Research Report Qikiqtaruk

Interim Report - May 2020

Project title: Disentangle the drivers of Arctic greening and biodiversity change

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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 on Qikiqtaruk - Herschel Island in 2019 (for more information see https://teamshrub.com/).

This proposed research follows on from fieldwork conducted on Qikiqtaruk – Herschel Island in 2014 – 2018. This research was conducted under the Science and Explorers Licences 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. We will continue to conduct a variety of different research projects and data collection to explore rates of vegetation change and permafrost thaw on Qikiqtaruk – Herschel Island, outlined below.

Background: Vegetation changes in a warming Arctic

Global warming is changing environments all over the world, but the changes are particularly pronounced at northern latitudes[1]. The Arctic is warming twice as fast as the rest of the planet[2]. The higher temperatures and longer growing seasons are causing notable changes in the vegetation of the Arctic tundra[3]. Plants are growing more and the tundra is getting "greener"[4,5]. Particularly, shrubs are increasing in height and abundance[6–8], which is likely in response to climate warming[4,9].

Research on Qikiqtaruk – Understanding vegetation changes

The aim of our research on Qikiqtaruk is to better understand vegetation change, the causes and effects of that change to tundra ecosystems and the climate. We carry out a variety of data collection, including ground and drone monitoring of tundra plants and landscapes. The majority of our research contributes to ongoing multidecadal projects that allow us to better understand what is causing change over time. Qikiqtaruk is at the northern end of the distribution of tall shrubs. It is also an icy permafrost environment that is especially vulnerable to climate warming[10,11]. This unique setting within the Arctic makes Qikiqtaruk particularly interesting to site-specific and global studies of tundra change.

Ecological monitoring on Qikiqtaruk

The Qikiqtaruk ecological monitoring program is a two decade long unique collaboration 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.

Research Activities on Qikiqtaruk in 2019

1. Long-term ecological monitoring

In 2019, we continued the long-term ecological monitoring protocols on Qikiqtaruk contributing to the understanding of ongoing vegetation change and the drivers of that change on the island. We also carried out drone surveys, measured phenology, carried out biodiversity protocols and gathered hyperspectral data to help understand vegetation change on Qikiqtaruk (see below).

Figure 1. The 2019 Team Shrub field research crew.

2. Surveys of landscape-level change

In 2019, we conducted surveys of landscape-scale vegetation change, permafrost thaw and coastal erosion using drones continuing our time series of five years of drone data collection. We continued to measure the active layer depth to understand how permafrost thaw may be influencing plant communities on Qikiqtaruk. We have found rapid rates of coastal erosion and permafrost thaw in certain years, such as 2017.

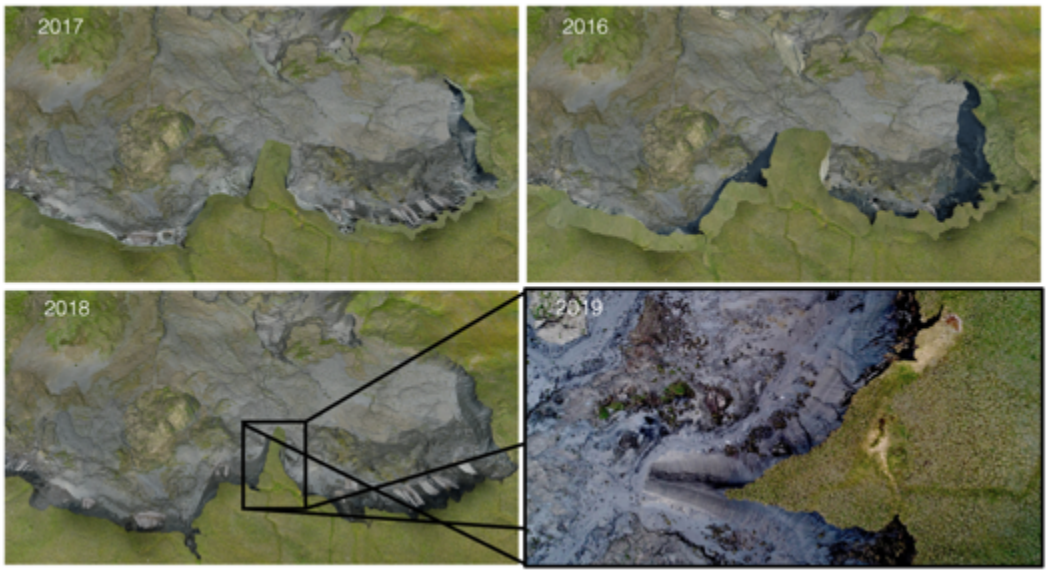

Figure 2. Drone surveys are allowing us to capture permafrost thaw, coastal erosion and vegetation change in high resolution on the island. In these drone models, permafrost thaw can be seen the large retrogressive thaw slump called Slump D.

3. Plant phenology monitoring

In 2019, 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. These data are allowing us to understand how growing seasons are advancing earlier and shifting as the climate warms. In the future, we are particularly interested in better capturing the start and end of plant growth and flowering each season across different parts of the landscape using time lapse camera photography.

Figure 3. In addition to the long-term phenology monitoring conducted by park rangers, We are using phenocams - time-lapse cameras - to capture phenology change in high resolution across the landscape.

4. 'Dark' biodiversity monitoring

We continued surveys of the landscape to capture plant species that are not currently found in the long-term monitoring plots to better understand future biodiversity change. In 2019, we expanded on data collection in 2018 following the International Tundra Experiment species pool monitoring protocol. We identified the plant species found in 100 m radius from the plots and noted their distance from the centre plot and precise location across the landscape. We found that there were 13 to 26 plant species within 100 m of the long-term monitoring plots, indicating that there is potential for future increases in plant species diversity over time in the long-term monitoring plots. We are in the process of analyzing the species pool data and integrating the ground plant observation with the landscape-scale drone imagery to test whether tundra biodiversity hotspots are located in warmer microclimates.

Figure 4. A surprisingly high number of plant species can be found close by to the long-term monitoring plots on Qikiqtaruk that have yet to be observed inside of the plots (species in grey) - suggesting potential for future increases in biodiversity in the long-term monitoring record.

5. Hyperspectral data

In 2019, we collected hyperspectral data of Qikiqtaruk building on preliminary data collection in 2018. The NASA ABoVE project (https://above.nasa.gov/) surveyed the island twice on the 2nd and 27th of July capturing hyperspectral data, reflectance of the tundra across the full light spectrum. Within a few days of this data collection, we measured hyperspectral data on the ground to compare with the plane data. We have found distinct differences in the spectral signatures of different plant communities in the 2019 data. We will be conducting further analyses to determine if remotely-sensed data can be used to monitor the biodiversity of these tundra ecosystems in collaboration with the Canadian Airborne Biodiversity Observatory project (http://www.caboscience.org/).

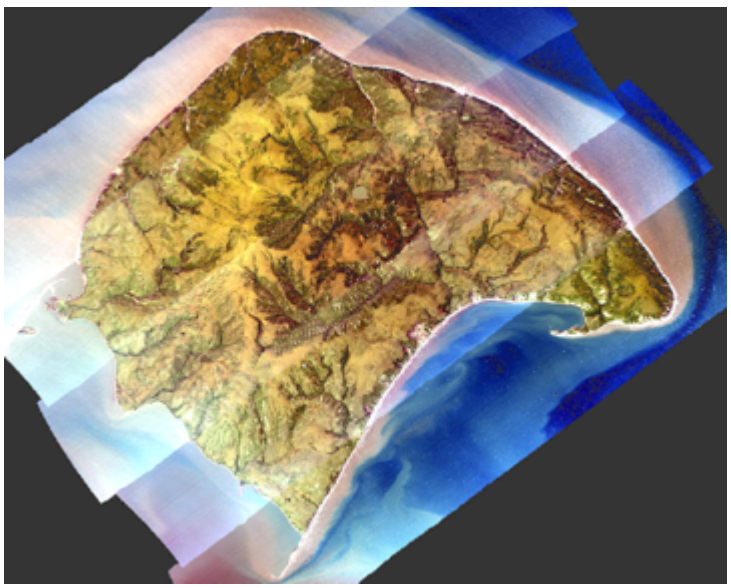

Figure 5. Hyperspectral plane surveys were conducted of Qikiqtaruk in collaboration with the NASA ABoVE project in 2019.

Recent research findings on Qikiqtaruk:

The findings from the past 18 years of ecological monitoring have recently been published in the scientific journal *Ecological Monographs*[8]. Our local collaborators with Yukon Parks including park rangers who conduct much of the ecological monitoring program are co-authors on this manuscript.

The study's findings indicate that rapid vegetation change is underway on Qikiqtaruk:

1. Shrub canopies are getting taller – shrubs have more than doubled in height in long-term monitoring plots since 1999.
2. Plants are greening up earlier in spring and flowering earlier in the summer – with green up occurring more than two weeks earlier than 18 years ago.
3. The cover of tundra plants is increasing and bare ground is decreasing – plant cover has more than doubled and bare ground has decreased by more than half, nearly disappearing in some plots over the period of ecological monitoring.

These vegetation changes are likely due in part to the indirect, rather than only the direct effects of warming temperatures, such as a deepening of the thawed soil layer above the permafrost and increasing length of the growing season.

A summary of the study is available on the Team Shrub website https://teamshrub.com/2019/03/15/collaboration-is-key-for-arctic-change-research/

Scientific article:

Myers-Smith IH, MM Grabowski, HJD Thomas, S Angers-Blondin, GN Daskalova, AD Bjorkman, AM Cunliffe, JJ Assmann, JS Boyle, E McLeod, S McLeod, R Joe, P Lennie, D Arey, RR Gordon, and CD Eckert. 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

1. Plants are greening up and flowering earlier in the spring

Team Shrub has been contributing to the ecological monitoring program on Qikiqtaruk since 2008, but the ecological monitoring program is now entering its 20th year. The Yukon Government Territorial Park rangers have been monitoring the annual date of leaf bud burst, flowering and senescence (autumn leaf fall) for 20 individuals of three plant species on Qikiqtaruk (mountain avens or *Dryas integrifolia*, arctic willow or *Salix arctica* and tussock cottongrass or *Eriophorum vaginatum*). The results of this research were included in a recent publication in Ecological Monographs[8] (see above), a synthesis of plant phenology from four coastal tundra sites around the Arctic[10] and in a synthesis of 23 sites from around the tundra biome[11,12].

The major findings from those studies are:

1. On Qikiqtaruk, plants are greening up earlier in spring and flowering earlier in the summer – more than two weeks earlier than 18 years ago[8].
2. Spring is arriving earlier in the Arctic tundra and plants are responding to earlier snowmelt in addition to the warming temperatures[10].
3. Warmer temperatures are leading to a shorter flowering season in tundra ecosystems due to a greater advancement in the flowering times of late-flowering species than early-flowering species[11].

In 2018, snow melted later, sea ice remained along the coast for more of the summer and conditions were cooler. We found that phenology data from 2018 had a similar timing to years in the early 2000s, providing a contrast to the earlier spring and warmer temperatures experienced in other recent years.

Scientific articles:

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, IH Myers-Smith, AB Phillimore, AD Bjorkman, RE Ennos, JS Prevéy, GHR Henry, NM Schmidt, RD Hollister. 2019. Local snowmelt and temperature – but not regional sea-ice – explain variation in spring phenology in coastal Arctic tundra. *Online Early. Global Change Biology*. doi: http://doi.org/10.1111/gcb.14639

Prevéy J, *et al.* IH Myers-Smith... 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

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2. Shrubs, grasses and cottongrass are increasing and bare ground is decreasing

We continued monitoring plant community composition at twelve 1 x 1m long-term monitoring plots located on Collinson Head (Figure 3). The findings from 2019 follow ongoing positive trends in shrub and graminoid cover and a decrease in bare ground in the plots. We have contributed these data to data syntheses and have found that shrubs are increasing at sites around the tundra biome.

Scientific articles:

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

García Criado M, IH Myers-Smith, AD Bjorkman, CE Lehmann, N Stevens. 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

Bjorkman AD, MG Criado, IH Myers-Smith, *et al.* 2019. Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring. *Ambio*, pp.1-15. doi: http://doi.org/10.1007/s13280-019-01161-6

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3. The tundra on Qikiqtaruk is 'greening' as seen from above

Much of our understanding of changes in tundra vegetation across regions and around the pole comes from satellite data. However, the satellite images are coarse compared to our fine-scale observations on the ground[5]. Qikiqtaruk is one of the focal research sites that are part of the High Latitude Drone Ecology Network (HiLDEN) where 42 different tundra landscapes located around the Arctic are being monitored using drones. We are finding that greenness perceived by satellites and drones align, yet satellite data do not capture the greenest parts of the landscape nor where bare ground has been exposed

A summary of the recent High Latitude Drone Ecology working group meeting: https://arcticdrones.org/2019/04/15/hilden-working-group-arctic-drone-synthesis-to-bridge-the-gap-from-plants-to-pixels/

Scientific articles:

Myers-Smith IH, JT Kerby, *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

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

Assmann JJ, IH Myers-Smith *et al.* 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

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4. Tundra plants are responding in different ways

We have found that plants at various locations around the Arctic, different types of tundra plants and different specific species are responding in divergent ways as the climate warms. Some plant species are increasing and some are decreasing within and among tundra locations[8,13,14]. We have found that tundra plants have very similar characteristics to plants from the rest of the world and thus have many ways of dealing with the cold Arctic climate[14].

Scientific articles:

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

Bjorkman AD, MG Criado, IH Myers-Smith, *et al.* 2019. Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring. *Ambio*, pp.1-15. doi: http://doi.org/10.1007/s13280-019-01161-6

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

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5. Permafrost is thawing and the coast is eroding

We have been monitoring coastal erosion and permafrost thaw disturbances on Qikiqtaruk using drones. We found that the rates of coastal erosion documented in recent years were more than six times faster than the long-term average rate of $2.2 \pm 0.2\ m\ a^{-1}$ from 1952 - 2017 in the coastline to the East of the Pauline Cove settlement[15].

Scientific article:

Cunliffe AM, *et al.* IH Myers-Smith*. 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

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

6. Herbivores influence tundra ecosystems

One of the reasons that plants such as shrub species could be increasing in tundra ecosystems might be a reduction in the number of animals feeding on those plants over time. Large mammal

populations of caribou and muskox have been relatively stable on Qikiqtaruk over the past 19 years, apart from the drop to three male muskox in recent years residing on the island in the summer (*Pers. Comm.* Herschel Island – Qikiqtaruk Territorial Park Rangers, Cameron Eckert). We have contributed to assessments of herbivore densities and impacts on plant communities around the tundra biome coordinated by the Herbivory Network (https://herbivory.lbhi.is/).

Scientific article:

Barrio, IC *et al.* IH Myers-Smith … Developing common protocols to measure tundra herbivory across spatial scales. *Arctic Science*. doi: https://doi.org/10.1139/AS-2020-0020

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

Databases

We contributed data from Qikiqtaruk to the following databases[16–18]:

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

International Tundra Experiment Database (https://www.gvsu.edu/itex/).

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Yukon-based Outreach

The research team gave a talk about our research for the Youth and Elders program on Qikiqtaruk 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/2019/03/15/collaboration-is-key-for-arctic-change-research/

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4. Bjorkman, A.D. et al. *Nature* **562**, 57–62 (2018).
5. Myers-Smith, I.H. et al. *Nat. Clim. Change* **10**, 106–117 (2020).
6. Myers-Smith, I.H. et al. *Environ. Res. Lett.* **6**, 045509 (2011).
7. García Criado, M., Myers-Smith, I.H., Bjorkman, A.D., Lehmann, C.E.R. & Stevens, N. *Glob. Ecol. Biogeogr.* **29**, 925–943 (2020).
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11. Prevéy, J.S. et al. *Nat. Ecol. Evol.* **3**, 45 (2019).
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14. Thomas, H.J.D. et al. *Nat. Commun.* **11**, 1351 (2020).
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16. Kattge, J. et al. *Glob. Change Biol.* **26**, 119–188 (2020).
17. Lembrechts, J.J. et al. *Glob. Change Biol.* **n/a**,
18. Bjorkman, A.D. et al. *Glob. Ecol. Biogeogr.* (2018).doi:https://doi-org/10.1111/geb.12821