Limitations to shrub expansion in a warmer Arctic

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Introduction: Over the last 50 years, the warming Arctic has seen a steady increase in plant growing season length as winter snowpack has melted earlier and arrived later in the year. In some regions of the circumpolar north, lengthening growing seasons and warmer temperatures have led to increases in tundra plant growth, however other regions have seen a decline in plant greenness. Some of the hypothesized reasons for observed declines in Arctic greenness have been attributed to plant water limitation and herbivory, yet few studies have examined how collective changes in seasonality, hydrology, and plant-herbivore interactions might restructure Arctic tundra ecosystems. Therefore, working in West Greenland (Fig. 1), my research is exploring potential landscape changes from the late-1960s to present, and current abiotic (*i.e.* water) and biotic (*i.e.* herbivory) controls on modern-day shrub growth and distribution.

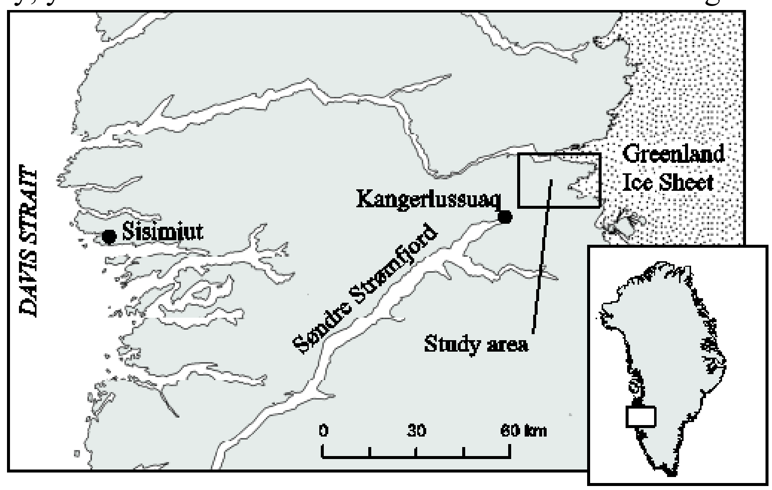


Figure 1: Map of study area in West Greeland. Image from Ruth Heindel.

Purpose: While conducting field work in the Kangerlussuaq region of West Greenland from May 25-July 28, 2017, I collected data on plant growth traits, herbivory, and plant-soil interactions to track regional variations in shrub growth and biomass. I also collected numerous GPS points for ground truthing aerial and satellite imagery to detect if landscape-levels shifts in vegetation or hydrology have occurred over the last 50+ years.

Additionally, from July 7-28th I collaborated with the Joint Science Education Program (JSEP) as a Graduate Fellow through Dartmouth College and the National Science Foundation. JSEP is an international experiential learning collaboration between the USA, Greenland, and Denmark where 20 students are selected from the three collaborating countries for an immersive field school in Kangerlussuaq and Summit Station (located atop the Greenland Ice Sheet). My duties included leading a learning module on tundra soils (Fig. 2) and mentoring a research group of 4 students as they conducted their own independent research project.

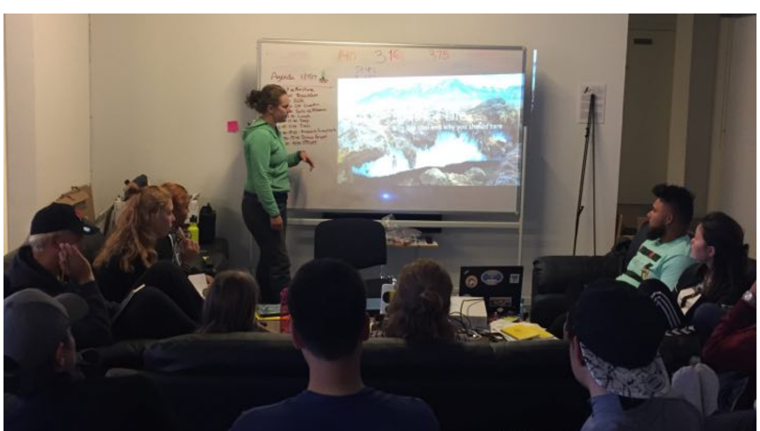


Figure 2: Rebecca Finger leading a lecture on arctic permafrost soils and plant-soil linkages to the carbon cycle.

Methods: For the 2017 fields season, I was joined by several other Dartmouth personnel including undergraduate and graduate students, post-docs, and faculty members. Most of our research team stayed a field camp located approximately 20 km east of the town of Kangerlussuaq, Greenland in order to more readily access field sites. Laboratory and logistical support was provided by CHM2Hill Polar Services and the Kangerlussuaq International Science Station, both contracted through the National Science Foundation.

To track seasonal growth patterns of vegetation, I monitored deciduous shrub leaf elongation, from bud burst to peak summer biomass, at 16 sites along a climate and elevational gradient from Kangerlussuaq to the margin of the Greenland Ice Sheet. Half the sites (8) where closer to town and designate “warm sites” while the other half of sites were located near the Greenland Ice Sheet and designated “cold sites”. At each site, I flagged 10 shrubs of both gray willow and dwarf birch for a total of 20 plants per site for repeated sampling. Approximately every 5 days I visited the sites to collect foliar samples for leaf area, chemical analysis, and herbivory damage assessment. Towards the end of the growing season (late July), I measured shrub dimensions and percent cover of vegetation to estimate vegetation biomass at all study plots.

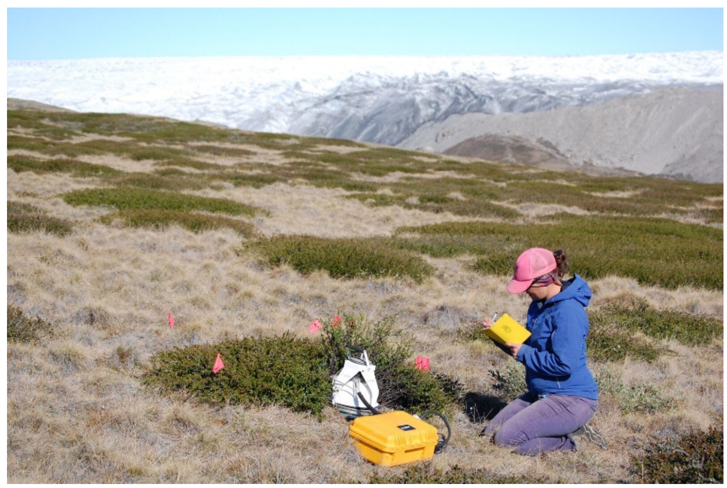
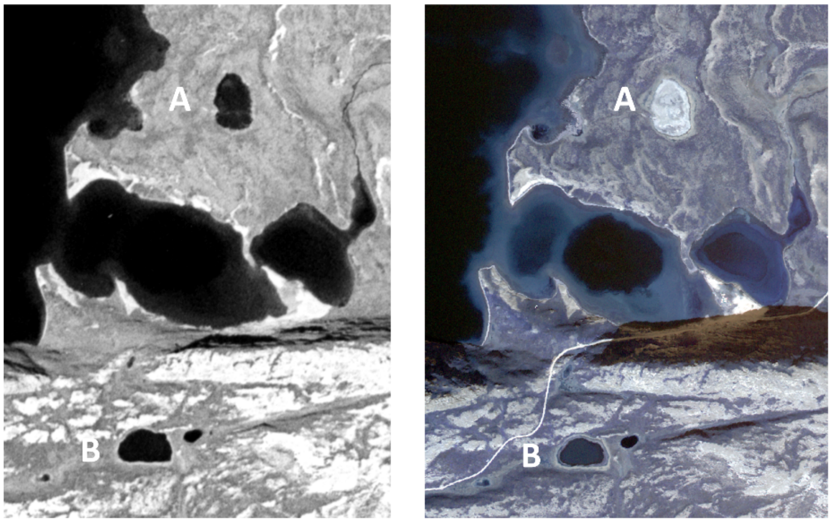


Figure 3: Rebecca Finger measuring soil CO_2 respiration using a Licor 8100 at 2017 defoliation manipulation field sites.

In addition to my observational study exploring growing season controls on shrub-insect herbivory, I also started a field manipulation to explore the impact of insect defoliation on plant-soil feedbacks. Starting on June 15th, 2017, twelve birch shrubs were selected and randomly assigned one of four possible treatments: control, partial defoliation, partial defoliation + fertilization, and complete defoliation. Prior to shrubs being defoliated, round PVC collars where placed in the soil for ongoing and continued soil CO_2 respiration using a Licor 8100 Infared Gas Analyzer (Fig. 3). Shrubs were defoliated manually by removing leaves from branches and completely removing the removed biomass from the study plots. For complete defoliation, as many leaves as possible were removed from the branches; however due to shrub architecture, approximately 90% of the leaves were removed. Partial defoliation entailed stripping approximately every other branch. A day after shrubs had been defoliated, soil respiration measurements were conducted at all study plots, and 10 g/m^2 of Urea fertilizer was added to the partial defoliation + fertilization plots. Soil respiration measurements were then collected about two weeks later and one month later for a total of 4 soil respiration measurements throughout the 2017 field season.

Discussion: Preliminary analyses of remote sensing satellite photography are suggestive that the Kangerlussuaq region of western Greenland has seen a decrease in terrestrial water availability. By comparing high resolution imagery from the 1968 CORONA mission with 2013 commercial satellite imagery (World View 3), I am beginning to see patterns of decreasing surface lake area and lake drying (Fig. 4). In addition to remote sensing, I have also compiled and modelled



August 1, 1968 August 26, 2014

Figure 4: Comparison of aerial photography from 1968 CORONA mission (left) and 2014 World View 3 (right) imagery. Letters denote same locations between the two images.

weather data from 1973 to present for my study area, which shows an increase in mean annual temperatures, resulting in increasing growing season length, at a rate of approximately 3.5 days per decade. Warmer ambient air temperatures likely have led to greater surface water loss due to increasing rates of evaporation, as precipitation patterns have not changed significantly over the same time period. If, in fact, Greenland is getting drier, this could be a very plausible limit to woody vegetation expansion across the tundra. Additionally, abnormally dry soil conditions are suggested to be a major contributing factor to a major tundra fire that broke out about 100 miles NW of my study area during early August 2017. If these drier trends continue, Greenland could experience more disturbance events such as soil wind erosion and wildfire in the coming decades.

Climate change might also lead to more severe or more frequent insect outbreaks which could also reduce shrub growth and expansion. Recorded and observed outbreaks from 2004-05 and 2011-12 have left several areas of the tundra denuded of foliage, and in some areas shrubs have even been overtaken by grasses. My research aims to better understand shrub recovery and resiliency to insect outbreak through observational and experimental data, which is yet to be fully analyzed. However, the 2017 field season proved to be extremely productive for developing methodology and initiating an experiment that will be revisited during the 2018 field season.

Thanks to support from the American Alpine Club, Dartmouth College, and the National Science Foundation, I have been able to pursue my interests and passion in Arctic ecology in Greenland. This type of work is inherently complicated, expensive, and demanding, and simply would not be possible without a tremendous amount of support. Funding from the American Alpine Club helped with transportation and equipment costs. Personally, it is also an honor to represent the AAC as a grant recipient and I will be sure to keep in touch as my research progresses.

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