50 Peaks Project: Quantifying Alpine Plant Morphology in Washington

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INTRODUCTION

Alpine plants are exceptionally diverse and exist at the upper elevational limits of the habitable environment. However, the morphological distinction between alpine and non-alpine plants is poorly understood in Washington. Here, we quantify trait variation in Washington's native Angiosperm flora to determine how alpine plants are morphologically distinct and what patterns drive those differences.

METHODS

The 50 Peaks Project generated species lists for 55 peaks in Washington's Cascade Range. To expand on these data, we created a traits database for Washington's native Angiosperm flora that includes discrete and continuous floral, aboveground, and belowground characters. We used R to calculate a Gower distance matrix for our dataset and performed non-metric multi-dimensional scaling (NMDS) ordinations. We did this for both the entire Washington flora and for Washington Rosaceae to demonstrate how variation trends shift with taxonomic scale. We used permutational multivariate analysis of variance (PERMANOVA) to compute the percent of trait variation explained by alpine status. Additionally, Chi-Squared and Analysis of Variance (ANOVA) tested discrete and continuous variables, respectively, to identify specific traits that vary with alpine status.

DISCUSSION

Alpine status explains a small amount of trait variation on an angiosperm flora scale that may not be biologically significant (Fig. 3). However, when filtered to a family, such as Rosaceae, the R^2 increases, though this is not consistent across all families. These findings support the idea that some taxonomic groups may possess unique suites of morphologically strategies to cope with alpine conditions. More variation may be explained by exploring how non-taxonomic groupings account for traits such as groups of species that indicate a common environmental condition.

Eight categorical traits for both alpine vs non alpine species and alpine generalist vs alpine specialist species were distinct, and five of these traits were common across both comparisons (Fig. 5). Alpine specialists differ in height from both alpine generalists and non alpine species (Fig. 6). These differences in height may explain how alpine generalists may outcompete specialists and point towards the need to develop a better understanding of generalists and specialist population shifts as climate changes in the alpine.

SAMPLING LOCATIONS

Figure 1: Map of 55 peaks surveyed from 2021-2025 for the 50 Peaks Project

Figure 2: Alpine areas on select peaks: (A) Nelson Ridge, (B) Horsehead Pass, (C) Old Snowy Mountain and (D) Hidden Lake Peak North

RESULTS: PERMANOVA

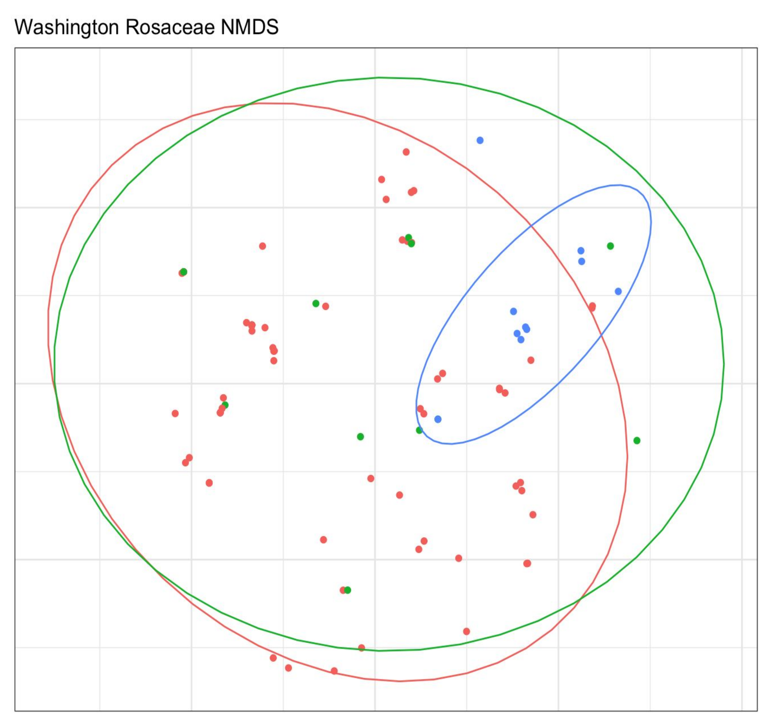

Figure 2: NMDS ordination of Gower distances among Washington's native Rosaceae species. Morphologically similar species are plotted closer together. PERMANOVA shows that alpine status explains 9.50% of trait variation (p = 0.001).

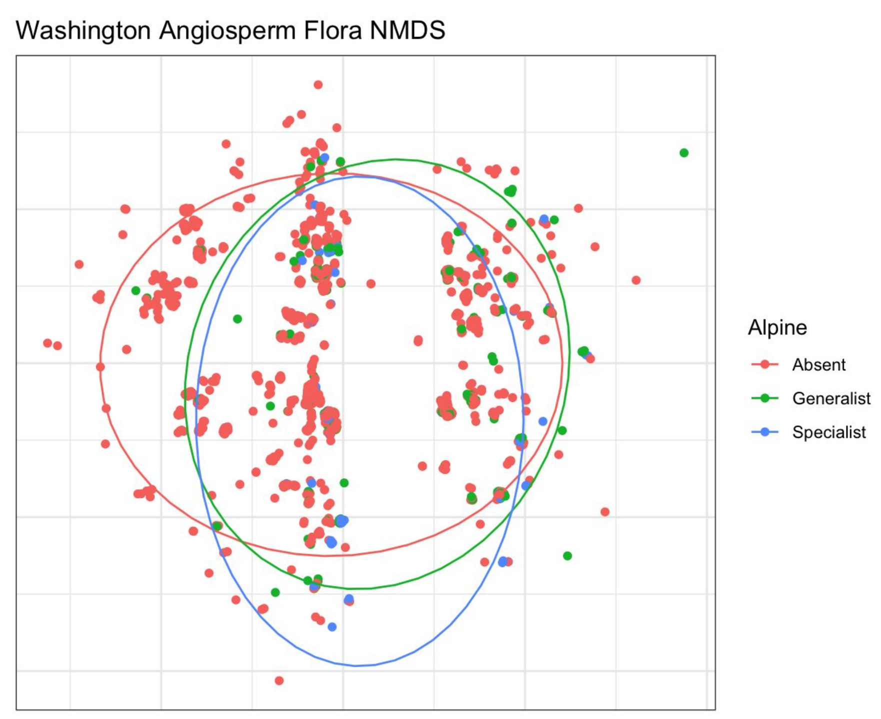

Figure 3: NMDS ordination of Gower distances among entire Washington native flora. Morphologically similar species are plotted closer together. PERMANOVA shows that alpine status explains 2.16% of trait variation (p = 0.001).

RESULTS: CHI SQUARED AND ANOVA

Trait	Significant x^2 in Alpine vs Non- Alpine	Significant x^2 in Specialist vs Generalist
Life cycle	X	
Woodiness		X
Mat/cushion forming	X	X
Belowground storage		
Stolon/rhizome	X	X
Taproot		X
Leaf type	X	
Leaf modification		
Floral symmetry	X	X
Corolla fusion	X	
Ovary position	X	X
Fruit dehiscence		X
Fruits fleshy	X	X
Bulbils		

Figure 5: A chi-squared test of independence on species counts by alpine status for each trait. Significant x^2 value are marked with an "X" and traits that are significant in both comparisons are bolded. Pink traits are restricted to angiosperms.

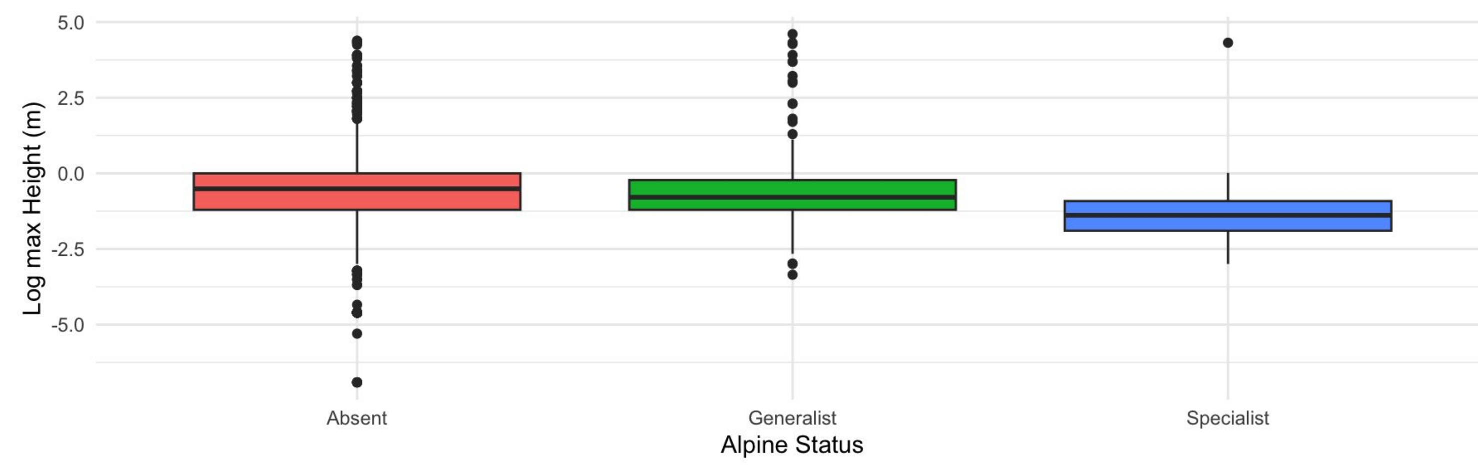

Figure 6: ANOVA of maximum plant height for species of varying alpine status, transformed on log scale. Heights grouped by alpine status are not equal (p < 0.001) and Tukey's test shows specialists differ from non-alpine species (p < 0.0001) and from generalists (p < 0.0001).

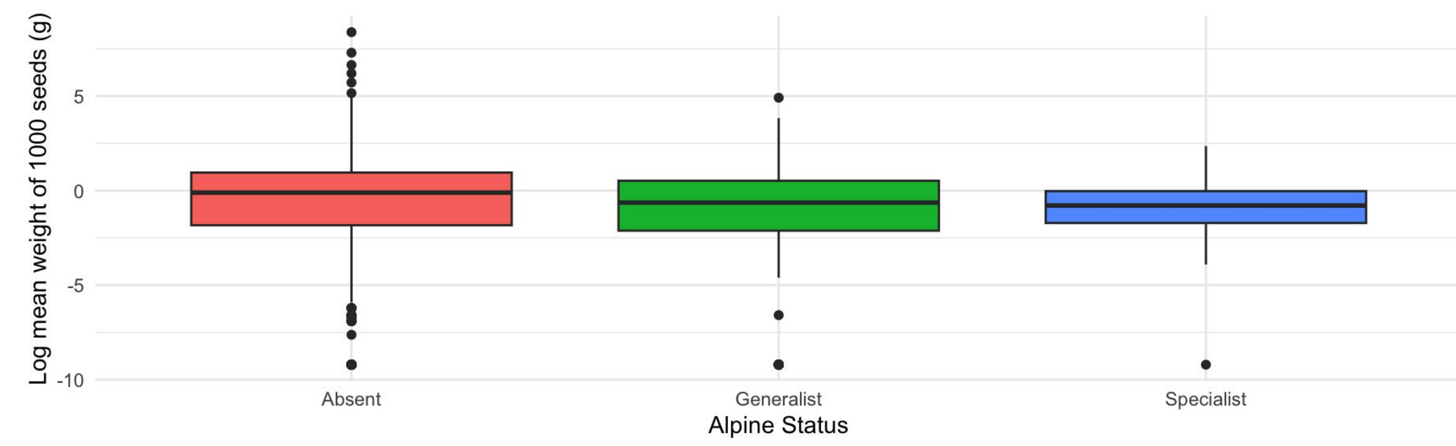

Figure 7: ANOVA of mean weight of 1000 seeds for species of varying alpine status, transformed on log scale. Seed weights grouped by alpine status are not equal (p = 0.007) and Tukey's test shows that alpine generalist differ from absent species. (p = 0.005)

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