Reproductive Responses of Arctic Plants to Temperature Variation

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Introduction

Climate Change and the Arctic

While Global Climate Change is predicted to severely impact the vast majority of earth's ecosystems, it is believed that the Arctic (**Figure 1**) is one of the most vulnerable for the reasons listed below.

- The Arctic is warming at a greater rate than any other biome on earth (IPCC 2007)

- The Arctic is predicted to warm a greater amount than any other biome on earth (IPCC 2007)

-Warming has & will continue to drastically affect Arctic organisms, which are adapted to cold climates (ACIA 2004)

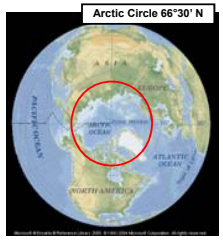

Figure 1. View of the World from the North Pole. The Arctic circle is shown in red.

The Importance of Arctic plants

As tundra plants respond to warming, they will alter the Arctic and other ecosystems (ACIA 2004). Some of the main effects are shown in **Figure 2**.

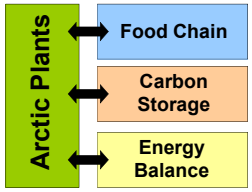

Figure 2. The role of Arctic plants in local & global processes. Arrows illustrate direction of impact. Changes in production of flowers and leaves will directly impact herbivores, indirectly affecting carnivores (Food Chain). As plants grow they sequester carbon in their tissues (Carbon Storage) and absorb more heat & warm the area around them (Energy Balance).

Methods

Chambers

One widely used technique for predicting plant responses to climate change is to artificially warm them using a fiberglass chamber (**Figure 3**). Chambers allow light to pass through while trapping heat (like a greenhouse).

Figure 3. An Open Top Chamber in the tundra at Barrow, Alaska.

Study Sites

This study looked at plant responses at field sites in Barrow and Atqasuk, Alaska, over the course of over 10 years. Within Barrow and Atqasuk there are two sub-sites: One in a dry heath and one in a wet meadow. At each sub-site there are 24 control plots and 24 chambered plots (**Figure 4).**

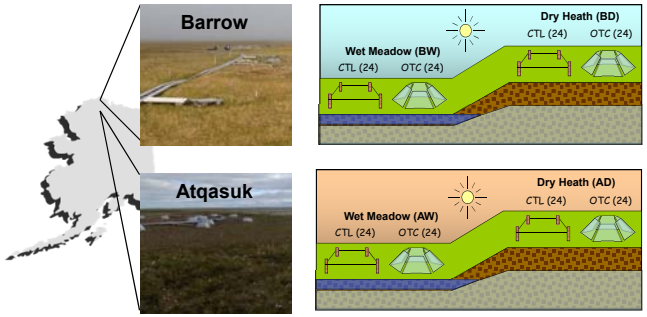

Figure 4. Experimental setup at field sites in Barrow and Atqasuk, Alaska. Plots were either chambered (OTC) or left alone (CTL).

Thawing Degree Days

Temperature data was converted into Thawing Degree Days from Snowmelt (TDD_{sm}) to show heat experienced over the season. To calculate TDD_{sm}, temperatures above 0°C are added together over time, starting at 0 TDD_{sm} on the first day the site is snow free. In the example to the right (**Figure 5**) average daily temperature is used to calculate TDD_{sm}. However, this study used average hourly temperature, meaning that even a cold day could have produced TDD_{sm}.

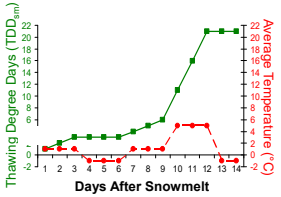

Figure 5. Converting temperature into Thawing Degree Days from Snowmelt (TDD_{sm}). Average Temperature is shown in red while TDD_{sm} is shown in green. Note that temperatures below 0°C are not figured into TDD_{sm} calculations.

Collecting Data

The height and flowering of Arctic plants are generally the most responsive traits to temperature (Arft et al 1999, Hollister et al 2005). After snowmelt, the growth & development of plants in the study sites was observed. Up to 3 individuals of each species were followed in each plot throughout the season. Data collection methods are depicted in **Figure 6**.

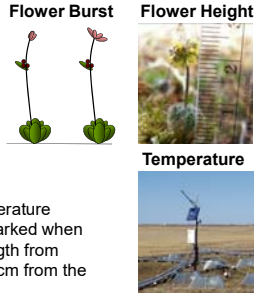

Figure 6. Flower burst, Flower Height, and Temperature measurements at field sites. Flower Burst was marked when petals opened. Flower Height was defined as length from ground to tip. Temperature data was collected 13cm from the ground using probes and data loggers.

Statistical Analysis

Linear regressions (SAS v 9.1) were done on trait vs temperature data for both treatments. Data were averaged for each species in each plot, site, and year. Treatments were separated to determine treatment effect and combined to determine temperature effect.

Results/Discussion

Flower Height

Response to temperature was examined in 37 species total. Overall, 62% of species responded to temperature and 74% of these showed no treatment effect (**Figure 7**). The other 38% of species did not respond to temperature and 85% of these showed no treatment effect (**Figure 7**). The small proportion of species that showed a treatment effect indicates that chambers may be producing some undesired effects.

Flower Burst Date

Reponse to temperature was examined for 42 species total. Overall, 52% of species responded to temperature and 95% of these showed no treatment effect (**Figure 8**). The other 48% of species showed no response to temperature and 95% of these showed no treatment effect (**Figure 8**). The small proportion of species that showed a treatment effect indicates that chambers relatively few undesired effects.

Sources & Acknowledgements

ACIA 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press.

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Hollister, R.D., P.J. Webber, and C.E. Tweedie. 2005. The response of Alaskan arctic tundra to experimental warming: Differences between short- and long-term responses. Global Change Biology 11(4): 525-536. Hollister, R.D. and P.J. Webber 2000. Biotic validation of small open-top chambers in a tundra ecosystem. Global Change Biology 6(7): 835-842.

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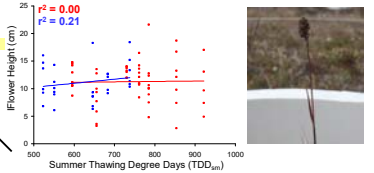
Site	Species	Temp	Treat
AW	Eriophorum russeolum	N	Y
AD	Luzula confusa	N	Y
BD	Saxifraga foliolosa	N	N
BD	Draba lactea	N	N
BD	Draba micropetela	N	N
AW	Dupontia psilosantha	N	N
AD	**Luzula arctica**	**N**	**N**
AD	Polygonum bistorta	N	N
BW	Eriophorum russeolum	N	N
AD	Diapensia lapponica	N	N
AW	Carex aquatilis	N	N
AW	Eriophorum angustifolium	N	N
BW	Eriophorum triste	N	N
BW	Hierachloe alpina	N	N
BW	Calamagrostis holmii	Y	Y
BW	Poa arctica	Y	Y
BW	Saxifraga cernua	Y	Y
BD	Luzula arctica	Y	Y
BD	Papaver hultenii	Y	Y
BD	Potentilla hyparctica	Y	Y
BD	Senecio atropurpureus	Y	N
BD	Stellaria laeta	Y	N
BW	Cardamine pratensis	Y	N
BW	Juncus biglumis	Y	N
BW	Luzula arctica	Y	N
BW	Luzula confusa	Y	N
AD	Hierachloe pauciflora	Y	N
BD	Arctagrostis latifolia	Y	N
BD	Poa arctica	Y	N
BW	Carex stans	Y	N
BW	Draba lactea	Y	N
BW	Saxifraga foliolosa	Y	N
BW	**Saxifraga hieracifolia**	**Y**	**N**
BW	Saxifraga hirculus	Y	N
BW	Dupontia fisheri	Y	N
BD	Luzula confusa	Y	N
BD	Saxifraga punctata	Y	N

Example of 38% of species that did not respond to temp.

Luzula arctica



Example of 62% of species that responded to temp.

Saxifraga hieracifolia

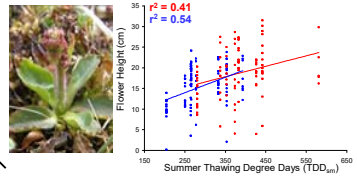
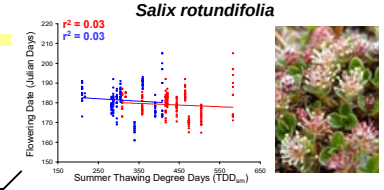


Figure 7. Flower height responses to seasonal TDD_{sm} (Temp.) and chambers (Treat.) by site (AW = Atqasuk Wet, AD = Atqasuk Dry, BW = Barrow Wet, and BD = Barrow Dry). Species that responded to Temp. or Treat. are marked with a "Y". *Luzula arctica* from the Atqasuk Dry site and *Saxifraga hieracifolia* from the Barrow Wet Site are shown and represent the two major responses to warming. Chamber treatments are shown in red and control in blue.

Site	Species	Temp	Treat
BD	Arctagrostis latifolia	N	Y
AD	Cassiope tetragona	N	N
BW	Luzula arctica	N	N
BW	Saxifraga cernua	N	N
BD	Senecio atropurpureus	N	N
AW	Dupontia psilosantha	N	N
BD	Poa arctica	N	N
BD	**Salix rotundifolia (M)**	**N**	**N**
AD	Luzula arctica	N	N
BD	Draba lactea	N	N
BW	Stellaria laeta	N	N
BD	Salix rotundifolia (F)	N	N
AD	Polygonum bistorta	N	N
BD	Draba micropetela	N	N
AW	Eriophorum angustifolium	N	N
BW	Juncus biglumis	N	N
BD	Luzula arctica	N	N
BW	Poa arctica	N	N
AW	Eriophorum russeolum	N	N
AD	Hierachloe alpina	N	N
BW	Hierachloe pauciflora	Y	Y
BW	Cardamine pratensis	Y	N
BW	**Carex stans**	**Y**	**N**
BD	Stellaria laeta	Y	N
BW	Dupontia fisheri	Y	N
AW	Carex aquatilis	Y	N
BW	Saxifraga foliolosa	Y	N
BW	Saxifraga hirculus	Y	N
BW	Saxifraga hieracifolia	Y	N
BD	Potentilla hyparctica	Y	N
AD	Ledum palustre	Y	N
BW	Draba lactea	Y	N
BW	Eriophorum russeolum	Y	N
BD	Cassiope tetragona	Y	N
BD	Luzula confusa	Y	N
AD	Diapensia lapponica	Y	N
BW	Eriophorum triste	Y	N
AD	Vaccinium vitis-idaea	Y	N
AD	Luzula confusa	Y	N
BD	Papavel hultenii	Y	N
BD	Saxifraga punctata	Y	N
BW	Luzula confusa	Y	N

Example of 48% of species that did not respond to temp.

Salix rotundifolia



Example of 52% of species that responded to temp.

Carex stans

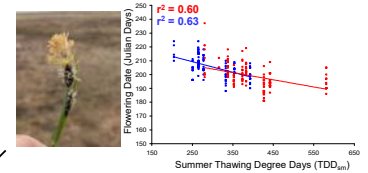


Figure 8. Flower burst responses to seasonal TDD_{sm} (Temp.) and chambers (Treat.) by site (AW = Atqasuk Wet, AD = Atqasuk Dry, BW = Barrow Wet, and BD = Barrow Dry). Species that responded to Temp. or Treat. are marked with a "Y". *Salix rotundifolia (male)* from the Barrow Dry site and *Carex stans* from the Barrow Wet Site are shown on the right and represent the two major responses to warming. Chamber treatments are shown in red and control in blue.