Landscape Level Analyses of Vegetation Cover Change in Northern Alaska

Timothy F. Botting and Robert D. Hollister
Grand Valley State University, Allendale, Michigan, United States

Introduction

Several International Tundra Experiment (ITEX) studies have been conducted to identify vegetation changes from control plots over time (e.g. Elmendorf et al. 2012, Oberbauer et al. 2013). However, knowledge gaps remain. Most of these studies are conducted at the plot level, not the landscape level, potentially masking larger scale impacts of change. For example, most ITEX studies focus on vegetation changes in only one or a few vegetation communities. Landscape level analyses allows for more vegetation communities to be analyzed. As a result, observed changes could be different at the landscape scale compared to within a specific vegetation community. The goal of this project will be analyze how vegetation cover and diversity has changed from 2010 to 2013 along the landscape near Barrow and Atqasuk, Alaska (**Figure 1**). This study will serve as a baseline for later analyses to document and predict vegetation community changes as a result of anticipated warming.

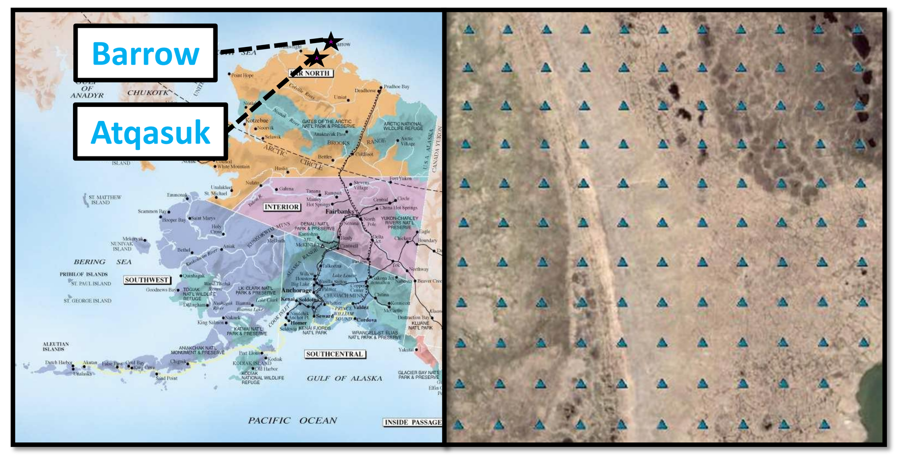


Figure 1. A map showing the location of study sites (left). An image showing the ARCSS grid in Barrow; each triangle represents the location of a 1m^2 vegetation plot placed every 100 meters across a 1km^2 grid (right).

Methods

Arctic Systems Science (ARCSS) program grids were established near Barrow and Atqasuk in the early 1990's to document change. In 2010, approximately 100 vegetation plots were established at each site. Vegetation plots are 1-m^2, are spaced 100 m apart and span 1 km^2.

Vegetation cover was collected using the point frame method (Molau & Mølgaard 1996). A 75cm^2 frame was utilized with 100 points spaced 7.5cm apart (**Figure 2**). A graduated ruler was used to measure the height of each encounter relative to the ground at each point. All plants were identified to species and live or dead status was recorded. In July of 2010 and 2013, all plots at both sites were sampled; in 2012 a subset of 30 plots at each site were sampled. Species were grouped into the following functional groups before analysis: graminoids, forbs, bryophytes, lichens, deciduous shrubs, evergreen shrubs, leaf litter and standing dead plant matter.

Gamma diversity was defined as the total number of vascular plant species found at each site. Alpha diversity was calculated as the average number of vascular species in each plot. Beta diversity was calculated as alpha diversity / gamma diversity.

From 2010 to 2013, the change in cover of each functional group and changes in alpha and beta diversity across each site were compared using two sample t-tests or Mann-Whitney U tests if square root or log transformations failed to achieve approximately normal distributions. All statistical analyses were run using R 3.0.2 (R Core Team 2013) with alpha level set at 0.05. If a functional group was found in less than three plots it was excluded from analysis.

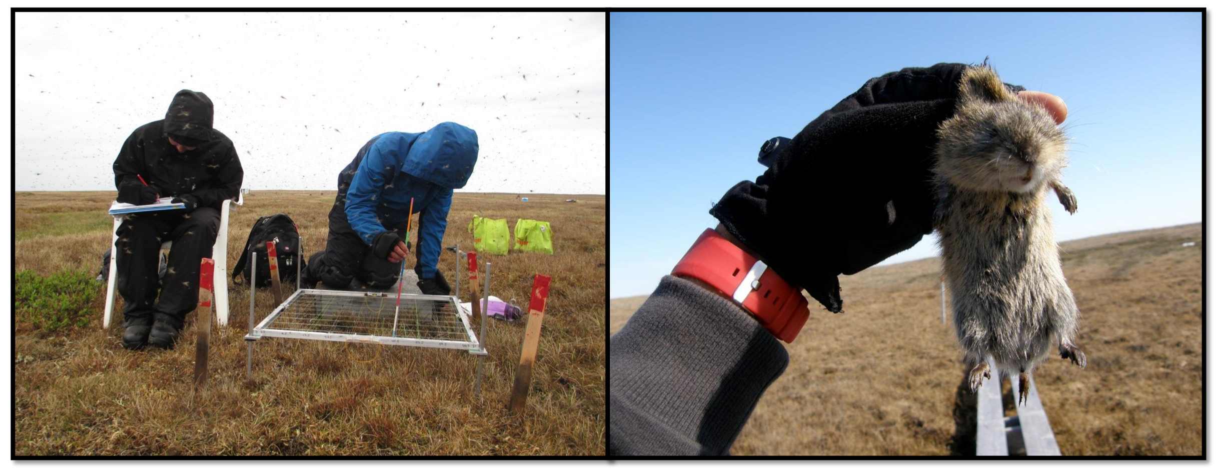
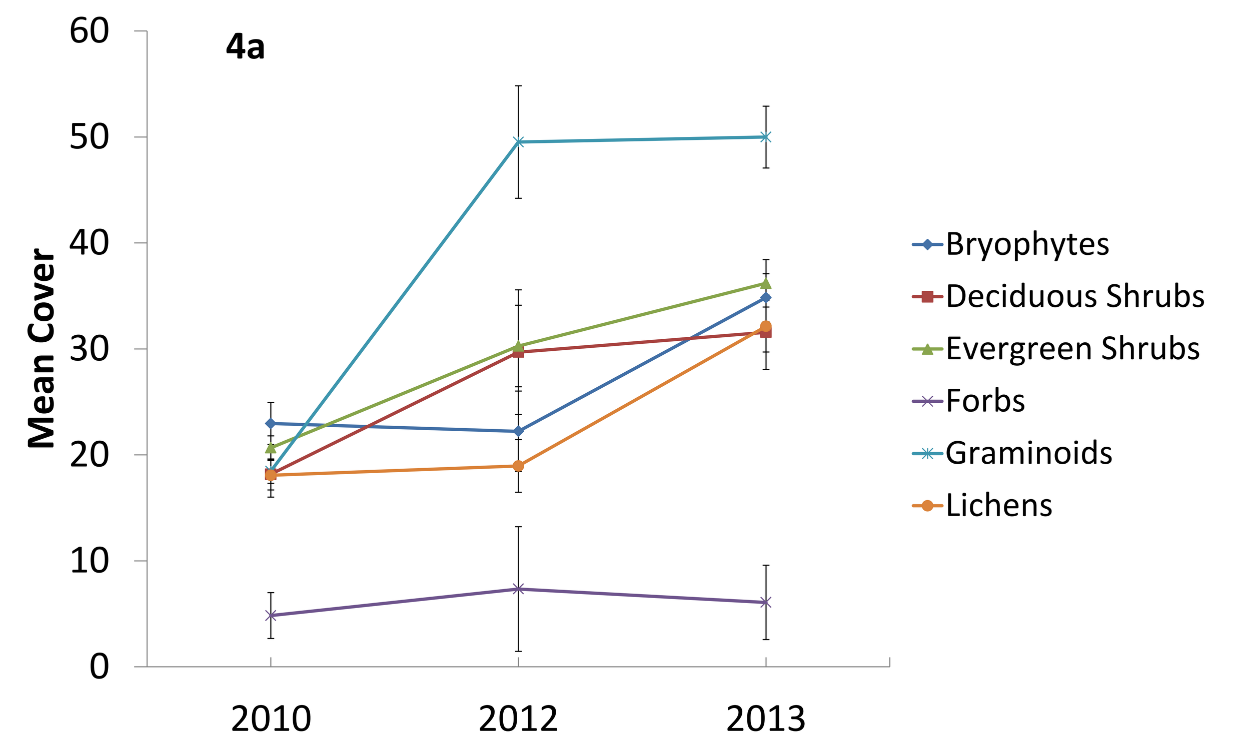


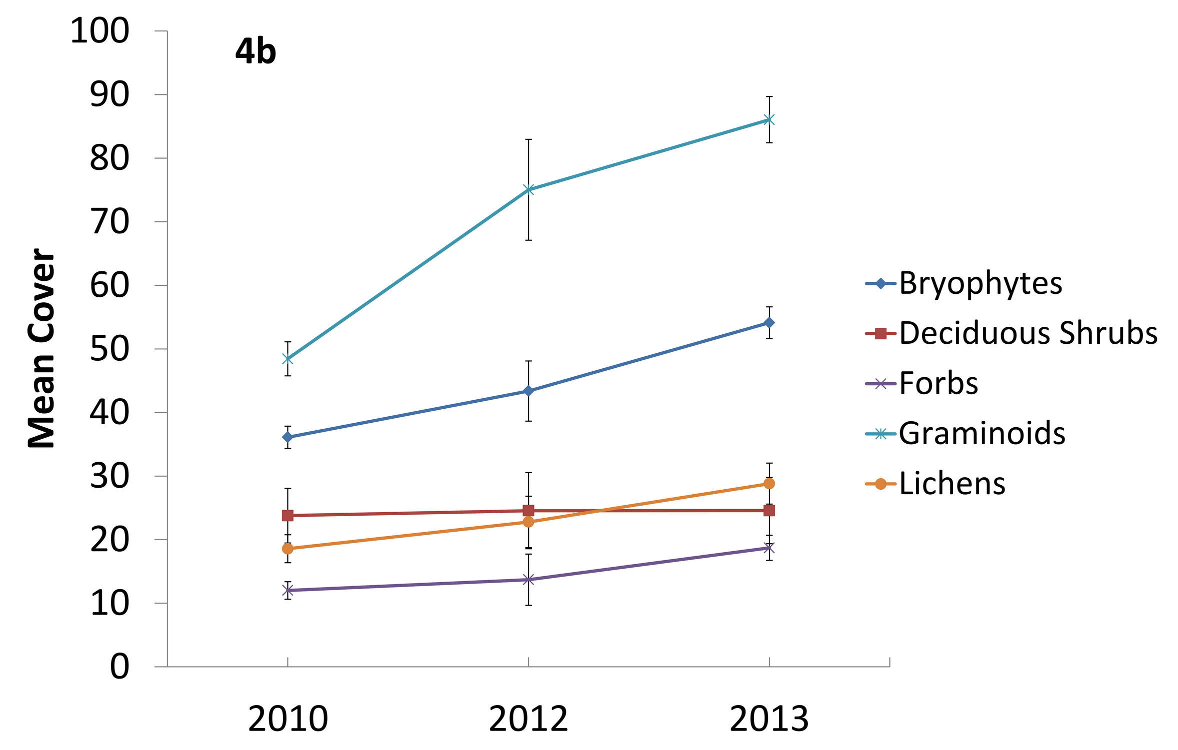
Figure 2. Vegetation cover was identified using the point frame method (left). Herbivores such as lemmings can significantly alter vegetation communities in Arctic regions (right).

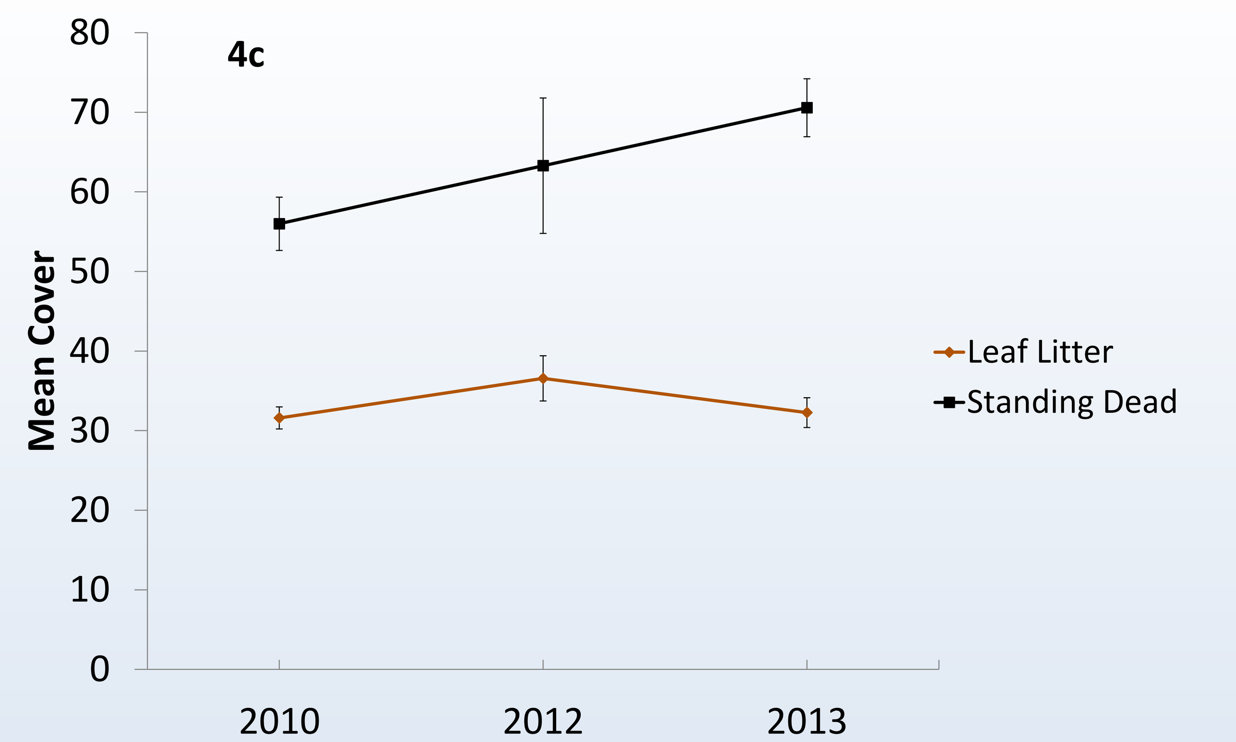
Figure 3. Sedges such as *Eriophorum vaginatum* (left) and *Carex aquatilis-stans* (right) are driving the changes in graminoid cover in Atqasuk and Barrow.

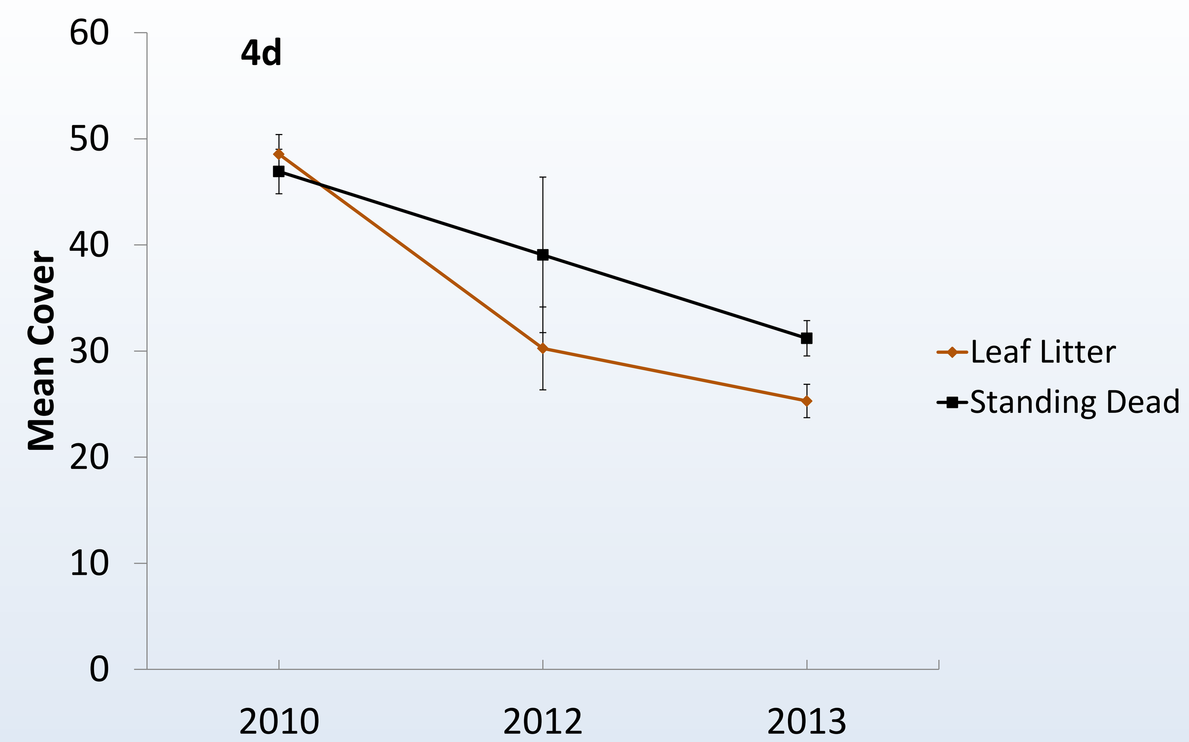
Atqasuk

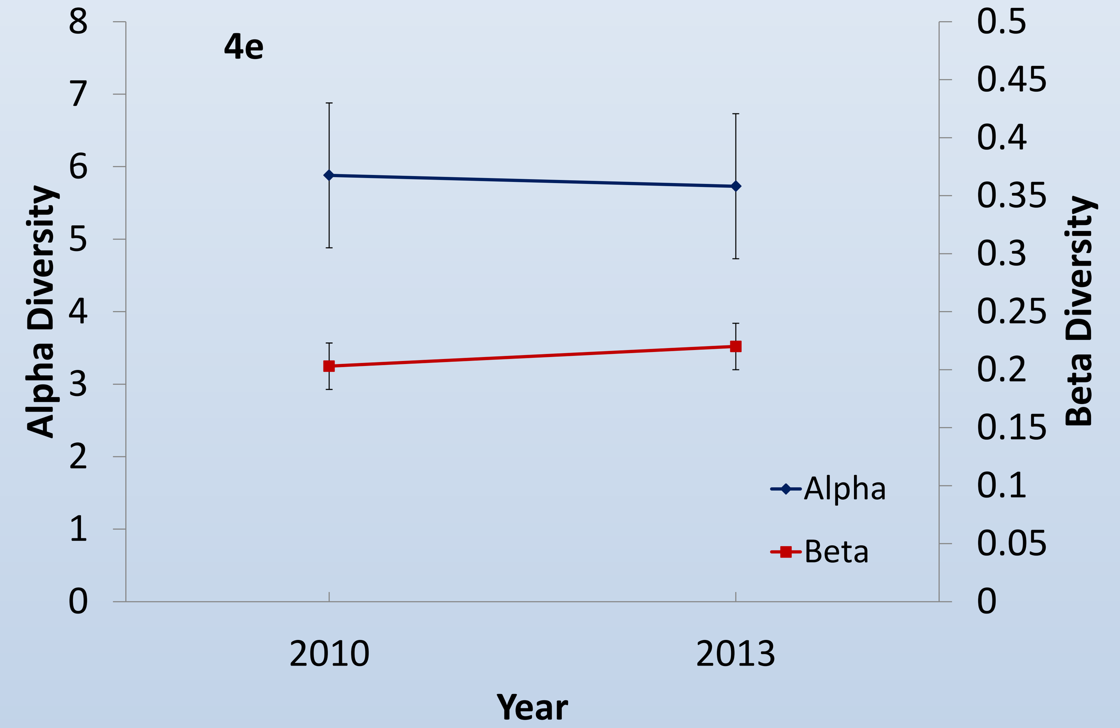


Barrow

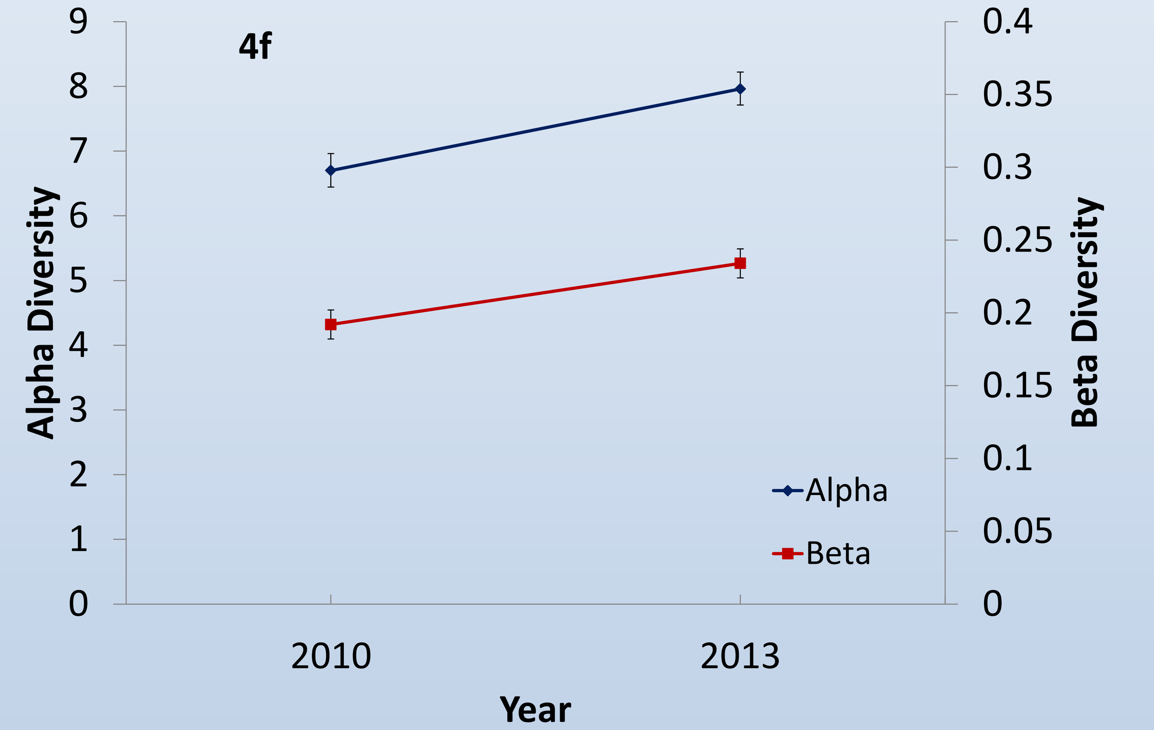








Figures 4a-d. Change in mean cover of live plants (a,b) and dead plant material (c,d) from 2010 to 2013 at Atqasuk (a,c) and Barrow (b,d).



Figures 4e-f. Change in alpha and beta diversity from 2010 to 2013 in Atqasuk (e) and Barrow (f). Standard error of the mean is shown in all figures.

Results

In Atqasuk (**Figures 4a, c**), there were significant increases in bryophyte cover (11.9%, p<0.01), lichen cover (14.1%, p<0.01), deciduous shrub cover (14.3%, p<0.01), evergreen shrub cover (15.5%, p<0.01), graminoid cover (31.5%, p<0.01) and standing dead plant material (14.6%, p<0.01). There were no significant differences in forb cover (1.2%, p=0.321) and leaf litter (0.7%, p=0.619). In Barrow (**Figure 4b, d**), there were significant increases in bryophyte cover (18.0%, p<0.01), lichen cover (10.2%, p=0.040), forb cover (6.7%, p<0.01) and graminoid cover (37.6%, p<0.01) and significant decreases in leaf litter (-23.3%, p<0.01). There was no change in standing dead plant material (15.7%, p=0.103) or deciduous shrub cover (0.8%, p=1) and not enough evergreen shrubs for analysis. Across both sites, graminoid cover exhibited the greatest change over time.

In 2010, species richness (gamma diversity) was 29 vascular plant species in Atqasuk and 35 plant species in Barrow. In 2013, species richness was 26 plant species in Atqasuk and 34 plant species in Barrow. There was a significant increase in the number of vascular plant species per plot (alpha diversity) in Barrow (1.26, p<0.01) but no difference in Atqasuk (-0.15, p=0.727) (**Figures 4e, f**). Beta diversity significantly increased in Barrow (0.042, p<0.01) but not in Atqasuk (0.179, p=0.28).

Discussion

Across the grids, modest changes in live vascular cover were seen from 2010 to 2013 with bryophytes, lichens, deciduous shrubs, evergreen shrubs, and forb cover. This was likely due to the short time span of the study. Surprisingly, there were dramatic increases in live graminoid cover at both sites. Those changes appear to be driven by a few dominant sedges such as *Eriophorum vaginatum* in Atqasuk and *Carex aquatilis-stans* in Barrow (**Figure 3**). Increases in thawing degree days after first snowmelt in subsequent years may also have played a role, especially in Barrow. There was also a distinct decrease in leaf litter and standing dead plant cover in Barrow. Villareal et al. 2012 found that lemmings altered Barrow vegetation communities from 2008-2010 following a lemming outbreak in 2008. Lemmings are a likely explanation for the decline in leaf litter and standing dead plant matter in this study **(Figure 2)**. Increases in standing dead in Atqasuk may be explained by trampling from caribou herds noticed during the 2012 and 2013 field seasons.

Little change in alpha and beta diversity was seen Atqasuk. This was, again, likely due to the short length of the study. However, there were significant increases in alpha and beta diversity in Barrow, indicating vegetation communities became more dissimilar across the landscape.

This study will be the foundation for later work. Abiotic data such as soil moisture and thaw depth will be used to help explain vegetation changes. Data from ITEX passively warmed plots will be utilized to predict how these vegetation communities will respond in the future to anticipated warming. Finally, conservation implications for tundra vegetation will be formulated based on those predictions.

Acknowledgements

We would like to thank the National Science Foundation for funding, UMIAQ and the Barrow Arctic Science Consortium for logistical support, as well as past and present Grand Valley State University Arctic Ecology Program members for data collection, help with analyses and insightful ideas.

References

Elmendorf, S. C., Henry, G. H. R., Hollister, R. D., Bjork, R. G., Boulanger-Lapointe, N., Cooper, E. J., Cornelissen, J. H. C., Day, T. A., Dorrepaal, E., Elumeeva, T. G., Gill, M., Gould, W. A., Harte, J., Hik, D. S., Hofgaard, A., Johnson, D. R., Johnstone, J. F., Jonsdottir, I. S., Jorgenson, J. C., Klanderud, K., Klein, J. A., Koh, S., Kudo, G., Lara, M., Levesque, E., Magnusson, B., May, J. L., Mercado-Diaz, J. A., Michelsen, A., Molau, U., Myers-Smith, I. H., Oberbauer, S. F., Onipchenko, V. G., Rixen, C., Schmidt, N. M., Shaver, G. R., Spasojevic, M. J., Porhallsdottir, P. E., Tolvanen, A., Troxler, T., Tweedie, C. E., Villareal, S., Wahren, C. H., Walker, X., Webber, P. J., Welker, J. M. & Wipf, S. (2012) Plot-scale evidence of tundra vegetation change and links to recent summer warming. *Nature Climate Change,* **2,** 453-457.

Molau, U., & Mølgaard, P. (1996) ITEX Manual, Second Edition, Danish Polar Center, Copenhagen.

Oberbauer, S. F., Elmendorf, S. C., Troxler, T. G., Hollister, R. D., Rocha, A. V., Bret-Harte, M. S., Dawes, M. A., Fosaa, A. M., Henry, G. H. R., Hoye, T. T., Jarrad, F. C., Jonsdottir, I. S., Klanderud, K., Klein, J. A., Molau, U., Rixen, C., Schmidt, N. M., Shaver, G. R., Slider, R. T., Totland, O., Wahren, C. H. & Welker, J. M. (2013) Phenological response of tundra plants to background climate variation tested using the International Tundra Experiment. *Philosophical Transactions of the Royal Society B-Biological Sciences,* **368**, 1-13.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Villarreal, S., Hollister, R. D., Johnson, D. R., Lara, M. J., Webber, P. J. & Tweedie, C. E. (2012) Tundra vegetation change near Barrow, Alaska (1972-2010). *Environmental Research Letters,* **7,** 1-10.