**PROJECT TITLE: Winter Dynamics of Vulnerable Trout Streams: Central Minnesota**

**I. PROJECT STATEMENT:** For almost a decade, Ferrington (PI) has studied the winter dynamics of trout streams in the Driftless Region **(DR)** of Minnesota. The **DR** was not glaciated during the most recent glaciation of MN and presently is relatively devoid of lakes. However, the geology consists of extensive karst landscape conducive to groundwater flows that re-surface at well-developed spring or seepages and buffer temperature regimes of streams. These point sources of groundwater keep streams cold in summer (but warm in winter!), contributing to high quality habitat for trout. More than 170 streams of the **DR** are managed in Minnesota for trout sport fishing, with considerable impact on local economies, estimated in 2008 by Trout Unlimited to be valued at 1.1 billion dollars. In contrast to the **DR**, glaciated regions of **central MN** have differing surficial landscapes and underlying geology, resulting in short stretches of stream that often receive flow from lakes and larger, more diffuse lateral wetlands, that feed streams as more diffuse groundwater discharge directly to stream courses, resulting in less buffered stream temperatures and warmer summer water temperatures. With this project, we are proposing to investigate and model winter dynamics of stream temperature buffering, trout movement and roles of lakes and/or wetlands as refugia in winter, so that management efforts can be targeted to marginal trout streams intended to reduce the impact of increasing thermal regimes predicted by global warming models.

**II. PROJECT ACTIVITIES AND OUTCOMES: We will intensively map and sample eight streams/year that span a wide range of groundwater input intensities, and differ in geologic setting (compared to streams of the *DR)* to generate results leading to improved habitat management guidance. Our specific objectives are to:**

● identify how groundwater, air temperature, and geology of central MN differ from conditions of the ***DR***, and interact to determine habitat and fish movement patterns in this contrasting geologic landscape;

● understand how the changes in geology & groundwater input affect stream temperatures andtherefore influence food availability during winter, and ultimately trout growth, movement and abundance;

● create quantitative models relating winter thermal regimes to food availability for trout consumption;

● quantify and model trout movements in winter in relation to groundwater inputs/thermal regimes;

● recommend ways that our quantitative models can guide efforts to enhance trout productivity via habitat modifications to protect or improve stream temperature or refugia, with a focus on the winter period;

● Trout in Minnesota’s streams have great economic, sport and aesthetic importance. Trout depend on cold, clean stream water, a resource threatened by gradual groundwater warming. Minnesota’s environmental managers and landowners need to understand what actions can reduce impacts of warming and by how much. Consequently, we will **develop a web-based program that educates and utilizes citizen volunteers** to assist monitoring the dynamics of winter-emerging populations of aquatic insects in a large number of trout streams in central Minnesota.

***Activity 1:******Thermal Modeling******and Winter Insect Abundances and Genetics***

*We will build on past research findings to model how groundwater inputs interact with geology and streambed conditions to buffer trout streams, and will determine how genetic patterns differ among abundant winter active insects, and how genetic variability aligns with abundances as a function of water temperatures across streams.*

**Description:** Activity 1 will allow us to predict ranges of thermal suitability for brook trout, and how they vary among streams, which will enable managers to position and tune restoration efforts with greatest impact in extending the moderating influence of groundwater on stream temperature. We will use historical and newly measured air and water temperatures (8 streams/yr.) to map groundwater influences at fine spatial scales. Models we develop will relate local geological conditions to a statistical model for prioritizing management actions. We anticipate the models will contrast with results of our previous/current LCCMR-funded projects based in the ***DR.*** We will determine the genetic patterns of winter-active insects, and how their genetic variability aligns with abundances and water temperatures across streams. **ENTRF BUDGET: $ 261,653**

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| **Outcomes Activity 1: The following outcomes will be accomplished in 8 streams/year** | **Completion Date** |
| *1.* Yr 1: Develop thermal models (TM) 8 streams; determine insect genetic patterns | *June 2021* |
| *2.* Yr 2:Develop TM for 8 more streams; collect/determine genetic patterns of insects | *June 2022* |
| *3.* Yr 3:Develop TM for 8 more streams; collect/determine genetic patterns of insects | *June 2023* |

***Activity 2: Assess brook trout (BKT) movement in relative to groundwater, invertebrate emergence, and winter habitat*.**

**Description:** Though much is known about summer movement of BKT, winter movement is less well understood, especially as it relates to water temperature and insect emergence. It is important to understand whether BKT overwinter in streams, or leave streams to enter deeper water lake habitats (that may act as winter refugia) and how this movement choice is related to water temperature and, consequently, groundwater input. The goal of this activity is to assess winter trout movement in relationship to stream groundwater inputs, winter insect emergence patterns, and winter refugial habitat in central Minnesota streams. Fish sampling will be coordinated with insect and water temperature sampling from Activity 1. BKT will be implanted with passive integrated transponder (PIT) tags and tracked by 1) two fixed antennae stations which will record BKT passage remotely and 2) manually using a hand held locator. Finally, BKT movement patterns will be related to winter water temperature and insect emergence data from Activity 1 **ENTRF** **BUDGET: $ 295,222**

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| **Outcomes: Brook Trout (BKT) Movements** | **Completion Date** |
| *1.* Yr 1: Install two fixed stations (November) to remotely monitor brook trout movement  to potential winter refuges and measure in-stream habitat variables for modeling | *June 2021* |
| *2.* Yr 2: Supplement brook trout movement via fixed station with tracking using handheld  antennae, continue measuring in-stream habitat variables in additional streams | *June 2022* |
| *3.* Yr 3:Correlate brook trout movement patterns with both water temperature data and  insect emergence data from Activity 1, refine and finalize modeling activities | *June 2023* |

***Activity 3: Develop a communication and educational research and outreach program***

**Description:** The goal of the communication and outreach program is to improve public engagement with science and to increase understanding of how specific actions impact trout stream conditions. The engagement of community volunteers or “citizen scientists” will be a key to the success of this communication program and research project. The study will focus on discovering how to best reach, engage and motivate citizen volunteers as they become aware of the project and actively participate. Roles that citizen science plays can have great impact on local communities, as well as influence economic factors for other Minnesota areas relying upon tourism revenue. Other audiences include landowners in NW MN, stakeholders, and conservation organizations, especially as we must gain access to both public and privately owned land to collect data. Research based upon our communications plan will determine the perceived benefits and motivations for participating in a citizen natural resource monitoring program and will evaluate the engagement needs of these citizen scientists. Focus groups and survey research will be conducted to gain insight into the participants’ experiences, attitudes and behaviors in regards to this project. Based on this study, outreach materials (e.g., training videos, online media groups, websites) will be developed to recruit, engage and retain Minnesotans as active citizen monitors, especially during winter. Stakeholders include outdoor recreationalists, 4-H clubs, nature centers, K - 12 educators, Trout Unlimited, and Minnesota Master Naturalists. **ENTRF BUDGET: $ 210,185**

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| **Outcomes: Develop communication, educational research & and outreach programs** | **Completion Date** |
| *1.* Yr 1: Determine benefits, motivations, and engagement needs of key stakeholders | *August 2021* |
| *2.* Yr 2: Develop and refine outreach materials and platforms for engaging stakeholders | *August 2022* |
| *3.* Yr 3:Implement and evaluate effectiveness of outreach products for key stakeholders | *June 2023* |

**III. PROJECT PARTNERS AND COLLABORATORS:** We have coordinated with personnel at regional DNR fisheries offices in the central region, and have already obtained access to some historical water temperature data. We will coordinate with managers & staff to involve them in our planning and execution of our project. We will coordinate with Drs. Jim Perry and Bruce Vondracek (who have been part of our previous research teams).

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:** We will continue to work with fisheries biologists and coordinate with Trout Unlimited to keep them informed of our findings. We will continue to seek funding from other sources during the execution of this project to leverage LCCMR-funded efforts, and use University-based internships, work-study and Undergraduate Research Opportunities as resources to extend our student staff.