**PROJECT TITLE: Estimating Fish Production in Stressed Minnesota Lakes**

**I. PROJECT STATEMENT**

**Our goal is to predict how disruption of primary (algae) and secondary (e.g., zooplankton) production changes fish production in Minnesota Lakes. Using data collected through the Sentinel Lakes Program, we will test a bioenergetics-based method for (1) estimating seasonal and annual carbon flow through the primary and secondary trophic levels of study lakes using existing lake ecosystem models; and (2) linking seasonal production estimates to annual lake cisco (*Coregonus artedi*) production in these same Sentinel Lakes.**

Our project will quantify how the key drivers of water quality and hydrology contribute to fish productivity in Minnesota lakes. The outcome from the lower-trophic level bioenergetics model will be used to estimate how seasonal contributions from changing phytoplankton and zooplankton communities support fish production by the northern lake cisco (*Coregonus artedi*), an open-water, zooplanktivorous fish that plays a critical role as a forage fish in Minnesota walleye lakes. The model will be developed and validated in three Sentinel Lakes using long-term data including annual estimates of cisco abundance and biomass.

***WHY: Changes at lower trophic levels caused by numerous stressors have cascading effects on algae, zooplankton and fish.*** Changing stressor gradients in lakes have increased the frequency and intensity of algal blooms and reduced biomass of native zooplankton by as much as 60 percent. These changes produce less food or poorer quality food for zooplankton, forage fish, and larval game fish such as walleye and largemouth bass that depend upon zooplankton production during their first year of growth. Observed reductions in the quality of phytoplankton and the quality and quantity of zooplankton food resources are predicted to reduce the net flow of energy available for fish growth, increasing overwintering mortality of young of year (YOY) fish and reducing recruitment. Fisheries managers in Minnesota need a tool that can predict how changes in the algae and zooplankton resources of the lower trophic levels of the food web drive changes in fish production.

**HOW:** ***Estimates of seasonal changes in primary and secondary production will allow us to use carbon-based production models to predict changes in cisco production based on changes at lower trophic levels***. Existing ENRTF-funded lake ecosystem models will be integrated into fish bioenergetics models to predict how different densities of phytoplankton and zooplankton change the carbon and energy flow available to sustain cisco growth. Integrated models will predict how changes in phytoplankton and zooplankton change cisco growth and production. Model predictions will be calibrated against independent estimates of primary and secondary production and fish biomass production data from Minnesota DNR (MNDNR) fish population surveys.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1: Predict carbon-based, primary and secondary production in study lakes using water chemistry and ecosystem models**Existing lake ecosystem models will be updated using a dynamic food-web sub-model and used to predict the amount of carbon-based energy available for fish production. Proposed study lakes include vulnerable Sentinel Lakes: Trout Lake, Elk Lake, Lake Carlos, and Ten Mile (figure 1). The potential study lakes are popular recreation lakes and represent a broad gradient in climate, primary productivity, and cisco population size.  | **Budget: $290,000** |
| **Outcome Activity 1** | **Completion Date** |
| 1. Calibrated lake ecosystem models for each test lake that predict how current phytoplankton and zooplankton production change food available for fish | Dec 31, 2021 |
| 2. Validation of carbon flow available for fish growth and recruitment | June 30, 2022 |
| 3. Final report to LCCMR and draft USGS Scientific Investigations Report | June 30, 2023 |

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| **Activity 2: Validate the primary production rates from Activity 1 using dissolved oxygen data to estimate primary and secondary production and calculate cisco population production rates from available fish biomass survey data**.Continuous dissolved oxygen data collected through the Sentinel Lakes Program will be used to validate the energy flow in lakes between major trophic levels: from algae to zooplankton and from zooplankton to fish. Algal (primary) and zooplankton (secondary) production will be quantified using observed changes in oxygen concentrations and zooplankton populations through time. Pelagic cisco fish biomass data from annual fish population surveys (vertical gillnets and hydroacoustic surveys) will be used to validate the model results under Activity 1.  | **Budget: $126,500** |
| **Outcome Activity 2** | **Completion Date** |
| 1. Collect and quantify size-class specific phytoplankton and zooplankton carbon from three Sentinel Lakes; quantify nutrient-dependent phytoplankton growth | Dec 31, 2021 |
| 2. Quantify algal, zooplankton, and fish production from existing and new data | June 30, 2022 |

**III. PROJECT PARTNERS AND COLLABORATORS:**

The Principal Investigators for this project are Richard Kiesling and Erik Smith, USGS Upper Midwest Water Science Center (UMidWSC). Dr. Smith is an expert in lake ecosystem model development and validation having published models for five Sentinel Lakes and Lake St. Croix in the past five years. He will direct Activity 1 and manage data collation and ecosystem model updates with assistance from Jeff Ziegeweid, USGS UMidWSC biologist with expertise is fish growth rates and production estimates. Dr. Kiesling is an expert in lake water quality and lake metabolism and will serve as Project Manager while directing Activity 2 and supervising a graduate student research assistant for the project. Dr. Casey Schoenebeck, Sentinel Lakes Program Coordinator, Division of Fish and Wildlife, MNDNR, will oversee project coordination and provide access to Sentinel Lakes Program data through Program staff as necessary.

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

The proposed research ties directly to the Minnesota DNR strategic plan by forecasting the impacts of large-scale stressors on multiple trophic levels in Minnesota lakes. Secondly, the proposed research fits with several Section of Fisheries Information Need Priorities including those related to what drives the pelagic fish community, zooplankton and secondary production, and identifying the impacts of climate change and other stressors on lake trophic levels. Outcomes from the study will provide information necessary to manage Minnesota lake fish communities in ways that mitigate impacts of stressors on primary and secondary production. Finally, the proposed research will further the key mission of the Sentinel Lakes Program, a Section of Fisheries priority, which is to nurture monitoring and research efforts across multiple agencies and partners to better understand the drivers of ecological change in aquatic resources.

**Timeline Requirements**

Three years of funding are being requested for this study beginning July 1, 2020 and ending June 30, 2023

**V. SEE ADDITIONAL PROPOSAL COMPONENTS:** A, B, F and G