**Problem Statement and Hypotheses**

Streams and rivers play a critical role in the global carbon cycle ([*1*](#_ENREF_1)). Ecosystem respiration (ER) is the main biological process regulating the flux of dissolved organic carbon (DOC) in stream water to dissolved inorganic carbon (DIN) that can enter atmospheric pools through evasion as CO2 ([*1-3*](#_ENREF_1)). In high latitude Arctic streams, the input of DOC is particularly sensitive to subtle changes in temperature ([*4*](#_ENREF_4)). Therefore, it is essential to parameterize and quantify ER and the portion of ER occurring in the hyporheic zone (hyporheic respiration - Rh) across multiple stream networks to evaluate the effect of arctic warming on the global carbon cycle ([*5*](#_ENREF_5)). Relatively few studies have directly measured the contribution of Rh to ER ([*6-8*](#_ENREF_6)), and even fewer have developed methods to potentially predict how these carbon fluxes may change across a river network ([*9*](#_ENREF_9)*,* [*10*](#_ENREF_10)). This research aims to elucidate the influence of spatial scale on metabolic processes (i.e., respiration and production) and develop an approach for predicting stream respiration rates using an easily measured hydraulic descriptor. A nested study approach will be employed to test metabolic scaling between habitat-patches (size = 100 m2) and reaches (size = 102 m2) using chamber and whole-stream methods. The resulting patch to reach relationships will be used in conjunction with measured specific stream power (ω) to create a predictive model of carbon flux in Arctic stream networks. The proposed research will address three hypotheses:

*Hypothesis H1—*Metabolism of native stream habitat-patches will scale to the reach.

*Hypothesis H2—*Streams with larger, more active hyporheic zones will have greater ER and Rh.

*Hypothesis H3—*Specific stream power can be used to predict rates of ER and Rh.

**Expected Significance and Broader Impacts**

*Intellectual Merit—*The importance of the proposed research is rooted in its simplicity and potential for broad-scale application. If a minimally parameterized metric like ω can be used to help predict respiration activity in streams, then ω could be incorporated into carbon models to further refine flux estimates at a global scale. Moreover, ω could be used to identify hotspots of biogeochemical activity to monitor as the Arctic climate continues to change. The hypotheses presented in this proposal will build upon the objectives of the NSF-funded Scale, Consumers and Lotic Ecosystem Rates (SCALER) project which is currently exploring affects of consumers on patch to reach-scale biogeochemical processes. As a graduate student working on the SCALER project in the Arctic, I believe my hypotheses provide a critical link between physical stream characteristics and biogeochemical function, which have far-reaching applications for global scaling. My role in the SCALER project will help leverage the resources needed to meet the high logistical demands of carrying out this research in the Arctic, while expanding the knowledge base within the field.

*Broader Impacts—*In addition to my proposed research, I plan to develop a series of mini-labs to promote advanced scientific discovery and understanding through experiential learning at the high school level. Labs will focus on fundamental concepts of aquatic ecology emphasizing the need for multidisciplinary thinking. I will work with the Vermont EPSCoR’s Center for Workforce Development and Diversity to identify local schools where the program can be implemented. This presents a unique opportunity for me to mentor and educate students outside of a university setting where I currently mentor four undergraduate students. Additionally, I will lead publically accessible interactive web-based seminars facilitated by the Association of Polar Early Career Scientists for those who share my interests of the Arctic environment. The societal contributions I can make through this research are as exciting as the research itself, and the dissemination of knowledge through new partnerships will remain an utmost priority.

**Methods**

*Location—*This research will be carried out in streams on the North Slope of Alaska. Arctic streams are an ideal choice because their hyporheic zones are isolated from groundwater sources by continuous permafrost ([*10*](#_ENREF_10)) and because they are rich with terrestrially-sourced DOC ([*5*](#_ENREF_5)).

*Habitat-Patch to Reach Scaling (H1)—*Reach metabolism will be measured using the two-station diel difference method ([*11*](#_ENREF_11)*,* [*12*](#_ENREF_12)). Separate measures of respiration in the hyporheic zone and benthic surface will be conducted using chamber techniques ([*6*](#_ENREF_6)*,* [*8*](#_ENREF_8)*,* [*13*](#_ENREF_13)). To address the spatial heterogeneity encountered in streams, reaches will be delineated with a high-resolution Global Positioning System (GPS) into distinct habitat-patches based on substrate size and flow characteristics. The benthic surface respiration (Rbs) and corresponding Rh of patches will be normalized by areal contribution and regressed against whole stream measures to test whether or not carbon fluxes scale linearly.

*Hyporheic Contribution to Ecosystem Respiration (H2)—*The cross-sectional area of the hyporheic zone will be quantified using plateau solute injection experiments on the reach scale ([*6*](#_ENREF_6)*,* [*14*](#_ENREF_14)). Surface-subsurface exchange rates of habitat-patches will be determined using patch-scale solute injections through a network of mini hyporheic piezometers ([*15*](#_ENREF_15)*,* [*16*](#_ENREF_16)) and three-dimensional solute transport modeling ([*17*](#_ENREF_17)*,* [*18*](#_ENREF_18)). The hyporheic zone area will be normalized by stream cross-sectional area and evaluated against the reach ER and Rh. Biogeochemical constituents (e.g., DOC, DIN, and other nutrients) will also be measured and correlated with surface-subsurface exchange processes.

*Specific Stream Power as Predictive Tool (H3)*—Sites will be selected across a gradient of slope, discharge, and morphologies to capture the variation of ω observed in arctic streams. The ω will be measured in the field during metabolism studies and using Geographic Information Systems (GIS) to determine the accuracy of remotely sensed estimates of ω. The relationships between ω and respiration will be validated at new sites, where predicted rates of Rh and ER (from estimated ω) will be tested against measured Rh and ER rates.

**Anticipated Results**

*H1*—The relationship between patches and reach dynamics will be linear in reaches with homogeneous habitats due to decreased variance in dispersal of respiring microbial and benthic communities. In reaches with increased spatial heterogeneity these relationships will be non-linear, because respiring communities will be highly variable in their dispersal amongst patches.

*H2—*Arctic streams with larger hyporheic zones and faster surface-subsurface exchange rates will have increased rates of Rh and ER, because recent research indicates that the hyporheic zone is hydrologically active and an important site of biogeochemical processing in areas of continuous permafrost ([*16*](#_ENREF_16)*,* [*19*](#_ENREF_19)). The relationship between hyporheic zone size and respiration has also been demonstrated in some temperate streams ([*6*](#_ENREF_6)*,* [*7*](#_ENREF_7)*,* [*9*](#_ENREF_9)).

*H3*—Specific stream power can be used to predict rates of ER and Rh. Zarnetske *et al.* ([*10*](#_ENREF_10)) found ω to positively correlate with hyporheic storage exchange rates and negatively with reach hydraulic retention, both factors that have been linked to respiration ([*6*](#_ENREF_6)*,* [*16*](#_ENREF_16)). As stream power increases the surface-subsurface exchange of nutrients and dissolved oxygen are expected to increase, thus promoting Rh and ER and increasing the localized flux of DOC to CO2.

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