Research Report Kluane

Interim Report, April 2022

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 2022 (for more information see https://teamshrub.com/).

This proposed research follows on from fieldwork conducted in the Kluane Region from 2014 – 2021. This research was conducted under the Scientists and Explorers Licences 19-63S&E, 18-68S&E, 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, May 2021.

Purpose and objectives of the project:

Climate change has already altered tundra ecosystems, with further change projected for the future[1–3]. Perhaps the most dramatic example of this is the expansion of shrubs; in the last 50 years, rapid shrub expansion has been documented across the circumpolar Arctic and in alpine ecosystems[4–6]. However, not all regions are responding equally, with some communities showing strong resistance to change[7]. This is likely due to differences in community composition or local genetic adaptation of species[8]. We still have a limited understanding of how shrub growth is controlled by climate versus other biological or environmental factors[9]. As such, it is very difficult to predict the rate and extent to which climate change will alter tundra vegetation. Hyperspectral sensing is a relatively new tool used to monitor biodiversity patterns[10] and its application in Arctic systems could expand the spatial resolution of current biodiversity monitoring[11].

In our research, we are exploring rates of shrub expansion in the alpine tundra of the Kluane Region and test the accuracy of using hyperspectral signatures to predict plant traits. We are addressing the following research objectives:

1. Investigate growth rates of tundra shrubs in warmer growing conditions using a common garden experiment
2. Measure ecological plant traits (whole plant, leaf and stem characteristics) and plant phenology (the timing of leaf and flower development over the growing season) and relate these to leaf level hyperspectral signatures of tundra shrubs.

See our previous research reports for a summary of our previous research (https://teamshrub.com/research-reports/).

Progress and current findings

1. Common Garden Experiment

The common garden experiment (Figure 1) was established in 2013 at the Kluane Lake airstrip near Silver City, Yukon. Since its creation we have propagated 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 2021, 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. We also collected leaf-level hyperspectral measurements to investigate how well hyperspectral signatures predict tundra plant traits, and how these spectra vary over time. 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. Aerial view of the common garden experiment that tests how plants from different latitudes 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: Iain Myers-Smith).

Our initial results indicate that:

1. Tall willows from the alpine and same latitude grew faster and taller than willows from 1000 km to the north in the Arctic. The southern shrubs from the tall willow species were two to six times taller and twice to three times as fast as the Arctic shrubs reaching average heights of 1 m and growing at rates of on average 5 cm and up to 20 cm per year in eight years since planting.
2. The dwarf willow species *Salix arctica* from the south and north sites have grown equally well with no difference in canopy height, plant size or growth rates. The size of the plants and their leaves is similar between the Arctic and alpine plants after six years since planting.
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, but we shouldn't necessarily expect different shrub species to respond in the same ways north to south across the tundra biome. 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.

Blog post:
https://teamshrub.com/2021/08/30/willow-a-sequel/

2. Plant Traits

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).

We collected information on plant traits (leaf length, stem elongation, leaf area, and stem width, Figure 2) from the willow individuals growing in the common garden and along an altitudinal gradient along the

Kluane Plateau mountain. The information from this research informs ongoing efforts to study changes in plant traits across the tundra biome. As part of an ongoing collaboration with the Canadian Airborne Biodiversity Observatory (CABO, https://www.caboscience.org), we also collected leaf-level hyperspectral measurements on willow individuals growing in the common garden experiment and along the Kluane Plateau altitudinal gradient. These measurements will help us best inform the use of hyperspectral sensing to monitor biodiversity in tundra landscapes.

Scientific articles:

Bjorkman AD, IH Myers-Smith, et al. 2018. 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, 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

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, 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

3. Herbivory pressure across altitudinal and latitudinal gradients

We continued to collaborate on a seed herbivory experiment across a global latitudinal gradient. 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 2021, 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. Seed predation intensity more than doubles from the Arctic to the equator and from 4000 m above sea level to sea level.
2. 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

4. Tundra plant phenology

Understanding how the timing of life cycle events (phenology) might shift with climate change is important to predicting how tundra ecosystems will change. Using phenocams set up above treeline along an altitudinal gradient along the Kluane Plateau mountain, we captured images of the plant community over the season to track changes in phenology (e.g., bud burst, yellowing leaves at the end of the season). We also installed soil cores that are part of an international study led by Team Shrub to understand below-ground phenology and root growth. These soil cores were installed in mid-August and will be removed over summer 2022 to investigate how roots grow over a season.

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

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/
Canadian Airborne Biodiversity Observatory: https://www.caboscience.org/
Team Shrub Blog Posts: https://teamshrub.com/2018/10/26/willow/

References:

1. IPCC Working Group I. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://www.ipcc.ch/report/ar6/wg1/ (2021).

2. Arctic Monitoring and Assessment Programme (AMAP). *Arctic Climate Change Update 2021: Key Trends and Impacts*. (2021).

3. Meredith, M. *et al. Chapter 3: Polar regions — IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. https://www.ipcc.ch/srocc/chapter/chapter-3-2/ (2019).

4. Myers-Smith, I. H. *et al.* Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. *Environ. Res. Lett.* **6**, 045509 (2011).

5. García Criado, M., Myers-Smith, I. H., Bjorkman, A. D., Lehmann, C. E. R. & Stevens, N. Woody plant encroachment intensifies under climate change across tundra and savanna biomes. *Glob. Ecol. Biogeogr.* **29**, 925–943 (2020).

6. Myers-Smith, I. H. & Hik, D. S. Climate warming as a driver of tundra shrubline advance. *J. Ecol.* **106**, 547–560 (2017).

7. Hudson, J. M. G. & Henry, G. H. R. High arctic plant community resists 15 years of experimental warming. *J. Ecol.* **98**, 1035–1041 (2010).

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9. Myers-Smith, I. H. *et al.* Climate sensitivity of shrub growth across the tundra biome. *Nat. Clim. Change* **5**, 887–891 (2015).

10. Cavender-Bares, J. *et al.* Integrating remote sensing with ecology and evolution to advance biodiversity conservation. *Nat. Ecol. Evol.* 1–14 (2022) doi:10.1038/s41559-022-01702-5.

11. Nelson, P. R. *et al.* Remote Sensing of Tundra Ecosystems Using High Spectral Resolution Reflectance: Opportunities and Challenges. *J. Geophys. Res. Biogeosciences* **127**, e2021JG006697 (2022).