Response of Graminoids to Increased Temperature in the Arctic

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Introduction

The effects of global climate change have been most pronounced in the Arctic, and recent warming has been linked to shifts in arctic plant communities (IPCC 2007). Tundra plants impact many ecosystem processes globally (IPCC 2007). Many studies suggest that plant response to warming varies over time and location (Arft et al., 1999). Also, it has been shown that there may be differences in short-term and long-term responses to warming (Hollister et al., 2005a). The objective of this study was to determine the consistency of the response of graminoids to warming in Northern Alaska. The study examined the impact of experimental warming and natural temperature variation at ITEX sites at Barrow and Atqasuk, Alaska. Species were classified in to species response types as in Hollister et al. (2005b) in order to compare short term (1994-2000) and long term (1994-2010) responses across sites, species, and growth forms.

Methods

Sites were established at Barrow (71°18'N, 156° 44'W) in 1994 and 1995 and at Atqasuk (70°29'N, 157°25'W) in 1996 (**Figure 1**). Plots of vegetation ($1m^2$) were warmed on average 1°C to 3°C over the summer using open-top fiberglass chambers (**Figure 2**). This increases the thawing degree day (TDD_{sm}) in the experimental plots. TDD_{sm} is the cumulative amount of degree days (which relate time and temperature) after snow melt. Each location contains a dry heath and wet meadow site with 24 control and 24 experimental plots each (**Figure 3**). The response of leaf length, inflorescence height, and number of inflorescences for 13 graminoid species from 1994-2010 is reported here. Data was collected June through August in each control and experimental plot containing the species. A species was only included if it was present in more than 5 control and 5 experimental plots for a given year. Correlation with TDD_{sm} and the response to warming were used to classify graminoid species into temperature response types, as in Hollister et al. (2005b). If the trait was significantly correlated with TDD_{sm}, then temperature was considered to control the response and was a "dominant factor", and if the trait responded to the warming treatment but was not significantly correlated with TDD_{sm}, then temperature was considered a "subordinate factor" (Hollister et al., 2005b). Relationships were considered significant if $P<0.05$. If there was no overall correlation with TDD_{sm} and no significant response to warming treatment, then the trait was classified as "unresponsive" to temperature (Hollister et al., 2005b). The response was then classified as positive or negative based on the directionality of change in growth and reproductive effort. If the response was positive in some years but negative in others, it was considered an inconsistent response. The results of the analysis including years 1994-2010 were considered the "long-term" response, while the results from Hollister et al. 2005, including years 1994-2000, were considered the "short-term" response.

Figure 1: Photos of research sites in Barrow and Atqasuk.

Table 1: Assigned temperature response types of species at the four study sites. Response types are positive dominant (P), positive subordinate (p), negative dominant (N), negative subordinate (n), inconsistent dominant (I), inconsistent subordinate (i), and unresponsive (U). "Long term" response types include data from 1994-2010, while "short term" response types were those reported in Hollister et al. 2005, for years 1994-2000.

Species by Site	Leaf Length		Inflorescence Height		Number of Inflorescences	
	Long term	Short term	**Long term**	Short term	**Long term**	Short term
Atquasuk dry heath						
Hierochloe alpina	**P**	P	**P**	p	**U**	p
Luzula arctica	**U**	U	**U**	U	**U**	i
Luzula confusa	**P**	U	**I**	n	**U**	i
Trisetum spicatum	**P**	...	**...**	...	**...**	...
Atquasuk wet meadow						
Carex aquatilis	**P**	p	**p**	p	**I**	i
Dupontia fisheri	**P**	U	**P**	U	**U**	U
Eriophorum angustifolium	**P**	P	**P**	i	**I**	U
Eriophorum russeolum	**P**	P	**p**	p	**p**	U
Luzula wahlenbergii	**U**	P	**...**	...	**...**	...
Barrow dry heath						
Arctagrostis latifolia	**P**	U	**p**	p	**I**	U
Luzula arctica	**U**	U	**p**	p	**U**	U
Luzula confusa	**P**	p	**P**	p	**I**	U
Poa arctica	**P**	p	**P**	p	**U**	U
Barrow wet meadow						
Carex aquatilis	**p**	p	**P**	P	**U**	U
Dupontia fisheri	**P**	U	**P**	P	**N**	i
Eriophorum angustifolium	**P**	U	**P**	U	**P**	p
Eriophorum russeolum	**P**	p	**p**	P	**U**	U
Hierochloe pauciflora	**P**	P	**i**	i	**U**	n
Jungus biglumis	**P**	U	**P**	P	**U**	U
Luzula arctica	**p**	U	**P**	P	**U**	U
Luzula confusa	**I**	U	**P**	P	**U**	U
Poa arctica	**I**	U	**p**	P	**U**	U

Results & Discussion

In the long-term study, plants responded to temperature in 45 of 62 measured traits of a species in a site (Table 1, 73%). This is greater than the amount found in the short-term study (Table 1, 57%, Hollister et al. 2005b). The traits of leaf length and inflorescence height had a higher percentage of measured traits that responded to temperature (Table 1, 38/42 traits, 90%). This indicates that certain traits may be more influenced by warming than others, which is consistent with the findings of Hollister et al. 2005b. In the long term study, most of the traits that were responsive were considered to be dominantly controlled by temperature (Table 1, 35/45 traits, 78%). This differs from the findings in Hollister et al. 2005b, which found that only 46% of responsive traits were dominantly controlled (Table 1, 12/26 traits). Overall, 35 of 61 traits (Table 1, 57%) changed response types between the short-term and long-term analysis. This supports the findings of previous studies showing that even within the same research sites, the response to warming can vary over time (Hollister et al. 2005a). Only 1 of the 45 responsive traits in the long term study was classified as a negative response (Table 1, 2%), indicating that graminoids tend to respond positively to warming.

Previously, there were no apparent patterns of plant response among growth forms (Hollister et al. 2005b). However, in the long-term study, grasses and sedges had a higher proportion of traits respond to temperature (Table 1, 17/22 traits, 77% and 16/18 traits, 89%, respectively) than did rushes (Table 1, 12/22 traits, 55%). This indicates that rushes may be less responsive to changing temperature than grasses and sedges. The Atqasuk dry heath had the lowest proportion of responsive traits (Table 1, 50%, 5/10 traits), while the Atqasuk wet meadow had the highest (Table 1, 11/13 traits, 85%). The Barrow dry heath and Barrow wet meadow had a similar amount of traits respond to temperature (Table 1, 9/12 traits, 75% and 20/27 traits, 74%,respectively). This may indicate that in a naturally warmer area, where temperature is less limiting, there is more variation in response between habitat types. Overall, this study indicates that graminoids tend to respond consistently to temperature, and generally have a positive response. However, variation can still be seen between growth forms, sites, and over time.

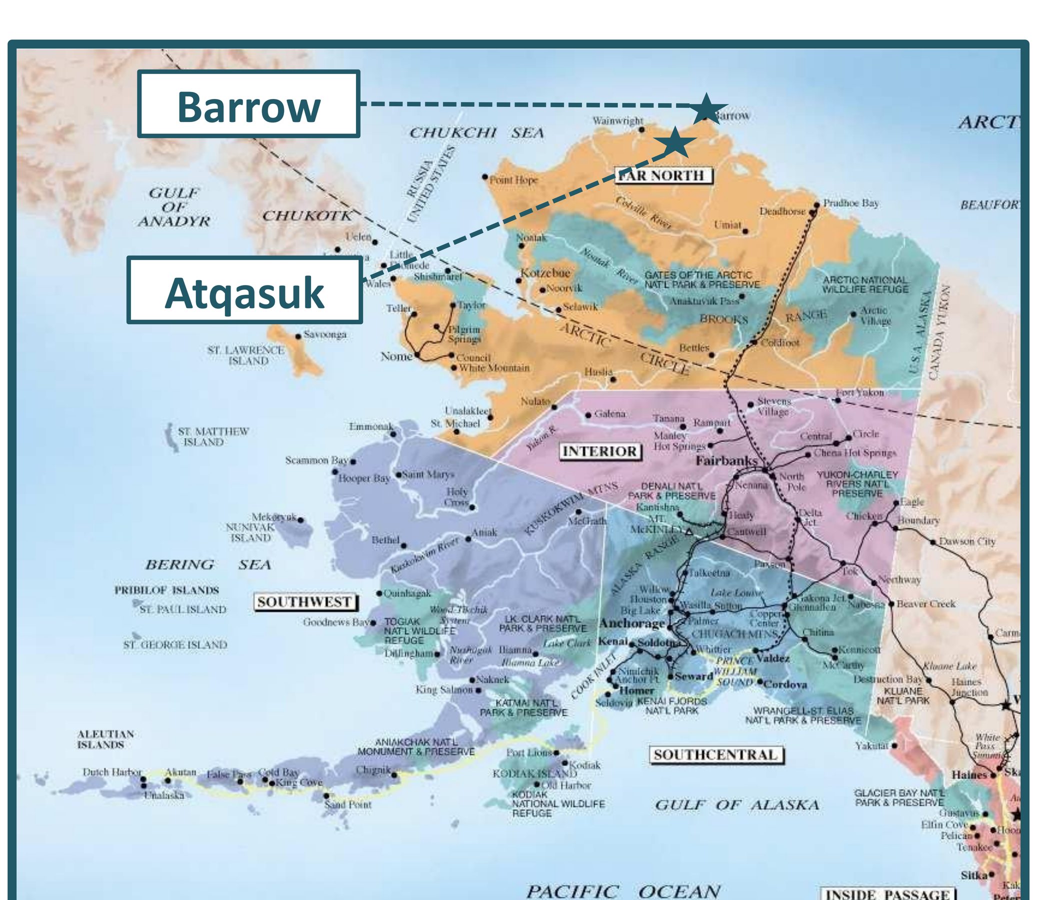

Figure 1 (Left): Location of study sites at Barrow and Atqasuk, Alaska

Figure 2 (Below): Open-top chamber used to warm experimental plots

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