2026 Summer Rocky Mountain Biological Laboratory Research Project

Independent Research and Course

Shifts in *Lasioglossum* Abundance Across an Elevational Gradient in Response to Climate Change

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Abstract

Solitary bees make up the majority of bee species locally and globally, and are important pollinators. *Lasioglossum* is a common genus of generalist solitary bees found throughout Colorado that occupy a variety of temperature niches and elevations. Halicadea, the family *Lasioglossum* is in, is the second largest bee family and among the most abundant. Changes in *Lasioglossum* abundance and distribution could shape plant-pollinator interactions and impact pollination services. The effects of climate change may be affecting bee pollinator populations throughout the mountains of Colorado. Warmer and drier summers shift species composition of bee communities. This study examines if and how *Lasioglossum* abundance is changing in relationship to interannual climate variation. This research utilizes historical weather data and a long-term bee data set collected at the Rocky Mountain Biological Laboratory. Bees are collected and trapped across 16 different sites along an elevational gradient during the summer foraging period, with collected individuals representing species presence and abundance. *Lasioglossum* increased in abundance as summer temperatures increased, and decreased in abundance as annual precipitation increased. Different *Lasioglossum* species vary in how significantly they respond to climate variables. The species composition of *Lasioglossum* changed as summer temperatures increased and precipitation increased.

Introduction

The effects of climate change are prevalent in high elevation montane ecosystems and affect the distribution and abundance of solitary bees (Parmesan et al., 2006; Quinlan et al., 2025; Kazenel et al., 2024). Warming has caused decreased winter snowpack and increased drought and heat stress during summer growing seasons (Milly et al., 2020). Bee species with colder temperature niches find refuge in the mountains and are particularly susceptible to declines as these ecosystems warm (Noroozi et al., 2018). Solitary bees play an important role as pollinators within montane ecosystems (Bartra, 1984). Changes in solitary bee abundance could decrease pollination services and change biological and chemical soil properties, leading to

declines in other economically important ecosystem functions (Mallinger et al., 2019; Tschanz et al., 2025).

Rising temperatures have resulted in shifting thermal niche distributions of North American bumble bee species assemblages (Hemberger et al., 2024). Bumble bee communities increasingly consist of fewer cold adapted species and more warm adapted species, with these changes being most pronounced in middle to high latitudes in the American Rockies (Hemberger et al., 2024). There has also been an observed decrease in overall bumble bee population abundance, as well as upward elevational shifts in recent decades (Pyke et al., 2016).

While these patterns have been documented in social bees such as bumble bees, responses of solitary bees remain poorly understood. Few studies have examined how *Lasioglossum* abundance, a common group of solitary sweat bees, is responding to climate change over time, and little is understood on *Lasioglossum* sensitivity and trends. This is a critical gap in research as *Lasioglossum* is commonly the most abundant solitary bee genus in a given community, meaning that *Lasioglossum* contributes a significant portion of pollination services (Dar et al., 2018; Nelson et al., 2023). *Lasioglossum* is a widely distributed genus made up predominantly of small solitary bees, with over 1200 species (Nelson et al., 2023). Most *Lasioglossum* are solitary but, notably, some are primitively eusocial (Danforth, 2003). *Lasioglossum* species are prominent in the Rocky Mountains of Colorado, occupying a wide variety of elevations, consisting of differing climate niches. *Lasioglossum* contribute a significant amount of pollination as generalist pollinators, visiting a wide range of native and exotic flower species (Dar et al., 2018; Nelson et al., 2023), there are even records of *Lasioglossum* species collecting pollen from flowering grasses (Immelman et al., 2000; Joseph et al., 2020). Although this genus occupies every continent except Antarctica and contributes a substantial portion to solitary bee species diversity, there has been little focus on *Lasioglossum* range shifts in response to climate change (Nelson et al., 2023). One reason for this dearth of knowledge is the difficulty of identifying solitary bees – and *Lasioglossum* in particular – to species in field and laboratory settings.

As the climate warms, predicting how Lasioglossum ranges may shift across elevational gradients and understanding which *Lasioglossum* species are likely to undergo significant changes in abundance can help us predict where *Lasioglossum* are likely to be found, how plant-pollinator interactions are likely to shift, and what ecosystems might look like in the near future

(Pardee et al., 2022). Characterizing species-level population trends and climate sensitivities will allow us to predict which *Lasioglossum* species will be most vulnerable to climate change, and which species might be more tolerant and increase in abundance as temperatures rise. This knowledge can be applied to land management and conservation efforts to maintain pollination services, important for wild ecosystems and agriculture.

A decadal trend in *Lasioglossum* abundance may reflect the effects of climate change or other systemic ecosystem changes, but such a trend is likely to be weaker than interannual variation in abundance. Interannual differences in abundance reflect the influence of year-to-year climate variation, such as average temperature and precipitation over the summer foraging period. When looking at interannual changes, one year time-delayed responses were also considered to capture the effects of lower fecundity from floral resource limitation. Examining interannual variation, allowed the extrapolation of future *Lasioglossum* abundance trends in response to projected climate scenarios.

This study analyzes bee abundance time series data collected from 16 different sites across an elevation gradient from approximately 2,400 meters to 3,400 meters in the Elk Mountains of central Colorado, U.S.A. The data come from a continuous long term monitoring project that spans over 8 years from as far back as 2010, through 2018. The hypotheses are that 1.) Climate drives *Lasioglossum* distribution and abundance across time and space. 2.) Sensitivity to climate change varies across species due to differences in climate niche adaptations. 3.) Higher temperatures increase the abundance of Lasioglossum with warm temperature niches across elevations.

Research Question: How is *Lasioglossum* abundance changing in response to climate variation?

Methods

This study was conducted throughout the meadows of the Elk Mountains, around the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado, U.S.A (elevation 2978 meters). These montane meadows are home to over 200 bee species and over 20 Lasioglossum species. Many of the sites are in subalpine areas, and are especially susceptible to climate change (Dianese et al., 2024). A trend of increased temperatures and earlier snowmelt has been

occurring across the years the bee data set spans (2010-2018). However spring and summer weather patterns remain highly variable, with some years being drier and hotter, while others experience cooler temperatures and increased precipitation (Pardee et al., 2022). Drier summers and earlier snowmelt are expected in the future growing seasons under long-term climate change projections (Milly et al., 2020).

Bee and Environmental Data:

The *Lasioglossum* being studied here have been collected among 16 different sites along an elevational gradient from approximately 2,400 meters to 3,400 meters. The exact coordinates of the sites have been mapped with GPS units as seen in table 1. Each site contains two 42m transects running parallel to each other. Each transect contains three 2 x 2 plots where flower surveys are conducted. Four sites are low in elevation near Almont, nine sites are mid elevation around Gothic, another mid-elevation site is at Rustlers Gulch, and two high elevation sites, near the Mexican Cut. The 9 sites around Gothic are grouped in 3 blocks, block A, B, D. Each of the blocks consist of three dominant habitat types, dry meadow, *Salis*-dominated wet meadow, and *Veratrum*-dominated wet meadow. The bees are sampled and flower surveys are conducted at each site every two weeks during the foraging season. 15 painted bee bowls are placed along each transect in varying colors of white, fluorescent yellow, and fluorescent blue, and they remain out for approximately 6 hours on clear sunny days, and trap solitary bees. Netting is also done for 1 hour in both the morning and afternoon at each site, for 2 hours total. Solitary bees caught in nets or trapped in bee bowls are lethally sampled in ethanol vials and brought back to the lab where they are labeled, pinned, and later identified to represent data points in this study. Female *Lasioglossum* are used exclusively in this study due to challenges associated with the taxonomic identification of males.

Historical weather data was accessed from Prism for Almont, Gothic and the Mexican Cut. Monthly average precipitation and temperature were used, as well as monthly maximum temperature. The weather data was manipulated in the coding software R to get yearly average precipitation, temperature, maximum temperature, average temperature across the summer months (April-September), summer precipitation (April-September), and average wet year precipitation to estimate winter precipitation. The climate data from each location represented

climate variables at low elevations (Almont), middle elevations (Gothic), and high elevations (the Cut). Sampling sites were correlated with these three elevation levels and tied to the climate data.

Statistical Analysis:

All data analysis and cleaning was done in the coding software R version 4.4.2. Pearson product-moment correlation test was used to test the association of the climate variables, mean annual precipitation and the mean summer precipitation.

To test if overall *Lasioglossum* abundance was associated with both precipitation and temperature, two generalized linear mixed models (GLMM) with negative binomial error distribution were used with the glmmTMB package in R. A negative binomial distribution was applied to account for the over dispersion in the data. Average foraging temperature (°F) and annual precipitation (in) were fixed effects, with site and species as random effects. Statistical significance of the fixed effects were tested using Wald z-tests on model coefficients. Nakagawa's marginal R^2 was used to explain fixed effects variance using the MuMIn package. For visualization a simplified negative binomial GLM was used to show the overall trend in Figure 1 and 2, all reported statistics come from the full GLMM.

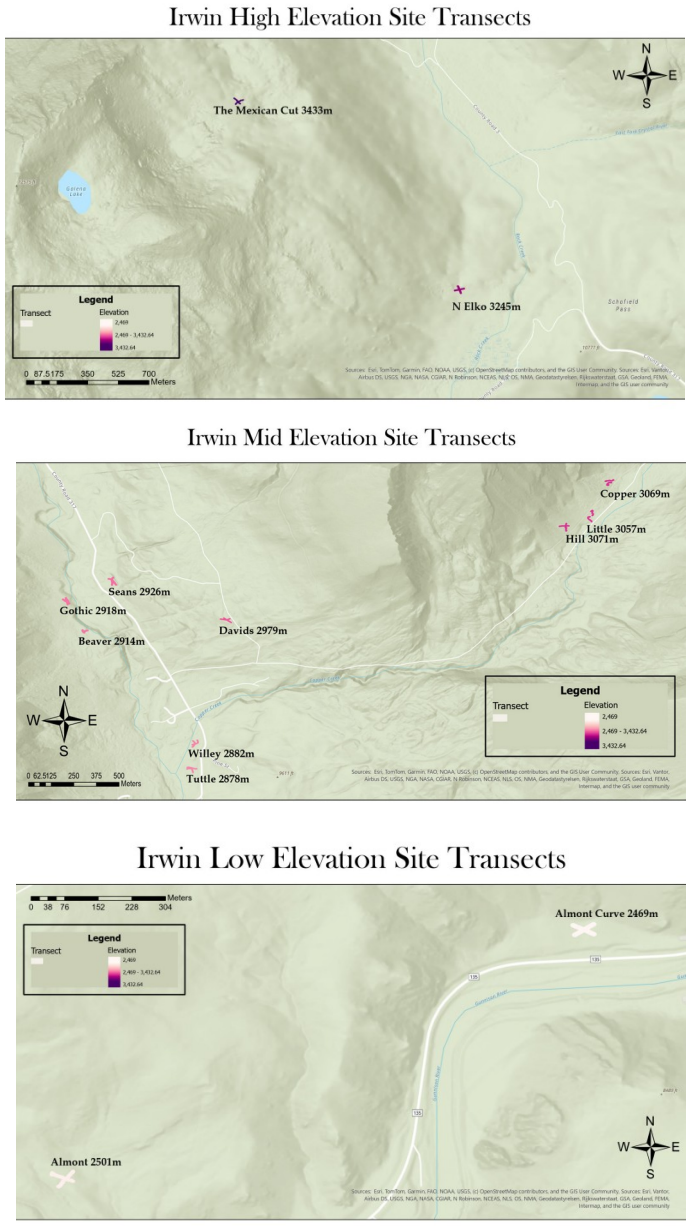
The 5 most abundant *Lasioglossum* species, out of the 21 present in the sampling data, were identified by summing the total abundance across all years and sites. These species were then fit to separate GLMMs with a negative binomial distribution to model this abundance with the climate variables. Fixed effects coefficients, standard errors, z-statistics, and p-values were extracted for each species using the broom.mixed package. *Lasioglossum* species were also ranked from least to most abundant and looked at number 6-10 using the same methods described above, to examine how more rare species are responding to the climate variables. The 5 least common species were not used as there were not enough data points to visualize a trend.

To evaluate whether a species thermal index has an effect on the relationship between *Lasioglossum* abundance and the climate variables *Lasioglossum* species were grouped into 3 equally sized groups, the low-range, mid-range, and high-range. A GLMM with a negative binomial error distribution was then fit, predicting abundance as a function of mean annual precipitation, species temperature index (STI) group and their interaction, with site included as a

random intercept. The interaction term (precipitation x STI_group) tested whether the slope of the precipitation-abundance relationship differed significantly among STI groups.

To look at whether *Lasioglossum* species composition shifted in response to temperature, precipitation; temperature and precipitation were binned. Temperature was converted into 1°F bins, precipitation was converted into 1in bins. Total abundance for each species was summed within each site, year and bin combination. Chi-squared tests of independence were conducted on contingency tables to test whether species composition was independent, because of low counts a Monte Carlo simulation (10,000 replicates) was used to obtain a p value. Community composition was also tested using a permutational multivariate analysis of variance based on Bray-Curtis dissimilarity. Multivariate dispersion was examined using betadisper on the same Bray-Curtis dissimilarity matrix to determine if the PERMANOVA result reflected real differences in average composition.

Maps



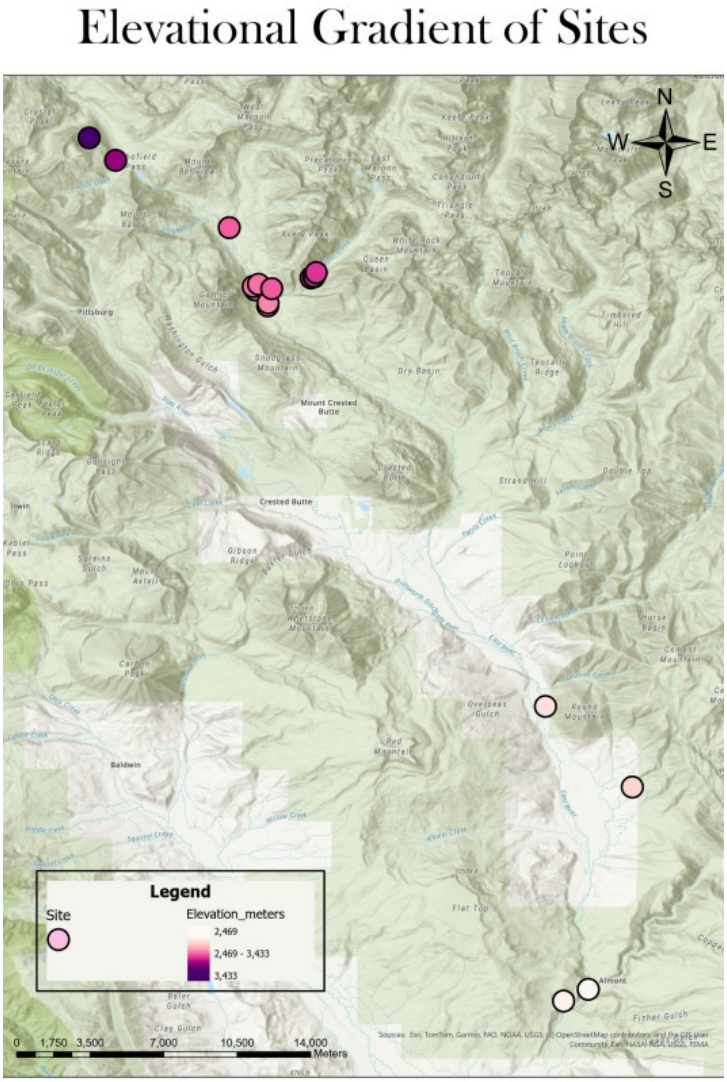


Figure 1

Maps of 15 of the site transects with elevation, map of all 16 sites showing the elevational gradient across sampling locations.

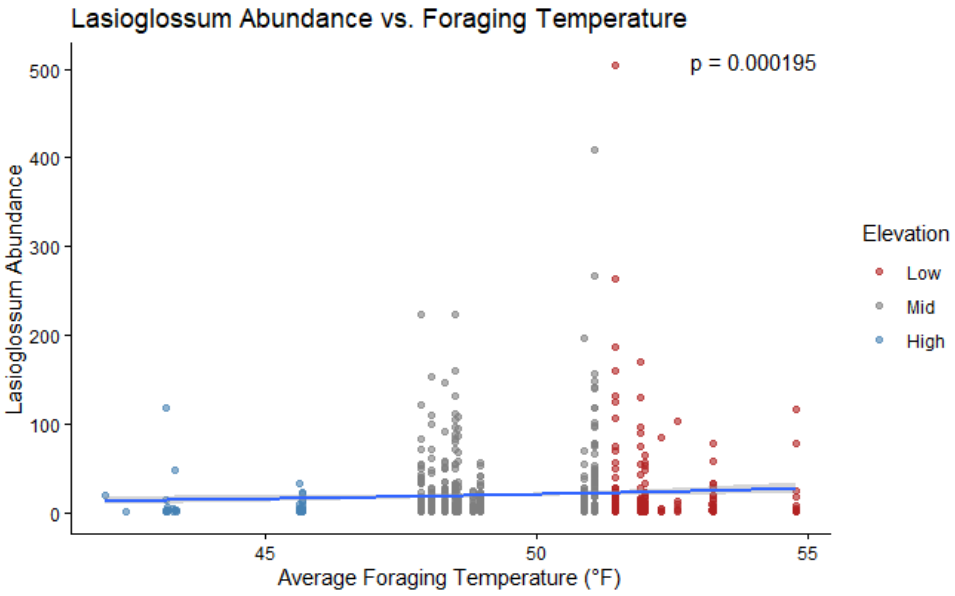
Table 1

Sampling site information including, name, elevation (m), latitude and longitude.

Site Name	Elevation (m)	Latitude	Longitude
Davids	2979	38.962124	-106.986896
Tuttle	2877	38.954751	-106.988704
Willey	2884	38.955971	-106.988482
Gothic	3001	38.963088	-106.994866
Seans	2931	38.964099	-106.992616
Beaver	2921	38.961597	-106.993975
Copper	3072	38.96896	-106.96801
Hill	3069	38.96677	-106.97009
Little	3061	38.96732	-106.96885
Almont	2569	38.65622	-106.86203
Mexican Cut	3438	39.02685	-107.06513
Almont Curve	2456	38.66125	-106.85152
CDOT	2588	38.78257	-106.87002
Lypps	2639	38.74812	-106.83269
Rustlers	2977	38.9885	-107.00512
N. Elko	3230	39.01245	-107.05279

Results

Mean summer temperature and mean annual precipitation were strongly negatively correlated across the 112 unique site-year combinations sampled (Pearson's $r = -0.88$, 95% CI [-0.92, -0.83], $t(110) = -19.57$, $p < 0.001$).



GLMM Results: Lasioglossum Abundance ~ Foraging Temperature

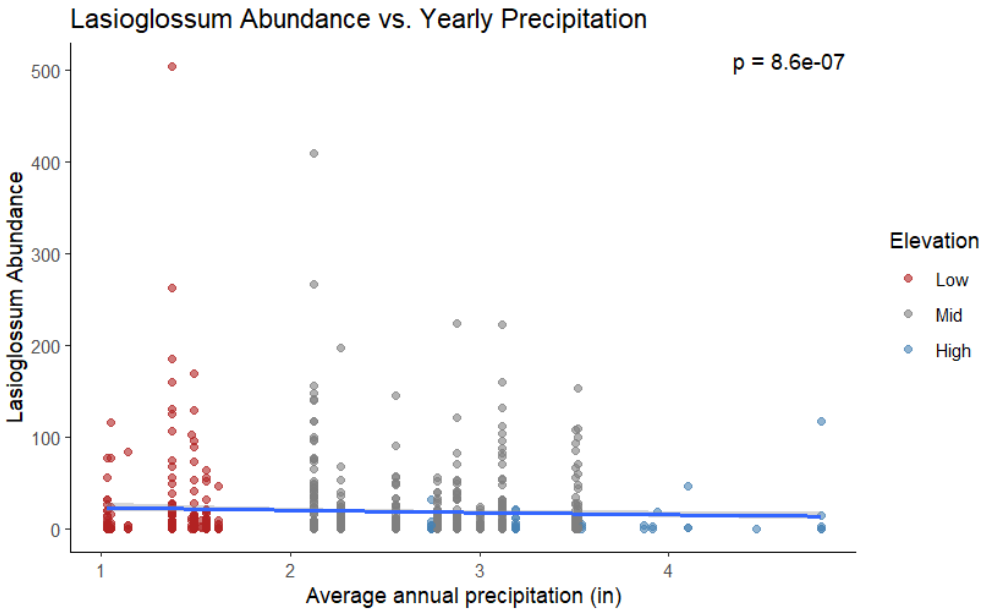
effect	component	group	term	estimate	std.error	statistic	p.value
fixed	cond	NA	(Intercept)	-3.750	1.5000	-2.49	0.012700
fixed	cond	NA	Foraging_avg_temp	0.111	0.0297	3.73	0.000195

Figure 2

***Lasioglossum* abundance by average foraging temperature (°F)**

(exp(0.111)-1)*100= 11.7

Across all *Lasioglossum* species and elevations combined there is a significant effect on *Lasioglossum* abundance by the average foraging temperature ($z = 3.73$, $p < 0.001$). Abundance increases as temperature increases, with each 1° F increase in mean foraging temperature associated with approximately an 11.7% increase in expected *Lasioglossum* abundance.



GLMM Results: Lasioglossum Abundance ~ Precipitation

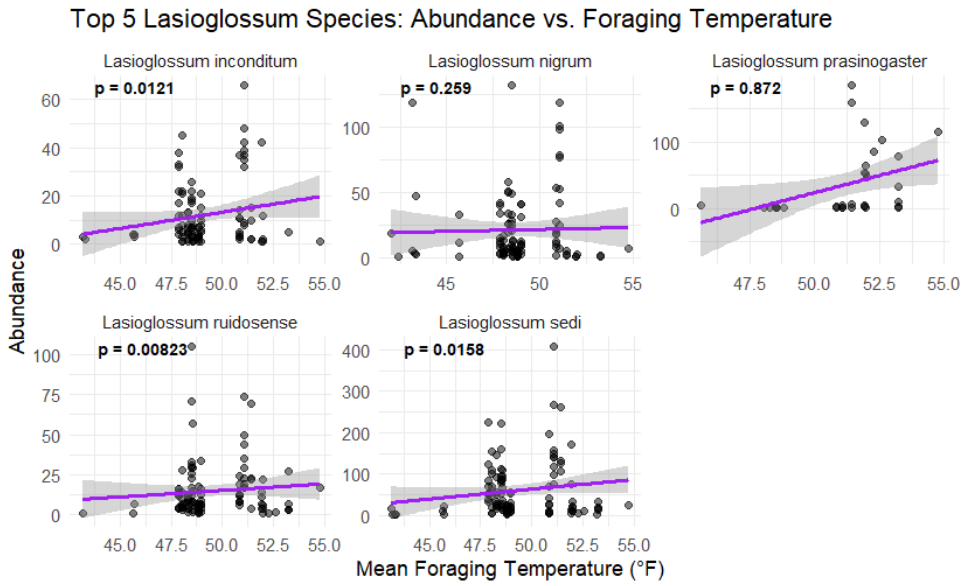
effect	component	group	term	estimate	std.error	statistic	p.value
fixed	cond	NA	(Intercept)	2.660	0.3200	8.29	1.13e-16
fixed	cond	NA	mean_ppt_in	-0.379	0.0769	-4.92	8.60e-07

Figure 3

***Lasioglossum* abundance by average annual precipitation (in)**

(exp(-.379)-1)*100= -31.5

Across all *Lasioglossum* species and elevation combined there is a significant negative relationship between precipitation and abundance ($z = -4.92$, $p < 0.001$). With each 1 inch increase in annual precipitation there is approximately a 31.5% decrease in *Lasioglossum* abundance.



GLMM Results: Abundance ~ Foraging Temperature by Species

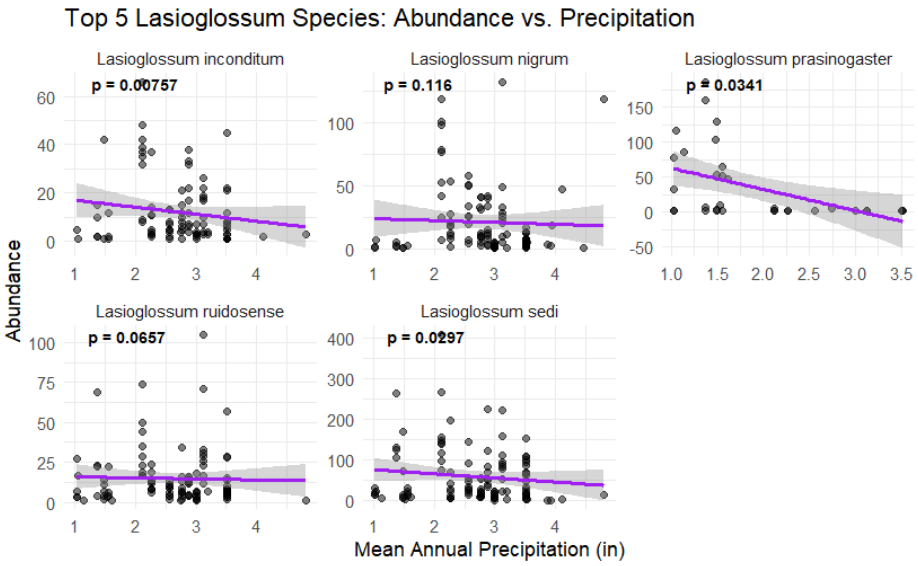
Estimate	SE	z	p-value
Lasioglossum nigrum			
0.096	0.085	1.130	0.25900
Lasioglossum ruidosense			
0.154	0.058	2.643	0.00823
Lasioglossum inconditum			
0.158	0.063	2.508	0.01210
Lasioglossum sedi			
0.147	0.061	2.414	0.01580
Lasioglossum prasinogaster			
0.022	0.139	0.161	0.87200

Figure 4

Abundance of the top 5 most common *Lasioglossum* species in our data set by average foraging temperature (°F).

At the species level foraging temperature was significantly positively correlated with abundance for 3 of the 5 most common species. L. Ruidosense ($\beta = 0.154$, $z = 2.64$, $p = 0.008$), L. Inconditum ($\beta = 0.158$, $z = 2.51$, $p = 0.012$), and L. Sedi ($\beta = 0.147$, $z = 2.41$, $p = 0.016$) were all statistically significant. There was no significant relationship detected for L. Nigrum ($\beta = 0.096$, $z = 1.13$, $p = 0.259$) or L. Prasinogaster ($\beta = 0.022$, $z = 0.16$, $p = 0.872$),

despite visual trends. L. Prasinogaster had comparatively fewer data points, limiting statistical power.



GLMM Results: Abundance ~ Precipitation by Species

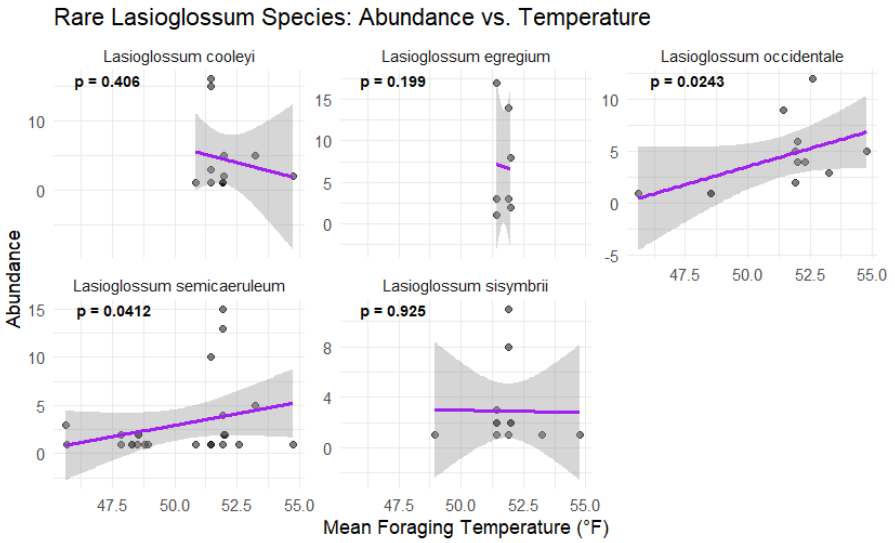
Estimate	SE	z	p-value
Lasioglossum nigrum			
-0.383	0.244	-1.571	0.11600
Lasioglossum ruidosense			
-0.275	0.150	-1.840	0.06570
Lasioglossum inconditum			
-0.465	0.174	-2.671	0.00757
Lasioglossum sedi			
-0.329	0.151	-2.174	0.02970
Lasioglossum prasinogaster			
-0.882	0.417	-2.118	0.03410

Figure 5

Abundance of the top 5 most common *Lasioglossum* species in our data set by average annual precipitation (in).

At the species level precipitation was significantly negatively correlated with abundance for 3 of the 5 most common species. L. Inconditum (β = -0.465, z = -2.671, p= 0.00757), L. Sedi (β = -0.329, z = -2.41, p = 0.0297), and L. Prasinogaster (β = -0.882, z = -2.118, p = 0.0341),

were all statistically significant. There was no significant relationship detected for L. Ruidosense (β = -0.275, z = -1.840, p = 0.0657), and L. Nigrum (β = -0.383, z = -1.571, p = 0.116).



GLMM Results: Abundance ~ Temperature by Species

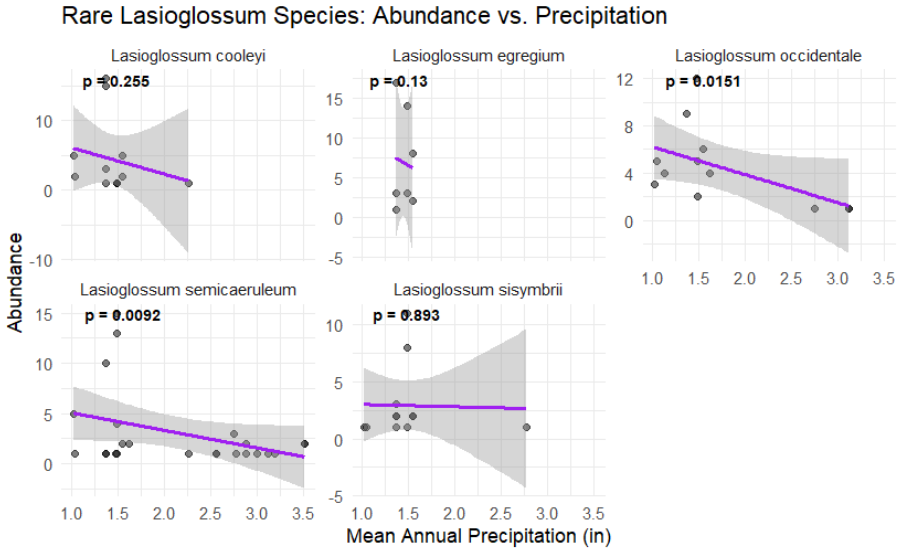
Estimate	SE	z	p-value
Lasioglossum egregium			
-0.739	0.576	-1.284	0.1990
Lasioglossum sisymbrii			
-0.024	0.256	-0.095	0.9250
Lasioglossum cooleyi			
-0.257	0.310	-0.830	0.4060
Lasioglossum occidentale			
0.230	0.102	2.252	0.0243
Lasioglossum semicaeruleum			
0.188	0.092	2.042	0.0412

Figure 6

More rare *Lasioglossum* species by mean foraging temperature (°F). Species number 6-10 ranked from least abundant to most abundant in the data set.

At the species level temperature was significantly positively correlated with abundance for 2 of the 5 less common *Lasioglossum* species, L. Occidentale (β = -0.230, z = 2.252, p =

0.0243) and L. Semicaeruleum (β = 0.188, z = 2.042, p = 0.0412). There was no significant relationship for L. Egregium (β = -0.739, z = -1.284, p = 0.1990), L.Sisymbrii (β = -0.024, z = -0.095, p = 0.9250), and L. Cooleyi (β = -0.257, z = -0.830, p = 0.4060). The less common *Lasioglossum* species have fewer data points and limited statistical power.



GLMM Results: Abundance ~ Precipitation by Species

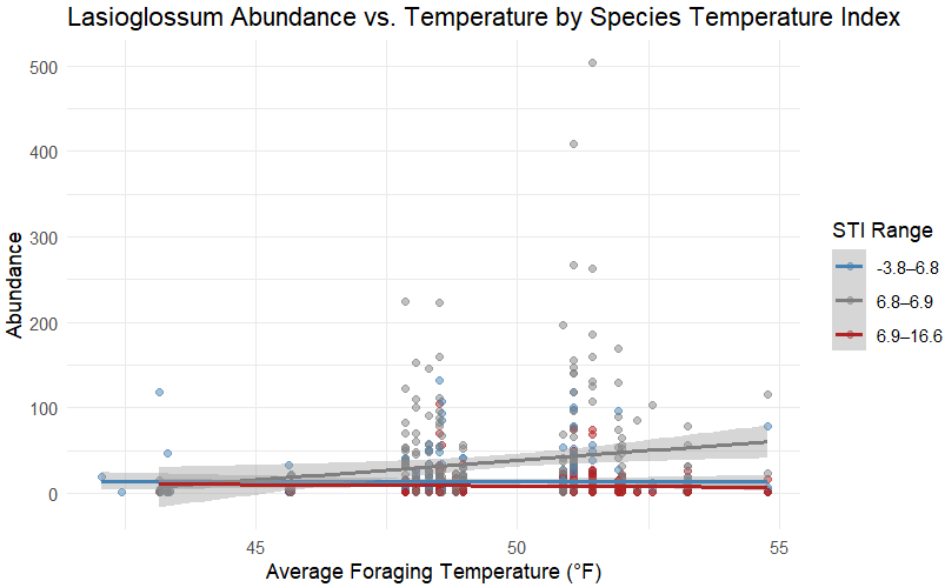
Estimate	SE	z	p-value
Lasioglossum egregium			
-2.965	1.960	-1.513	0.1300
Lasioglossum sisymbrii			
-0.104	0.777	-0.134	0.8930
Lasioglossum cooleyi			
-1.393	1.225	-1.137	0.2550
Lasioglossum occidentale			
-0.808	0.333	-2.430	0.0151
Lasioglossum semicaeruleum			
-0.652	0.250	-2.605	0.0092

Figure 7

More rare *Lasioglossum* species by precipitation (in). Species number 6-10 ranked from least abundant to most abundant in the data set.

At the species level precipitation was significantly negatively correlated with abundance for 2 of the 5 less common *Lasioglossum* species, L. Occidentale (β = -0.808, z =

-2.430, p = 0.0151) and L. Semicaeruleum (β = -0.652, z = -2.605, p = 0.0092). There was no significant relationship for L. Egregium (β = -2.965, z = -1.513, p = 0.1300), L. Sisymbrii (β = -0.104, z = -0.134, p = 0.8930), and L. Cooleyi (β = -1.393, z = -1.137, p = 0.2550). The less common *Lasioglossum* species have fewer data points and limited statistical power.



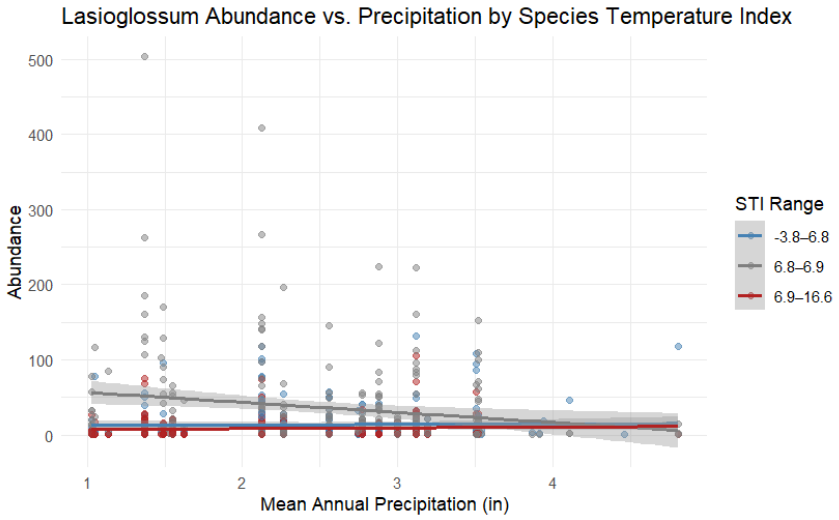
GLMM Results: Abundance ~ Temperature × STI Group

effect	component	Term	Estimate	SE	z	p-value
fixed	cond	(Intercept)	2.130	1.863	1.144	0.253000
fixed	cond	Foraging_avg_temp	0.009	0.038	0.246	0.806000
fixed	cond	STI_group6.8–6.9	-8.596	2.619	-3.282	0.001030
fixed	cond	STI_group6.9–16.6	0.456	2.951	0.155	0.877000
fixed	cond	Foraging_avg_temp:STI_group6.8–6.9	0.192	0.053	3.636	0.000277
fixed	cond	Foraging_avg_temp:STI_group6.9–16.6	-0.018	0.059	-0.308	0.758000

Figure 8

***Lasioglossum* species grouped by STI range by temperature (°F).**

The relationship between foraging temperature and abundance differed significantly by STI group. The mid-STI group (6.8-6.9) showed a significantly steeper positive relationship between temperature abundance compared to the low-STI reference group (β = 0.192, z = 3.64, p < 0.001). No significant interaction was detected for the high-STI group relative to the reference β = -0.018, z = -0.31, p = 0.758) , and the main effect of temperature within the low-STI reference group alone was not significant (β = 0.009, z = 0.25, p = 0.806).



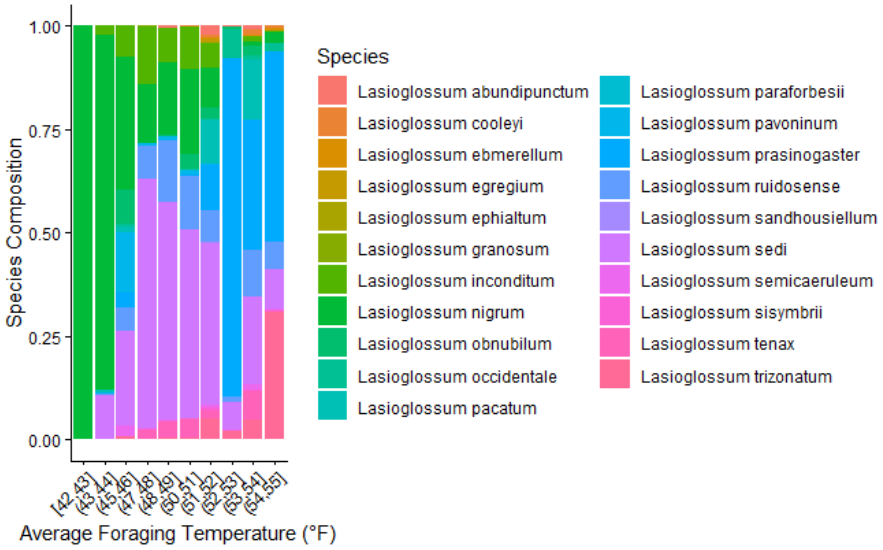
GLMM Results: Abundance ~ Precipitation × STI Group

effect	component	Term	Estimate	SE	z	p-value
fixed	cond	(Intercept)	2.654	0.288	9.207	3.35e-20
fixed	cond	mean_ppt_in	-0.028	0.105	-0.265	7.91e-01
fixed	cond	STI_group6.8–6.9	2.045	0.365	5.606	2.07e-08
fixed	cond	STI_group6.9–16.6	-0.558	0.362	-1.542	1.23e-01
fixed	cond	mean_ppt_in:STI_group6.8–6.9	-0.447	0.138	-3.250	1.15e-03
fixed	cond	mean_ppt_in:STI_group6.9–16.6	0.046	0.143	0.320	7.49e-01

Figure 9

***Lasioglossum* species grouped by STI range by precipitation (in).**

The relationship between precipitation and abundance also differed significantly by STI group. The mid-STI group (6.8-6.9) showed a significantly more negative relationship between precipitation and abundance than the low-STI reference group ($\beta = -0.447$, $z = -3.25$, $p = 0.001$). No significant interaction was detected for the high-STI group ($\beta = 0.046$, $z = 0.32$, $p = 0.749$), and the main effect of precipitation within the low-STI reference group alone was not significant ($\beta = -0.028$, $z = -0.27$, $p = 0.791$).



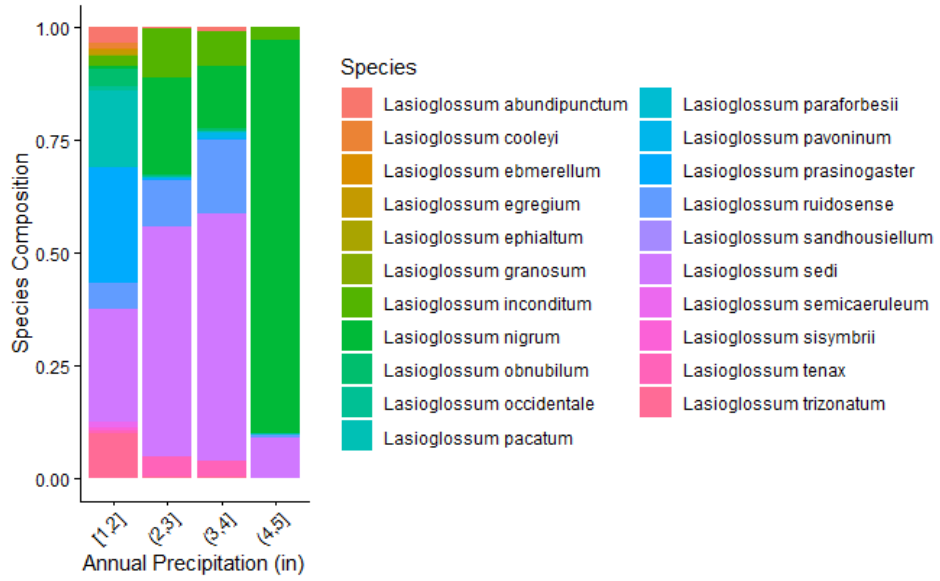
Statistical Tests: Species Composition ~ Temperature Bin

Test	Test Statistic	R^2	p-value
Chi-square (composition ~ temp bin)	X^2 = 8302.7	—	< 0.001 (simulated)
PERMANOVA (composition ~ temp bin)	Pseudo-F(9,102) = 4.97	0.305	0.001
Multivariate dispersion (betadisper)	F(9,102) = 4.24	—	< 0.001

Figure 10

***Lasioglossom* species composition across average foraging temperatures.**

Species composition notable shifts across the foraging temperature gradient. At cooler temperatures (42°F-46°F) species composition is dominated by L. Nigrum. At warmer intermediate temperatures (47°F-52°F) composition becomes predominantly composed of L.Sedi, with more L. Prasinogaster and L. Trizonatum at the hottest temperatures (53°F-55°F). Species compositional shifts across temperature consist of significant compositional differences as seen by the chi-square ($\chi^2 = 8302.7$, simulated $p < 0.001$) and PERMANOVA (pseudo-$F_{9,102} = 4.97$, $R^2 = 0.305$, $p = 0.001$). Multivariate dispersion across bins ($F_{9,102} = 4.24$, $p < 0.001$) most likely shows the same pattern of change.



Statistical Tests: Species Composition ~ Precipitation Bin

Test	Test Statistic	R^2	p-value
Chi-square (composition ~ precip bin)	X^2 = 9176.9	NA	< 0.001 (simulated)
PERMANOVA (composition ~ precip bin)	Pseudo-F(3,108) = 9.58	0.21	0.001
Multivariate dispersion (betadisper)	F(3,108) = 5.08	NA	0.00249

Figure 11

***Lasioglossum* species composition across mean annual precipitation.**

Species composition differed significantly across precipitation bins (χ^2 = 9176.9, simulated $p < 0.001$). PERMANOVA shows that precipitation bin explained 21% of the variance in species composition (pseudo-$F_{3,108}$ = 9.58, R^2 = 0.21, p = 0.001). Multivariate dispersion differed significantly across precipitation bins ($F_{3,108}$ = 5.08, p = 0.002). At higher annual precipitation (4-5in) L. Nigrum dominates species composition, at lower precipitation levels (1-2in) species composition is more diverse, dominated by L. Prasonogaster and L. Sedi.

Discussion

Both of our climate variables, mean summer temperature and mean annual precipitation are strongly negatively correlated with each other. It is difficult to determine which climate variable has a more significant impact on *Lasioglossum* abundance, however they both do have a significant effect on abundance.

As summer temperatures increase and annual precipitation decreases, it was found that Lasioglossum abundance is increasing in response. *Lasioglossum,* which are commonly known as sweat bees, occupy a wide range of temperature adaptations, but the genus typically dominates in temperate environments (Dar et al., 2025). As climate change impacts these montane regions, and the climate becomes warmer and drier, resembling a more temperate environment, we can expect to see an increase in *Lasioglossum* abundance and a shift in species composition with increased species diversity. Most likely this is notable as the environment more closely matches the common temperature adaptations of *Lasioglossum,* becoming a more viable habitat for these species. *Lasioglossum* nest in the ground so increased precipitation could be negatively impacting abundance through habitat degradation. Precipitation strongly correlates with floral resource availability which could limit abundance (Quinlan et al., 2025), however even as annual precipitation decreases floral resources and precipitation are still present, as we see precipitation decrease even more this could potentially start negatively impacting abundance.

The most common *Lasioglossum* species as well as the more rare species show a similar trend of increasing abundance as temperature increases and decreasing abundance as precipitation increases. For the more rare species it is interesting to see how some species, such as L. Egregium, are limited to smaller temperature and precipitation windows. The more rare species mostly showed a trend visually but did not significantly show the same results, most likely because of fewer data points limiting statistical power. Overall most species of *Lasioglossum* show a similar response to the climate variables.

Species temperature index did have an effect on how different *Lasioglossum* species respond to changing climate variables. With species in the mid-STI range (6.8-6.9) having the most pronounced response, species on the lower and upper STI range did not significantly respond to changing climate variables. Species in the middle STI range might be able to take more advantage of the changing climate, compared to species on the more extreme ends of the temperature adaptations. The mid-STI range (6.8-6.9) is also significantly smaller than the low-STI range (-3.8-6.8) or the high-STI range (6.9-16.6), the species in the mid-STI range might be responding to climate differences more similarly because the range is so small, where as the low and high STI range might be more noisy across a wider range showing less statistical significance for correlation between STI range and changes in abundance.

Species composition is shifting as temperature increases and precipitation increases. There is greater species diversity in the composition at higher temperatures, probably because warmer temperatures match temperature adaptations for more *Lasioglossum* species. Greater species diversity most likely is an important factor for the greater abundance we are seeing as well.

Future work could look more closely at the climate variables to better understand what is driving changes in abundance. Examining how snowpack, summer precipitation, snow patchyness, and frost free growing days impact abundance could provide more nuanced insight into why *Lasioglossum* abundance is changing as the climate changes.

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