Linking Vegetation Change with Functional Traits in a Changing Arctic

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Introduction

The Arctic is the fastest warming biome in the world, with average temperatures increasing twice the rate of the global average (IPCC 2018). Plant communities are particularly sensitive to changes in temperature, and this effect is exaggerated in the Arctic where a short growing season and low average temperatures severely limit plant growth. Many studies have documented changes in community composition in the Arctic with increases in evergreen shrubs, deciduous shrubs, and graminoids and decreases in bryophytes and lichens being the most consistent trends across sites (Elmendorf et al. 2012; Hollister et al. 2015). Recent studies have documented shifts in plant performance with increased climate warming, causing plant functional traits to become increasingly popular in recent years to study vegetation responses to changing environmental conditions (Hudson et al. 2011; Bjorkman et al. 2018). Plant functional traits strongly correlate with ecosystem functioning which further impact climate changes (Cornelissen et al. 2007; Pearson et al. 2013). In this study we examine 10 functional traits related to plant size and leaf economics across three sites in northern Alaska (Fig 1). We aim to 1) determine whether there is a direct relationship between shifts in species abundances and specific trait values and 2) assess whether community-weighted trait mean values are shifting with species cover over time.

Fig 1: Location of study sites near Utqiaġvik, Atqasuk, and Toolik Lake, Alaska.

Materials and Methods

Study sites are arranged along a latitudinal gradient on the North Slope of Alaska. Cover was estimated for 30 plots at each site using the non-destructive point frame method outlined in the ITEX Manual (Molau and Mølgaard, 1996) (Fig 2). Samplings took place three times over a 10-year period (2008-2018). Ten functional traits were measured on 10 individuals for 12 species across the three sites: **plant height** (*cm*), **leaf area** (cm^2), specific leaf area (**SLA**; cm^2/mg), water band index (**WBI**), normalized difference vegetation index (**NDVI**), **leaf thickness** (*mm*), leaf dry matter content (**LDMC**; *mg/g*), photosynthetic capacity (**A_{max}**; $\mu mol\ CO_2/m^2/sec$), leaf nitrogen content (**Leaf N**; *%*), and carbon to nitrogen ratio (**C:N Ratio**). Traits were collected as outlined by Cornelissen et al. 2003. Community-weighted trait means (**CWM**) were calculated by multiplying the trait mean by the cover of the species and summing each species within a plot according to Duarte et al. 2018. Repeated measures ANOVA were used to identify changes in species cover and shifts in CWM over time.

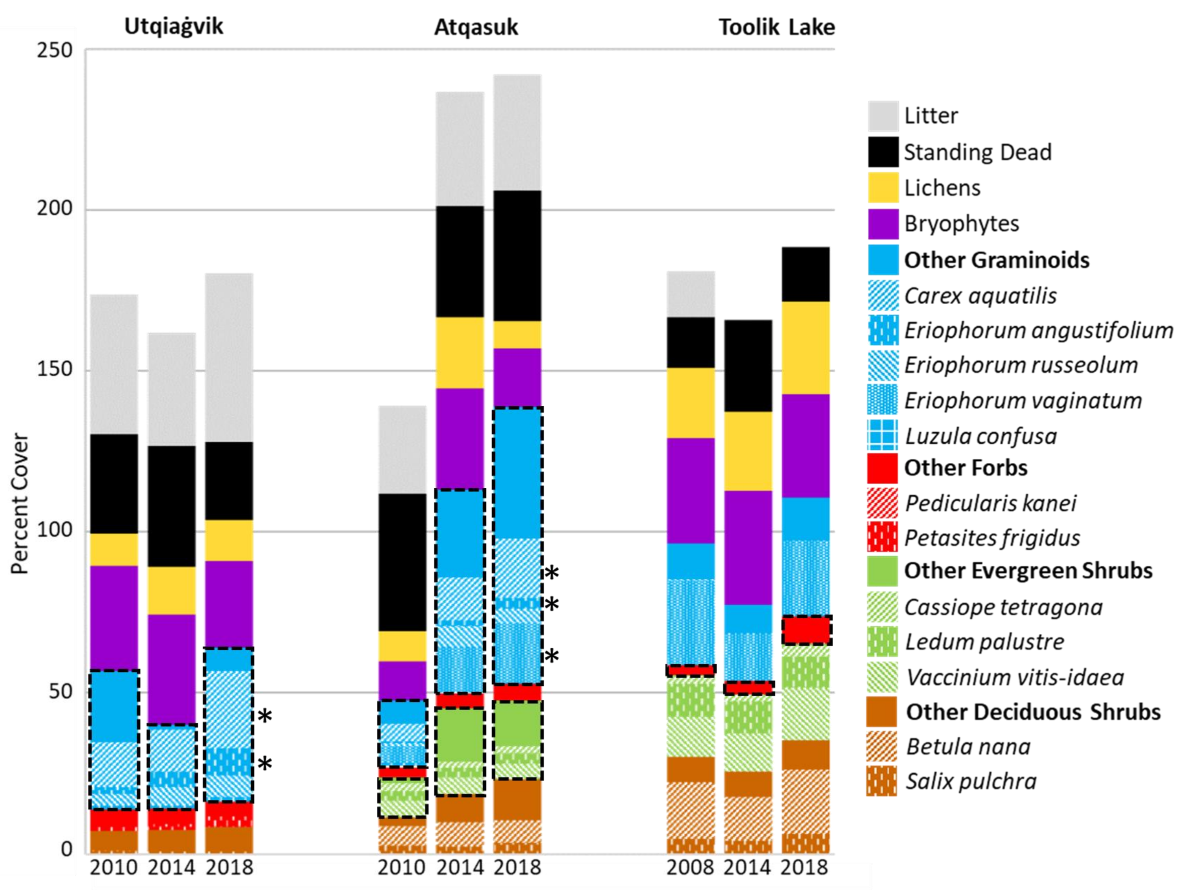

Fig 2: Average cover of sampled species within 30 plots at Utqiaġvik, Atqasuk, and Toolik Lake during each of the three years of sampling used in this analysis. Significant changes in species or growth forms are denoted with asterisks (*) or dashes, respectively.

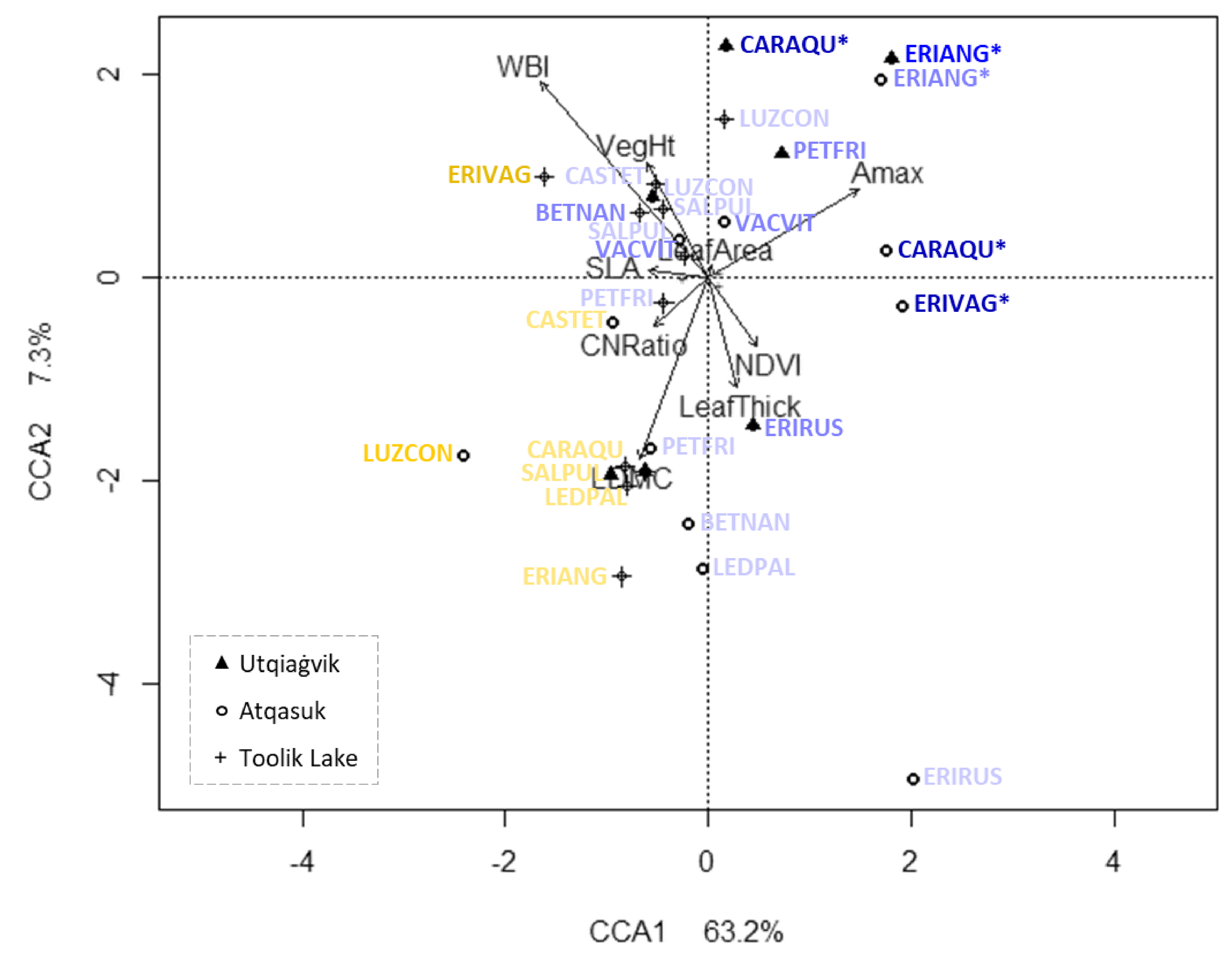

Fig 3: Canonical correspondence analysis (CCA) of average cover values from each year of sampling and average trait values for 12 Arctic plant species. Species codes follow the pattern of *Genus species* = GENSPE. Proportions of unconstrained variation explained are expressed on the axes. Results from post hoc analysis (999 permutations) indicate that the model (p<0.01) and first axis (p<0.01) are significant. Species in blue increased in cover from the first to last sampling with darker shades increasing the most and lighter shades increasing the least. Species in yellow decreased in cover from the first to last sampling. Species that significantly increased (repeated measures ANOVA) are indicated with an asterisk (*).

Results & Discussion

Canonical correspondence analysis (CCA) suggests patterns between change in cover and traits (Fig 3). Leaf N was eliminated from the ordination due to variance inflation with C:N ratio. Significant increases in cover seem to be associated with high A_{max}, particularly at Utqiaġvik and Atqasuk. Decreases in cover seem to be associated with high LDMC. Results from Pearson and Spearman correlations, however, do not support these trends (Table 1). Plant height is negatively correlated and NDVI is positively correlated with change in cover at Toolik Lake, but no correlations were significant at Utqiaġvik or Atqasuk. Utqiaġvik and Atqasuk did, however, show consistent shifts in CWM over time for all traits (Fig 4). These shifts are likely driven by drastic changes in cover by a few dominant species rather than the community as a whole. Therefore, it is important that researchers focus on species specific responses to changing environmental conditions rather than broad functional groups or community types.

Table 1: Pearson or Spearman correlations of average trait values for each species and change in average cover values of that species from first to last sampling at each site. Pearson correlations were used for parametric data and Spearman correlations (in *italics*) were used for nonparametric data. Significant correlations are indicated in bold. Plant height, leaf area, leaf thickness, and leaf dry matter content were log transformed.

	Utqiaġvik	Atqasuk	Toolik Lake	All Sites
Plant Height	*0.194*	*0.455*	**-0.613**	*-0.008*
Leaf Area	*0.169*	*0.077*	-0.198	*-0.057*
SLA	*0.088*	*-0.245*	-0.023	*-0.066*
WBI	*0.125*	*-0.014*	-0.081	*-0.085*
NDVI	*-0.169*	*0.119*	**0.602**	*0.084*
Leaf Thickness	*-0.038*	*-0.021*	-0.169	*0.030*
LDMC	*-0.557*	*-0.028*	0.201	*0.021*
Amax	*0.194*	*0.441*	-0.104	*0.325*
Leaf N	*0.181*	*0.077*	*-0.259*	*0.005*
C:N Ratio	*-0.325*	*-0.077*	*0.336*	*0.016*

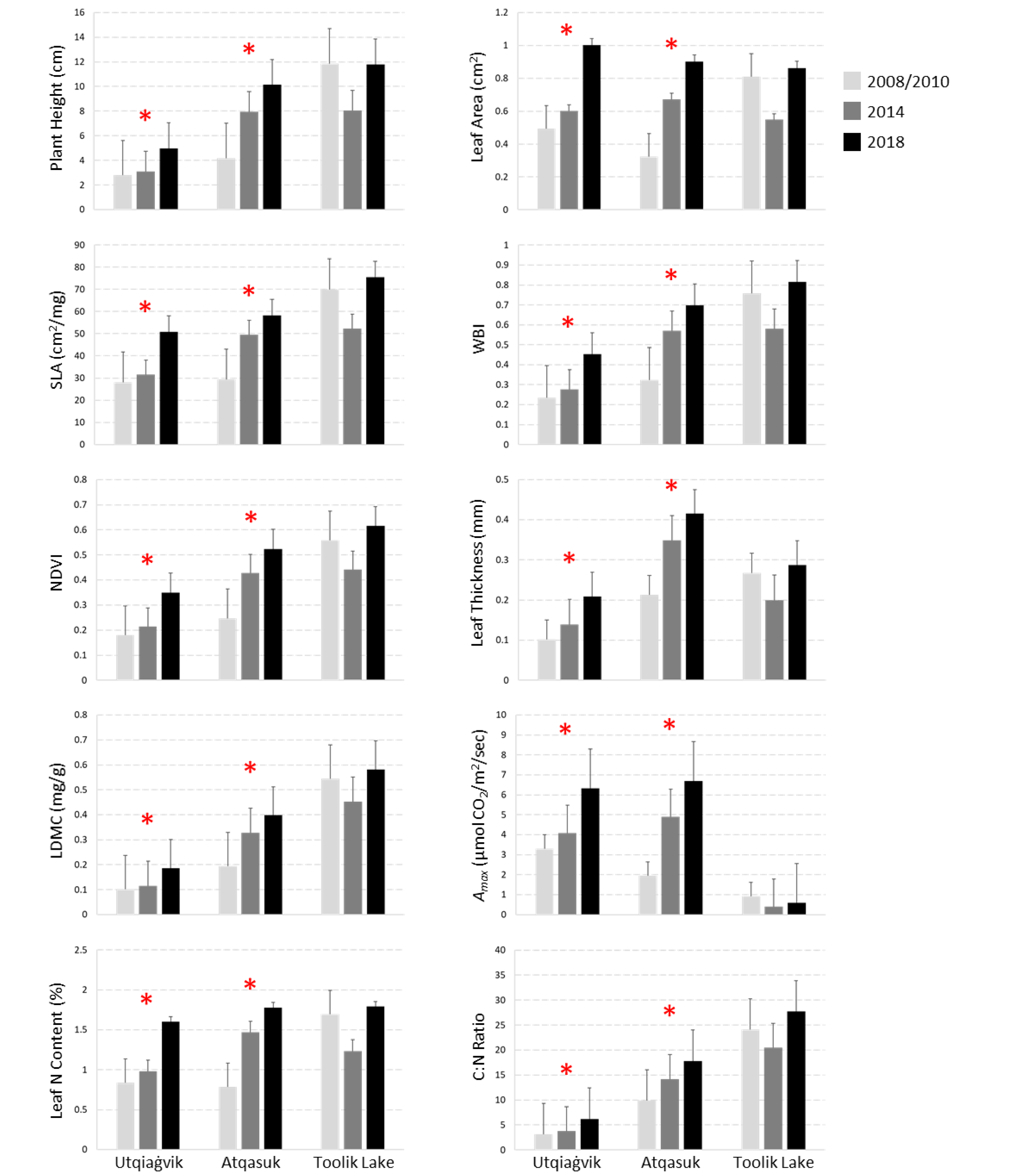

Fig 4: Shifts in **CWM** for 10 different functional traits from first to last sampling at Utqiaġvik, Atqasuk, and Toolik Lake. Sites denoted with a red asterisk (*) have a significant difference in **CWM** between years as a result of repeated measures ANOVA.

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