

**The Effect of Changing Floral Density on Pollinator Networks in a Subalpine Meadow
Environment**

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Abstract

Plant-pollinator networks shape the populations of flowering plants across the world. Ecosystems face increasing challenges that decrease floral density and threaten to restructure plant-pollinator networks. The responses of these networks will play a critical role in the fates of plant species, because pollinator foraging decisions are made in the context of a multispecies floral community. Pollinators make foraging decisions to optimize the foraging cost/benefit ratio based on factors including energy expended and gained. The loss of a single generalist plant species has been observed to disproportionately impact the pollinator network, decreasing visitation rates to surrounding plants. However, it is unknown how the concurrent decline of multiple flower species might affect the pollinator community and network. Understanding the impact of floral density on the pollinator network is critical for predicting the effects of ecosystem change. We applied clipping treatments to thirty-six eight-by-eight meter plots to create gradients of floral density for four wildflower species. Pollinator observation data was used to quantify pollinator community variation across plots and calculate network metrics to understand the impact of floral density on the pollinator network. Our findings suggest that changing floral density affects pollinator composition, total pollinator visits, and visitation rate, and has no effect on nestedness or specialization. This has implications for the resilience of plant-pollinator networks and their ability to withstand future threats because these relationships have the potential to increase or decrease plant resilience, an outcome that will help determine the fate of plant populations as they respond to environmental change.

Introduction

Plant-pollinator networks shape the populations of flowering plants across the world (Stephens et al., 2023). Unfortunately, ecosystems face challenges that decrease the biodiversity of the floral community and threaten to restructure plant-pollinator networks. The responses of these networks will play a critical role in the fates of plant species, because pollinator foraging decisions are made in the context of a multispecies floral community.

In order to attract pollinators, flowering plants provide rewards, such as pollen or nectar. They often coevolve with their pollinators which can result in the specialization of either species. A specialist pollinator pollinates only a specific few flower species while a generalist pollinates many. Rare and dispersed plants frequently use specialized pollinators to prevent interspecies transfer of pollen while plants that are very prevalent often have generalized pollinators (Johnson & Steiner, 2000). Most plant-pollinator networks are highly nested, which means that specialist species interact with generalist species and comprise a subset of the generalist interactions. This creates a central core of interactions that increases the resilience of the network, including the plant community (Bascompte, 2003).

Optimal foraging theory states that pollinator visitation rates are higher in areas of higher floral density while in sparse populations pollinators switch between plants less frequently (Charnov,

1976; Grindeland et al., 2005; Mustajärvi et al., 2001). Various factors influence these decisions, and a pollinator often chooses which flowers to visit to optimize the cost/benefit ratio of foraging rewards, such as energy expended as compared to pollen or nectar obtained. This ratio increases the further apart floral resources are and decreases if a flower has a higher pollen or nectar reward. Pollinators generally visit larger or closer patches more frequently in order to optimize this cost/benefit ratio. Because multiple factors influence this ratio, pollinators use many environmental signals to decide which flowers to visit (Murakoshi, 2024). Another factor that influences pollination decisions is foraging currency. Species either maximize energetic efficiency, defined as the net energy intake divided by the energy used, or maximize the net rate of energy intake (NREI), the net energy intake divided by the time spent. The foraging currency of a pollinator affects their distribution: species who maximize energetic efficiency are often found in dense floral environments while those who maximize NREI are found in sparse environments. Other factors that influence how floral density affects pollinator visitation include search speeds, flower handling times, predation rates, and more (Essenberg, 2013). Whether the density-visitation relationship is positive, negative, or neutral varies by plant-pollinator pair because plant and pollinator traits both influence the foraging cost/benefit ratio and consequently pollinator foraging decisions. It is likely that different pollinator species will respond differently to changing floral density and composition, leading to different impacts on the plant community (Essenberg, 2012; Essenberg, 2013; Grindeland et al., 2005; Murakoshi et al., 2024; Mustajärvi et al., 2001).

While many of the factors influencing pollinator visitation decisions are well understood, it is unclear how multispecies changes to floral density, caused by population decline, might affect network structure. The removal of a generalist flower species from a network has disproportionate effects on the remaining plants as well as on the pollinator network. Previous work found that the removal of *Helianthella quinquenervis*, an abundant generalist flower, led to a decline in pollinator visitation rates, increased the specialization of the network, and changed the pollinator composition. Generalist plants are prevalent and interact with many other plants through competition and facilitation. Consequently, their loss restructures the plant-pollinator network and can have widespread effects, including increasing the sensitivity of the remaining plant species to future threats and causing the loss of pollinator species from an area (Bain et al., 2022). Knowing how the density of a multi-species floral community affects the plant-pollinator network is important for predicting the effects of ecosystem change that will likely impact many plant species simultaneously, consequently reshaping pollination systems. As plant populations decline, will the pollinator network help recover the plant population? Or will it respond in a way that declines the plant population even more sharply? Understanding this would help us predict some of the effects of ecosystem change and implement effective conservation strategies (Johnson & Steiner, 2000).

This project explored how changing density of multiple flower species affected the pollinator network and composition by evaluating the metrics of specialization, nestedness, visitation rate, and total visits. Multispecies plant communities introduce more complexity because a generalist pollinator may see a multispecies ecosystem as dense while a specialist sees it as sparse, meaning that even within the same floral neighborhood, different pollinator species behave differently (Essenberg, 2013). Because plant-pollinator networks nearly always include multispecies plant and pollinator communities, it is critical to explore how changing density of a multispecies plant community affects the pollinator network. We hypothesized that decreasing multispecies floral density would decrease the nestedness and total pollinator visits and increase the specialization and visitation rate, but that the effect on the pollinator network would differ in magnitude by plant species. We expected decreased nestedness, as was observed by (Bain et al., 2022), because all four study species in this project are generalists. In highly nested networks, specialist species primarily interact with generalist ones. Consequently, decreasing the density of generalist plants will likely decrease the nestedness. Additionally, we predicted that specialization would increase because as generalist plants are lost, there are less for the pollinators to interact with, and specialization will increase. Finally, visitation rates were predicted to increase because as density decreases, the pollinator to flower ratio increases and each individual flower receives more visits, increasing the per-flower visitation rate. However, total visits were predicted to decrease because as density decreases, floral patches lose the benefit of short travel distances for pollinators and become less attractive, therefore receiving less visits.

Specific Methodologies

This project involved four study flower species: *Helianthella quinquenervis* (HEQU), *Erigeron speciosus* (ERSP), *Hymenoxys hoopesii* (HYHO), and *Senecio crassulus* (SECR). All four species are asters (Family: Asteraceae) with similar floral structure, varying degrees of overlap in flowering phenology, and several pollinator species in common.

Clipping treatments were applied to thirty-six eight-by-eight meter plots. Flowers of each species were clipped to varying degrees across the plots to artificially create gradients of floral density, from zero to the full natural density, for each of the four study species. These treatments were applied pseudorandomly to avoid choosing the degree of flower clipping for each species purely based on its pre-existing density and to ensure that the resulting density gradient of each species would not have wide gaps between low, medium, and high densities.

After the clipping treatments were applied, pollinator interactions with the four study flower species were recorded. An interaction was defined as anytime an insect came into contact with the reproductive parts of an open flower. The species of both the flower and the pollinator were recorded, with pollinators recorded to species or using morphospecies identification when necessary (Bain et al., 2022). Limited voucher specimens were collected (less than five

individuals per species) to aid in identification and otherwise floral visitors were identified on the wing or by catch-and-release in the field.

Each observation period was fifteen minutes, during which the observer moved slowly throughout the plot recording any pollinator interactions observed (Bain et al., 2022). A wide counterclockwise circle followed by a smaller circle was made in each plot and repeated until the fifteen minute observation period was complete. The order in which the plots were visited was determined randomly, with the constraint that each plot received an equal number of visits in the morning (observation period beginning before 12 pm) and afternoon (observation period beginning after 12 pm) over the study period. A plot was never visited twice in one day.

Pollinator observation data were used to evaluate the pollinator composition and network structure of each plot. All analyses were conducted in R. p -values are described with the language used in (Bain et al., 2022) which states that $p > 0.1$ constitutes no evidence, $p < 0.1$ is weak evidence, $p < 0.01$ is strong evidence, and $p < 0.001$ is very strong evidence.

Non-metric multidimensional scaling ordination and permutational multivariate analysis of variance with Bray-Curtis or Gower dissimilarity were used to evaluate the effects of floral density on observed pollinator community composition. The marginal effects of the individual plant densities and observation date (to account for the effect of timing) were tested in order to determine the variation in pollinator composition explained by each term independently.

The bipartite package in R was used to calculate the network structure metrics of nestedness and specialization (Bain et al., 2022). Total visitation rate was calculated as the total pollinator visits to a plot divided by the total flowers in the plot (Essenberg, 2012). Linear regression (LM), generalized additive (GAM), negative binomial regression (NB), and generalized linear (GLM) models were used to evaluate the impact of floral density on visitation rate, total visits, nestedness, and specialization (Dormann, 2007). For each of twenty-eight relationships that were examined, a Shapiro-Wilk test was run to determine if the data was normally distributed (See Tables 1-4). If it was not, the same test was run on log transformed data.

For the relationships involving total density and either total visits or visits to an individual species, a GLM with Poisson distribution, GAM, NB, and GAM with a negative binomial family were run. The most appropriate model was selected based off akaike information criterion (AIC), dispersion, and other factors. For the relationships between visits to a specific flower species and the density of that flower species, a LM with log transformed data (not run for SECR), GLM with Poisson distribution, NB, and GAM with a negative binomial family were run and the most appropriate model was chosen using the same selection criteria. To model any relationships involving total or individual visitation rate, a GLM with Poisson distribution, GLM with gamma distribution, LM on log transformed data, and GAM were run and the same criteria were used to

evaluate the models. A LM and GAM were run for the relationships between nestedness and density as well as for the relationships between specialization and density, and the most appropriate model was selected for each.

Results

Non-metric multidimensional scaling (NMDS) ordination was used to compare pollinator community composition across plots (Figure 1). A permutational multivariate analysis of variance (permanova) with Bray-Curtis dissimilarity was subsequently used to quantify the variation between plots. Running the permanova on the pollinator matrix yielded an r^2 value of 0.278, which means that floral density explained 27.8% of the variation in pollinator community composition across plots. The permanova had an F-statistic of 2.99 and a significant p -value of 0.001. Another permanova, this time testing the marginal effects of the densities of the four flower species, was run to determine if individual flower species densities affected pollinator composition. The densities of HYHO, ERSP, and SECR all had a significant independent impact, to different degrees, on the pollinator community. HYHO had a p -value of 0.008 and explained 7.81% of the variation in pollinator composition, ERSP had a p -value of 0.001 and explained 15.6% of the variation, and SECR had a p -value of 0.016 and explained 6.83% of the variation. HEQU did not have a significant impact on pollinator community composition ($p=0.070$).

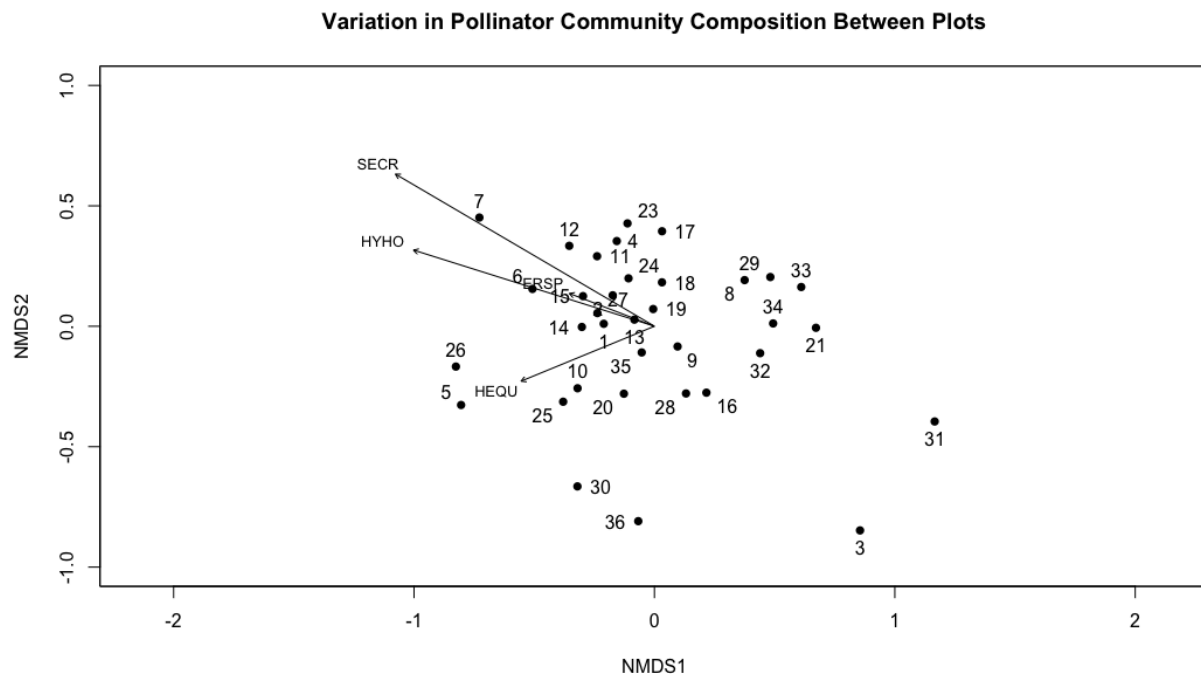


Figure 1: Non-metric multidimensional scaling with four environmental variables (HEQU density, HYHO density, ERSP density, and SECR density).

Another NMDS and permanova were run to examine how much of the relationship between density and pollinator composition was due to the date of observation. Pollinator observations were conducted over a twenty-three day period, during which the four study species went through different stages of flowering. Because of this, we evaluated whether the impacts of floral density were independent from date. Together, the total floral density and date significantly ($p < 0.001$) accounted for 3.87% of the variation in pollinator community composition. Looking at the impact of each term independently (date, HEQU density, HYHO density, ERSP density, and SECR density), ERSP density and date both had a significant and independent effect on pollinator community composition: date explained 1.46% of the variation in pollinator composition ($p < 0.001$) and ERSP density explained 1.25% of the variation in pollinator composition ($p < 0.001$). There was no significant relationship between pollinator composition and SECR density ($p = 0.066$), HEQU density ($p = 0.66$), or HYHO density ($p = 0.22$).

Plot density significantly impacted total pollinator visits a plot received, especially at low densities. A generalized additive model with a negative binomial family found a significant ($p < 0.001$) adjusted r squared value of 0.242, suggesting that there is very strong evidence the total plot density explains 24.2% of the variation in total visits. As total density increases from zero, total visits increase, but this effect disappears at higher densities (Figure 2).

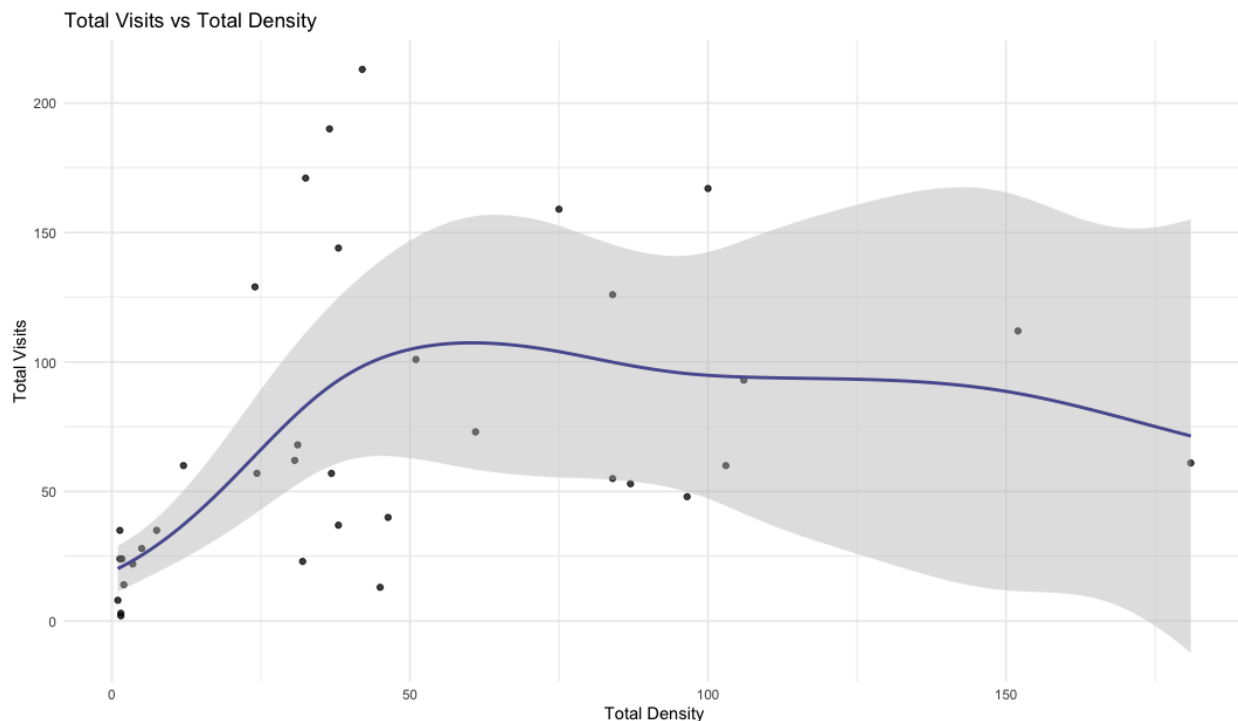


Figure 2: Total Visits vs. Total Density using a generalized additive model with a negative binomial family.

When the relationship between density and total visits was examined by study species, there was no evidence of a significant relationship between total visits and HEQU, HYHO, or SECR densities. A negative binomial regression returned insignificant p -values of 0.67, 0.119, and 0.92 for HEQU, HYHO, and SECR, respectively. A p -value of 0.004 was found for ERSP density, suggesting that increasing ERSP density increases total visits to all study species (Figure 3).

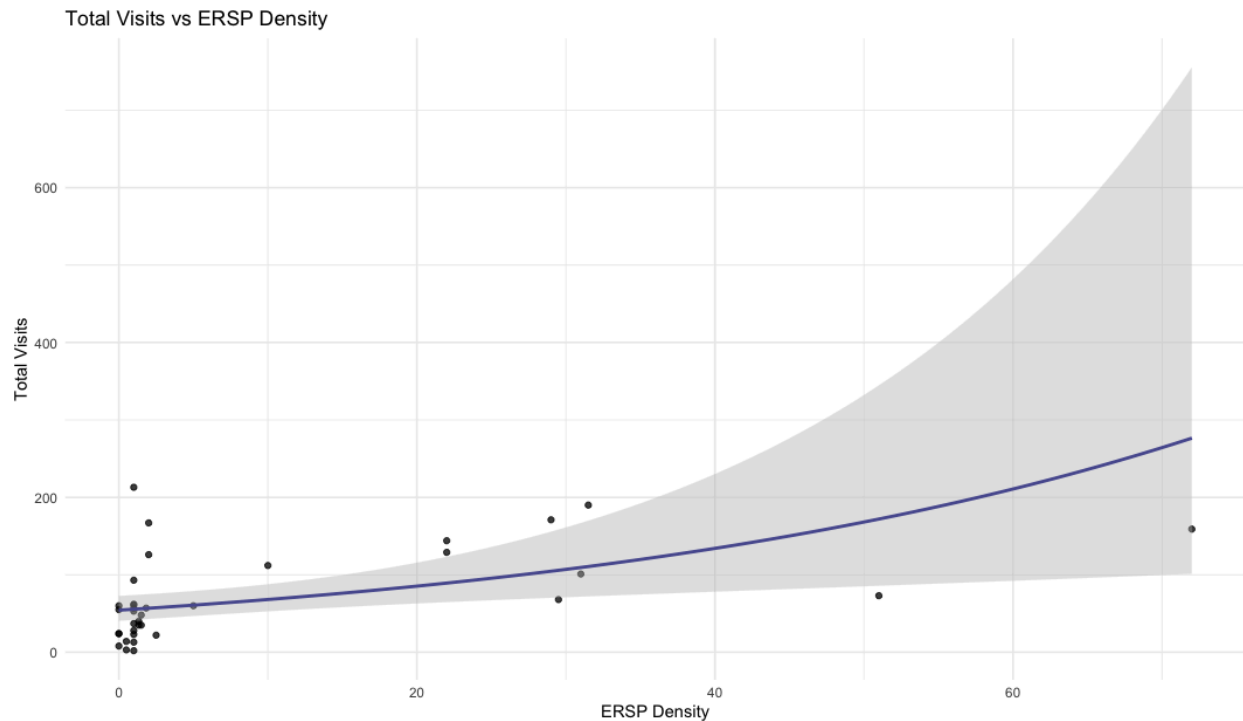


Figure 3: Total Visits vs. ERSP Density using a negative binomial regression.

A linear model on log transformed data was used to find that there was a significant ($p < 0.001$) relationship between the density of HEQU flowers in a plot and the total visits to HEQU, with the addition of one HEQU plant increasing the total visits to HEQU by 2.76%. Similarly, there was a significant ($p < 0.001$) relationship between the density of ERSP and the total visits to ERSP, and the addition of one ERSP increased the total visits to ERSP by 5.86%. There was also a significant ($p < 0.001$) relationship between the density of HYHO and total visits to HYHO, with the addition of one HYHO plant increasing the total visits to HYHO by 9.38%. Finally, a negative binomial regression found that there is a significant ($p < 0.001$) relationship between SECR density and SECR visits where the addition of one SECR increased the total visits by 2.13%. These results suggest that the density of each individual plant has an impact on the amount of visits that particular species receives such that as the densities increase, so do the total visits.

Increased density decreased the visitation rate. Running a linear model on log transformed data yielded a significant p -value < 0.001 , suggesting that there is a significant relationship between

total density and visitation rate such that the addition of one plant causes a 1.77% decrease in visitation.

Comparing the total visitation rate against the densities of each individual study flower using a linear model with log transformed data yielded a significant ($p=0.048$) relationship between the density of HEQU and the total visitation rate as well as a significant ($p<0.001$) relationship between the density of SECR and the total visitation rate. This suggests that there is strong evidence that increasing the density of SECR decreases the total visitation rate by 1.54% per additional SECR and moderate evidence that adding an additional HEQU will decrease the visitation rate by 1.33%. There is no significant relationship between the densities of HYHO ($p=0.083$) or ERSP ($p=0.75$) and total visitation rate.

The relationship between individual flower species density and visitation rate to that specific species was evaluated using a linear model with log transformed data for HEQU, HYHO, and ERSP and with a GLM with gamma distribution for SECR. There was a significant relationship between the densities of HEQU ($p=0.014$), ERSP ($p=0.013$), and SECR ($p=0.004$) and the visitation rates to HEQU, ERSP, and SECR, respectively, but not a significant relationship for HYHO ($p=0.55$). There is moderate evidence that increasing the density of HEQU by one plant will decrease the visitation rate to HEQU by 2.04% and that the addition of an ERSP plant will decrease the visitation rate to ERSP by 2.19%. The addition of one SECR plant significantly decreased the visitation rate to SECR by 1.65%.

The impacts of density on the network structure metrics of nestedness and specialization were also examined. A generalized additive model did not indicate a significant relationship between nestedness and total density ($p=0.36$). Similarly, it was determined with a linear model that there is no significant relationship between nestedness and the individual densities of HEQU ($p=0.80$), HYHO ($p=0.51$), ERSP ($p=0.33$), or SECR ($p=0.70$).

Using a generalized linear model to evaluate the relationship between specialization and total density yielded an insignificant p -value of 0.26. Additionally, it was found using a GLM that there is no significant relationship between specialization and the individual densities of HEQU ($p=0.167$), HYHO ($p=0.84$), ERSP ($p=0.83$), or SECR ($p=0.74$).

Discussion

This project manipulated floral densities across thirty-six plots in a subalpine meadow to understand the impact of changing density of multiple flower species on the pollinator composition and network. We found that changing floral density has a significant impact on pollinator community composition, even after the date of observation is accounted for, consistent with previous studies (Bain et al., 2022; Essenberg, 2013). As flowers are removed, pollinators may reevaluate visitation decisions because of the changed distances between flowers, potential

differences in floral rewards, and other reasons. Because pollinators work to optimize the foraging cost/benefit ratio, factors impacting this ratio, such as floral density, may cause pollinators to change their behavior, likely leading to shifts in pollinator community composition (Murakoshi et al., 2024).

Although total floral density had a significant impact on pollinator composition, not every study species had an independent effect. ERSP density had an impact on the pollinator community when date of observation was accounted for but the relationship between pollinator composition and both HYHO and SECR disappeared. This suggests that the impacts of HYHO and SECR density on pollinator composition was more influenced by the timing of floral processes than by density, a result that is inconsistent with previous studies that found significant impacts of density regardless of timing (Bain et al., 2022). It is possible that the effects of timing, which influence plant-pollinator interactions, were strong enough to erase the relationship between HYHO density and pollinator composition (Kehrberger & Holzschuh, 2019). Additionally, many SECR plants were observed to have significantly decreased visitation in the latter portion of the observation period, likely due to wilted floral displays and going to seed. The timing of life cycle events may have influenced plant-pollinator interactions strongly enough to cause the relationship between density and pollinators to disappear (Kehrberger & Holzschuh, 2019).

Plot density significantly explained nearly a quarter of the inter-plot variation in total visits in our study. Interestingly, there is a lack of consensus on whether there is a positive relationship between visitation and density with some previous studies finding no effect of density on total visits while others have found a positive or negative relationship (Grindeland et al., 2005). Our findings suggest that density positively affects visitation at low density ranges, but this effect disappears at higher densities. Increasing visits with increasing density is expected: more flowers in a plot mean that there are more floral resources available at a lower cost, which attracts pollinators (Bain et al., 2022). The lack of a relationship between density and total visits at higher densities is likely due to insufficient data to determine the relationship at high densities and might become clear with more data points. Total visits increased as ERSP density increased and increased density of each individual study species led to increased visits to that species. These results are consistent with optimal foraging theory, which predicts that there will be higher visitation in areas of higher floral density (Charnov, 1976; Grindeland et al., 2005; Mustajärvi et al., 2001).

Density and visitation rate were significantly correlated, such that increasing density led to decreased visitation rate. This applies to HEQU, ERSP, and SECR independent from each other as well: increased density of each individual species led to a decrease in the visitation rate to that particular species. This result supports our hypothesis that increasing density would decrease visitation rate and corroborates previous studies that have found a similar result of sparse populations receiving more visitors per plant (Mustajärvi et al., 2001). However, these results

disagree with yet other studies that have found that visitation rate increases with density or have found no effect (Essenberg, 2012; Essenberg, 2013; Grindeland et al., 2005). Both results are tenable. As density increases, the pollinator to flower ratio decreases, making it less likely that each flower will continue to receive as many visits as it would in a sparser patch, consequently lowering the visitation rate, as was observed in this study (Essenberg, 2012; Essenberg, 2013). The opposite result, which we observed with the positive relationship between increasing ERSF density and increasing total visitation rate, is also plausible. Increasing density reduces travel time between flowers, allowing each flower to be visited more frequently and therefore increasing the visitation rate (Essenberg, 2013).

In contrast to our hypothesis, there was no significant relationship between nestedness and density, both total density and individual species density. Similarly, there was no significant relationship between specialization and density, both total and individual density. Both of these results disagree with previous studies that found that a decrease in floral density leads to lower nestedness and higher specialization. Networks that have higher specialization and lower nestedness are often less stable, thus it is reasonable that previous studies found this in plots that experienced the disruption of floral removals (Bain et al., 2022). It is possible that the manipulation of the densities of four species along a gradient rather than the complete removal of one led to the lack of a significant relationship between density and either of these network metrics. Multiple species were clipped to partial densities in many plots instead of being fully present or absent. The nonzero densities of the study species in many plots may have created a buffering effect that allowed plots with different densities of the four study species to maintain a similar enough network structure that there was no significant relationship between density and either nestedness or specialization.

However, it is also likely that the absence of a significant relationship is due to a lack of data. There was not a lot of data for high floral densities and although there was a lot of data for low densities, it had variation. Both of these factors make it difficult to determine a trend from the data and could have contributed to the absence of a significant relationship between density and nestedness or specialization. This limitation provides opportunities for future research. Collecting more pollinator observation data across a wider and more consistent density gradient would provide insight into the effects of floral density on various network structure metrics, multiple of which are not significant in our findings.

Additionally, although this study focused exclusively on interactions between pollinators and the four study flower species, there were many other wildflower species present in the plots. A future direction could be to explore how manipulating the density of a select few study species impacts the other flower species present and their interactions with pollinators.

The results of this study have important implications for understanding the impacts of future environmental change. Our finding that changing floral density affects pollinator community composition may have detrimental impacts on plant communities. Contributions of individual pollinator species to ecosystems are influenced by the pollinator community, meaning that small shifts in pollinator composition have widespread impacts on plant communities. Additionally, the loss of a single pollinator species has been shown to lead to reduced plant reproduction (Brosi & Briggs, 2013). It is possible that shifts in the pollinator community caused by declining plant populations will lead to reduced plant reproduction and cause plant populations to decline even more rapidly.

The absence of a significant relationship between specialization and density or nestedness and density could suggest a high level of ecosystem resilience and would be supported by future even higher powered study. If these network structure metrics are not affected by declining plant populations, the plant-pollinator network may be able to withstand some degree of environmental change, even if it decreases plant populations.

Another safeguard for plant populations is our result that visitation rate increases as density decreases, allowing each plant to be visited more often. This has the potential to recover struggling plant populations because the increased pollinator to flower ratio in sparse environments provides each plant more opportunities to reproduce (Essenberg, 2013). Such adaptation of interactions in plant-pollinator communities and networks may help sustain and recover populations should they begin to decline due to ecosystem threats.

Our findings suggest that changing floral density impacts pollinators, an interaction that will affect the health of plant populations. This has implications for the resilience of plant-pollinator networks and their ability to withstand future threats because these relationships have the potential to increase or decrease plant resilience, an outcome that will help determine the fate of plant populations as they respond to environmental change. Understanding these interactions is critical for implementing effective conservation strategies so that plant populations can be sustained through harmful environmental change.

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Tables and Figures

Figure 4: Site Map with points at plot corners and at the location of every study species within the plots.



Model Selection Process: the following tables describe the results of models run for a subset of the twenty-eight relationships that were examined to demonstrate how the most appropriate models were selected.

Table 1: Total Visits vs. Total Density

Mode	<i>p</i> -val	F-stat	AIC	Null	Resid	Dispe	Dispe	Multi	Adjus	Theta	Estim
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l/Test	ue	istic		Devia nce	ual Devia nce	rsion Ratio	rsion	ple r^2	ted r^2		ate
Shapi ro-Wi lk Test	0.002 244	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shapi ro-Wi lk Test on Log Trans forme d Data	0.011 43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gener alized Linea r Mode l with Poiss on Distri butio n	2e-16	NA	1589. 4	1553. 6	1380. 2	44.61 123	1	NA	NA	NA	0.005 4093
Gener alized Addit ive Mode l	0.013 8	3.98	388.0 037	NA	NA	NA	2414. 97	NA	0.256	NA	NA
Negat ive Bino mial Regre ssion	0.004 38	NA	378.3 4	45.10 1	39.63 3	NA	1.119 098	NA	NA	1.605	0.008 607
GAM with a Negat ive Bino mial Famil y	6.82e- 07	NA	366.5 415	NA	NA	NA	1	NA	0.242	NA	NA

Table 2: Visitation Rate vs. Total Density

Model/Test	p-value	F-statistic	AIC	Null Deviance	Residual Deviance	Dispersion Ratio	Dispersion	Multiple r^2	Adjusted r^2	Theta	Estimate
Shapiro-Wilk Test	6.389e-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shapiro-Wilk Test on Log Transformed Data	0.5452	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GLM with Poisson Distribution	2.09e-14	NA	Infinitely	171.059	77.016	2.510735	1	NA	NA	NA	-0.028352
GLM with Gamma Distribution	1.04e-07	NA	146.52	44.567	19.730	NA	0.586788	NA	NA	NA	-0.019496
Linear Model on Log Transformed Data	1.24e-06	34.55	90.29964	NA	NA	NA	NA	0.504	0.4894	NA	-0.017898
Generalized Additive	0.00104	6.832	212.8006	NA	NA	NA	18.66458	NA	0.36	NA	NA

Model											
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Table 3: Nestedness vs. Total Density

Model/Test	p-value	F-statistic	AIC	Null Deviance	Residual Deviance	Dispersion Ratio	Dispersion	Multiple r^2	Adjusted r^2	Theta	Estimate
Shapiro-Wilk Test	0.2338	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Linear Model	0.0465	0.5471	295.0469	NA	NA	NA	NA	0.01681	-0.01391	NA	-0.05070
Generalized Additive Model	0.362	1.324	293.6547	NA	NA	NA	282.4182	NA	0.0614	NA	NA

Table 4: Specialization vs. Total Density

Model/Test	p-value	F-statistic	AIC	Null Deviance	Residual Deviance	Dispersion Ratio	Dispersion	Multiple r^2	Adjusted r^2	Theta	Estimate
Shapiro-Wilk Test	0.006072	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gamma Generalized Linear Model	0.642	0.702	-4.852447	NA	NA	NA	0.04340393	NA	0.0132	NA	NA
Generalize	0.264	NA	-17.38	11.390	10.957	NA	0.4024891	NA	NA	NA	-0.003199

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Table 5: Observed Pollinators. This table contains observed pollinators identified to species, genus, family, or order. In cases where pollinators were not able to be identified to species, they were identified to the next narrowest classification possible. This resulted in fewer entries to the following list than there were total pollinators observed as there are instances where multiple different species are identified to the same broader classification.

Pollinator Identification
Aedes cataphylla
Anthomyiidae sp.
Arctophila flagrans
Bombus (Psithyrus) insularis
Bombus bifarius
Bombus flavifrons
Bombus frigidus
Bombus sylvicola
Bombyliidae sp.
Cartosyrphidae tarda
Chinavia hilaris
Chrysotoxum ventricosum
Cicadellidae sp.
Coccinella transversoguttata
Coelioxys (Coelioxys) sodalis
Deraeocorinae sp.
Empididae sp.
Epicauta pruinosa
Eulophidae sp.

Eupeodes volucris
Eupithecia cretacea
Fanniidae sp.
Gasteruptiidae sp.
Gasteruption kirbii
Geron sp.
Halictus (Seladonia) virgatellus
Halictus rubicundus
Ichneumonidae sp.
Lasioglossum (Evyllaes) nigrum
Lepidoptera sp.
Lycaeides melissa
Lycaena rubidus sirius
Lygaeidae sp.
Lygus sp.
Megachile (Xanthosarus) melanophaea
Meromyza sp.
Metasyrphus lapponicus
Miridae sp.
Morellia sp.
Paragus tibialis
Perdita tortifoliae
Plebejus acmon lutzi dos passos
Psila dimidiata
Pyraloidea sp.
Rhyssa persuasoria
Scarcophagidae sp.
Schinia sp.

Schinia villosa
Speyeria mormonia eurynome
Sphaerophoria robusta
Sphex procerus
Systoechus sp.
Tachinidae sp.
Tenebrionidae sp.
Tenthredinidae sp.
Tephritidae sp.
Thricops septentrionalis and villacrura (female)
Thricops septentrionalis and villacrura (male)
Trypoxylon frigidum
Ulidiidae sp.