Spotlight on Student Research: Studying the mechanisms that influence shrub expansion on the Canadian tundra

Rapid climate change in the low Arctic tundra has caused temperatures to warm by at least 3°C over the past 50 years. This warming is driving the proliferation of tall shrubs across the tundra biome with implications for energy balance, hydrology, nutrient cycling and tundra biodiversity, and scientists expect these changes to continue.

Katie working in the Trail Valley Creek watershed with green alders.

These warming temperatures are why Katie Black is investigating how topographic features, moisture, and nutrient availability control the growth and distribution of green alder (*Alnus viridis*) shrubs at Trail Valley Creek near Inuvik, Northwest Territories.

According to Katie's thesis work, changes in tundra plant water use attributable to shrub expansion are predicted to increase evapotranspirative water loss which may amplify local warming and reduce run-off. However, little is known about the degree to which tall shrubs will enhance evapotranspirative water loss in these systems.

Understanding the drivers and limitations of green alder expansion across the low Arctic tundra

Having started her master's program in integrative biology in 2015 under the supervision of CCRN co-investigator Dr. Jennifer Baltzer at Wilfrid Laurier University in the Forest Ecology Research Group, Katie was recently awarded the prestigious W. Garfield Weston Award for Northern Research for her work in Canada's western Arctic. In addition, Katie has received funding from the Canadian Polar Commission's Northern Scientific Training Program, the Ontario Graduate Scholarship program, and NSERC's Canadian Graduate Scholarship.

Trail Valley Creek research camp.

Katie's MSc project aims to investigate the influence of moisture and nutrient availability on green alder expansion across topographic gradients and to characterize shrub water use. Conducting her research at Trail Valley Creek, NWT, (approximately 50 km north-northeast of Inuvik, NWT, understanding the drivers and limitations of green alder expansion is essential for predicting future tundra conditions, she says.

Katie's work is part of CCRN's Theme B which aims to improve the understanding and diagnosis of local-scale change. Using pre-existing aerial imagery, Katie selected shrub patches located in each of four topographic categories: plateaus, hill slopes, hill bottoms, and channels. Shrubs at each of these topographic positions were (1) instrumented with sap flow sensors to understand shrub water use, (2) measured for seasonal variation in stem water potential using a pressure chamber to gain insight into shrub water stress, (3) measured for seasonal changes in soil moisture and active layer depth to characterize water availability, (4) installed with soil nutrient probes to characterize nutrient availability, and (5) quantified for foliar nitrogen content to determine shrub nitrogen uptake.

Although Katie is still currently collecting data and is in the early stages of data analysis, preliminary results suggest that shrubs located in downslope locations are less drought-stressed throughout the growing season and have higher foliar nitrogen compared to shrubs located upslope. This is potentially due to the higher soil moisture and deeper frost table found in downslope locations.

Shrubs growing in water tracks leading into and along Trail Valley Creek.

Productivity and nutrient cycling rates are suggested to be greater in tundra areas with high water content and drainage, such as floodplains, channels, slopes of hills and valleys and bottoms of hills. Higher soil water content and water flow in these areas not only transports nutrients laterally, but also increases the active layer thickness, allowing root systems to extend down. The high thermal conductivity of water may increase the soil heat flux in moist areas which could help promote root growth and nutrient uptake for a longer period during the growing season as well as enhance microbial activity and thus nitrogen mineralization. Katie's work will help untangle which of these factors is most important in determining shrub distribution and productivity.

Implications of shrub expansion critical on the hydrological cycling of Arctic tundra

Katie's study will be the first to provide field measurements on water and nutrient relations of shrub expansion across topographic gradients. Although green alder is the largest shrub currently undergoing expansion and may thus have the greatest impact on tundra ecosystems, few studies have investigated the constraints on green alder expansion. Green alders have the ability to access atmospheric nitrogen due to a symbiotic relationship with nitrogen-fixing *Frankia* bacteria – meaning moisture availability may be a more important limitation in green alder expansion rather than nitrogen availability, which has been shown to be important for other arctic shrub species such as willow (*Salix* spp.) and birch (*Betula* spp.).

Katie hugging her favourite green alder.

The data from this research will provide insight into how tall shrubs use available water and nutrients on the tundra as well as the degree to which tall shrub expansion will enhance evapotranspirative water loss. Improving the understanding of what constrains why shrubs are growing where they are will help predict what shrub cover may look like in the future and help inform the adaptation of northern communities. Having empirical characterization of shrub water use across topographic gradients will help modelers build this information into hydrological predictions for the Trail Valley Creek research basin.

Katie's work is part of a much larger integrative study (funded by ArcticNet and Polar Knowledge Canada) aimed at understanding the cryosphere-freshwater-vegetation interactions in the western Canadian Arctic through a multidisciplinary program with modelling outcomes. The changes in function of the tundra ecosystem associated with shrub expansion will be incorporated into models that will be important for the assessment, regulatory approvals, management and development of the north.

The Changing Cold Regions Network (CCRN) is a Canadian research network that aims to understand, diagnose, and predict the rapid environmental change occurring in the interior of western Canada. The Network is funded over five years (2013–2018) by the Natural Sciences and Engineering Research Council of Canada (NSERC) through its Climate Change and Atmospheric Research Initiative. To learn more, visit our webpage at www.ccrnetwork.ca.

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