**PROJECT TITLE:** Cascading effects of ice-cover onsummer water quality

**I. PROJECT STATEMENT**

Records indicate recent years with more extreme meteorological conditions, such as warmer winter and spring air temperatures, are leading to shorter ice cover duration on lakes that may extend to warmer waters during the summer. **We aim to determine the importance of year-to-year differences in ice cover conditions on summer water quality in a diverse set of Minnesota lakes**. Cyanobacteria (blue green algae) blooms are noxious and cause unsafe, unsightly, and undesirable conditions in our lakes. Sometimes we find high cyanobacteria concentrations in lakes not typically considered at risk for algal problems (e.g., forested, protected). Two factors that are likely playing roles in their increased abundance are excess nutrient levels, especially phosphorus, and warmer surface waters. Both surface water temperatures and phosphorus are predicted to be influenced by changing ice cover duration.

*Our project will use existing MN DNR Sentinel Lakes data and new data to assess how years with extreme vs typical ice cover duration across a range of lake types:*

* influence the amount of phosphorus and oxygen in bottom-waters in the summer (activity 1)
* influence the amount of harmful cyanobacteria in the summer (activity 1)

*Findings in activity 1 will enable us to*:

* identify which lake and watershed types are more vulnerable to changing ice conditions (activity 2)
* make recommendations to lake managers (e.g., MN DNR, MN PCA, lake associations) on lake and watershed management strategies (activity 2)
* share findings and streaming data via displays with over 500,000 public visitors (activity 3)

We hypothesize that shorter ice cover duration will negatively influence water quality and ultimately, fish habitat, by increasing summer lake surface water temperatures and cyanobacteria dominance, reducing oxygen in the deep parts of lakes, and increasing phosphorus release from lake sediments. More phosphorus can fuel additional algal growth to create a feedback loop decreasing overall water quality. We currently cannot predict how variable ice cover duration and changing water temperatures influence these key lake variables and which lake types (deep, large, shallow, agricultural, urban, etc.) may be sensitive to or buffered by extreme conditions.

Lakes in the first two activities are: (Sentinel Lakes italicized, NSF equipment in underlined lakes) Cedar Bog (Anoka Co.), *Carlos* (Douglas Co.), *Elk* (Clearwater Co.), *Greenwood* (Lake Co.), Itasca (Clearwater Co.), *Madison* (Blue Earth Co.), *South Center* (Chisago Co.), and *Trout* (Cook Co.). The third activity, showing streaming data, will use the underlined lakes.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1 Title:** Investigate how variable ice cover conditions affect summer water quality  **Description:**It was historically difficult to study late winter and early spring because of unsafe ice conditions. We will use new sensor technologies that allow us to collect information remotely. Our project will leverage: 1) data from six MN DNR Sentinel Lakes and two additional lakes, and 2) recent infrastructure funding to Knoll and Cotner from the National Science Foundation ($391,050).  When ice-out occurs earlier, surface waters may warm faster and stay warmer over the summer. In turn, lakes may stratify into distinct layers earlier with overall longer and stronger stratification during the summer. This type of change in stratification may provide an ideal environment for enhanced phosphorus accumulation and oxygen depletion in deep-waters as well as increased cyanobacteria in surface waters. We will use automated sensors to define stratification start and end dates, quantify stratification strength, and monitor deep oxygen conditions.  **ENRTF BUDGET: $101,900** | | |  |
| **Outcome** | **Completion Date** |
| *1. Collect water samples (900) and phytoplankton samples (40)* | *September 2022* |
| *2. Maintain temperature/oxygen sensors (some managed by UMN and some by MN DNR)* | *June 2023* |
| *3. Analyze 940 samples in the laboratory* | *December 2022* |

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| **Activity 2 Title:** Predict the lake and watershed types that are sensitive to extreme ice conditions and make recommendations to lake managers on management strategies  **Description:** We will use existing and new data on 8 lakes (up to 15 years of data) to develop models. The models can be used to predict trends across Minnesota and identify which lake and watershed types may need modified management strategies. For example, water quality for some lake types or lakes in certain watershed types may be more sensitive to variable ice conditions than others and knowing this will benefit management and help prioritize conservation efforts. We will use our results to provide recommendations to lake managers (e.g., MN DNR, MN PCA, lake associations) by highlighting at-risk lake and watersheds types.  **ENRTF BUDGET: $29,000** | | |  |
| **Outcome** | **Completion Date** |
| *1. Collate data (new and historical)* | *February 2023* |
| *2. Develop predictive models to understand the role of variable ice conditions on summer water quality by lake type* | *June 2023* |
| *3. Provide recommendations on best management strategies* | *June 2023* |

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| **Activity 3 Title:** Usestreaming lake data for website and public outreach displays/programs  **Description:**We will create a public website showing streaming data on three lakes. Anglers in particular are often interested in lake temperature and how it changes with depth and over the season. Our website will provide this and other water quality values. We will also create displays with streaming data for the visitor centers of Itasca State Park (Clearwater Co.) and Cedar Creek Ecosystem Science Reserve (Anoka Co.). Both reach a large annual audience of public and K-12 visitors (500,000+ Itasca, 10,000+ Cedar Creek). Public programs will complement established relationships with Itasca State Park.  **ENRTF BUDGET: $60,100** | | |  |
| **Outcome** | **Completion Date** |
| *1. Create website with streaming data* | *July 2021* |
| *2. Create educational displays with streaming data from website* | *July 2021* |
| *3. Offer public programming to the 500,000+ annual visitors of Itasca State Park* | *June 2023* |

**III. PROJECT PARTNERS AND COLLABORATORS:** James Cotner (co-investigator), University of Minnesota; Casey Schoenebeck (partner), Minnesota DNR; Gretchen Hansen (partner), University of Minnesota

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:** Our proposed project will provide data and models for water quality (MN PCA) and fish management (MN DNR) in Minnesota. We will leverage existing projects, equipment, and infrastructure that are part of the Sentinel Lakes Program and a NSF award to Knoll and Cotner.