Research Report Qikiqtaruk

Interim Report – May 2024

Project title: Capturing tundra biodiversity and plant phenology above and below ground

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This interim report provides a summary of the research conducted by Prof. Isla Myers-Smith and her research group (Team Shrub) from the University of Edinburgh, Scotland, UK and Université de Sherbrooke on Qikiqtaruk - Herschel Island in 2023 (for more information see teamshrub.com).

This proposed research follows on from fieldwork conducted on Qikiqtaruk – Herschel Island in 2014 to 2019 and 2022 to 2023. This research was conducted under the Science and Explorers Licences 23-58S&E, 22-52S&E, 19-63S&E, 18-62S&E, 17-42S&E, 16-48S&E, 15-50S&E, 14-45S&E. See reports submitted April 2016, April 2017, May 2018 and May 2019, May 2020, April 2022 and May 2023 (https://teamshrub.com/research-reports/).

We also have produced the following reports that can be provided if requested:

- Youth Internship Report for Qikiqtaruk – Herschel Island August 2023, Finalized in November 2023
- Permafrost thaw and the development of active layer detachments on Qikiqtaruk – Herschel Island in August 2023 after an exceptionally warm summer - Finalized in April 2024

Figure 1. The 2023 Team Shrub field research crew.

Ecological monitoring on Qikiqtaruk

The Qikiqtaruk ecological monitoring program is an ongoing unique collaboration that began in 1999 that brings together university researchers, government scientists and local park rangers to study tundra vegetation change over time on Qikiqtaruk-Herschel Island, on the Arctic coast of the Yukon Territory, Canada. This unique setting within the Arctic makes Qikiqtaruk particularly interesting to site-specific and global studies of tundra change. Team Shrub has been working on Qikiqtaruk since 2008. We aim to build upon this long-term research program with the Canada Excellence Research Chair project on the Global Change Ecology of Northern Ecosystems from 2023 to 2032. This new research program will investigate how warming temperatures and shifting seasonality affect Arctic tundra, alpine, and boreal forest ecosystems, including changes in plant growth, habitat composition, wildlife movement and species ranges expanding on our research to date.

Background

The climate is changing rapidly at the extreme latitudes of our planet[1,2]. Indigenous people of the Canadian North have well-developed knowledge of how the climate is changing[3]. Warming temperatures, melting sea ice, and thawing permafrost are transforming the Arctic[4]. With changes to the environment, Arctic vegetation[5–8] and phenology, the timing of life cycle events such as flowering, are shifting[9–12]. There remain critical knowledge gaps around the extent of plant phenology changes and their potential implications for future Arctic ecosystem productivity, carbon cycling and wildlife habitats.

Bare ground is becoming vegetated and plants are now growing larger[7,13] – changes that could alter global-scale climate feedbacks. Qikiqtaruk is experiencing rapid vegetation change including increased cover of shrubs, grasses and sedges and decreased bare ground cover[14]. In the Arctic, the relationship between the timing of above- and below-ground plant growth has been observed to be out of sync, and the below-ground growing season can be up to 50% longer than the above-ground growing season[15]. If plants green up earlier and grow faster in a warmer Arctic, that could influence the habitats for wildlife including potentially influencing migration or other behaviours[16].

Concurrent with vegetation change, permafrost is thawing on the island with a nearly doubling of the active layer depth[14], the seasonally unfrozen ground. Up to a third of the world's soil carbon is stored in frozen soils, and if released, this carbon would accelerate climate warming for the entire planet[17]. However, we remain uncertain about how feedbacks might unfold, especially given the diverse landscapes in the Arctic. Increases in plants are thought to be leading to a 'greening' and permafrost thaw and other disturbances to a 'browning' of tundra landscapes, but there is complexity with the interpretation of satellite data[18].

Changes to Arctic vegetation and permafrost thaw could have potentially strong influences on wildlife habitats and the global climate and therefore of interest to both people living in the Arctic and around the world.

Research Activities on Qikiqtaruk in 2023

Over the summer 2023 field season, our field team collected data on: 1) Biodiversity monitoring of tundra plant community composition, 2) Above and below ground phenology of tundra plants and 3) Landscape surveys of permafrost thaw.

1. Biodiversity monitoring of tundra plant community composition

Research question: How does tundra plant biodiversity shift with warming over time?

In 2023, we contributed to the three-decade long ecological monitoring program on Qikiqtaruk to track vegetation change and the drivers of that change. We also carried out drone surveys, measured phenology, plant growth above and below ground, carried out biodiversity protocols and gathered hyperspectral data to help understand vegetation change on Qikiqtaruk.

We continue to track vegetation change on Qikiqtaruk that contribute to site specific studies and international data synthesis. In 2024, we are in the process of publishing a data synthesis of tundra biodiversity change from sites around the Arctic including Qikqitaruk[8]. We found no overall increase or decrease in tundra plant biodiversity. However, most plots experienced changes in the amount of plants over time and over half of plots experienced losses and gains of species. The number of species increased most where temperatures had warmed most over time, and shrub expansion led to greater species losses and decreasing number of species in tundra plots over time. Our results show a variety of diversity trends, which could be precursors of future changes in Arctic plant biodiversity.

2. Above and below ground phenology of tundra plants

Research question: How does plant phenology above and below ground vary across microclimates among years and with warming over time?

In 2023, we continued monitoring plant phenology – the timing of the growth and flowering of plants – using time lapse cameras and shrub expansion using repeat photography and drone surveys. We maintained our time lapse camera network of 20 cameras across different environments on the island. These data are allowing us to understand how growing seasons are advancing earlier and shifting as the climate warms.

We removed and reinstalled clusters of soil cores at 12 of the locations of our time lapse cameras. As the plants grow and flower during the summer of 2024, these cores will fill with roots from surrounding plants. We will harvest these cores throughout summer 2024 to track the phenology of root growth, and compare the timing of root growth to the timing of above-ground phenology. We are currently processing the data from 2023.

Preliminary findings from all of the sites involved in this research indicate that the above ground phenology of plants is decoupled from the growth of roots below ground. We find that plants begin to senesce above ground in early August, when root growth continues into August. We find that grass and sedge roots have a pulse of root growth at the end of the tundra plant growing season.

Figure 2. We collected root ingrowth cores in 2023 and re-installed this experiment for 2024 to measure the timing and biomass of root growth below ground on Qikiqtaruk.

3. Landscape surveys of permafrost thaw

Research question: How are rates of permafrost thaw changing with warming over time?

In 2023, we conducted surveys of landscape-scale vegetation change, permafrost thaw and coastal erosion using drones continuing our time series of drone data collection. We continued to measure the active layer depth to understand how permafrost thaw may be influencing plant communities on Qikiqtaruk.

During the exceptionally warm summer of 2023 in the ice-rich permafrost landscapes of Qikiqtaruk – Herschel Island, Yukon Territory, a dramatic thaw event occurred across the island (Figure 1). July temperatures were 5°C warmer than average in the final two weeks of July and active layer thaw depths reached over one metre, exceeding the previously recorded deepest measurement of 89.6 cm in 2017. Active layer depths on the island have been increasing over time from ~40 cm in the 1980s to up to ~80 cm in 2023 in the same locations[14].

Substantial permafrost thaw led to the formation of dozens of active layer detachments (ALDs). From 1st August 2023 onward, disturbed tundra slid down slopes, removing the vegetation layer. The ALDs formed ribbon-like patterns over hillsides with soils accumulating in valley bottoms thus changing local hydrology by blocking streams and shifting flow paths. Coastal ALDs deposited soils into the ocean increasing sedimentation of coastal waters and altering the coastline of the island.

Preliminary analysis from satellite imagery reveals upwards of 50 ALDs across the island by September 2023. The ALDs occurred during an exceptionally warm and dry summer without July precipitation on a range of slopes, aspects, inclination, encompassing varied topography. We will return to Qikiqtaruk in 2024 to quantify the extent of the disturbances and document any further thaw. The 2023 ALD event on Qikiqtaruk illustrates how summer Arctic heat waves can push systems beyond thaw tipping points with cascading impacts across landscapes.

Figure 3. One of the first coastal active layer detachments (ALDs) observed at Pauline Cove in the summer of 2023. These photographs are from 10th August, the day of this ALD formation (foreground) and 11th August 2023 (background). Photo credit Cameron Eckert (foreground) and Isla Myers-Smith (background)

Figure 4. Drone surveys are allowing us to capture permafrost thaw, coastal erosion and vegetation change in high resolution on the island. This is an image of the biggest retrogressive thaw slump on the island in 2023.

4. Hyperspectral data

As remote sensing technology has improved, hyperspectral data (patterns of light reflectance beyond what our eyes can detect) are increasingly being used to study plant communities. Over summer 2023, we collected leaf level hyperspectral data of common tundra plants in collaboration with the Canadian Airborne Biodiversity Observatory project (caboscience.org). These tools are often used to look at what species are present and in what abundance and their trait values (e.g., leaf size). Plant traits like leaf area influence how plants interact with their environment and are a useful tool for predicting how plant communities will change with continued warming[19].

Collecting plant trait data in the field can be time and labor intensive and require significant lab processing, limiting our ability to collect data over broad areas, especially in more remote sites like alpine or Arctic tundra. Other scientific studies have shown that leaf hyperspectral signatures can predict many common leaf traits, reducing processing time and destructive sampling[20].

We collected plant trait and hyperspectral data on common tundra plants in alpine Kluane and Qikiqtaruk to examine if trait-spectral relationships are consistent in the tundra. External models calibrated on temperate plant spectra showed poor performance in predicting tundra leaf traits, but training models using tundra plant data produced predictions of similarly high accuracy as in other biomes.

As tundra landscapes experience a short growing season and leaf hyperspectral signatures change over time, we were interested in investigating how leaf stage (green, peak season leaves versus yellow leaves) influences our ability to discriminate between common willow shrubs using hyperspectral data. Our results also demonstrate that while spectra change over the growing season, spectral data distinguished tundra shrub species with similar accuracy both at peak season and during senescence. Our results help to guide how and when to collect and analyze spectral data for future biodiversity monitoring.

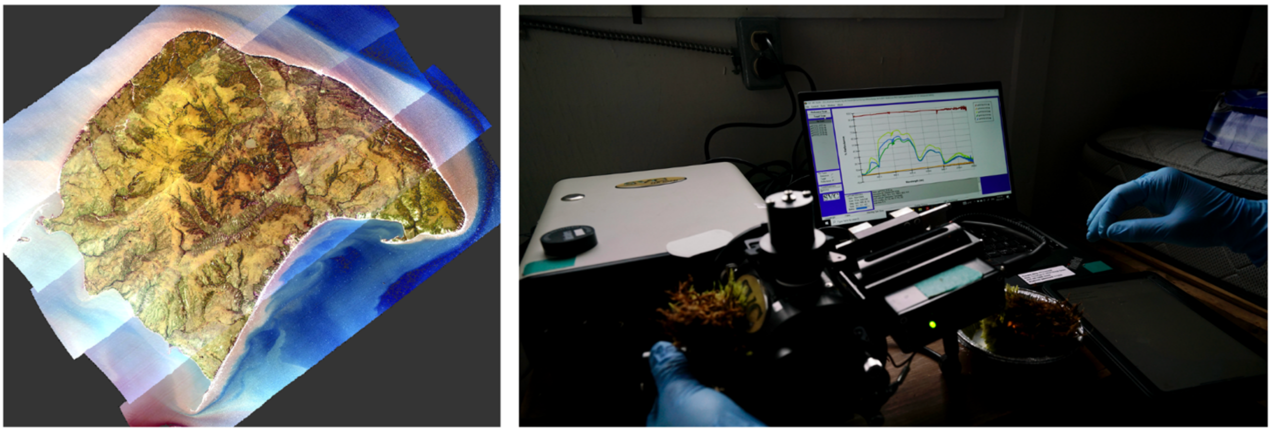

Figure 5. Hyperspectral plane surveys were conducted of Qikiqtaruk in collaboration with the NASA ABoVE project in 2019 and leaf and plot-level spectra were collected in 2022 and 2023.

5. Microclimate data

In 2023, we maintained a network of microclimate loggers to record surface temperature, soil temperature, and soil moisture at different locations around the island. In total, there are 40 temperature loggers (TOMST) to record continuous soil temperature and soil moisture content and two weather stations (HOBO, at the phenology transects and on Collison Head). In addition, we have used digital elevation models to produce modelled maps of microclimate across the island. These measurements will help us determine how phenology and root growth differs across different microclimates across Qikiqtaruk.

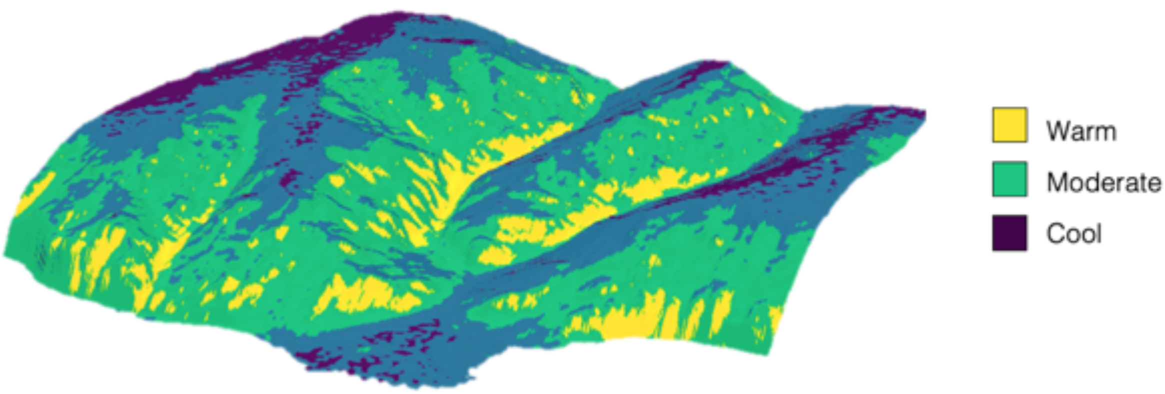

Figure 6. We are using temperature sensors and drone imagery to build maps of microclimates across the landscape on Qikiqtaruk to compare to plant growth and phenology.

Recent publications from the research on Qikiqtaruk (2019 to 2024):

Gallois E *et al.* 2023. Summer litter decomposition is moderated by scale-dependent microenvironmental variation in tundra ecosystems. Oikos e10261. doi: https://doi.org/10.32942/osf.io/crup3

García Criado M *et al.* 2023. Plant traits poorly predict winner and loser shrub species in a warming tundra biome. Nature Communications 14: 3837. doi: https://doi.org/10.1038/s41467-023-39573-4

Heijmans M *et al.* 2022. Tundra vegetation change and impacts on permafrost. Nature Reviews Earth & Environment 3: 68-84. doi: https://doi.org/10.1038/s43017-021-00233-0

Boyle JS *et al.* 2022. Summer temperature—but not growing season length—influences radial growth of Salix arctica in coastal Arctic tundra. Polar Biology 45(7): 1257-1270. doi: https://doi.org/10.1007/s00300-022-03074-9

Vuorinen K *et al.* 2022. Growth rings show limited evidence for ungulates' potential to suppress shrubs across the Arctic. Environmental Research Letters 17(3): 034013. doi: https://doi.org/10.1088/1748-9326/ac5207

Lindén E *et al.* 2022. Circum-Arctic distribution of chemical anti-herbivore compounds suggests biome-wide trade-off in defence strategies in Arctic shrubs. Ecography, p.e06166. doi: https://doi.org/10.1111/ecog.06166

Curasi S *et al.* 2022. Range shifts in a foundation sedge potentially induce large Arctic ecosystem carbon losses and gains. Environmental Research Letters 17:045024 doi: https://doi.org/10.1088/1748-9326/ac6005

Rixen C *et al.* 2022. Winters are changing: snow effects on Arctic and alpine tundra ecosystems. Arctic Science 8(3). doi: https://doi.org/10.1139/AS-2020-0058

Stanski K, IH Myers-Smith, CG Lucas. 2021. Flower detection using object analysis: New ways to quantify plant phenology in a warming tundra biome. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 14: 9287-9296. doi: https://doi.org/10.1109/JSTARS.2021.3110365

Cunliffe AM *et al.* 2021. Global application of an unoccupied aerial vehicle photogrammetry protocol for predicting aboveground biomass in non-forest ecosystems. Remote Sensing for Biodiversity & Conservation 8(1): 57-71. doi: https://doi.org/10.1002/rse2.228

Prevéy J *et al.* 2021. The tundra phenology database: More than two decades of tundra phenology responses to climate change. Arctic Science 1-14. doi: https://doi.org/10.1139/AS-2020-0041

Mekonnen ZA *et al.* 2021. Arctic tundra shrubification: a review of mechanisms and impacts on ecosystem carbon balance. Environmental Research Letters 16(5), p.053001. doi: https://doi-org/10.1088/1748-9326/abf28b

Lembrechts JJ *et al.* 2021. Global maps of soil temperature. Global Change Biology. doi: https://doi.org/10.1111/gcb.16060

Barrio IC *et al.* 2021. Developing common protocols to measure tundra herbivory across spatial scales. Arctic Science 1-42. doi: https://doi.org/10.1139/AS-2020-0020

Myers-Smith IH *et al.* 2020. Complexity revealed in the greening of the Arctic. Nature Climate Change 10:106-117. doi: https://doi.org/10.1038/s41558-019-0688-1

Assmann JJ *et al.* 2020. Drone data reveal fine-scale variation of tundra greenness and phenology not captured by satellite and ground-based monitoring. Environmental Research Letters 15:125002. doi: https://doi.org/10.1088/1748-9326/abbf7d

García Criado M et al. 2020. Woody plant encroachment intensifies under climate change across tundra and savanna biomes. Global Ecology and Biogeography 29:925-943. doi: https://doi.org/10.1111/geb.13072

Cunliffe AM *et al.* 2020. Aboveground biomass corresponds strongly with drone-derived canopy height but weakly with greenness (NDVI) in a shrub tundra landscape. Environmental Research Letters 15:125004. doi: https://doi.org/10.1088/1748-9326/aba470

Buchwal A *et al.* 2020. Divergence of Arctic shrub growth associated with sea ice decline. PNAS 117 (52) 33334-33344. doi: https://doi.org/10.1073/pnas.2013311117

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Lembrechts JJ *et al.* 2020. SoilTemp: a global database of near-surface temperature. Global Change Biology 26(11): 6616-6629. doi: https://doi.org/10.1111/gcb.15123

Myers-Smith IH *et al.* 2019. Eighteen years of ecological monitoring reveals multiple lines of evidence for tundra vegetation change. Ecological Monographs 89(2):e01351. doi: http://doi.org/10.1002/ecm.1351

Assmann JJ *et al.* 2019. Snow-melt and temperature - but not sea-ice - explain variation in spring phenology in coastal Arctic tundra. Global Change Biology 25(7):2258-2274. doi: http://doi.org/10.1111/gcb.14639

Bjorkman AD *et al.*, 2019. Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring. Ambio 49:678-692. doi: http://doi.org/10.1007/s13280-019-01161-6

Cunliffe AM *et al.* 2019. Rapid retreat of permafrost coastline observed with aerial drone photogrammetry. The Cryosphere 13:1513-1528. doi: http://doi.org/10.5194/tc-2018-234

Prevéy J *et al.* 2019. Warming shortens flowering seasons of tundra plant communities. Nature Ecology and Evolution 3:45-52. doi: http://doi.org/10.1038/s41559-018-0745-6

Databases

We contributed data from Qikiqtaruk to the following databases:

- **The Tundra Phenocam Database**
  To be complied in 2024 - 2025

- **The ITEX+ plant composition database**
  Data paper to be published in 2024

- **The ITEX phenology database**
  Prevéy J, *et al.* IH Myers-Smith… 2021. The tundra phenology database: More than two decades of tundra phenology responses to climate change. *Arctic Science* 8(3): 1026-1039. doi: https://doi.org/10.1139/AS-2020-0041

- **The TRY plant database**
  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

- **The Soil Temp Database**
  Lembrechts JJ *et al.* IH Myers-Smith... 2020. SoilTemp: a global database of near-surface temperature. Global Change Biology 28(9): 3110-3144. doi: https://doi.org/10.1111/gcb.15123

- **The Tundra Trait Team Database**
  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 27(12): 1402-1411. doi: http://dx.doi.org/10.1111/geb.12821

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/
Canadian Airborne Biodiversity Observatory: https://www.caboscience.org/
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/lab-blog/

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19. Myers-Smith, I. H., Thomas, H. J. D. & Bjorkman, A. D. Plant traits inform predictions of tundra responses to global change. *New Phytol.* **221**, 1742–1748 (2019).

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