**PROJECT TITLE: How to save the cisco-trout lakes**

**I. PROJECT STATEMENT**

The purpose of this project is to find out why important Minnesota lakes are losing their cisco-trout-friendly waters so that remedial measures can sustain cold water fisheries. Our purpose is to elucidate the mechanism of oxygen loss so that we can design cost-effective measures to save this important and disappearing fishery. Remediation could include deep-water reoxygenation, iron oxidation, or other approaches that work only for specific mechanisms of oxygen loss. Downing’s parents and grandparents caught lake trout in Itasca County’s Wabana Lake since 1908; there are none left there now and only a few ciscos. Adjacent lakes have a few ciscoes and trout but the squeeze between warming surface waters and increasing loss of deep-water oxygen is isolating cold-water fish in a thin layer during crucial times of year. This is an unexpected problem because deep-water oxygen loss is normally only found in lakes with poor water quality – and yet these cisco-trout lakes have clear water and little algae.

We can do little about warming weather but we can manage oxygen if we know why it is disappearing so fast. Current management assumes that we can protect cisco-trout lakes by protecting watersheds from excess development and nutrient loss to lakes. Shoreline development-driven oxygen loss is important but not sufficient to explain rates of deoxygenation observed in pilot studies of these lakes. For example, some cisco-trout lakes have rates of oxygen depletion after ice-out that are 2-5-times faster than expected based on the watershed-driven nutrient supply.

Although oxygen uptake through microbial decomposition of algae and other organic matter is often an important mechanism for oxygen removal from deep waters of lakes, there are several other mechanisms, including chemical oxygen demand and catalytic pathways that can remove infinite amounts of oxygen, especially when deep groundwater supplies iron and organic matter. Each mechanism of oxygen loss implies different remediation. There are 176 cisco lakes in Minnesota, according to Mr. Peter Jacobson of the Minnesota Department of Natural Resources. The purpose of this project is to determine how much oxygen is removed from a subset of Tier 1 cisco-trout lakes by different mechanisms, estimate the joint-effect of temperature and deoxygenation on cisco-trout habitat in these lakes, and thereby determine how this problem can be fixed.

**II. PROJECT ACTIVITIES AND OUTCOMES**

**Activity 1 Title: Field measurements of oxygen demand, temperature, and chemistry in Tier 1 cisco lakes**

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| **ENRTF BUDGET: $124,487** |  |

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| **Outcome** | **Completion Date** |
| *1. Complete seasonal lake profiles and water chemistry* | *December 2021* |
| *2. Measure oxygen demand and partition among mechanisms* | *April 2021* |

**Description:** *We will measure oxygen and temperature profiles every second week from ice-out to ice cover in 12 Tier 1 cisco-trout lakes (see map) over one full year. Two under-ice profiles will also be measured in each lake. Chemical measurements of nutrients, chlorophyll, iron, and dissolved organic carbon, as well as titration with acidic potassium permanganate will allow us to distinguish decompositional, catalytic, chemical and biochemical oxygen demand. We feel certain that we can complete this work in a single year (calendar year 2021).*

**Activity 2 Title: Determine difference between lakes that have lost ciscoes and trout and those where they still are found**

**Description:** *We will search Minnesota DNR fisheries files to find moderate-large lakes where ciscoes or trout have disappeared over recorded time. Also, we will search MN Lake Finder for data on characteristics of these lakes and use Geographical Information Systems to characterize current landscape and land use information. We will then perform a multi-dimensional analysis to find how lakes retaining ciscoes and trout differ from those from which they have been lost. This will tell us how many there once were and where and why they have been lost.*

**ENRTF BUDGET: $51,171**

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| **Outcome** | **Completion Date** |
| *1. Student builds database of lakes where ciscoes or trout have disappeared historically.* | *June 2021* |
| *2. Augment lake data with chemical, physical, and GIS data on lakes with and without ciscoes or trout* | *June 2021* |
| *3. Analyze characteristics of lakes that distinguish cisco-trout lakes that have lost vs retained populations* | *June 2021* |

**Activity 3 Title: Report on remedial measures to fix the problem and bring back ciscoes-trout in other lakes****Description:** *Based on the partitioning of oxygen demand among mechanisms of oxygen uptake, we will compile the best and most cost-effective approaches to remediation to use in these valuable lakes. These recommendations will be supplied for each of the study lakes.* |  |

**ENRTF BUDGET: $9,780**

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| **Outcome** | **Completion Date** |
| *1. Compile a compendium of approaches to re-oxygenation that have been well tested and work specifically to reverse oxygen loss due to diverse mechanisms.* | *June 2022* |
| *2. Determine costs of diverse approaches of re-oxygenation that will not alter stratification while sustaining cold water habitat* | *June 2022* |
| *3. Make recommendations of lake-specific approaches to enhancing cisco-trout habitat and reproductive success.* | *June 2022* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

**John A. Downing,** Sea Grant College Program, Large Lakes Observatory, and Department of Biology, University

 of Minnesota (Duluth); **Christopher T. Filstrup,** Natural Resources Research Institute, University of Minnesota (Duluth); **John R. Jones,** School of Natural Resources, University of Missouri, Columbia, MO. Dr. Jones summers in Deer River, MN and will provide his expertise in limnology and biogeochemistry at no cost to the project.

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

The results of this study will inform future management of the cisco-trout lakes of Minnesota. One of the principal outcomes will be to define management strategies for retaining cold water fisheries in Minnesota. Execution of management actions, in some cases, will require funding to treat low oxygen conditions as well as operation of this infrastructure. If innovative methods to inactivate specific processes are needed, funding proposals to USGS, the National Science Foundation, and NOAA will be submitted.