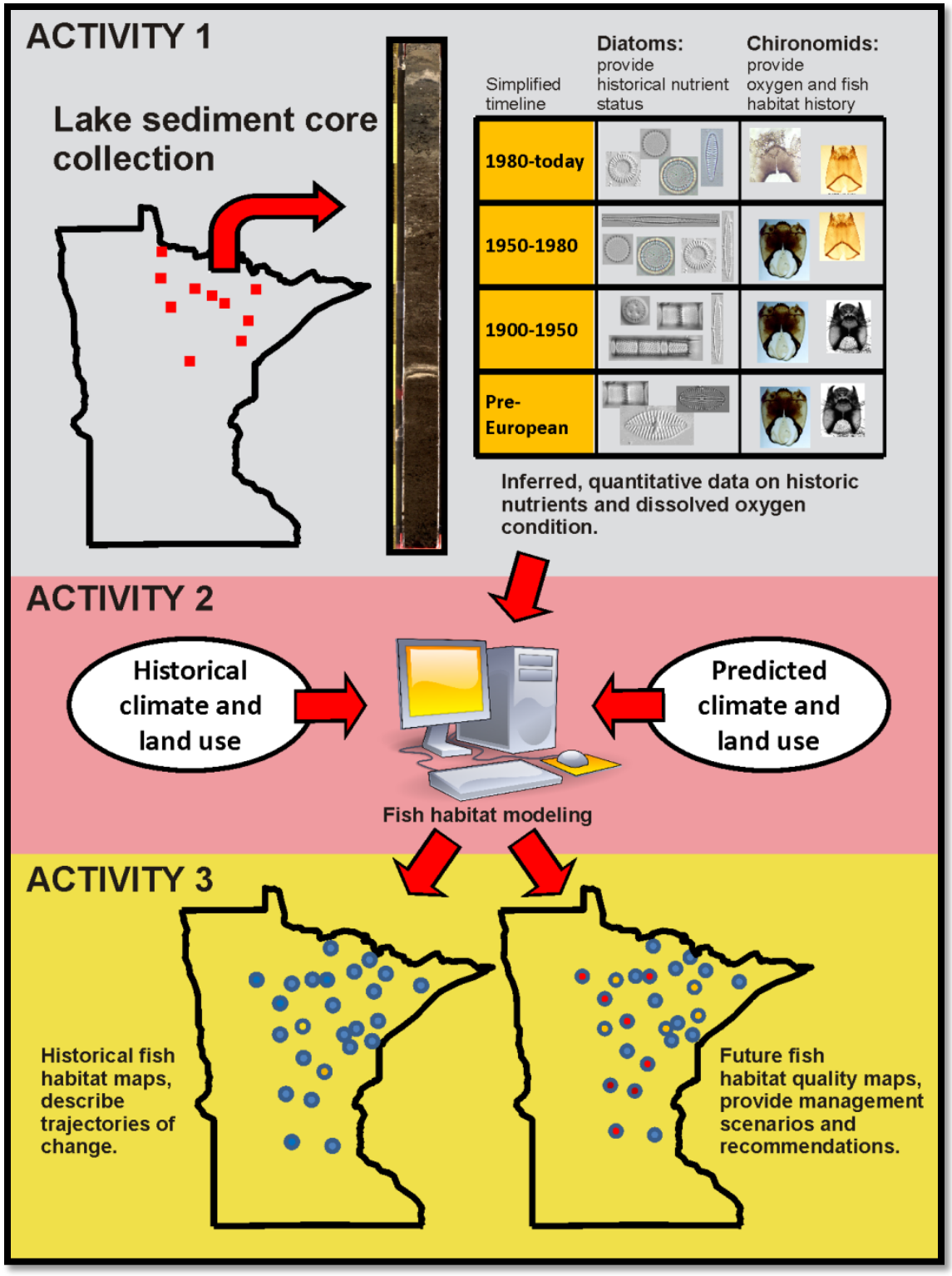
Project Title: Past and future of Minnesota's coldwater fish habitat

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

BUDGET ITEM	AMOUNT	
Personnel:	$	628,934
Euan Reavie, project manager (66.3% salary, 33.7% benefits); 5% FTE each year for 3 years	$ 21,857	
Valerie Brady, co-manager (66.3% salary, 33.7% benefits); 10% FTE each year for 3 years	$ 30,591	
William Herb, co-manager (66.3% salary, 33.7% benefits); 40% FTE yr 1; 50% FTE yrs 2 & 3	$ 105,309	
Lucinda Johnson, co-manager (66.3% salary, 33.7% benefits); 4% FTE each year for 3 years	$ 24,283	
Andrew Bramburger, co-manager (66.3% salary, 33.7% benefits); 20% FTE each year for 3 years	$ 59,623	
Josh Dumke, data manager (66.3% salary, 33.7% benefits); 10% FTE each year for 3 years	$ 20,157	
Jeremy Erickson, GIS mapping (66.3% salary, 33.7% benefits); 10% FTE years 1 & 3	$ 16,899	
Mei Cai, statistical analysis (66.3% salary, 33.7% benefits); 10% FTE year 2; 15% FTE year 3	$ 22,822	
Robert Hell, taxonomist (72.6% salary, 27.4% benefits); 40% FTE yrs 1 & 2; 20% FTE year 3	$ 58,734	
Kari Hansen, midge prep (72.6% salary, 27.4% benefits); 100% FTE yrs 1 & 2; 30% FTE year 3	$ 98,956	
Kathleen Kennedy, sediment prep (72.6% salary, 27.4% benefits); 20% FTE each year for 3 years	$ 33,419	
Graduate research assistant, diatom taxonomy (82.4% salary, 17.6% benefits + $18.48/hr tuition); 50% FTE each year for 2 years	$ 96,182	
Temp lab tech, sample prep/storage (92.1% salary, 7.9% benefits); 40% FTE yrs 1 & 2; 15% FTE year	$ 27,120	
Administrative support: budget reports, tracking activity costs, drafting work plans and progress reports (72.6% salary, 27.4% benefits); 7% FTE each year for 2 years	$ 12,982	
Professional/Technical/Service Contracts:	$	20,500
St. Croix Watershed Research Station: 10 cores X $2000/core	$ 20,000	
NRRI Analytical Lab	$ 500	
Equipment/Tools/Supplies:	$	8,800
Computer and mapping: software license, statistical package updates, website fees etc	$ 1,000	
Sediment lab: sample containers, reagents, slides, coverslips, mountant, and disposables.	$ 4,000	
Invertebrate Lab: Ultrasonic cleaner $500, 2500 slides @ $0.15 ea=$375, 20,000 cover slips @ $0.07 ea=$1400, CMC-10 mounting media @ $0.06 ea=$150, 200 vials @ $0.20 ea=$40, 2,106 um sieves @ $220 ea=$440, 2, 212 um sieves @ $210 ea=$420, 5 forceps various styles=$200, EtOH preservative=$25, nitrile gloves=$50, 4 Bogorov counting troughs @ $50 ea = $200	$ 3,800	
Travel:	$	11,501
Collaboration meetings betw Duluth & MSP; mileage for 4 trips per year x 3 yrs (ea trip=325 mi RT x $0.575=$187 + $10 vehicle rent fee)	$ 2,364	
Field work: Field work for two people - coring excursions during Y1-2	$ 5,950	
Conference: MSP, 3 days, 4 ppl: lodg $1080; meals $710; transp $197; registration $1200	$ 3,187	
Additional Budget Items:	$	600
Expedited mail service i.e. FedEx: cost to rapid-mail subsamples for analysis (isotopes)	$ 600	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$	670,335

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:		
If awarded, NRRI will contribute with time/effort as needed for successful completion of project without requesting further funds from LCCMR for the following: consultant fee for training on chironomid sample processing and identification by world expert, plus staff travel expenses to training location (2 analysts).	$	Pending
NRRI will pay the expense for staff training of new graduate student for sedimentary diatom processing and analysis - includes staff time, class fee and all travel expenses to training location for one student.	$	Pending
Foregone Indirect Costs of 52% MTDC (TDC less grad student tuition & fringe (TDC=$670,335-36,388)	$ 329,650	Secured
In-kind Services To Be Applied To Project During Project Period:		
100 hrs of effort from Peter Jacobson, MN DNR fisheries research supervisor, for each of three years (advice on lake selection and existing temperature and fish data, plus participation in developing management recommendations to protect coldwater fish habitat)	$ 17,000	Secured
Funding History:	n/a	
USDI Cooperative EcosystemStudies Unit, "Managing the Nation`s Fish Habitat at Multiple Spatial Scales"	$ 269,648	
MN Department of Natural Resources, "Impacts of land development climate change on Lake Superior"	$ 79,930	
LCCMR, "Assessing the consequence of ecological drivers of change on water quality and habitat dynamics of deep-water lakes with coldwater fish populations"	$ 825,000	
Remaining $ From Current ENRTF Appropriation:	n/a	



Flow diagram of the proposed project. Activity 1: sediment cores will be collected and analyzed for fossil material, which are then used to reconstruct quantitative data on long-term lake conditions and oxygen. Activity 2: relate reconstructed data to historical records on land use and climate to develop predictive models. Activity 3: develop ecological trajectories for lakes and provide predictions of future conditions relevant to fish habitat (e.g. cisco habitat suitability).

LCCMR 2016 LCCMR 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 and center Assistant Director 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 (e.g. diatoms) that inform on the effects of stressors such as nutrient loads, harmful algal blooms and climate change. Reavie will be supported by Dr. Lucinda Johnson, an expert in forecasting fish habitat conditions based on land use and climate; by Dr. Valerie Brady, an expert in the use of aquatic macroinvertebrates to indicate aquatic habitat condition; by Dr. Bill Herb, an expert in aquatic habitat modeling and forecasting. and Mr. Peter Jabocson, MN DNR Fisheries Research, who has worked extensively with coldwater fish and climate change impacts.

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

Selected Grants
PI: USEPA Great Lakes National Program Office, $2,000,000, 2011-17, Great Lakes monitoring: phytoplankton + paleolimnology
PI: MPCA + MN Sea Grant (two grants supporting a project), $404,983, 2014-16, Paleolimnology and delisting of the St. Louis River Area of Concern
PI: Lake County Soil and Water Conservation District, $95,000, 2011-14, Paleolimnology of the White Iron Chain of Lakes
PI: MPCA, $108,000, 2011-13 Paleolimnology of Lake of the Woods to support TMDL development
PI: Northeast-Midwest Institute, NOAA and others, $910,000 (to date), 2006-16, Development of ballast water treatment technologies

Selected Publications:
Shaw Chraïbi, V.L., A.R. Kireta, E.D. Reavie, T.N. Brown, M. Cai 2014. A paleolimnological assessment of human impacts on Lake Superior. J. Great Lakes Research 40(4): 886–897.
Reavie, E.D., A.J. Heathcote, V.L. Shaw Chraïbi 2014. Laurentian Great Lakes phytoplankton and their water quality characteristics, including a diatom-based model for paleoreconstruction of phosphorus. PLoS ONE 9(8): e104705.
Reavie, E.D., A.R. Kireta 2015. Centric, Araphid and Eunotioid Diatoms of the Coastal Laurentian Great Lakes. Bibliotheca Diatomologica, J. Cramer, Berlin. 183 pp.
Reavie, E.D., R.P. Barbiero, L.E. Allinger, G.J. Warren 2014. Phytoplankton trends in the Laurentian Great Lakes: 2001-2011. J. Great Lakes Research 40(3): 618-639.
Allinger, L.E., E.D. Reavie 2013. The ecological history of Lake Erie according to the phytoplankton community. Journal of Great Lakes Research 39: 365-382.
Reavie, E.D., M.D. Edlund 2013. Assessing the performance of a diatom transfer function on four Minnesota lake sediment cores: effects of training set size and sample age. Journal of Paleolimnology 50: 87-104.

The Natural Resources Research Institute is a part of the University of Minnesota Duluth. Its mission is to promote private sector employment based on natural resources, in an environmentally sensitive manner. NRRI scientists have extensive experience in managing large, interdisciplinary projects with objectives that include the development of tools for environmental assessment and resource management. These tools promote citizen education leading to improved understanding of how human activities influence water quality and ecosystem health.