Changes in distribution of northern and southern Arctic plant species due to warming

Jennifer A. Liebig, Robert D. Hollister, & Jeremy L. May
Grand Valley State University

ABSTRACT

Vegetation in high latitude regions is expected to respond to climate change more than vegetation in other parts of the world. In this study we examine the response to experimental warming of plant species at four sites in northern Alaska. Data collected in 2007 and 2008 are used; plant cover was sampled using a point frame method. Previous studies have found that when compared to the control plots, the warmed plots show an increase in the cover of vascular plants. For this study we classified the species' historical geographical distribution using four zones. Zone 1 species occur in the northernmost Arctic, while Zone 4 species only occur in the southernmost Arctic. We found that species from the two southernmost zones are not well represented in our sites. Zone 1 species did not perform well under the warming treatment and in three of the four sites showed a decrease in cover in response to warming. Zone 2 species showed an average 21% increase in cover in the warmed plots, with an increase at all four sites. This analysis showed that the general increase in cover in warmed plots is being driven by Zone 2 species. Thus, the study supports the prevailing wisdom that warming results in an increase in cover of southerly species.

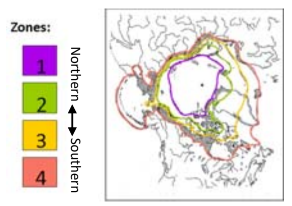


Fig 1. Map of the Arctic with zones indicated by colored lines. The area inside the purple line designates the location of northern limits of Zone 1 species, and so on.

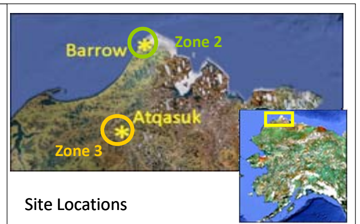
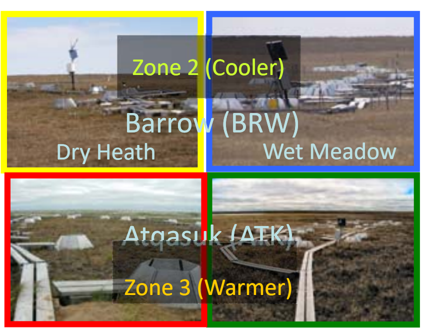


Fig 2. The city of Barrow and the village of Atqasuk in Alaska, located at 71°17'44"N 156°45'59"W and 70°28'40"N 157°25'5"W, respectively. The two locations are found in different zones.

INTRODUCTION

The poles are experiencing greater effects of climate change compared to mid- and low-latitude regions, and the severity of the climate dictates that tundra plants have adapted to these conditions in order to successfully colonize the region. Thus small changes in climate could have a large impact on the plant community. This study seeks to predict the response of plant species to climate change in association with the International Tundra Experiment (ITEX), by using experimental warming to simulate climate change. Previous studies have found that when compared to the control plots, the warmed plots show an increase in the cover of vascular plants1,2,. The prevailing wisdom is that species that are predominantly distributed in low Arctic regions will respond faster to warming. These low Arctic species are expected to increase in cover and distribution, and as this happens, cover and distribution of species primarily found in the high Arctic will decrease. Classifications of low and high Arctic species exisit3,4,5, with one specific system coming from Steven Young (1971). He surveyed St. Lawrence Island and classified the vegetation into four zones based on the northern limit of their circumpolar distributions, with Zone 1 being the most northern and Zone 4 the most southern6 (FIG 1). A species that is found in Zones 2, 3, and 4 is classified as a Zone 2 species; a species that grows in Zones 2, 3, 4 and is rarely found in Zone 1 is classified as a Zone 2 species as well. A species growing in the zone where it is classified is expected to outcompete species from more northerly zones. The goal of this study is to examine trends in the changing distribution of Arctic vegetation using experimental warming data and Young's classification scheme.



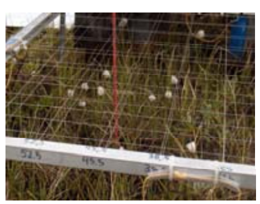


FIG 3 (above) The point frame grid with a ruler dropping to the ground for the bottom hit.

FIG 4 (left) The four study sites. OTCs are visible on the experimental plots.

METHODS

The experiment was conducted at two locations on the North Slope of Alaska (FIG 2). At each location a dry heath site and a wet meadow site were established (FIG 3). At each site there are 24 control plots and 24 plots under Open-Topped Chambers (OTCs). The OTCs (FIG 3) warm the experimental plots on average between 1 and 3 0Celsius for the growing season, depending on the site and weather conditions for the year7. Data on vegetation cover was collected using a point frame method. At each intersection of a 75cm x 75cm 100 point grid, a ruler was dropped (FIG 3). Every occurrence of a plant species was identified by species and recorded as alive or dead. This was done for all control and experimental plots.

The species present were classified by distribution into one of Young's four zones6. Zone 4 species were not used in this study due to the extremely low occurrence of those individuals in the plots. The point frame data was then summed by zone classification, and for each zone we calculated the percent change of cover from control to warmed at each site. We used an ANOVA to analyze the distribution of the species from each zone in the warmed and the control plots.

RESULTS

Each site had a different distribution of species (FIG 5). Both Barrow sites had significant changes in cover for Zone 1 species and Zone 2 species, and in Atqasuk, a significant change occurred for Zone 2 species at the wet site and for Zone 1 and Zone 3 species at the dry site. Zone 1 species and Zone 2 species each showed significant and opposing differences in cover between warmed and control plots (FIG 6). Zone 2 species increased on average at each of the four sites, and was significant in three sites: Barrow dry (19.1%), Barrow wet (28.8%), and Atqasuk wet (20.0%). There was an increase of 91.6% for Zone 1 species in the Barrow dry site, but an average decrease at the other three sites. The decrease was significant at the Barrow wet site, where cover decreased 23.9%, and at the Atqasuk dry site, where it decreased 30.4%. Zone 3 species only showed significant change in cover in the Atqasuk dry site, where it decreased 21.8 %.

CONCLUSIONS:

The findings of the study agree with previous studies that have found that Arctic vegetation is responding to warming. Warmed plots showed an overall increase in cover, but species in each distributional zone responded in different ways. In classifying these ways, Young's zonation scheme proved to be a useful tool. The zones are reasonably defined, and species of the different zones respond differently from each other. Zone 4 species were not seen in any of the four sites; this agrees with the geographical distribution of the zones, since Barrow and Atqasuk are in zones 2 and 3. We did not expect to find any zone 4 plants when their northern limits lie further south than the experimental sites. The distribution of Zone 3 species was small enough that observing significant changes is difficult; however, there was a significant decrease in the warmed plots at the Atqasuk dry site. Though the expectation would be that southerly distributed species such as those from Zone 3 would increase growth under warm conditions, the warmed plots at the Atqasuk dry site are under increased water stress. As an already dry environment, the dry heath site becomes harsher due to warming, possibly causing the decrease in cover of Zone 3 species.

Changes in Zone 1 and Zone 2 species were more significant. Because the zonation scheme separates species by northern limitation, with no definition of a southern limit, we would expect to find species from all four zonation groups in a zone 4 location and Zone 1, Zone 2, and Zone 3 species in a zone 3 location, etc. With research sites in zones 2 and 3, Zone 1 species and Zone 2 species are abundant at these locations. When Zone 2 are considered more southerly in this context, with Zone 1 then being more northerly, the change in cover supports the prevailing wisdom that warming will increase cover of southerly species and decrease cover of northerly species. In all sites, Zone 2 species increased in cover in warmed plots. The expectation would then be for cover of Zone 1 species to decrease, and this what happened, with the notable exception of the Barrow dry site. At that site both Zone 1 and Zone 2 species showed an increase in cover. Elsewhere the warming treatment caused a decrease in cover for Zone 1 species. In summary, the warmed plots are known to have increased in cover overall, and Zone 1 species have generally decreased. This increase is being driven primarily by Zone 2 species.

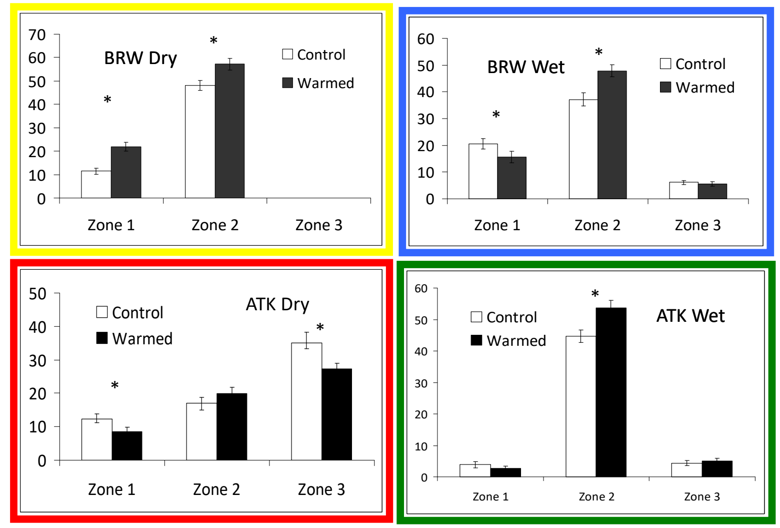


FIG 5. The average number of encounters per plot for species from each of the three zones occurring at the sites. Zone 4 species are absent at these Zone 2 (Barrow) and Zone 3 (Atqasuk) sites. Zone 3 species are absent in the Barrow dry site and were low-occurring elsewhere. Black bars represent warmed plots and white bars represent control plots. The colors around each chart correspond to the colors around the pictures of the sites in figure 4. Species from Zone 2 are widely distributed in all the sites. The asterisk represents p< .05.

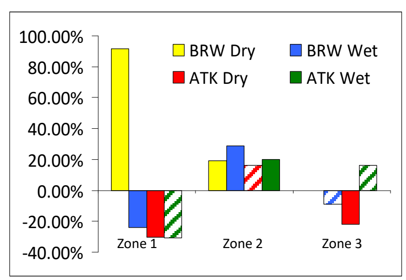


FIG 6. Percent change in cover for all sites and species from all zones. Colors correspond to figures 4 and 5. Solid bars represent p < 0.05. Striped bars are not significant.

ACKNOWLEDGEMENTS

Thanks to the members of the Arctic Ecology Program in 2007-2008: Jeremy May, Robert Slider, Jean Marie Galang, Amanda Snyder, and Michael Lothshutz.

Thanks to the National Science Foundation for funding and the Barrow Arctic Science Consortium for providing logistics in Alaska.

REFERENCES

1. Hollister, R.D., P.J. Webber, and C. Bay. 2005. Plant response to temperature in northern Alaska: Implications for predicting vegetation change. *Ecology* 86(6): 1562-1570.

2. Walker, D. A., Raynolds, M. K., Daniëls, F. J. A.,Einarsson, E., Elvebakk, A., Gould, W. A., Katenin, A. E., Kholod, S. S., Markon, C. J., Melnikov, E. S., Moskalenko, N. G., Talbot, S. S., Yurtsev, B. A. & the CAVM Team 2005. The Circumpolar Arctic Vegetation Map. – *Journal of Vegetation Science* 16 (3): 267-282.

3. Edlund, S. A. & Alt, B. T. 1989. Regional congruence of vegetation and summer climate patterns in the Queen Elizabeth Islands, Northwest Territories, Canada. *Arctic* 42 (1): 3-23.

4. Gould, W. A. & Walker, M. D. 1999. Plant communities and landscape diversity along a Canadian Arctic river. *Journal of Vegetation Science* 10 (4): 537-548.

5. Walker, M.D., C.H. Wahren, R.D. Hollister, G.H.R. Henry, L.E. Ahlquist, J.M. Alatalo, M.S. Bret-Harte, M.P. Calef, T.V. Callaghan, A.B. Carroll, H.E. Epstein, I.S. Jónsdóttir, J.A. Klein, B. Magnússon, U. Molau, S.F. Oberbauer, S.P. Rewa, C.H. Robinson, G.R. Shaver, K.N. Suding, C.C. Thompson, A. Tolvanen, Ø. Totland, P.L. Turner, C.E. Tweedie, P.J. Webber, and P.A. Wookey. 2006. Plant Community Responses to Experimental Warming Across the Tundra Biome. *Proceedings of the National Academy of Science of the United States of America (PNAS)* 103(5): 1342-1346.

6. Young, S.B. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zontation in the arctic regions. *Contributions from the Gray Herbarium of Harvard University* 201: 11-115.

7. Hollister, R.D., P.J. Webber, F.E. Nelson, and C.E. Tweedie. 2006. Soil thaw and temperature response to air warming varies by plant community: Results from an open-top chamber experiment in northern Alaska. *Arctic Antarctic and Alpine Research* 38(2):206-215.