Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID:** **090-D**

Using CO2 to Control Fish in Shallow Lakes

Category: D. Aquatic and Terrestrial Invasive Species

Total Project Budget: $ 505,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

We will develop techniques for controlling nuisance and invasive fish species. Adding CO2 under ice is effective and inexpensive with great potential to improve water quality and habitat.

Name: James Cotner

Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This visual shows two problems for shallow lakes in the state (eutrophication and invasive fish) and shows a group of scientists and lake managers applying CO2 to a small lake. We also show a figure with data indicating that we successfully increased the CO2 concentration.

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

PROJECT TITLE: Using CO_2 to control fish in shallow lakes

I. PROJECT STATEMENT

Why this work needs to be done: Lake water quality and waterfowl habitat is increasingly threatened by eutrophication, invasive species and climate change. A lake management goal is to shift turbid, algal-dominated systems toward a clear, aquatic plant-dominated state and this can be done by lowering the lake level or killing bottom-feeding rough fish such as carp and bullheads. The Minnesota Department of Natural Resources (MN-DNR) spends $1.5-2 million each year to monitor, maintain and restore shallow lake ecosystems but new tools and strategies need to be developed to a) allow for removal of rough fish and invasive species from shallow lakes without using expensive and controversial compounds such as rotenone, b) provide new, more cost-effective treatments for inducing and maintaining the clear water state, and c) increase the overall success rate of shallow lake restoration projects.

The **Goals** of this project are to: **Develop a new method for controlling rough fish and invasive species in shallow lakes using under-ice additions of carbon dioxide (CO_2) and to evaluate the effectiveness of CO_2 in lake management practices.** At the completion of this project, lake managers will have an additional tool to 'reset' aquatic systems to a non-invaded state. Specifically, this work addresses LCCMR goals focused on water quality (B) and aquatic invasive species (D).

How we will achieve this: We will determine if CO_2 can be released into lakes to effectively kill rough and invasive species. 1. We will conduct laboratory experiments to determine what concentrations of CO_2 are toxic to various fish species. 2. We will add CO_2 to three lakes to evaluate field implementation practices and 3. We will evaluate toxicity on target and non-target species in the field and effectiveness in lake restoration. We have discussed this project with Dr. Peter Sorensen at the MN AIS Research Center and he has expressed great enthusiasm for this work and its potential for controlling invasive species.

II. PROJECT ACTIVITIES AND OUTCOMES

Overview. Our strategy is to first conduct laboratory experiments to determine lethal concentrations and optimal application timing relative to dissolved oxygen and ambient CO_2 levels using several fish species. We will then treat and monitor three lakes with CO_2 additions and compare them to three nearby control lakes. CO_2 will be added to lakes as solid (dry ice) or liquid form under the ice. This project has high probability for developing a new tool for managing invasive species. CO_2 is a known fish toxicant, but has not been tested in the field or on invasive fish species. Last winter, with support from MN-DNR, we treated a small, 1-acre pond with dry ice as proof of concept with great success, increasing dissolved CO_2 concentration by a factor of 5. We were not able to determine how effective the CO_2 was in killing fish in the lake but casual observations suggested that most fish died. This study will build upon these past findings and assess the overall ability of CO_2 to reduce invasive fish populations and restore shallow lakes to more pristine conditions with better water quality.

Activity 1: *Laboratory experiments to determine effective CO_2 concentrations to kill invasive species.*	**Budget: $78,000**

We will examine the effects of CO_2 additions on pH, dissolved CO_2, dissolved O_2 and other water quality parameters and the survival of fathead minnows, carp and black bullheads in the laboratory. These target species have potential to shift lakes from the clear to the turbid state, and are very common with high tolerance of extreme conditions (low O_2 and high CO_2) in natural ecosystems.

Outcome: Determine the effective concentrations of CO_2 needed to kill invasive species and rough fish	**Completion Date**
1. Assess the toxicity of CO_2 to fathead minnows, carp and bullheads in the laboratory.	1 Jul 2016
2. Use results from these species to inform field CO_2 delivery levels.	1 Jul 2016

Activity 2: *Add CO_2 to three lakes to evaluate field implementation practices.*	**Budget: $346,000**

We will deliver CO_2 into three shallow lakes using either solid (dry ice) or liquid CO_2. Our goal will be to exceed the toxicity levels that we assess from laboratory studies. In winter 2013, we successfully increased the dissolved CO_2 concentration in a shallow lake at the Carlos Avery Wildlife Nature Area from 19 mg/L to greater than 250 mg/L within a day.

Outcome: Develop a method for field implementation of CO_2 to kill invasive species and rough fish	**Completion Date**
1. Develop a method for field delivery of CO_2 under the ice.	1 Jul 2016
2. Deliver CO_2 under the ice into three lakes and assess effects on dissolved CO_2 concentrations.	1 Jul 2018

Activity 3: *We will evaluate toxicity on target and non-target species in the field as well as evaluating effectiveness in lake restoration.*	**Budget: $81,000**

We'll assess impacts of CO_2 on target and non-target species, water quality, and whether lakes shift states by sampling the three experimental lakes in the summer before and summer after the winter application of CO_2. We will also sample three control lakes not treated with CO_2 to serve as a reference for CO_2 effects, and all six lakes will be in turbid states with populations of fathead minnows, black bullheads, and carp at the beginning of the study. The project will assess abundance of fish, amphibians, aquatic invertebrates, submerged aquatic plants, algae, and phosphorus and nitrogen levels in the water. We expect that substantial reductions in fish abundance will increase aquatic invertebrates and plants, reduce algae, phosphorus, and nitrogen in the water column, and induce shifts to clear-water states the summer after CO_2 application. We also expect aquatic invertebrates and amphibians are less sensitive to CO_2 and will rebound quickly after CO_2 treatment.

Outcome: Restore water quality to shallow lakes invaded by invasive and rough fish species	**Completion Date**
1. Assess the efficacy of CO_2 as a fish toxicant and its effects on non-target species.	1 Jul 2017
2. Assess the efficacy of CO_2 in inducing a shift from clear to turbid water state.	1 Jul 2018

III. PROJECT STRATEGY

A. Project Team/Partners

This project will be carried out under the supervision of Dr. James Cotner (University of Minnesota-Twin Cities), with collaborators, Dr. Kyle Zimmer (University of St. Thomas), and Dr. Dalma Martinovic (University of St. Thomas), and with collaborators from MN-DNR (Nicole Hansel-Welch and Dr. Mark Hanson).

B. Project Impact and Long-Term Strategy

This project is a priority for the MN DNR Shallow Lakes Program and staff scientists will directly implement the findings. This project will fill a significant knowledge gap and will likely provide an additional tool for management and restoration of shallow lakes, as well as controlling invasive fish in shallow lakes and in other Minnesota habitats.

C. Timeline Requirements

This project will require three years to complete (initial, during and post-treatment assessments). Sampling will begin the fall of 2015 and will be completed in the summer of 2018. Final reports will be issued July 2018 and project scientists will begin disseminating results.

2015 Detailed Project Budget

Project Title: Using carbon dioxide to control fish in lakes

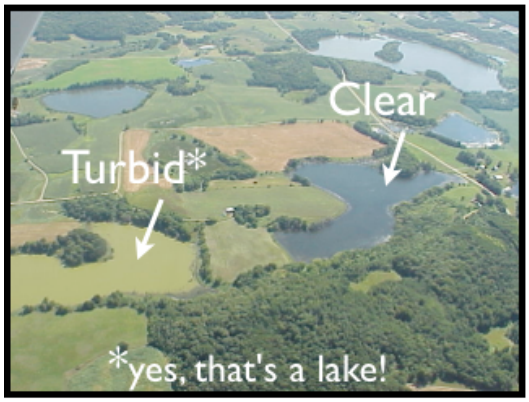
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel: Dr. James Cotner (PI) - (75% salary, 25% fringe) Dr. James Cotner will have overall responsibility for the project, and supervise a technician, post-doctoral associate, undergraduate students and graduate student. Cotner has asked for 1 month summer support in the last two years and a half month in year 1 for these efforts.	$ 39,000
Postdoc - 100% time for 3 years (83% salary, 17% fringe) - Funds are requested for a post-doctoral associate who will coordinate field and lab activities, develop methods for applying the CO2 into the lakes and publish scientific and management focused papers.	$ 157,000
Technician - 25% time for 3 years (73% salary, 27% fringe) The technician will prepare field equipment and sample containers, analyze samples, order supplies and facilitate database management.	$ 51,000
Graduate Student - 50% time during the summer for 3 years (81% salary, 19% fringe) The graduate student will assist with field work and data acquisition.	$ 29,000
Undergraduate Student - 15% time for 3 years (93% sa;ary, 7% fringe) The undergraduate students will assist with field work and data acquisition.	$ 12,000
Contracts: Subcontract to the University of St. Thomas - A portion of the work on this project will be done by Dr. Kyle Zimmer and Dr. Dalma Martinovic at the University of St. Thomas. Dr. Martinovic will conduct experiments on the effects of CO2 on fish mortality and Dr. Zimmer will collect field samples for invertebrate and fish community analyses. They will hire 3-5 undergraduates to assist with field work and experiments	$ 159,000
Equipment/Tools/Supplies: Laboratory supplies include analytical standards, reagents, solvents, disposable labware, filters, and maintenance costs of large equipment such as spectrophotometers, and fluorometer, microplate readers, etc. We have also requested funds for three carbon dioxide sensors that will be deployed under the ice, before, during and after dry ice application.	$ 44,000
Travel: Funds are requested for travel associated with the field work on this project for the P.I., post-doc, graduate student and/or technician or undergraduates. These annual expenses include vehicle rental and mileage, lodging and per diem.	$ 14,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 505,000

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

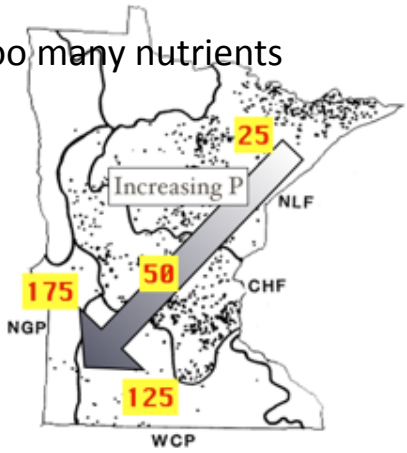
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: *N/A*	$ -	
Other State $ To Be Applied To Project During Project Period: *N/A*	$ -	
In-kind Services To Be Applied To Project During Project Period: Facilities and Administrative Costs from University of Minnesota (52% MTDC of project budget)	$ 192,000	*Secured*
Funding History: N/A	$ -	
Remaining $ From Current ENRTF Appropriation: *N/A*	$ -	

The Problem:



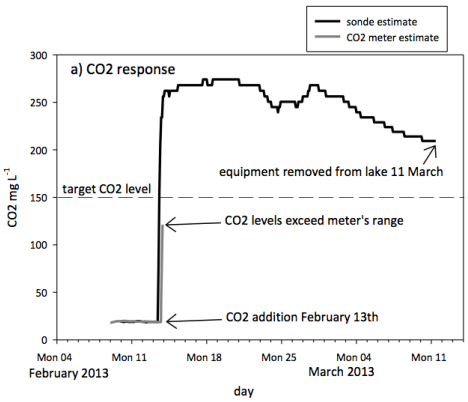
The Causes:

Too many nutrients



A Solution:

This picture shows our team adding dry ice into holes that were drilled into the lake.



We added CO_2 as dry ice in early Feb and there was an immediate increase of concentrations in the water that was maintained through early Mar

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Education:

Ph.D., University of Michigan, Ann Arbor, 1990, Biology; M.Sc., Kent State University, Kent, Ohio, 1984, Biology; B.A., Wittenberg University, Springfield, Ohio, 1981, Biology.

Research Experience and Current Projects:

Expertise: Biological limnology and oceanography; Biogeochemistry of wetlands and the Great Lakes; Microbial ecology. **Current Projects:** NSF: Homeostasis of prokaryotes in natural environments. Sea Grant: Wild rice and sulfur biogeochemistry

Current Position:

2008-present. Full professor, Malcolm Moos Chair in Freshwater Biology and Director of Undergraduate Studies, Department of Ecology, Evolution and Behavior, University of Minnesota.

Publications relevant to this proposal:

Theissen, KM, WO Hobbs, JM Ramstack Hobbs, KD Zimmer, LM Domine, JB Cotner, and S Sugita. 2012. The Altered Ecology of Lake Christina: A Record of Regime Shifts, Land-use Change, and Management From a Temperate Shallow Lake. The Science of the Total Environment 433: doi: 10.1016/j.scitotenv.2012.06.068.

Hobbs, WO, DR Engstrom, SP Scottler, KD Zimmer, and JB Cotner. 2013. Estimating Modern Carbon Burial Rates in Lakes Using a Single Sediment Sample. Limnology and Oceanography-Methods 11 (2013): doi:10.4319/lom.2013.11.316.

Cotner, JB, and EK Hall. "Comment on "A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus"." Science (New York, N.Y.) 332, no. 6034 (2011): doi:10.1126/science.1201943.

Kolka, R. K.; Mitchell, C.P.J.; Jeremiason, J. D.; Hines, N.A.; Grigal, D. F.; Engstrom, D. R.; Coleman-Wasik, J.K.; Nater, E.A.; Swain, E.B.; Monson, B.A.; Fleck, J.A.; Johnson, B.; Almendinger, J. E.; Branfireun, B.A.; Brezonik, P.L.; Cotner, J.B. 2011. Mercury cycling in peatland watersheds. In "Kolka, R.K.; Sebestyen, S. .; Verry, E. S.; Brooks, K.N., eds. Peatland biogeochemistry and watershed hydrology at the Marcell Experimental Forest. Boca Raton, FL: CRC Press: 349-370.

Cotner J.B., E.K. Hall, T. Scott and M. Heldal. 2010. Freshwater bacteria are stoichiometrically flexible with a nutrient composition similar to seston. Front. Microbio. doi: 10.3389/fmicb.2010.00132

Tranvik, L.J., J.A. Downing, J.B. Cotner and others. 2009. Lakes and reservoirs as regulators of carbon cycling and climate. Limnology and Oceanography 54: 2298-2314.

Hall, E.K., A.R. Dzialowski, S. M. Stoxen, and J.B. Cotner. 2009. The effect of temperature on the coupling between phosphorus and growth in natural bacterioplankton communities. Limnology and Oceanography 54: 880-889.

Stets, E.G., and J.B. Cotner. Littoral zones as sources of biodegradable dissolved organic carbon in lakes. Canadian Journal of Fisheries and Aquatic Science 65 :2454-2460.

Organization Description:

The University of Minnesota-Twin Cities is a research and teaching institution dedicated to educating a diverse community across the State of Minnesota, the nation and the world.