Project title: Climate as a Driver of Shrub Expansion and Tundra Greening

Interim Report - May 2019

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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 2018 (for more information see https://teamshrub.com/).

Premise: 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 at twice the rate than the rest of the globe[2] and the higher temperatures associated with longer growing seasons are causing notable changes in the vegetation of the Arctic tundra: plants are growing more and the tundra is getting "greener"[3,4]. Particularly, shrubs are increasing in height and abundance[5–7], which is likely in response to climate warming[8,9]. 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.

Figure 1. Sandra Angers-Blondin's award winning photograph of a Red Fox on Qikiqtaruk in 2018 from the British Ecological Society Photography Contest.

Research on Qikiqtaruk – Understanding vegetation changes

Our research aims to understand how tundra ecosystems are changing and what specific factors - warming temperatures, changing snowmelt, soil disturbances, interactions with animals and more - are

driving the changes that we are observing. We carry out a variety of experiments and surveys, including ground and drone monitoring of tundra plants and landscapes. The majority of our research contributes to ongoing long-term projects (more than 15 years) that allow us to better understand what is causing change over time. In the far north-west of the Yukon, 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 (Figure 1) 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 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 (Figure 2). The findings from the past 18 years of ecological monitoring have recently been published in the scientific journal *Ecological Monographs*.

Figure 2. Ecological monitoring on Qikiqtaruk is a collaboration between Yukon Park rangers and researchers. In this photo, we are assessing the flowering and leaves of plants along the phenology transects of the Qikiqtaruk Ecological Monitoring program.

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

- Shrub canopies are getting taller – shrubs have more than doubled in height in long-term monitoring plots since 1999.
- 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.
- 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 00(0):e01351. doi: http://doi.org/10.1002/ecm.1351

https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecm.1351

Ecological monitoring on Qikiqtaruk in 2018

In 2018, we continued the long-term ecological monitoring protocols on Qikiqtaruk (see above). Additionally, we conducted surveys of landscape-scale vegetation change, permafrost thaw and coastal erosion using drones.

1. Changes in spring leaf out, flowering and senescence

Team Shrub has been contributing to the ecological monitoring program on Qikqitaruk 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 (Myers-Smith et al. 2019, see above), a synthesis of plant phenology from four coastal tundra sites around the Arctic (Assmann et al. 2019) and in a synthesis of 23 sites from around the tundra biome (Prevéy et al. 2019).

The major findings from those studies are:

- On Qikiqtaruk, plants are greening up earlier in spring and flowering earlier in the summer – with a more than two weeks earlier than 18 years ago (Myers-Smith et al. 2019).
- Spring is arriving earlier in the Arctic tundra and plants are responding to earlier snowmelt in addition to the warming temperatures (Assmann et al. 2019).
- 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 (Prevéy et al. 2019).

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, 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 00(0):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. 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

2. Changes in plant community composition and shrub expansion

We continued monitoring plant community composition at twelve 1 x 1m long-term monitoring plots located on Collinson Head (Figure 3). The findings from 2018 are in line with ongoing positive trends in shrub and graminoid cover and a decrease in bare ground in the plots. Additionally, we continued monitoring plant phenology using time lapse cameras and shrub expansion using repeat photography and drone surveys (Figure 3).

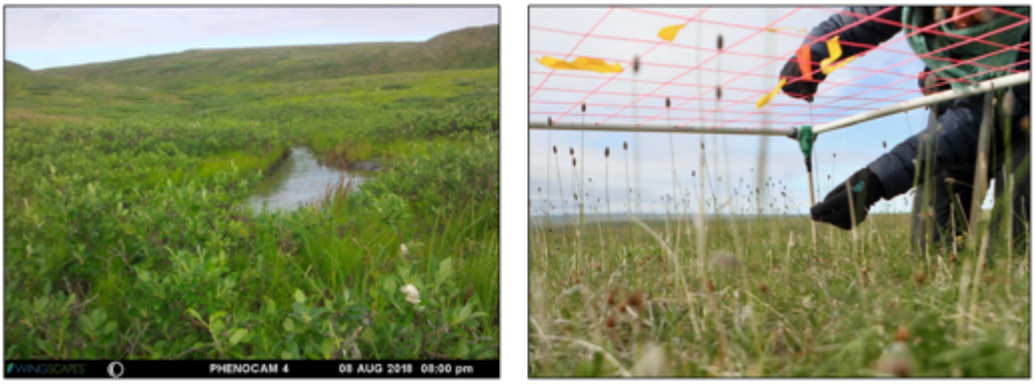

Figure 3. An image from one of our phenocams in Ice Creek (left) and a photograph of point framing (right) on Qikiqtaruk from the 2018 field season.

3. The landscape context of biodiversity change

To complement the long-term monitoring on Qikiqtaruk and at sites around the tundra, we are working to understand the landscape context of changes in plant species. To find out which plant species might colonize monitoring plots in the future, we surveyed the local species pool around the community composition plots 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 center plot and precise location across the landscape (Figure 4). Similarly to our species pool data from 2017, we found that there are between 15 and 20 species found in very close proximity to the long-term monitoring plots, but they have never been recorded inside the 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.

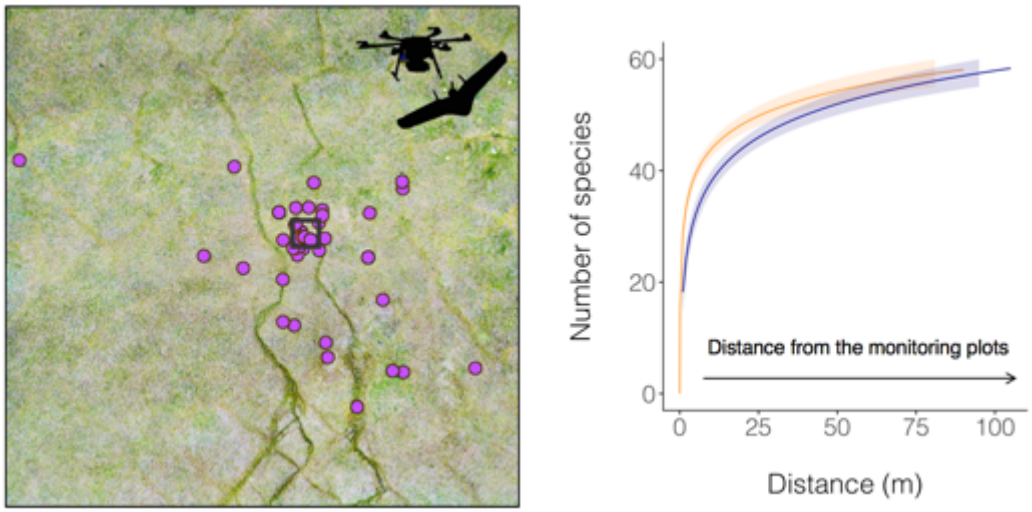

Figure 4. By combining drone data collection with detailed biodiversity surveys, we are capturing the landscape context of long-term monitoring plots on Qikiqtaruk and other sites around the Arctic.

Between 15 and 20 species have been found in close proximity to the long-term monitoring plots, but never inside those plots. We hope to figure out whether these species are likely to invade the plots in future and whether they come from warmer microclimates across the landscape.

4. Landscape-scale vegetation change

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. 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. Our initial results indicate 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 (Figure 5). Qikiqtaruk has more homogenously green tundra where disturbances are minimal than other sites around the tundra, and this could help explain why prominent greening is observed using satellite data in this part of the Western Arctic.

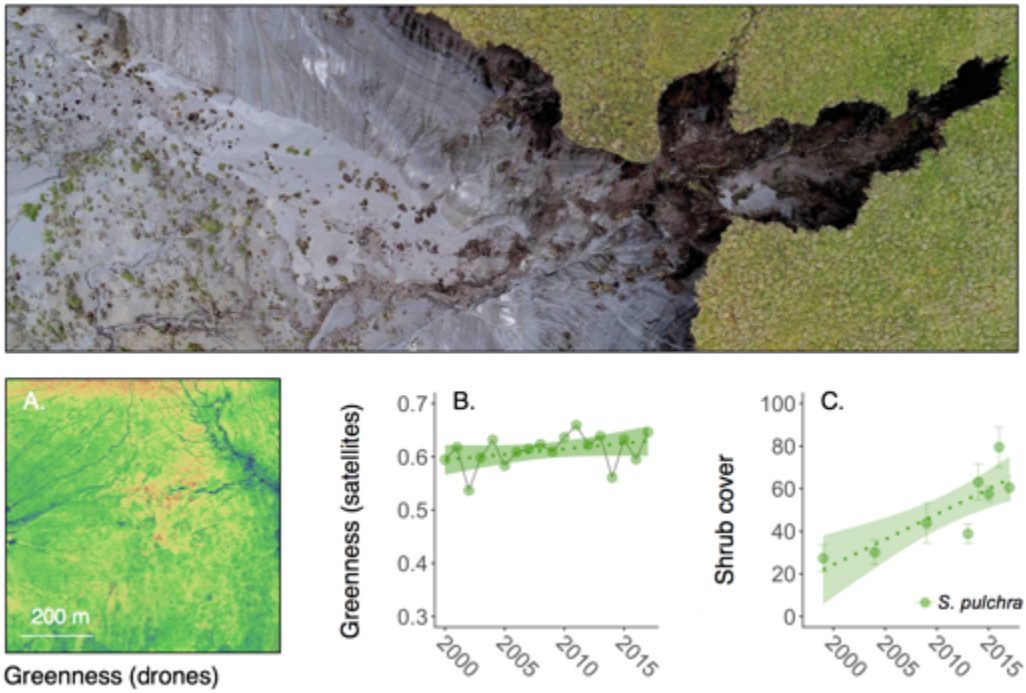

Figure 5. Drones can monitor the greenness and brownness of tundra ecosystems and can be used to measure vegetation change and permafrost disturbance. This photograph (top) illustrates how a permafrost thaw slump is cutting into the surrounding tundra over time on Qikiqtaruk. Across the High Latitude Drone Ecology Network we are observing a relationship between the consistency of the greenness of tundra and the change in greenness observed by satellites. Satellite data indicate both greening and no greening in sites that have undergone vegetation change. Future work will try and understand why Arctic greening patterns from satellites do not always match with on-the-ground observations.

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 article:

Myers-Smith IH, JT Kerby, et al. 2019. Complexity Revealed in the Greening of the Arctic. EcoEvoRxiv. doi: http://doi.org/10.32942/osf.io/mzyjk

5. Permafrost thaw and coastal erosion

We have been monitoring coastal erosion and permafrost thaw disturbances on Qikiqtaruk using drones. The coastal erosion results are published in a recent study. 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 ± 0.2 m a−1 from 1952–2017 (Figure 6).

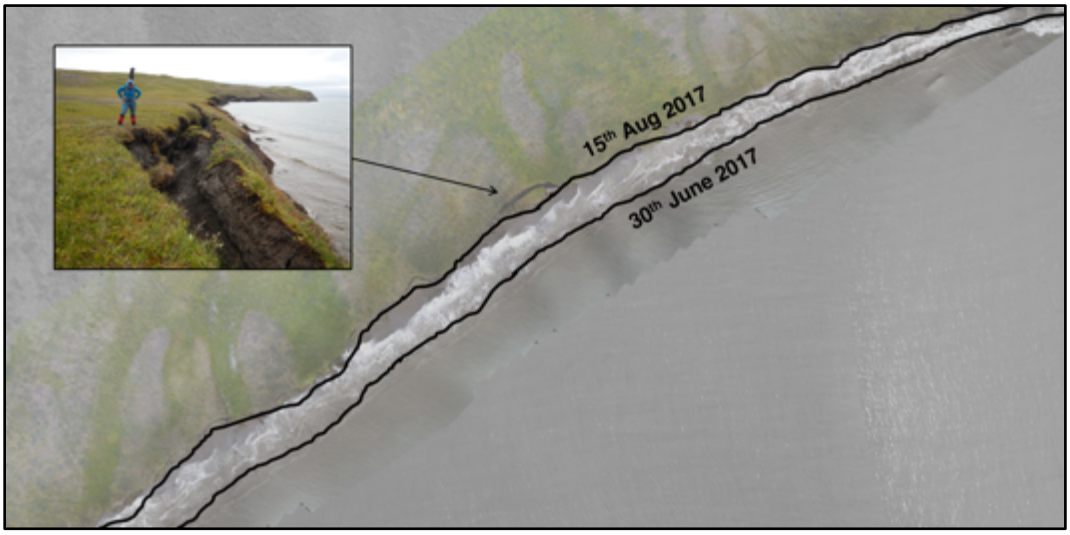

Figure 6. This drone map illustrates the nearly 15 m of coastal erosion that occurred along a half kilometer stretch of coastline near to Ilutaq - Pauline Cove on Qikqitaruk in 2017.

Scientific article:

Cunliffe AM, G Tanski, B Radosavljevic, WF Palmer, T Sachs, H Lantuit, JT Kerby, IH Myers-Smith. Rapid retreat of permafrost coastline observed with aerial drone photogrammetry. In review at The Cryosphere. doi: http://doi.org/10.5194/tc-2018-234

6. Herbivory monitoring

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). In 2018, there was a return of a larger herd of breeding muskoxen on the island (Figure 7). However, we do not know the exact impact of herbivores in the area where the long-term ecological monitoring occurs on the island over time as this information has not been consistently recorded.

Figure 7. Muskoxen on Qikiqtaruk in 2018. Understanding the impact of herbivores on tundra vegetation change on Qikiqtaruk and around the Arctic is a key challenge for future research.

In order to assess the role of herbivory, animals eating plants at these sites, we surveyed for animal signs such as feces, nests, wool (qiviat), and leaf damage from animals such as caribou, muskox, lemmings, ptarmigan and insects. We have been conducting these protocols over the past couple of years to contribute to assessments of herbivore densities and impacts on plant communities around the tundra biome coordinated by the Herbivory Network (https://herbivory.lbhi.is/).

Additional information:

Team Shrub at the University of Edinburgh https://teamshrub.com

The High Latitude Drone Ecology Network https://arcticdrones.com

International Tundra Experiment http://ibis.geog.ubc.ca/itex/, https://www.gvsu.edu/itex/

Herbivory Network http://herbivory.biology.ualberta.ca/

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/, https://teamshrub.com/2018/08/27/welcome-to-the-arctic-welcome-to-the-real-world/

Royal Meteorological Society Blog Post: https://www.rgs.org/geography/news/is-the-arctic-getting-greener/

Royal Meteorological Society Blog Post: http://www.theweatherclub.org.uk/node/553

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