**PROJECT TITLE:** **Best management practices for Minnesota coldwater lakes**

**I. PROJECT STATEMENT**

We will use a novel combination of lake sediment cores and water quality data to describe the 200-year history of coldwater fish habitat. Then, based on modern trajectories **we will predict future persistence of coldwater fish habitat** in these lakes so that best management practices are appropriately targeted. This effort is needed to ensure stable recreational fishing in Minnesota, which annually comprises $9 billion in salaries, wages, earnings, retail spending, tax revenues and economic impacts in the forms of gas, lodging and resort services.

Unfortunately, **coldwater fish** populations **have been declining in Minnesota lakes** since the 1970s. This alarming trend has been attributed to:

• more algae due to nutrient inputs (which reduces oxygen concentrations in the bottom waters of lakes);

• higher water temperatures (which heat surface waters beyond what fish can tolerate);

• longer ice-free seasons (which also reduces oxygen in deep waters);

• the combined effects of nutrients, algae and warming, which collectively “squeeze” fish between habitats that are too warm and those with too little oxygen.

To combat loss of fish habitat we need to focus remedial measures on lakes where best management practices will be most beneficial. **We will identify the causes and timing of coldwater fish habitat loss in three important Minnesota lakes** as it relates to cisco (a forage fish) and the game fish that feed on cisco (lake trout, walleye, pike). These lakes will range from good (stable fish population) to poor (declining water quality and fish). We will determine how nutrients and other stressors have affected lake temperature and oxygen levels over the last two centuries. The Sentinel Lakes Program (funded through ENRTF) provided some valuable data, but **the deepwater oxygen histories of Minnesota lakes are unknown**, so we do not know the trajectory of coldwater fish habitat. The major outcomes will be (1) a set of urgently needed management recommendations for lake water quality and (2) a confirmed method to characterize fish refuge lakes throughout the state.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1: Determine past water quality conditions for three representative coldwater lakes**  **Description:** The three coldwater lakes selected range from low-nutrient with healthy coldwater fish populations (Greenwood Lake) to a high-nutrient lake whose coldwater fish are in decline (Lake Koronis). Kabekona Lake is intermediate in its condition. Fish habitat will be reconstructed from lake bottom sediment cores using the fossil remains of algae (indicators of past nutrient stress) and midges (aquatic insects that can indicate deep-water oxygen levels), allowing us to reconstruct historic nutrient and oxygen levels.  **ENRTF BUDGET: $130,600** | | |  |
| **Outcomes** | **Completion Date** |
| 1. Collect 6 sediment cores from 3 coldwater lakes; date sediment profiles; analyze fossil remains; total 450 sample analyses. | January 2021 |
| 2. Reconstruct historic nutrients and environmental conditions using algae fossils. | December 2021 |
| 3. Reconstruct historic lake temperatures & oxygen levels using aquatic insect fossils. | December 2021 |

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| **Activity 2:** **Establish relationships between stress (nutrients and warming) and coldwater fish habitat**  **Description:** Past lake nutrient concentrations and deep-water dissolved oxygen levels reconstructed in Activity 1 will be related to historic air temperatures and land use.  **ENRTF BUDGET: $31,000** | | |  |
| **Outcomes** | **Completion Date** |
| 1. Quantify relationships between air temperature, water quality, and fish habitat for three coldwater lakes in Minnesota. | April 2022 |
| 2. Determine historic impacts of human stressors on coldwater fish habitat. | April 2022 |

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| **Activity 3: Predict extent of coldwater fish habitat in the future; identify savable lakes and recommend on-the-ground conservation measures; derive a plan to expand findings to all coldwater lakes in Minnesota.**  **Description:** We will determine which lake management practices are likely to be successful. Based on the causes of fish loss (from Activity 2) we will make projections of future coldwater fish habitat in our study lakes. Warming will likely continue, but we can manage nutrients to preserve deepwater oxygen. The outcome will be a set of management actions to promote the persistence or recovery of coldwater fish communities. Outcomes may range among the following scenarios: Worst case: lake is no longer a coldwater refuge; warming has been impacting fish for decades; management unlikely to be successful; low action priority. Best case: natural coldwater fish refuge; lake is unimpacted by nutrients and warming; existing or minimal management recommended. Action case: potential fish refuge; lake is little impacted by warming but is nutrient-enriched; catchment management recommended for restoration.  **ENRTF BUDGET: $38,053** | | |  |
| **Outcomes** | **Completion Date** |
| 1. Describe future fish habitat in the three lakes based on management scenarios. | June 2022 |
| 2. Tailor management recommendations for different lake types (range: low nutrient lakes with coldwater fish to productive lakes where coldwater fish have declined). Work directly with MNDNR personnel to ensure recommendations are considered. | June 2022 |
| 3. Develop a plan to extend this application to hundreds of threatened coldwater lakes throughout the state. | December 2022 |

**III. PROJECT PARTNERS AND COLLABORATORS:**

* Daniel Engstrom & Mark Edlund (funded), sediment dating specialists, St. Croix Watershed Research Station; will perform isotopic analyses; assist with data exchange from previous ENRTF projects
* Peter Jacobson & MNDNR (unfunded), Fisheries Habitat Research Supervisor, MNDNR; will provide temperature and fish data; help develop the management recommendations, including linkages to the Sentinel Lakes program (previously funded through ENRTF)
* Local user sectors (unfunded), e.g. angling groups, lake associations; will contribute to management recommendations

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

**Minnesota is losing coldwater fish habitat and populations, a trend that will have long-term impacts on angling and tourism. However, loss can be minimized or reversed with appropriate management options.** Using clear linkages among air temperature, nutrient stress, low oxygen and fish declines in the three selected lakes we will create management recommendations for improving water quality in lakes that can be saved. The data and results produced by this project **will guide coldwater lake conservation efforts**. Most importantly, we will confirm the utility of this method as a tool to reconstruct lake sensitivity and trajectory, which could then be used for similar assessments across the state. Future work representing more lake conditions in the state would allow us to make recommendations for hundreds of coldwater systems. Major long-term benefits will include **improved water quality, well-oxygenated fish habitat and greater stability in angling and tourism sectors**. We secured additional in-kind funding to provide training for young scientists and a student in the techniques used to complete this work.