**PROJECT TITLE:** Increasing resilience of lakes to extreme precipitation events

**I. PROJECT STATEMENT**

Coldwater fish habitat in Minnesota’s inland lakes is threatened by both climate and land use change. **As extreme precipitation events become more common in Minnesota, there is an urgent need to understand the drivers of coldwater fish habitat loss in order to design effective protection and conservation strategies.** Extreme rain events can reduce coldwater fish habitat because large influxes of sediments and nutrients enter lakes and deplete oxygen, causing fish kills. However, not all lakes respond in the same way, and lake and watershed characteristics can influence how dissolved oxygen responds following extreme precipitation events. Robust populations of coldwater fish such as cisco are vital for sustaining economically important fisheries such as walleye, northern pike, muskellunge, and lake trout. Watershed protections and best management practices can maintain coldwater fish habitat even as lakes warm and extreme rain events increase in frequency. Millions of dollars are being spent in Minnesota to protect watersheds of coldwater refuge lakes, but conservation targets are based on historical precipitation levels, and do not account for the impacts of extreme rain events as they increase in frequency and intensity. Indeed, in recent years, some of these refuge lakes have experienced fish kills following extreme precipitation events. As extreme precipitation events become more common under climate change, it is imperative that conservation funding decisions are based on comprehensive science. Watershed characteristics that increase the resilience of coldwater fish habitat to extreme storm events must be identified and used to prioritize protection and restoration actions to maximize their probability of success.

**The overall goal of this project is to identify watershed best management practices for increasing resilience of coldwater fish habitat in lakes to warming and extreme storm events.** This information will directly guide prioritization and protection efforts designed to conserve coldwater fish habitat throughout Minnesota. To support effective conservation of coldwater fish habitat and efficient use of public resources, we will 1. Assess oxygen and thermal conditions at high temporal resolution (i.e., minute- to hour-scale measurements) in lakes spanning a gradient of climate, watershed, and geomorphological conditions to quantify how extreme storm events influence coldwater fish habitat; 2. Identify watershed and lake characteristics that increase resilience of fish habitat to extreme precipitation events; and 3. Design and communicate watershed protection targets and best management practices that can reduce the vulnerability of lakes to loss of coldwater fish habitat, given predicted future frequency of extreme storm events.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1 Title:** Continuous monitoring of oxygen and temperature conditions across a range of lakes  **Description:**We will assess oxygen and temperature dynamics in 10 Minnesota lakes spanning a gradient of watershed and climate conditions. We will deploy vertically distributed oxygen and temperature sensors to assess hourly, daily, seasonal, and annual patterns of oxygen and temperature limits for fish habitat. The Minnesota DNR and the US Fish and Wildlife Service already maintain similar sensors in 16 additional lakes, and we will partner with both agencies to share data in order to increase the number of lakes included in this research. In order to assess lake-specific drivers of low dissolved oxygen, we will measure dissolved and particulate nutrients (C, N and P) and calculate biological oxygen demand seasonally for each lake. Several years of assessment across a gradient of lake conditions and locations will increase the probability that we will observe extreme precipitation events and capture the range of lake responses.  **ENRTF BUDGET: $145,138** | |  |
| **Outcome** | **Completion Date** |
| *1. Collect hourly oxygen and temperature data from 10 Minnesota lakes* | *10/30/2022* |
| *2. Collect nutrient and water quality data from each lake in each year* | *10/30/2022* |
| *3. Develop database for continuous dissolved oxygen data from Minnesota lakes* | *10/30/2022* |
| **Activity 2 Title:** Identify characteristics that increase resilience of fish habitat following extreme rain events  **Description:**Using data obtained from activity 1, we will link dissolved oxygen and temperature (oxythermal habitat) responses in each lake to precipitation events. We will use statistical models to quantify relationships between oxythermal habitat and watershed land use, temperature, precipitation, and other lake characteristics. We will use data collected in activity 1 to develop landscape-scale models of current and future oxygen conditions that account for increased frequency of extreme precipitation events for hundreds of Minnesota lakes in which continuous monitoring is not feasible. We will quantify the resilience of oxythermal habtitat in individual lakes to watershed development and climate change in order to identify lake-specific watershed development thresholds above which coldwater fish habitat is expected to disappear.  **ENRTF BUDGET: $111,944** | |  |
| **Outcome** | **Completion Date** |
| *1. Collate data on watershed landuse, shoreline disturbance, and lake morphometry* | *6/30/2021* |
| *2. Quantify relationships between watershed land use, climate (including temperature and precipitation), lake morphometry, and oxythermal habitat.* | *12/31/2023* |
| *3. Estimate lake-specific watershed protection targets for sustaining coldwater fish habitat under climate change* | *12/31/2023* |
| **Activity 3 Title:** Design and communicate management strategies for resilient coldwater fish habitat  **Description:**The primary output of this work will be an online communication tool to guide watershed protection efforts designed to sustain coldwater fish habitat in lakes throughout Minnesota. This tool will allow stakeholders to assess the resilience of oxythermal habitat in individual lakes to climate change and watershed development in order to support protection and restoration efforts at multiple scales. For example, the tool could be used by lake associations to identify watershed protection targets designed to maintain coldwater fish habitat specific to their lake. It could also be used more broadly at a regional scale to prioritize protection and restoration efforts on lakes that would benefit most in terms of watershed management actions designed to sustain coldwater fish habitat. This tool will be designed and developed in partnership with stakeholders to maximize the value of our key findings for a wide range of potential users.  **ENRTF BUDGET: $66,698** | |  |
| **Outcome** | **Completion Date** |
| *1. Data visualization tool* | *6/30/2024* |
| *2. Peer reviewed manuscript in scientific journal* | *6/30/2024* |
| *3. Present results and data visualization tool to stakeholders* | *6/30/2024* |

**III. PROJECT PARTNERS AND COLLABORATORS:** Peter Jacobson and Casey Schoenebeck, MN DNR; Jared Myers, US Fish and Wildlife Service. Lesley Knoll, Itasca Biological Station, U of MN; James Cotner, U of MN.

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

This project is a partnership between state (MN DNR and MN PCA, federal (USFWS), and University investigators and is a high priority for each of these groups. To date, the MN DNR and USFWS have committed over $100,000 for the purchase and maintenance of continuous monitoring of dissolved oxygen in Minnesota lakes and we will leverage those funds in this work. We will support implementation of efficient and effective management of coldwater fish habitat through our data visualization tool and will publicize this tool widely through presentations to stakeholder groups, social media, and the press. We will also make dissolved oxygen data publicly available for future collaborations, and plan to maintain data collection from at least a subset of these sensors in the long-term through the sentinel lakes program and USFWS monitoring activities.

**V. SEE ADDITIONAL PROPOSAL COMPONENTS:**

**A. Proposal Budget Spreadsheet**

**B. Visual Component or Map**

**C. Parcel List Spreadsheet**

**D. Acquisition, Easements, and Restoration Requirements**

**E. Research Addendum (Not required at proposal submission stage. Required later in process, if proposal is recommended. Staff will provide further information at that time)**

**F. Project Manager Qualifications and Organization Description**

**G. Letter or Resolution**

**H. Financial Capacity**