**PROJECT TITLE: Climate impacts on nitrogen gas release from lakes**

**I. PROJECT STATEMENT**

Microbes in lakes, streams, and wetlands (henceforth, water bodies) naturally remove nitrogen (N) pollution by converting dissolved N to gaseous forms (N2 and N2O) that are released into the atmosphere. This “exhalation” can permanently remove much of the N that enters wetlands and lakes leading to improved water quality. However, if N2O gas is produced, there is a negative impact for our climate. **Here we propose to** **determine how much N gas (N2 and N2O) is being produced by a diverse set of Minnesota waterbodies and how much is N2 vs. N2O**. N2O (but not N2) is a potent greenhouse gas and the amount of N2O produced relative to N2 depends on the dominant microbial process and lake conditions such as, nutrient pollution levels, water temperature, and the duration of lake stratification. *Ultimately, we will provide management guidance for enhanced N removal while maintaining low N2O production in lakes*.

Despite watershed nutrient management, N loads are predicted to increase in the future as a result of a wetter climate and larger storm events. Additionally, climate change may affect the efficacy of microbial N removal by altering lake conditions. For example, water temperature controls the reaction rates of microbial communities and warming temperatures due to climate change could lead to increased microbial reaction rates and therefore increased N gas production. Alternatively, longer growing seasons may prolong stratification, limiting the availability of essential reactants and decrease N gas production. **Our second goal is to assess how climate change will affect N gas production** since it is unclear if larger nutrient loads, longer growing seasons, and warmer summers will enhance or suppress N removal.

This project will provide data about the magnitude of N removal by Minnesota’s lakes and wetlands and help predict how N2O emissions will be affected by a changing climate. With this information we can **update N2O emissions estimates for Minnesota’s waterbodies** and develop a statistical model to predict how it will change with changing land use and climate conditions.

Our project will produce:

1. Management recommendations for low N2O production and high N removal in lakes responding to a changing climate;
2. Greenhouse gas budgets for N2O in waterbodies statewide.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1:** **Measure N gas emissions (both N2 and N2O) from waterbodies.**  Emissions of N2 and N2O in deep lakes, shallow lakes, and wetlands will likely have variable responses to climate change. **We will measure fluxes of N2 and N2O from 40 deep lakes, shallow lakes, and wetlands that are part of the Minnesota Department of Natural Resources (MDNR) Sentinel Lakes program or were restored by the United States Fish and Wildlife Service**. There is historical nutrient data on these sites and the MDNR Sentinel Lakes Program takes high frequency measurements of temperature and stratification. We will sample the lakes during late summer when the deep lakes are likely to be strongly stratified and the shallow lakes and wetlands are warmest. Five sites in each system (e.g. Sentinel Lakes and wetlands) will be sampled seasonally to identify temporal patterns in N gas emissions. We will develop a predictive model of N gas emissions that considers a broad suite of variables, but we will focus on the effects of temperature and stratification to better understand the effects of climate change.  **ENRTF BUDGET: $165,100** | | |  | |
| **Outcome** | **Completion Date** | |
| *1.* Measure N2O and N2 gas concentrations in 40 waterbodies throughout Minnesota. | *Fall 2022* | |
| *2.* A statistical model that relates stratification and water temperature to N gas production. | *Summer 2023* | |
| **Activity 2: Measure rates of microbial processes that produce N gas** **and quantify the effects of water temperature and stratification.**  **We will measure rates of two microbial processes that produce N2O, denitrification and nitrification.** Denitrification produces N2 and both nitrification and denitrification produce N2O. These processes vary in the amount of gas they produce and the environmental conditions they are favored in/inhibited by. *In order to manage waterbodies to increase Nremoval but not N2O production, it is necessary to understand when each process is favored and how to control them.* Lab based measurements of nitrification and denitrification are time and labor intensive, so we will focus on sampling a few sites multiple times over a two year period. We will pair these findings with N2O and N2 emissions data, and environmental data from the Sentinel Lake program and a previously funded LCCMR project in restored wetlands (J. Finlay, Univ. of Minn.).  **ENRTF BUDGET: $195,900** | | | |  | |
| **Outcome** | **Completion Date** |
| *1.* Dataset of rates of nitrification and denitrification in nine waterbodies seasonally. | *Fall 2022* |
| *2.* Management guidance for enhanced N removal while maintaining low N2O production in lakes. | *Spring 2023* |
| **Activity 3:** **Model N2O emissions from lakes across Minnesota.**  Using tools developed from previous LCCMR funded projects, specifically state-level estimates of lake bathymetry (J. Nieber, Univ. of Minn.) and water quality (J. Finlay, Univ. of Minn.), **we will develop models to estimate statewide N2O concentrations in lakes**. Current models only use watershed fertilizer application rates to estimate N2O and we will improve estimates by incorporating lake specific variables.  **ENRTF BUDGET: $ 91,000** | | | |  | |
| **Outcome** | **Completion Date** |
| *1.* Statewide N2O emission estimates for waterbodies across Minnesota. | *Summer 2023* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

Project Partners Receiving Funds: Dr. Nicole M. Hayes (Project Manager, University of Minnesota), Dr. James Cotner (Collaborator, University of Minnesota), Dr. Jacques Finlay (Collaborator, University of Minnesota), Sarah G. Winikoff, M. Sc. (Collaborator, University of Minnesota), Brianna Loeks-Johnson, M. Sc. (Collaborator, University of Minnesota), Erin Mittag (Collaborator, University of Minnesota)

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

This research will inform water quality management decisions by providing valuable data about the magnitude of current N removal by water bodies and help identify how climate change will affect removal rates and N gas production. Our findings can be used to make management recommendations to enhance N removal while minimizing greenhouse gas production. We will also generate emission estimates to describe N2O produced in water bodies currently. Ultimately, these N2O values can be added to statewide greenhouse gas budgets.