Examining Plant Traits as Drivers of Vegetation Change in Tundra Communities

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Introduction

Nearly all climate change scenarios predict that the greatest warming resulting from climate change will be in the Arctic. Low temperature is one of the greatest limiting factors to plant growth and reproduction in Arctic regions, so a rise in temperature is expected to impact plant community structure. The International Tundra Experiment (ITEX) uses open-top chambers to achieve experimental warming in small plots to study how tundra plants respond to an increase in temperature. Previous studies have shown that, in general, arctic plants respond to warming with increased growth and reproductive effort as well as earlier phenological development (Oberbauer et al. 2013, Barrett et al. 2015). Graminoids and shrubs have shown the strongest responses to warming with drastic increases in vegetative height and cover (Hollister et al. 2015). While these general trends have been observed, it is unclear why these particular growth forms are performing better with warming than others. Other studies have indicated that plant functional traits will be good predictors of changes in vegetation cover (Hudson et al. 2011, Soudzilovskaia et al. 2013). This study examined the plant traits (plant height, carbon:nitrogen ratio, leaf dry matter content (LDMC), leaf carbon content, leaf nitrogen content, leaf phosphorous content, dry seed mass, and specific leaf area (SLA)) and correlated them with changes in vegetative cover to see whether any show promise as potential cover change drivers.

Methods

The research sites were established in 1995 at Utqiaġvik, Alaska (Fig 1A). The Utqiaġvik Dry (BD) site is situated on a well-drained beach ridge and the Utqiaġvik Wet (BW) site is situated between the beach ridge of the dry site and a drained lake basin. Each site contains 24 control plots and 24 experimental plots fitted with fiberglass open-top chambers (OTCs) that raised the ambient air temperature 1°C to 3 °C (Fig 1B). Cover data was collected using a non-destructive point frame method as outlined in the ITEX Manual (Molau and Mølgaard, 1996) (Fig 1C). Data was grouped into growth forms for analysis. Plant trait data was obtained from the Tundra Trait Team (2018) and correlated with the change in cover between the first sampling and the last sampling.

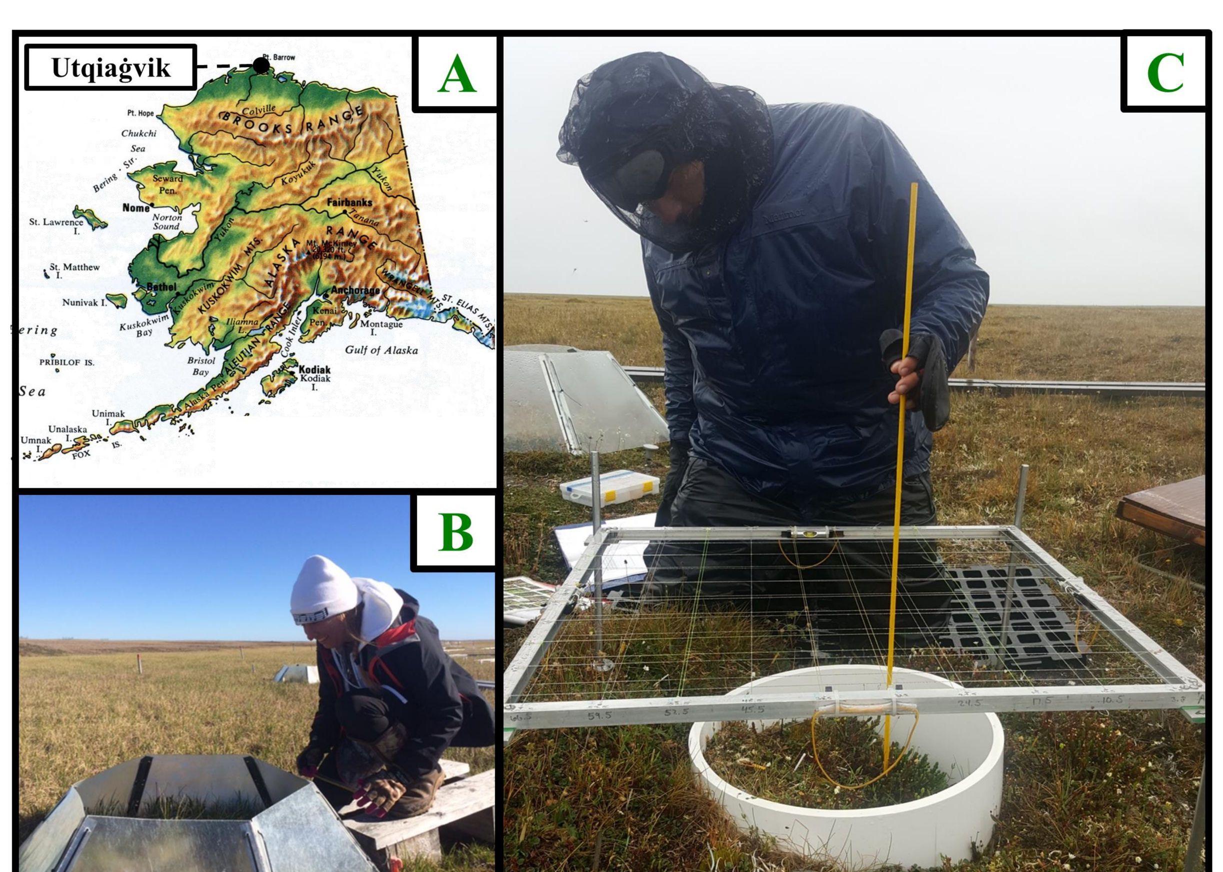

Fig 1A: Location of study site in Utqiaġvik, Alaska. B: Working at the Utqiaġvik Wet site over an OTC. C: Point framing at the Utqiaġvik Dry site.

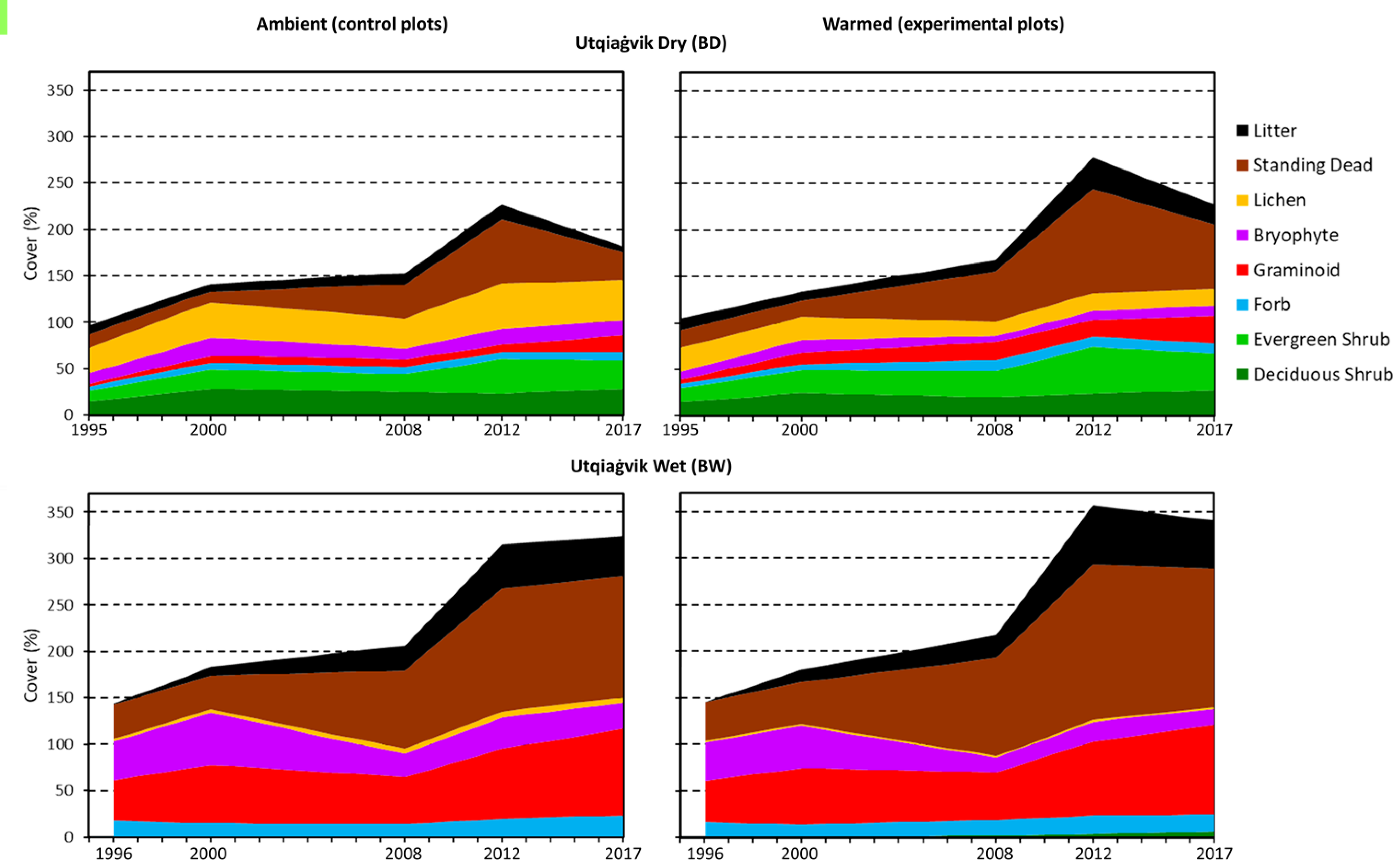

Fig 2: Changes in cover over time and with experimental warming at the Utqiaġvik study sites. Years sampled are shown on the axis.

Table 1: Change in plant cover with five samplings over time and with response to warming at the Utqiaġvik dry (BD) and Utqiaġvik wet (BW) study sites. The average cover is presented at each sampling for the control (C1, C2, C3, C4, and C5) and experimentally warmed (E1, E2, E3, E4, and E5) plots. The difference in cover between the control and experimental plots is also presented (W1, W2, W3, W4, and W5). The change in cover for each treatment is characterized as no change (.), inconsistent change (I), and cumulative directional change (D^+ – increase, D^- – decrease); responses to warming could also be categorized in relation to the control plots as a consistent change (C^+ – increase, C^- – decrease) and a cumulative directional change observed only in relation to the control plots is indicated with italics.

Taxa	C1	C2	C3	C4	C5		E1	E2	E3	E4	E5		W1	W2	W3	W4	W5
Utqiaġvik dry (BD) site																	
Deciduous Shrub	**15.0**	**28.5**	**24.5**	**23.0**	**28.3**	**I**	**14.9**	**24.3**	**20.0**	**24.1**	**27.2**	**.**	**-0.1**	**-4.2**	**-4.4**	**1.1**	**-1.2**
Salix rotundifolia	15.0	28.5	24.5	23.0	28.3	I	14.9	24.3	20.0	24.1	27.2	.	-0.1	-4.2	-4.4	1.1	-1.2
Evergreen Shrub	**11.4**	**20.4**	**19.5**	**37.1**	**30.3**	D^+	**15.2**	**24.8**	**27.7**	**50.2**	**40.2**	C^+	**3.8**	**4.4**	**8.2**	**13.0**	**9.9**
Cassiope tetragona	11.3	19.8	19.4	36.8	30.1	I	15.2	24.8	27.7	50.2	40.2	C^+	3.9	5.0	8.3	13.3	10.1
Vaccinium vitis-idaea	0.1	0.5	0.1	0.3	0.2	.	0.0	0.0	0.0	0.0	0.0	.	-0.1	-0.5	-0.1	-0.3	-0.2
Forb	**4.5**	**7.7**	**7.7**	**7.6**	**9.2**	D^+	**4.3**	**6.6**	**12.3**	**11.3**	**10.6**	**.**	**-0.3**	**-1.0**	**4.6**	**3.7**	**1.5**
Saxifraga punctata	0.3	1.3	1.8	1.3	2.2	I	0.6	0.8	1.9	1.4	2.1	.	0.3	-0.5	0.1	0.2	-0.1
Senecio atropurpurous	0.3	0.3	0.0	0.1	0.2	.	0.3	0.6	0.0	0.1	0.2	.	0.0	0.3	0.0	0.0	0.0
Stellaria laeta	1.6	3.0	1.5	1.5	2.5	I	1.0	2.8	3.7	3.0	3.0	C^+	-0.6	-0.1	2.2	1.5	0.5
Graminoid	**3.0**	**7.3**	**8.2**	**8.0**	**18.0**	D^+	**4.5**	**12.3**	**19.6**	**17.7**	**29.4**	D^+	**1.4**	**5.0**	**11.4**	**9.7**	**11.4**
Alopecurus alpinus	0.1	0.0	0.3	0.3	0.5	.	0.3	1.1	0.1	0.9	1.5	C^+	0.2	1.1	-0.1	0.6	1.0
Arctagrostis latifolia	0.8	2.1	1.4	1.1	2.8	.	1.0	3.1	3.5	2.1	6.6	C^+	0.3	1.0	2.1	1.0	3.9
Carex aquatilis	0.0	0.2	0.1	0.2	0.8	.	0.6	0.8	2.2	1.7	5.1	C^+	0.5	0.6	2.1	1.5	4.4
Luzula arctica	0.2	0.3	0.3	0.3	0.1	.	0.5	0.7	0.6	0.8	0.4	C^+	0.3	0.4	0.3	0.4	0.3
Luzula confusa	1.3	3.0	4.2	2.7	4.9	I	1.3	2.8	5.5	3.0	4.2	.	0.0	-0.2	1.3	0.4	-0.7
Poa arctica	0.5	1.6	2.0	3.0	8.5	I	0.6	3.8	7.7	9.1	11.3	I	0.2	2.1	5.7	6.1	2.8
Bryophyte	**11.0**	**19.8**	**11.8**	**17.5**	**16.8**	**I**	**8.4**	**13.8**	**6.3**	**9.6**	**11.5**	C^-	**-2.6**	**-6.0**	**-5.5**	**-7.9**	**-5.3**
Acrocarpous Moss	7.5	11.8	7.7	8.0	8.5	I	5.4	9.6	3.6	5.8	7.2	C^-	-2.1	-2.2	-4.1	-2.3	-1.3
Pleurocarpous Moss	2.0	5.7	3.1	9.0	7.7	I	1.3	3.2	2.1	3.5	3.8	C^-	-0.7	-2.5	-1.0	-5.4	-4.0
Lichen	**27.0**	**37.9**	**32.5**	**48.4**	**42.7**	**I**	**25.8**	**24.7**	**15.9**	**19.6**	**18.0**	**I**	**-1.3**	**-13.2**	**-16.6**	**-28.8**	**-24.7**
Crustose Lichen	3.0	3.1	0.5	1.1	0.5	I	3.0	2.9	0.5	0.8	0.4	.	0.0	-0.2	0.0	-0.4	-0.1
Foliolose Lichen	6.3	8.5	8.5	10.1	10.1	I	6.0	6.0	4.3	5.6	5.0	*D^-*	-0.3	-2.5	-4.3	-4.5	-5.2
Fruticose Lichen	16.7	26.3	23.4	37.2	32.0	I	15.7	15.8	11.1	13.3	12.6	I	-1.0	-10.5	-12.3	-23.9	-19.4
Utqiaġvik wet (BW) site													0.0	0.0	0.0	0.0	0.0
Deciduous Shrub	**0.2**	**0.0**	**0.0**	**0.3**	**1.0**	**I**	**0.3**	**0.7**	**1.8**	**3.8**	**6.1**	D^+	**0.2**	**0.6**	**1.8**	**3.5**	**5.1**
Salix pulchra	0.0	0.0	0.0	0.0	0.0	.	0.0	0.0	0.1	0.3	0.8	.	0.0	0.0	0.1	0.3	0.8
Salix rotundifolia	0.2	0.0	0.0	0.3	1.0	I	0.3	0.7	1.7	3.5	5.4	D^+	0.2	0.6	1.7	3.2	4.4
Forb	**17.8**	**14.6**	**14.0**	**19.1**	**22.3**	**.**	**15.6**	**13.1**	**16.5**	**19.5**	**18.2**	**.**	**-2.2**	**-1.5**	**2.5**	**0.4**	**-4.1**
Petasites frigidus	0.2	0.1	0.7	1.1	1.4	.	0.3	0.5	0.4	0.5	0.4	.	0.1	0.4	-0.3	-0.6	-1.0
Ranunculus nivalis	0.0	0.1	1.1	0.0	0.1	I	0.0	0.0	0.4	0.0	0.0	.	0.0	-0.1	-0.7	0.0	-0.1
Stellaria laeta	3.9	2.1	2.4	2.8	4.6	I	3.6	3.1	2.2	2.9	4.0	.	-0.3	1.0	-0.2	0.1	-0.6
Graminoid	**43.3**	**63.0**	**50.6**	**75.6**	**93.6**	D^+	**44.4**	**60.4**	**51.3**	**80.0**	**96.6**	**.**	**1.1**	**-2.5**	**0.7**	**4.5**	**3.0**
Carex aquatilis	17.0	12.7	23.2	26.3	44.5	I	23.0	16.3	32.3	37.9	51.5	C^+	6.0	3.6	9.1	11.7	7.0
Eriophorum angustifolium	9.7	19.0	5.8	12.8	10.6	I	8.4	18.6	4.6	12.6	9.9	.	-1.3	-0.4	-1.2	-0.1	-0.7
Luzula arctica	0.2	0.2	0.3	0.3	0.5	.	0.2	0.1	0.1	0.2	0.2	I	0.0	0.0	-0.2	-0.1	-0.4
Luzula confusa	0.2	0.0	0.0	0.4	0.5	.	0.2	0.1	0.4	0.2	0.4	.	0.0	0.1	0.4	-0.2	-0.1
Poaceae spp.	2.8	11.3	5.3	9.5	13.8	I	2.2	11.8	3.2	10.4	11.4	.	-0.6	0.5	-2.2	0.9	-2.4
Bryophyte	**42.0**	**56.4**	**25.1**	**34.0**	**27.6**	**I**	**42.0**	**45.6**	**16.1**	**20.7**	**17.5**	C^-	**0.0**	**-10.8**	**-9.0**	**-13.3**	**-10.1**
Acrocarpous Moss	17.2	25.1	9.1	16.4	8.3	I	16.5	20.6	7.4	10.8	6.4	C^-	-0.7	-4.5	-1.7	-5.6	-2.0
Pleurocarpous Moss	20.5	27.0	14.6	16.8	18.1	.	21.2	20.9	7.3	9.3	10.0	C^-	0.7	-6.1	-7.2	-7.5	-8.1
Lichen	**2.5**	**3.3**	**5.5**	**6.0**	**6.1**	**.**	**1.8**	**1.8**	**1.8**	**1.9**	**1.1**	*D^-*	**-0.8**	**-1.5**	**-3.8**	**-4.2**	**-5.0**
Foliolose Lichen	2.5	3.3	5.5	6.0	5.3	.	1.6	1.7	1.7	1.8	0.8	*D^-*	-0.9	-1.6	-3.8	-4.2	-4.5
Fruticose Lichen	0.0	0.0	0.0	0.1	0.8	I	0.2	0.0	0.1	0.1	0.3	.	0.2	0.0	0.0	0.0	-0.5

Table 2: Measurements of plant traits for each species at the Utqiaġvik Dry (BD) and Utqiaġvik Wet (BW) study sites. Traits measured include plant height (cm), carbon to nitrogen ratio (C:N Ratio), leaf dry matter content (LDMC; ratio), leaf carbon content (Leaf C; mg g^{-1}), leaf nitrogen content (Leaf N; mg g^{-1}), leaf phosphorous content (Leaf P; mg g^{-1}), dry seed mass (mg), and specific leaf area (SLA; mm^2 mg^{-1}). Plant height measurements are site specific. All other measurements are averages across multiple sites (Bjorkman et al. 2018).

Taxa	Plant Height	C:N Ratio	LDMC	Leaf C	Leaf N	Leaf P	Seed Mass	SLA
Utqiaġvik Dry (BD)								
Evergreen Shrub	**4.03**	**45.83**	**0.55**	**513.14**	**11.64**	**1.13**	**0.79**	**6.51**
Cassiope tetragona	7.07	48.91	0.59	533.71	11.64	1.15	1.35	5.54
Vaccinium vitis-idaea	1.00	42.76	0.51	492.58	11.64	1.10	0.23	7.48
Forb	**2.78**	**24.04**	**0.23**	**421.00**	**17.63**	**1.67**	**0.49**	**14.08**
Saxifraga punctata	3.88	24.04	-	421.00	17.63	1.67	-	-
Senecio atropurpureus	1.40	-	0.23	-	-	-	0.93	12.73
Stellaria laeta	3.08	-	-	-	-	-	0.04	15.43
Graminoid	**6.03**	**30.91**	**0.52**	**484.79**	**11.34**	**-**	**0.13**	**13.58**
Alopecurus alpinus	7.30	-	0.51	-	7.17	-	-	9.72
Arctagrostis latifolia	7.44	-	0.43	-	9.53	-	0.04	12.91
Carex aquatilis	8.89	-	0.62	-	-	-	-	18.28
Luzula arctica	1.39	-	0.53	-	-	-	0.16	15.47
Luzula confusa	5.09	30.91	-	484.79	17.32	-	0.20	-
Poa arctica	6.04	-	-	-	-	-	-	11.54
Utqiaġvik Wet (BW)								
Deciduous Shrub	**7.33**	**28.33**	**0.56**	**436.68**	**17.30**	**2.05**	**-**	**12.62**
Salix pulchra	7.33	28.33	0.56	436.68	17.30	2.05	-	12.62
Forb	**3.22**	**28.61**	**0.19**	**447.77**	**30.93**	**2.68**	**0.26**	**22.11**
Petasites frigidus	2.98	28.61	0.24	441.37	20.48	1.44	0.47	15.07
Ranunculus nivalis	2.11	-	0.14	454.18	41.38	3.92	-	35.82
Stellaria laeta	4.57	-	-	-	-	-	0.04	15.43
Graminoid	**8.54**	**30.91**	**0.54**	**486.71**	**18.91**	**2.20**	**0.21**	**13.90**
Carex aquatilis	13.84	-	0.62	-	-	-	-	18.28
Eriophorum angustifolium	9.61	-	0.49	488.63	20.50	2.20	0.26	10.32
Luzula arctica	3.66	-	0.53	-	-	-	0.16	15.47
Luzula confusa	7.80	30.91	-	484.79	17.32	-	0.20	-
Poa arctica	7.82	-	-	-	-	-	-	11.54

Table 3: Correlations of selected plant traits with vegetative cover change. R^2 values are presented with an asterisk for significance ($R^2 > 0.6$).

Site	Plant Height	C:N Ratio	LDMC	Leaf C	Leaf N	Leaf P	Seed Mass	SLA
Utqiaġvik	**0.45**	**0.72** *	**0.32**	**0.63** *	**-0.22**	**-0.39**	**0.73** *	**-0.16**
Utqiaġvik Dry (BD)	0.45	0.67 *	0.41	0.74 *	-0.26	-0.43	0.72 *	-0.42
Utqiaġvik Wet (BW)	0.53	-0.69 *	0.28	0.06	0.07	-0.43	0.31	0.07

Results & Discussion

At the Utqiaġvik Dry site, evergreen shrubs and graminoids are increasing in cover and bryophytes are decreasing in cover. At the Utqiaġvik Wet site, deciduous shrubs and graminoids are increasing in cover and bryophytes are decreasing in cover (Fig. 2; Table 1). However, not all of these trends are consistent in response to experimental warming. We examined eight different plant traits to see if they could help explain why some species change while others do not (Table 2). We correlated these traits with the change in vegetative cover from the first sampling to the last sampling. C:N ratio was the only significant trait at the BW site. Leaf carbon content and dry seed mass were significant at both the BD and BW sites (Table 3). However, when we combined the two Utqiaġvik sites C:N ratio, leaf carbon content, and dry seed mass all showed potential as cover change drivers. This is most likely due to a small sample size. We suspect that as gaps in the dataset are filled, more traits will show stronger correlations with cover change. We hope that future studies will help us better understand which species will become dominant as the region continues to warm.

Acknowledgements:

I would like to thank the National Science Foundation (NSF) for providing funding, UMIAQ for logistical support, and all members of the GVSU Arctic Ecology Program (AEP) for data collection, analysis, and inspiration. I would like to especially thank Jacob Harris, Jeremy May, Hana Christoffersen, and Kailey Keenan-Whittemore for their help and support.

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