Research Report Kluane

Interim Report - May 2020

Project title: Climate versus local controls on tundra shrub expansion – a common garden experiment

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This interim report provides a summary of the research conducted by Dr. Isla Myers-Smith and her research group (Team Shrub) from the University of Edinburgh, Scotland, UK in the Kluane Region over the summer of 2019 (for more information see https://teamshrub.com/).

This proposed research follows on from fieldwork conducted in the Kluane Region from 2014 – 2018. This research was conducted under the Scientists and Explorers Licences 18-68S&E, 17-41S&E, 16-47S&E, 16-48S&E, 15-48S&E and 15-49S&E. See reports submitted April 2016, April 2017, May 2018, May 2019.

Project objectives

Climate change has already altered tundra ecosystems, with further ecological and environmental shifts projected as the climate continues to warm[1]. Shrub and grass species are increasing over time[2–4] and the timing of life events such as the first green leaf and flower has shifted to earlier dates at some tundra sites[5]. In the last 50 years, rapid shrub expansion has been documented in Alaska, Yukon and Northwest Territories, including in the Kluane Lake region[6,13]. However, vegetation is not changing uniformly across all regions of the tundra biome[4]. In addition, tundra plants are growing taller[3] potentially altering how snow melts[14] and carbon cycles[15]. Ecological changes in the tundra might also influence the habitat and food for animals[16–18]. Research in the Kluane Lake region is valuable for both site-specific studies, as well as cross-site syntheses and experiments across the tundra biome and beyond. The Kluane Region provides both boreal and alpine habitats including elevational gradients that can inform studies of vegetation change at high latitudes.

The specific aims of this project are to:

1. Investigate growth rates of tundra shrubs in warmer growing conditions using a common garden experiment.
2. Measure plant traits (the characteristics of plant, such as leaf and stem length) and plant phenology (the timing of leaf and flower development over the growing season).
3. Investigate ecological interactions (seed herbivory and caterpillar predation) across an altitudinal gradient from the top to the bottom of the Kluane plateau.

Progress and current findings

1. Common Garden Experiment

The common garden experiment (Figure 1) has been running for the last seven years. The garden was established in 2013 at the Kluane Lake airstrip near Silver City and now contains over 800 cuttings of three common willow species (*Salix pulchra* - Diamond-leaf willow, *Salix richardsonii* -

Richardson's willow, and *Salix arctica* – Arctic willow). This experiment allows us to directly compare the growth of willow shrubs from two populations (Arctic and subarctic), testing whether responses to warming could be constrained by adaptation to local growing conditions. In 2019, we continued existing monitoring of plant growth and survival, as well as timing of leaf emergence (the opening of leaves in spring) and senescence (the yellowing of leaves in fall) through time-lapse cameras installed at the site. The common garden experiment (Figure 1) is an ongoing experiment and we plan to continue monitoring the willow's survival, growth and phenology in the future.

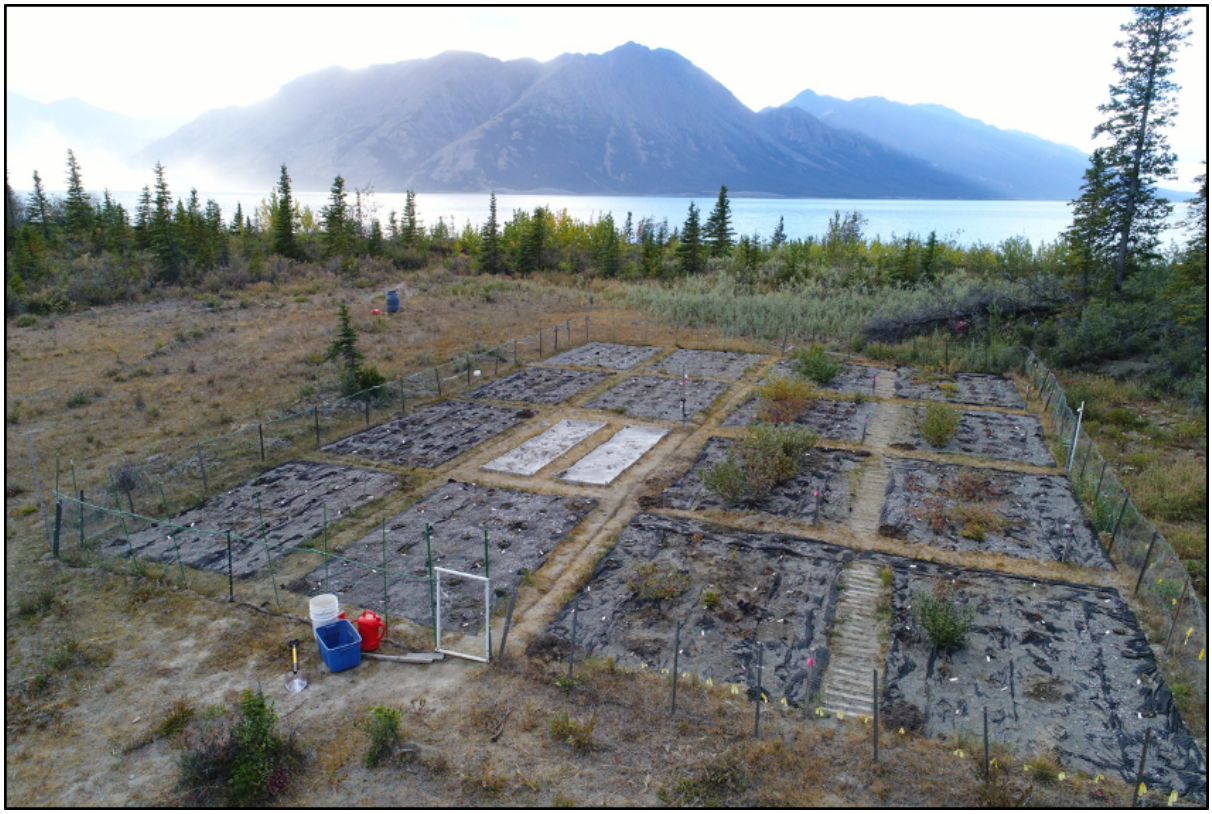

Figure 1. The common garden experiment tests how plants from different genetic origins grow in a warmer climate. Each year, we measure the survival and growth of individuals from three willow species commonly found across the tundra biome (photo credit: Gergana Daskalova).

Our initial results indicate that:

1. Willows are continuing to grow very rapidly as they experience warmer conditions. In 2016, we recorded over 1m of new growth recorded in one individual, far above the highest observations in tundra sites. This high growth rate continued in 2017, with some four-year old willows now over 1m in height and 2m in width. Growth rates were slower in 2018 likely due to the dry conditions. Growth was more variable in 2019 among individuals.
2. We have recorded substantial differences in growth between willow populations, with southern individuals growing much faster, with larger leaves and longer stems, than northern individuals. These growth differences are increasing over time as the willows age.
3. Differences in growth are driven in part by the timing of life events, which appear to more closely follow willows at 'home' sites than the common garden site. Southern species drop their leaves later in the season than northern species and therefore grow for longer across the summer.

These findings suggest the following: 1) That willows from Arctic populations of the Yukon Territory are adapted to their local growing conditions and in particular seasonal cues such as day length. 2) That at this boreal forest site, local willows from the alpine are better able to respond to improved growing conditions than those from 1000 km to the north. However, 3) that both Arctic and alpine willows are able to respond rapidly to improved growing conditions, with alpine willows reaching canopy heights of over a metre in just under a decade. These findings suggest that we should

expect rapid willow shrub expansion in tundra ecosystems in future in both the southern and northern Yukon with climate change.

2. Plant Traits

We collected information on plant traits (leaf length, stem elongation and stem width, Figure 2) from the willow individuals growing in the common garden and on the Kluane Plateau. The information from this research informs ongoing efforts to study changes in plant traits across the tundra biome. In 2018 and 2019, our team and our collaborators published five papers which included plant trait information from the Kluane Lake region.

Figure 2. Plant measurements, such as leaf length, provide valuable information about the growth of willow individuals in the common garden (photo credit: Gergana Daskalova).

Scientific articles:

Bjorkman AD, IH Myers-Smith, SC Elmendorf, S Normand, N Rüger, *et al.* Changes in plant functional traits across a warming tundra biome. *Nature* 562: 57–62. doi: http://dx.doi.org/10.1038/s41586-018-0563-7

Bjorkman AD, IH Myers-Smith, SC Elmendorf, S Normand, Thomas HJD, *et al.* Tundra Trait Team: A database of plant traits spanning the tundra biome. *Global Ecology and Biogeography*. doi: http://dx.doi.org/10.1111/geb.12821

Thomas HJD, IH Myers-Smith, AD Bjorkman, SC Elmendorf, D Blok, *et al.* 2018. Traditional plant functional groups explain variation in economic but not size-related traits across the tundra biome. *Global Ecology and Biogeography*. doi: http://doi.org/10.1111/geb.12783

Thomas HD, Bjorkman AD, IH Myers-Smith, SC Elmendorf, J Kattge, *et al.* 2020. Global plant trait relationships extend to the climatic extremes of the tundra biome. *Nature Communications* 11:1351. doi: https://doi.org/10.1038/s41467-020-15014-4

Kattge J, *et al.* Myers-Smith… 2020. TRY plant trait database–enhanced coverage and open access. *Global Change Biology*. 26(1): 119-188. doi: https://doi.org/10.1111/gcb.14904

Please contact us on Team Shrub for copies of any these papers.

3. Herbivory pressure across altitudinal and latitudinal gradients

The aim of the experiment, led by Dr. Anna Hargreaves from McGill University, was to test for geographic patterns in species interactions using a simple, standardized experiment conducted at a continent-wide scale. The focus of the experiment was seed predation and involved placing oat and sunflower seeds at different altitudes and recording any herbivory activity after 24 hours. The Kluane Lake region represented one of the two northernmost sites in the experiment. In 2018, we conducted an additional experiment and we used model caterpillars to test how predation varies across altitudes. The results of the seed component of the experiment have recently been published in the journal Science Advances, and research involving the caterpillars is ongoing.

The results of this cross-site experiment indicate that:

1. The number of seeds eaten increased by ~26% to 36% from the arctic to equator.
2. The number of seeds eaten also increased by ~41% from 4000 m elevation (high in the Andes) to sea level.
3. Seeds in the tropics and lowlands were mostly eaten by insects and other invertebrates, whereas seeds along the Kluane transects were mostly eaten by small mammals such as voles, ground squirrels and marmots.

For more information about the study:

Arctic-To-Equator Experiment Shows Seeds Are More Likely To Be Eaten In The Tropics And Lowlands, lay person summary by Dr Anna Hargreaves available at https://sciencetrends.com/arctic-to-equator-experiment-shows-seeds-are-more-likely-to-be-eaten-in-the-tropics-and-lowlands/

Scientific article:

Hargreaves A, *et al.* IH Myers-Smith… 2019. Seed predation increases from the Arctic to the Equator and from high to low elevations. *Science Advances* 5:2. doi: http://doi.org/10.1126/sciadv.aau4403

Please contact us on Team Shrub for copies of this paper.

Databases

We contributed data from Kluane to the following databases[6–8]:

Kattge J, *et al.* **IH Myers-Smith**... 2020. TRY plant trait database–enhanced coverage and open access. Global Change Biology. 26(1): 119-188. doi: https://doi.org/10.1111/gcb.14904

Lembrechts JJ *et al.* **IH Myers-Smith**... 2020. SoilTemp: a global database of near-surface temperature. Global Change Biology. doi: https://doi.org/10.1111/gcb.15123

Bjorkman AD, **IH Myers-Smith**, SC Elmendorf, S Normand, Thomas HJD, *et al.* 2018. Tundra Trait Team: A database of plant traits spanning the tundra biome. Global Ecology and Biogeography. doi: http://dx.doi.org/10.1111/geb.12821

Please contact us on Team Shrub for copies of any these papers.

Yukon-based Outreach

The research team gave a talk about our research to a field course at Kluane during the 2019 field season.

Additional information:

Team Shrub at the University of Edinburgh https://teamshrub.com
The High Latitude Drone Ecology Network https://arcticdrones.org/
International Tundra Experiment https://www.gvsu.edu/itex/
Herbivory Network https://herbivory.lbhi.is/
Team Shrub on Twitter https://twitter.com/TeamShrub
Team Shrub on Instagram https://www.instagram.com/teamshrub/
Photography websites: http://vanishingislandphoto.com/ , https://arcticabove.com/
Media coverage: https://teamshrub.com/media/
Team Shrub Blog Posts: https://teamshrub.com/2018/10/26/willow/

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