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Effects of Microclimate Variation on Diversity of Plants and Pollinators

Abstract

High alpine ecosystems have heterogeneous topography that provides microclimatic niches for species to inhabit. Due to climate change, alpine ecosystems are experiencing shifts in snowpack amount, snowmelt timing, and growing season lengths resulting in phenological and abundance responses within ecosystems. Although previous studies have focused on various microclimatic effects on plant communities, there is less known about the effect of snowmelt timing on floral abundance and pollinator diversity. This study investigates the effects of microclimate variation on diversity of plants and pollinators. We performed plant phenology and pollinator surveys along two established 50 meter transects at our Judd Falls and Snodgrass sites. Each transect was divided into 2 meter by 2 meter plots, which were observed twice a day for plant and pollinator interactions for a duration of 2 minutes. We found that although plant richness was higher on high microclimate heterogeneity transects, observed pollinator richness and floral abundance was not higher on high heterogeneity transects. However, transects with higher floral abundance had higher pollinator richness, suggesting that bees are responding more strongly to floral abundance than diversity. Our findings are relevant to understanding how microclimate variation is affecting plant and pollinator responses to climate change.

Introduction

Climate change is altering global temperatures and disrupting weather patterns, thus posing great threats to ecological communities. For instance, montane and alpine ecosystems are experiencing shifts in snowpack amount, snowmelt timing and growing season length (Inouye et al. 2020). Phenological responses to climate change, such as plants budding earlier due to premature snowmelt, have been observed (Inouye et al. 2008). Early budding can lead to the exposure of frost sensitive plants to frost kills. This results in the disruption of ecosystems, affecting plant-pollinator interactions and plant reproduction.

Heterogeneous landscapes provide organisms with a multitude of critical resources needed to survive. Heterogeneity refers to all aspects of habitat variability: amount, function, form, and shape (Thomsen et al. 2022). Habitat heterogeneity is considered a primary driver of ecological patterns and facilitates higher biodiversity (Thomsen et al. 2022). Heterogeneous habitats provide a multitude of ecological functions such as; physical structures for hiding or nesting, microclimatic niches for multiple organisms to inhabit, and various nutritional resources

(Ohler et al. 2020). High alpine ecosystems have heterogeneous topography, therefore evidence suggests that these habitats can support more species compared to low heterogeneity habitats (Thomsen et al. 2022). One consequence of landscape heterogeneity is the availability of a diversity of microclimate conditions, which can enable plant diversity and could in turn allow animal species, such as insect pollinators, to coexist through niche partitioning (Fründ et al. 2010). Under climate change, a diversity of available microclimates could thus enable diverse pollinator communities to persist (Ohler et al. 2020). Although previous scientific studies have focused on various microclimatic effects on plant communities, and to a limited extent pollinator interactions, the effect that snowmelt timing has on floral abundance and on pollinator diversity remains uncertain.

To address this gap, we studied the effects of snowmelt timing on diversity of plants and pollinators within pre-distinguished transects that represent high and low levels of microclimate heterogeneity. We hypothesized that transects with high microclimate diversity will have greater floral diversity, and in turn increased pollinator diversity. This study aims to understand the effect of snowmelt timing on plant-pollinator interactions within different microclimates, adding value to what is already known about the effects of climate change on ecological communities.

Methods

To study the effects of snowmelt timing on diversity of plants and pollinators, we sampled plant-pollinator interactions at Judd Falls and Snodgrass, two of Dr. Ian Breckheimer's established research sites near the Rocky Mountain Biological Laboratory in Gothic, CO, USA (Fig. 1). The Judd Falls site and the Snodgrass site both have one 50-meter transect that captures high microclimate heterogeneity and one transect that represents low microclimate heterogeneity. To select locations for each transect, factors such as variation in slope, aspect, and elevation at the site level were considered. Our sites, located in the Upper Gunnison Watershed, undergo high-altitude drone flights weekly. Aerial photography data were used to determine how timing of snowmelt affects plant diversity and species richness. The drone flights capture images that provide snowpack disappearance and landscape phenology data via a plant community "green-up" metric.

At each site, each transect was divided into 25 2 meter by 2 meter plots. Once per week on days with desirable weather conditions, at least 8°C with no active precipitation, we visited each site to record plant-pollinator interactions between 8:00 am and 5:00 pm. To do so, we walked each transect twice per day, once in the morning and once in the afternoon. Sampling for pollinators in both the am and the pm provides a more comprehensive data set because different pollinator taxa are active at different times of day. When beginning the data collection, we recorded the start time and weather. During each transect walk, we observed each plot for 2 minutes. The timer was paused when a pollinator was observed in contact with a flower's reproductive parts, and we recorded the pollinator's visit as a data point. The collection date,

time of day (AM or PM), site, and plant identity were recorded for each observed pollinator. The pollinators included in this study were bees, flies, butterflies, wasps, and moths. Bees, the focal pollinators for this study, were captured using an aerial net for species-level identification. When a *Bombus* (bumblebee) was captured, we would identify it in the field, mark it with a paint pen to avoid recounting it, and release it. Pollinators that could not be identified in the field were collected in vials containing 70 % ethanol; these were brought back to the lab and identified accordingly. Floral abundance was measured once a day by counting the number of open flowers within each of the 2m x 2m plots; this was done for each plant species present. Floral counts along each transect provided us with data that could be used to study plant richness in relationship to heterogeneity.

Statistical analysis was used to determine how heterogeneity relates to plant and pollinator diversity. All analyses were conducted in R. We used linear mixed effects models ('lme4' package) to examine how metrics of floral and pollinator diversity and abundance differed between high and low microclimate heterogeneity transects. All models contained the random effects of site and sampling date. Metrics considered as response variables for pollinators and flowers were richness, Shannon index (H'), evenness (Pielou's J), and total abundance. We used similar models to examine how metrics of bee diversity (richness and Shannon index) varied with either floral abundance, richness, or Shannon index.

A Trimble GeoXT 3000 Series GeoExplorer Geographic Information Data Collector was used in the field to collect GPS coordinates of the transects. The coordinates were uploaded to ARCGIS Online to map out field sites.

Results

Plant richness was higher on high microclimate heterogeneity transects (**Fig. 2**, $P = 0.0167$, $R^2 = 0.1424$). The plant Shannon diversity index was similarly higher on high microclimate heterogeneity transects (**Fig. 3**, $P = 0.1131$, $R^2 = 0.1027$). However, observed pollinator richness was not higher on high heterogeneity transects (**Fig. 4**, $P = 0.7875$, $R^2 = 0.00468$). Similarly, on average, across sampling dates there was little difference in pollinator Shannon diversity observed between high and low heterogeneity transects (**Fig. 5**, $P = 0.649$, $R^2 = 0.05155$). However, transects with higher floral abundance had higher pollinator richness (**Fig. 6**, $P = 0.209$, $R^2 = 0.04325$). Similar to the relationship between bee richness and floral abundance, there was also a positive correlation between bee Shannon diversity and total floral abundance (**Fig. 7**, $P = 0.1027$, $R^2 = 0.1121$). Floral abundance was not higher on high heterogeneity transects (**Fig. 8**, $P = 0.2128$, $R^2 = 0.04153$).

Figures

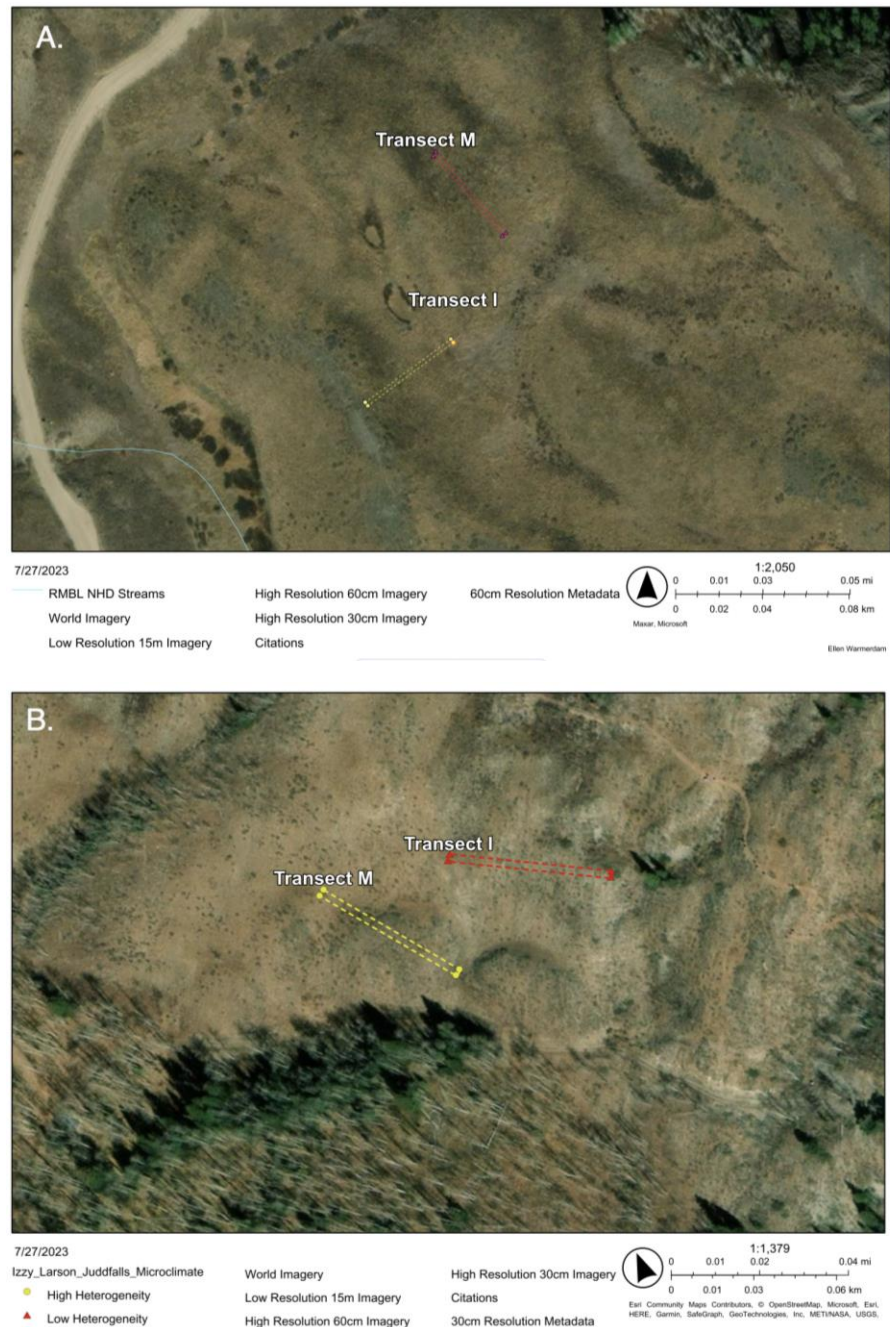


Figure 1| Maps of Field Sites.

A. Map of field site at the Snodgrass research site near Gothic, CO. Displayed are Transect M, which represents low microclimate heterogeneity, and Transect I, which represents high heterogeneity. **B.** Map of field site at Judd Falls, near Gothic, CO. Displayed are Transect M, which represents high microclimate heterogeneity, and Transect I, which represents low heterogeneity. Yellow signifies high microclimate heterogeneity. Red represents low heterogeneity.

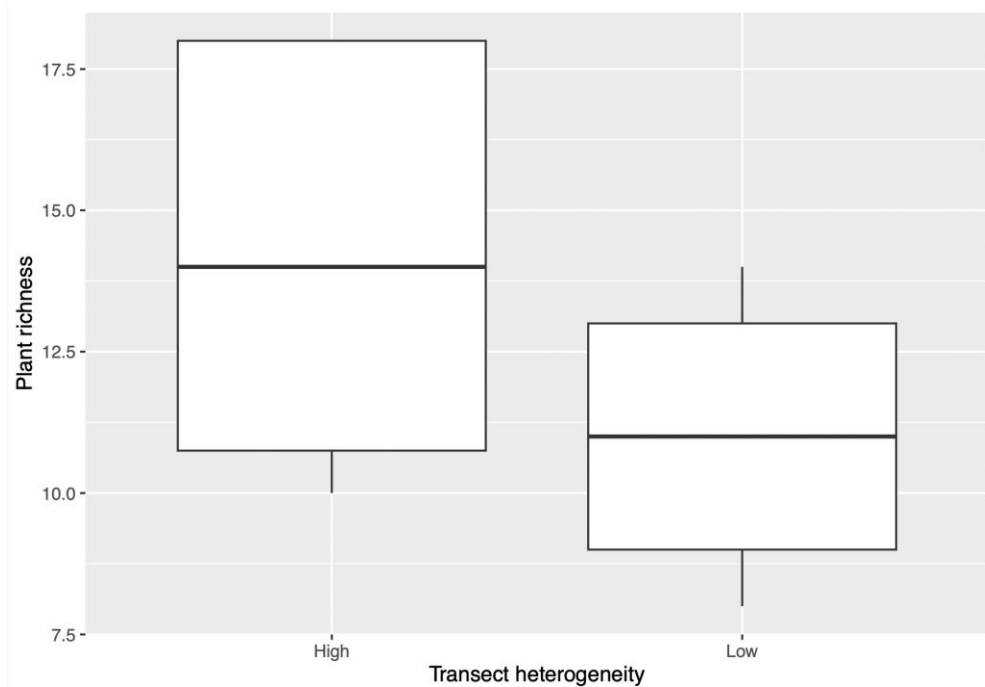


Figure 2| Plant Richness as a Function of Transect Microclimate Heterogeneity. Box plot displaying transect heterogeneity and the corresponding flowering plant richness. Plant richness was determined by counting the number of open flowers, by species, in each plot along each 50 meter transect.

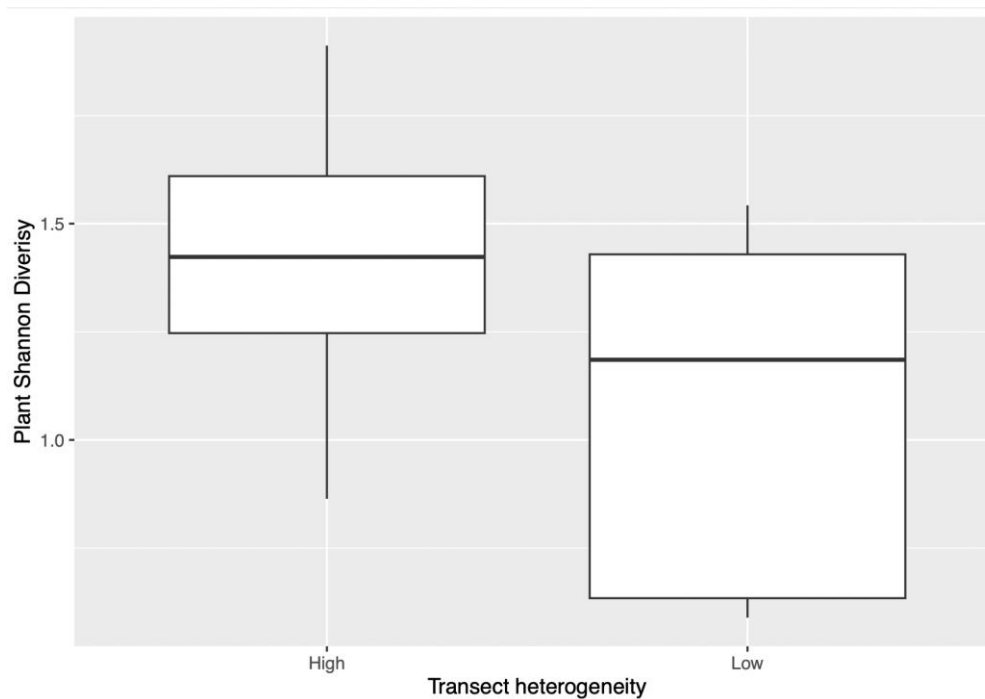


Figure 3| Plant Shannon diversity as a Function of Transect Microclimate Heterogeneity. Box plot displaying transect heterogeneity and the corresponding plant Shannon Diversity. Transects with higher heterogeneity had a greater plant Shannon diversity.

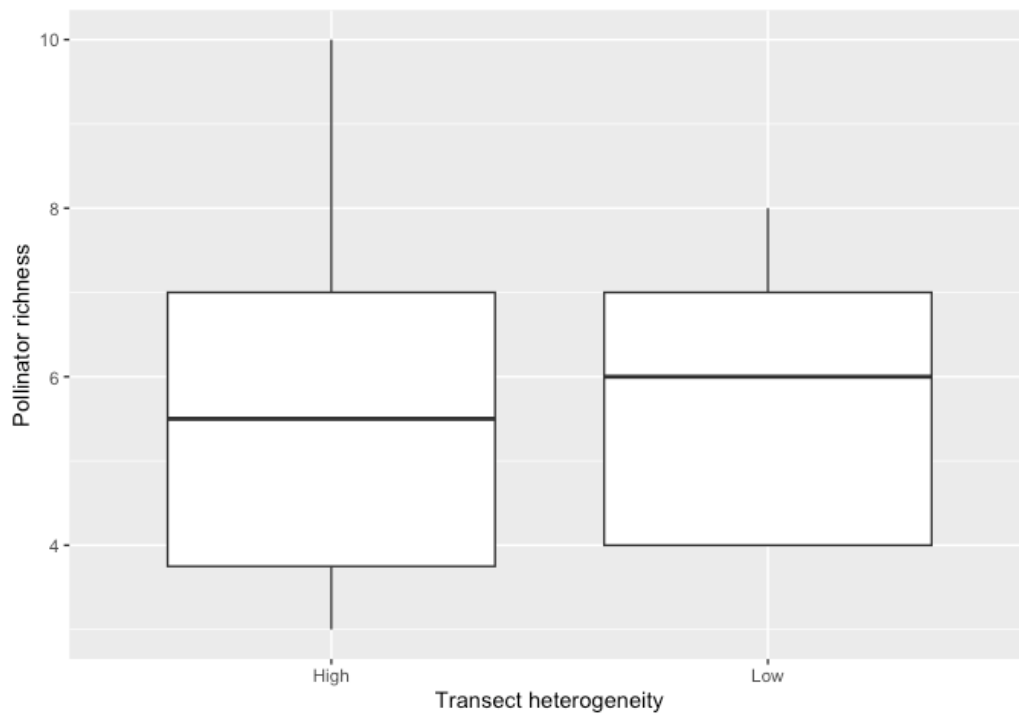


Figure 4| Pollinator Richness as a Function of Transect Microclimate Heterogeneity. Box plot displaying transect heterogeneity and the corresponding pollinator richness. There was no relationship between transect heterogeneity and pollinator richness.

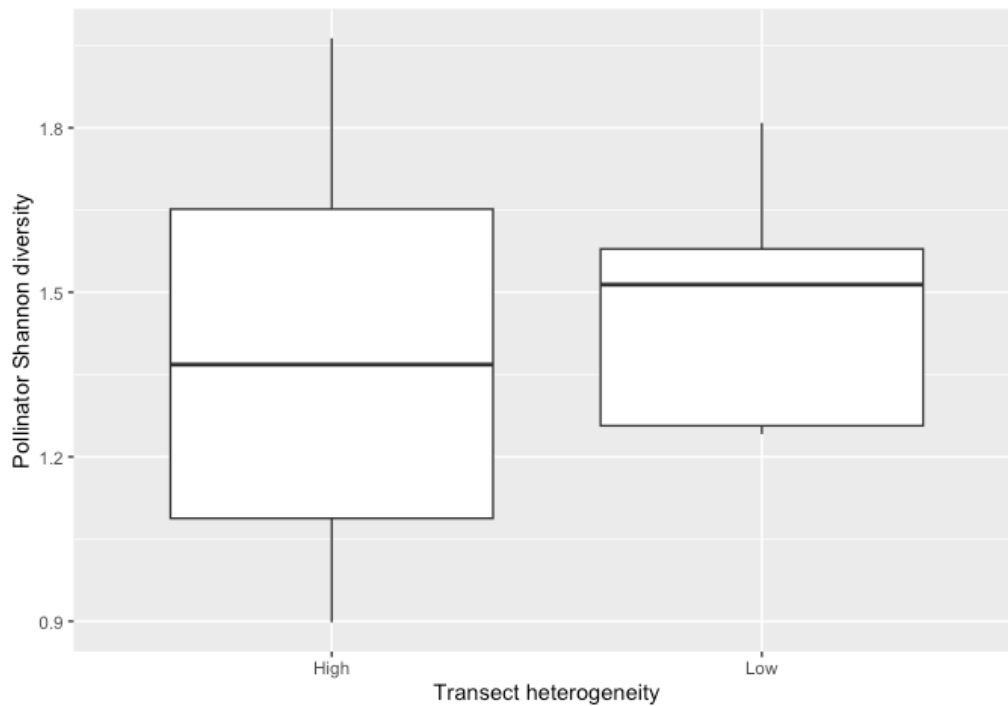


Figure 5| Pollinator Shannon Diversity as a Function of Transect Microclimate Heterogeneity. Box plot displaying transect heterogeneity and the corresponding pollinator Shannon Diversity. The Shannon Diversity index did not differ between high and low heterogeneity transects.

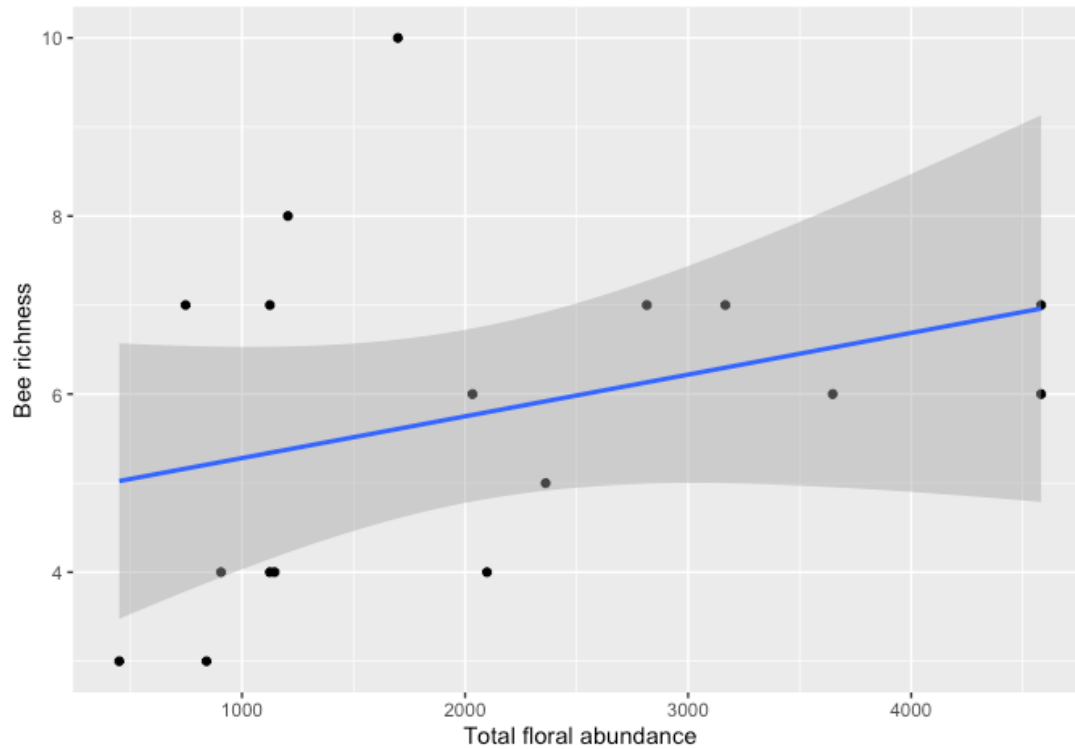


Figure 6| Bee Richness as a Function of Total Floral Abundance. Linear regression displaying a positive correlation between bee richness and total floral abundance. The points indicate total flowers that were counted and total observed bees on a given transect during a given sampling period. Generally, the greater the number of flowers the more pollinators were recorded.

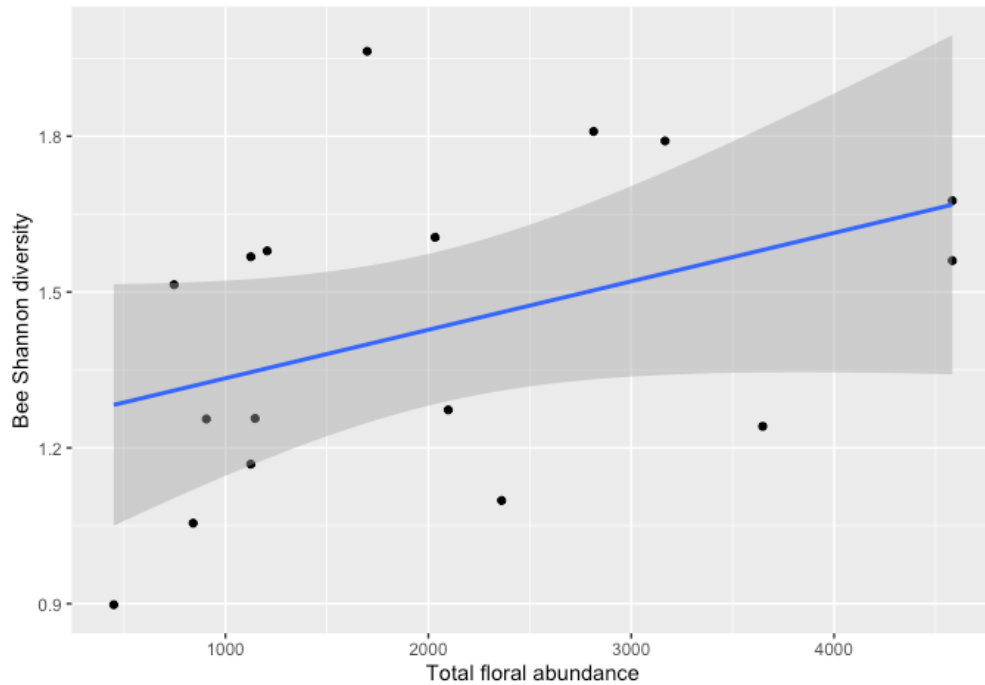
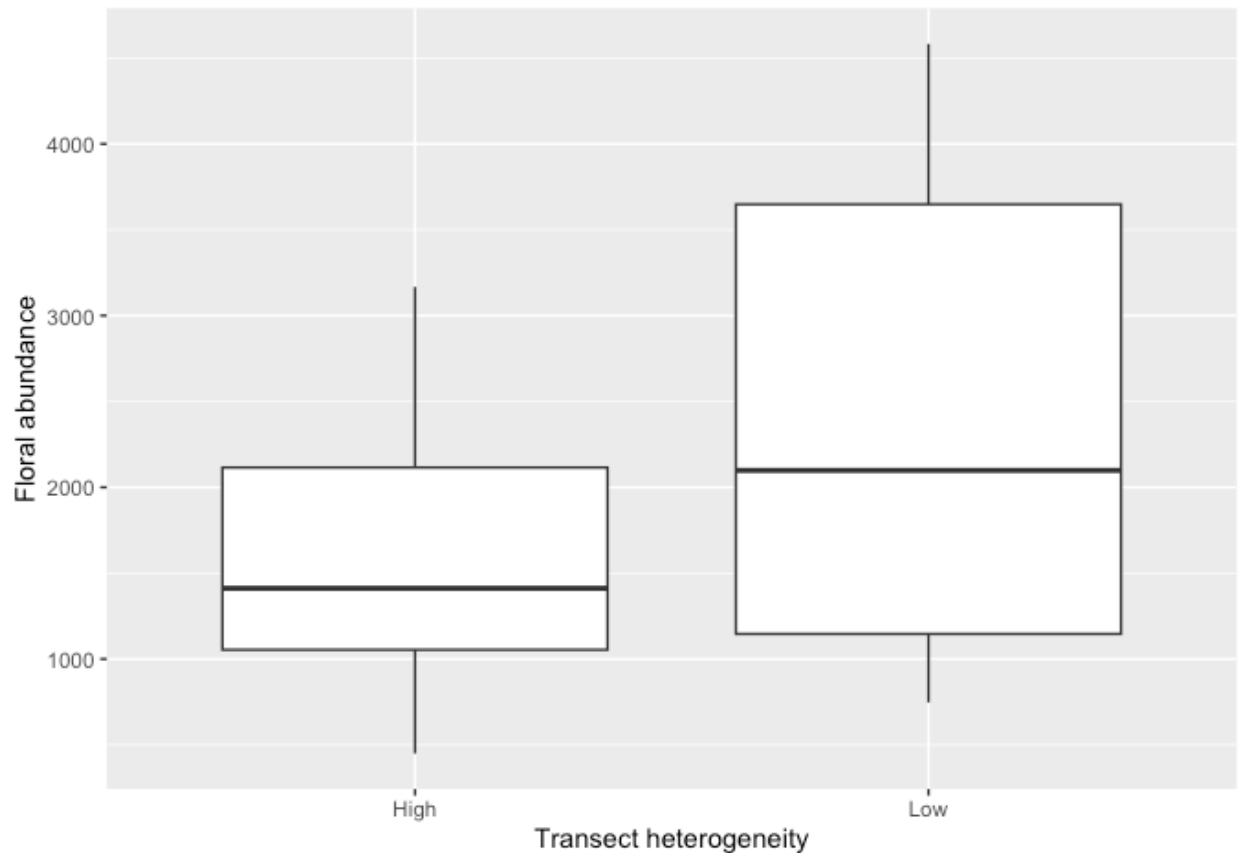


Figure 7| Bee Shannon Diversity as a Function of Total Floral Abundance. Linear regression displaying the positive relationship between bee Shannon Diversity and Total Floral Abundance. Each point on the graph represents the Shannon Diversity index, taking into account both species richness and relative abundance, compared to the total open flowers counted during sampling.



Figure| 8 Floral Abundance as a Function ofTransect Microclimate Heterogeneity. Box plot comparing floral abundance between high and low microclimate heterogeneity transects. Low and high heterogeneity transects did not differ in floral abundance.

Discussion

In recent years, scientists interested in community-level interactions have begun to study the effects of climate change on alpine plants and their pollinators (Inouye et al. 2020). Previous studies have focused on various microclimatic effects on plant communities (Ohler et al. 2020), however the effect that microclimate diversity has on floral and pollinator diversity has remained relatively uncertain. We investigated the effects of microclimate diversity on diversity of plants and pollinators within pre-distinguished transects that represent differing microclimate conditions. We found that high microclimate heterogeneity transects tended to have greater plant richness. This suggests that having a greater microclimate variation supports increased plant diversity due to the niche partitioning of different plants into suitable habitats (Thomsen et al. 2022). A possible explanation for this could be increased soil temperature due to early snowmelt. Soil temperature directly affects plant diversity and productivity (Ohler et al. 2020). Future research could focus on looking at soil temperature as a factor in microclimate variability and

how that affects plant communities and their pollinator interactions. To assess community and biodiversity we calculated the Shannon diversity index (H'). Plant Shannon diversity was greater on high microclimate heterogeneity transects. This result indicates that there was more plant evenness and richness along transects that had greater topographical variation. Plant richness and plant Shannon diversity indices followed a similar trend indicating a commonality between the variables.

When studying the relationship between microclimate heterogeneity and pollinator diversity, we found that pollinator diversity, as measured by both richness and Shannon diversity, did not differ between high and low microclimate heterogeneity transects. This finding did not support our initial hypothesis that high heterogeneity transects would have greater pollinator diversity. The relationship of heterogeneous microclimates and species richness and composition remains understudied; it is thought that plant-insect interactions are affected by climate warming leading to temporal and spatial mismatches along mutualistic partners (Ohler et al. 2020). Our data therefore suggest that the greater floral richness we found on high heterogeneity transects did not in turn support greater pollinator diversity. This result prompted further questioning and analysis regarding the effects of floral abundance on pollinator diversity. We found that pollinator diversity increased as floral abundance increased, and floral abundance did not differ between high and low heterogeneity transects. This finding supports the prediction that regardless of microclimate diversity, high floral abundance may lead to a greater diversity of pollinators. Floral abundance might yield greater pollinator diversity due to the fact that most bees are generalists, they are not partial to specific types of flowers and are drawn to greater floral abundance.

Greater floral abundance correlates to greater pollinator interactions. However, floral abundance was not higher on high heterogeneity transects. A possible explanation for these observations would be the snowmelt date; there is a significant relationship between snowmelt timing and the abundance of flowering for that growing season (Inouye et al. 2008). Early snowmelt coupled with a dry growing season could affect the abundance of plants and where they are able to grow. These factors may have been consistently important across all of our transects, driving floral abundance more strongly than microclimate variation. In addition, shifts in temperature and temperature niches could affect plant distribution and enhance competition (Ohler et al. 2020). Plant species may outcompete each other due to their need for specific environmental habitats. These factors may be at play consistently across levels of high and low microclimate heterogeneity as well. The purpose of this study was to determine the effects of microclimate variation on the diversity of plants and pollinators in high alpine environments. We found that microclimates may be good buffers for floral diversity in the face of climate change. Our work suggests less potential for microclimates to buffer bee diversity against climate change. On high heterogeneity transects, landscapes with greater microclimate variability, there was more floral diversity, potentially due to niche partitioning. However, evidence showed no relationship between transect heterogeneity and bee diversity. This could largely be due to bees responding more strongly to floral abundance than diversity. These findings are significant

because they will allow future experiments to further research the effect of microclimates on biodiversity and species abundance. Our work thus contributes to knowledge of ecosystems and understanding of plant and pollinator responses to climate change.

References

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