

How understory bee communities compare to open meadows in the Rocky Mountains
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Abstract

Forest associated species, bees and otherwise, are among the world's most vulnerable species due human activity such as deforestation. Even though bees are significant to ecosystem health by providing such important services as pollination, basic information on bee biodiversity and factors driving their distributions in temperate coniferous forest ecosystems are relatively scarce. It is likely that there are a minority of bee species that are associated with forest habitats; however, very few have been described. In Colorado, 34% of the landscape is forested. Montane regions such as the Gunnison Valley are predicted to experience the most extreme changes in climate, potentially making bee communities vulnerable. The goals of this research were to determine at which site (meadow or forest) and at what time of day were social and solitary bees most abundant around Gothic, Colorado. We used catch rate as a proxy for abundance. We found that social bees (*Bombus* spp.) have the same abundance in the meadow as the forest at any time of the day. Solitary bees, on the other hand, are more abundant in the meadow regardless of the time of day. This research project provides a baseline for further investigation of forest associated bees.

Introduction

Bees play important roles in many forest ecosystems (Bawa, 1990; Motten, 1986). They have key impacts on the assembly and genetic structure of plant communities, the maintenance of ecological networks, and the provisioning of ecosystem services, such as pollination (Loveless and Hamrick, 1984; Kremen et al., 2007 in Rhoades, 2018). The functional diversity in pollinator assemblages can promote recruitment and retention of diverse and species rich plant communities in forest ecosystems (Winfree et al, 2007 in Rhoades et al., 2018). Even though bees are significant to ecosystem health, basic information on bee biodiversity and factors driving their distributions in temperate coniferous forest ecosystems are relatively scarce. It is likely that there are a minority of bee species that are associated with forest habitats (Michener, 1979 in Smith et al., 2021); however, very few wild bee communities in forests have been described (Rhoades et al., 2018).

In eastern North America, a large percentage of bees could have historically been forest associated (Smith et al, 2021) and were likely the dominant bee fauna before European colonization and widespread deforestation (Davis, 1983, Russell and Davis, 2001 in Smith et al., 2021). The life histories of forest associated bees are unique as they are adapted to the phenology patterns of light and flower availability. Therefore, these bees are often active in the spring (Smith et al, 2021). In addition, Rhoades et al. (2018) found that in the mixed conifers of Pike's Peak National Forest, bee diversity and abundance were positively correlated with the understory flowering species richness and were inversely correlated with tree basal area. This means that overstory canopy gaps could increase site occupancy by forbs, which in turn could drive the local abundance and diversity of bee assemblages. Today, as habitats are transformed to anthropogenic landscapes, species may transition from forest associated to those that can tolerate human habitats (Smith et al., 2021). Smith et al. (2021) found that the richness of forest associated bees was positively correlated with larger forest area, but the richness of habitat generalists was not associated with forest area. Consequently, forest associated species, bees and otherwise, are among the world's most vulnerable species due human

activity that interrupts canopy cover and leads to widespread forest loss (Smith et al, 2021; Winfree et al, 2007 in Rhoades et al., 2018).

In Colorado, 34% of the landscape is forested (Bechtold and Patterson, 2005; USFS, 2016 in Rhoades et al., 2018). The diverse mix of conifer and deciduous trees make Colorado forested landscapes one of the most complex in the Intermountain West (Colorado State Forest Service, n.d.) Aspen and fir-spruce forest types populate the areas surrounding the Rocky Mountain Biological Lab. Aspen forest types make up 20% of Colorado's forested land and provide essential wildlife habitat. They are second to riparian areas for biodiversity richness. In addition, aspens are the first trees to inhabit a landscape after a disturbance. Spruce-fir make up 19% of state's forested land and is the most extensive of Colorado's forest types. They are the climax type forest and provide wildlife habitat (Colorado State Forest Service, n.d.).

Montane regions are predicted to experience the most extreme changes in climate, potentially making bee communities vulnerable (Ogilvie et al., 2017). Currently, the relative importance of direct and indirect climate effects on bee populations is undetermined. Data on the effects are necessary to construct better forecasts of bee population response to climate change, especially for ecosystem functioning (Ogilvie et al., 2017). There are many potential climate implications for forest associated bee species. If heat increases, forests could become a refuge for bee communities in future. Shade loving bee species could be present exclusively in the forested areas. Forests may change in structural and species composition over time, leading to changes in the pollinator assemblages. Therefore, more baseline data are needed for forest associated bee species.

Dr. Rebecca Irwin and other researchers at Rocky Mountain Biological Lab have been studying bee communities within various dominant ecosystems surrounding Gothic, Colorado (Gezon et al., 2015; Mitchell et al., 2009; Ogilvie et al., 2017; Stemkovski et al., 2020). These researchers have been observing and surveying climate change's impacts on phenology and native bees across three different meadow types. However, no work has been done to collect and catalog the bee species present and pollinating in the adjacent forest understories. The goals of this research were to determine at which site (meadow or forest) and at what time of day social and solitary bees were most abundant around Gothic, Colorado. We paired meadow data from 2022 with forest sampling from 2022 to ask: What is the catch rate of social versus solitary in forests versus meadows at different times of the day? Catch rate is a proxy for abundance and provides baseline data for bee preferences. We predicted there would be fewer bees caught in the forest versus the meadow with little variability in time of day and in social versus solitary bees.

Methods

Plots

Dr. Irwin's lab currently collects data on solitary and bumble bees within 16 meadow plots near Rocky Mountain Biological Lab (RMBL; 38°57.5 N, 106°59.3 W, 2900 m) in Colorado, USA. Sites are spread throughout the Gothic valley, Almont, and south of Crested Butte. The three meadow types are dry, wet (*Veratrum* sp.), and wet (willow).

We collected bees in four preselected plots (Rustlers Forest, Davids Forest, Seans #1 Forest/Seans #2 Forest, and North Elko Forest) that were paired with Dr. Irwin's meadow sites (Figure 1, Figure 2, Figure 3, and Figure 4, Figure 5, Figure 6). The forest sites were dominated by aspen or spruce-fir forests and were 30 by 30 meters each. We sampled for a total of nine days.

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Bee datasets

Samples were taken for one hour in the morning and one hour in the afternoon twice a week. As Gezon et al. (2015) described, collecting bees using lethal methods, such as pan traps and sweep netting, at two-week intervals over multiple years does not significantly affect wild bee community structure in terms of diversity and abundance. We netted bees that are clearly in contact with flower reproductive parts. Netted solitary bees were sacrificed and later pinned and identified. Any *Bombus* species were placed in a bee squeezer, identified in the field, recorded, marked with a generic paint pen, and released. The collector walked each plot in a random order and paused the clock when processing a bee and then restarted the clock when she was finished.

Plant dataset

Plants that were associated with the netted bees were recorded. Flowering plants inside the plot boundaries will also be identified and given an abundance ranking (1= 1-10 flower units, 2= 10-50 flower units, 3= 50+ flower units). Names and ranking categories are synonymous to those used by the Irwin lab. The floral dataset will not be analyzed in this research due to meadow data not being processed.

Forest dataset

We utilized a densiometer to determine canopy cover in the aspen and spruce-fir dominated forests. From plot center, the researcher walked 20 in each of the four cardinal directions and recorded the open canopy. We then averaged the total and multiplied by 1.04 to obtain the percent overhead area not occupied by the canopy.

Statistical analysis

We compared catch rates (bees per hour netted) between the two site types of meadow and forest on the same collection days. A new species list of flora and social bees collected in understory was created. After the summer, all specimens will be identified to species using keys created in the Irwin Lab and also keys published online and in journals/books. If the bees found in the understory are unique and different enough, future lab members or RMBL scientists can do further surveys.

We then used Rstudio software to combine social bee catch rate and solitary bee catch rate. We compared the catch rate for time of day, site type (forest site vs meadow site), bee type (social vs. solitary) using GGplots. Then we used a paired t-test to test the significance of all combinations of variables.

Results

Catch Rate

The relationship between catch rate, time, and site type for social and solitary bees was analyzed (Figure 7). We found that social bees (bumble bees) have the same abundance in the meadow as the forest at any time of day. $P=0.549$ for comparing forest AM and meadow AM; $P=.880$ for comparing forest PM and meadow PM. Solitary bees, on the other hand, are more abundant in the meadow regardless of the time of day. $P=0.002$ for comparing forest AM and meadow AM; $P<0.001$ for comparing solitary forest PM and meadow PM.

<Figure 7 here>

Densiometer

The densiometer measurements indicated that the aspen forest type had less open canopy than the spruce-fir forest type a majority of samples (Table 1). This research did not analyze in detail the difference between the aspen and spruce-fir understory or light composition.

<Table 1 here>

Discussion

The data indicate that solitary bees are more abundant in the meadow habitat, regardless of the time of day. On the other hand, the social bumble bees have the same abundance in the meadow as the forest at any time of day.

Our findings carry implications in terms of conservation and management decisions. Bumble bees are as abundant in the forest as in the meadow at any time of day; therefore in addition to meadows, forests may be important to conserve as part of bumble bees foraging and nesting area. Also, it was observed that bumble bees were often nesting within the forest. Although forests tend to be cooler than meadows, bumble bees have the ability to raise their internal temperature, which allows them to actively forage in temperatures too cold for other bees (Wilson & Carril, 2016) and may explain why they could be found in the forest. They are also considered resource generalists so it could be possible that they are also habitat generalists. In one study, *Bombus* spp. workers were found to be able to fly 11.6 km from their nest (Rao and Strange, 2012) and therefore may be able to nest further from an abundant food resource in such habitats as forests. Solitary bee conservation, on the other hand, should focus on meadows. A more detailed analysis to the species level of each group will yield more a defined prescription.

This project was baseline research with preliminary results that can be utilized in the future to further study bees in the forests and to determine: if there are any forest associated bees in the area, what is being pollinated in the understory, and if we are eliminating certain species by solely surveying the meadow. The results can guide foresters on how to manage forests and may also aid in projecting bee communities in different forest types or at different seral stages.

Therefore, we have several suggestions in order to enhance any future research of bees in forests. It was noted anecdotally by the lab and other labs at Gothic during 2022 that

the bees may have emerged later in the season due to phenology, which could explain the lack of bees collected at each forest site. This also may suggest that several years of studies would be advantageous for a better insight into bee populations and forest and meadow communities as well as phenological interactions. In addition, the sites received an ample amount of rain this season which created wet conditions in the forest for the following morning. This may have deterred bees from pollinating soggy flowers, which may have reduced abundance estimates. The rain also caused slippery conditions in an already challenging forest environment that contained lots of dead and down trees. Both factors could have reduced catch rate as opposed to the fairly open and obstacle-free meadow which dried out quickly in the morning sun.

In Smith et al. (2021), each site was situated in a homogeneous landscape, such that at least 80% of the surrounding land cover within a 1.5 km radius was either forest or anthropogenic land use—agriculture or development. Given the ability of bees to fly several hundred meters while foraging, this allowed the research team to assume that the bees collected in the habitat site were associated with that habitat site. Smith et al. (2021) was conducted in eastern North America where canopies can be contiguous and vast. However, in the montane region of the Rockies, forests are often interrupted by disturbance such as avalanches and beetle kill, which make the forest areas smaller. Therefore, we suggest that future experiments are designed to minimize ecotones between the meadow and forests in order to truly separate out forest associated and meadow bees. This will require paired forest sites that are more contiguous in canopy cover.

Furthermore, bees and their floral resources must be identified to a species level and analyzed further to understand what is pollinating which understory flowers as well as what the abundance, diversity, and richness of these resources are compared to meadow flowers. A pollen analysis is needed to truly determine the pollination of forest understory angiosperms. In terms of light response and angiosperms, a densiometer tells us about the canopy cover but not necessarily the amount of light penetration or direction, which may be influenced by leaf or needle shape, opacity, spacing, bud break time, etc. Although there was more open canopy in the spruce-fir forest types, there seemed to be more light in the aspen forest type. Further instrumentation and analysis are needed to understand light availability and floral resources.

A larger time scale and larger spatial scale are needed in order to have an adequate sample size for appropriate conclusions. For instance, forest associated bees in the Northeast have been unique life histories that reflect their adaptation to distinct phenological patterns of light and flower availability in temperate forests. During the spring, they are active as adults before the canopy closes when the light levels are high and the native species of forest flowers bloom (Smith et al., 2021). Therefore, it may be appropriate to measure bees earlier in the season than when this study was conducted.

The conclusion of this project is that bumblebees are abundant in the forest understory, a result that should encourage researchers to set up plots to survey native bees in both forests and the traditional “bee habitat” of open meadows that have plentiful resources of light and flowering plants. The results also indicate that conservation of meadows and

forests are important for social bees while conservation of meadows are important for solitary bees.

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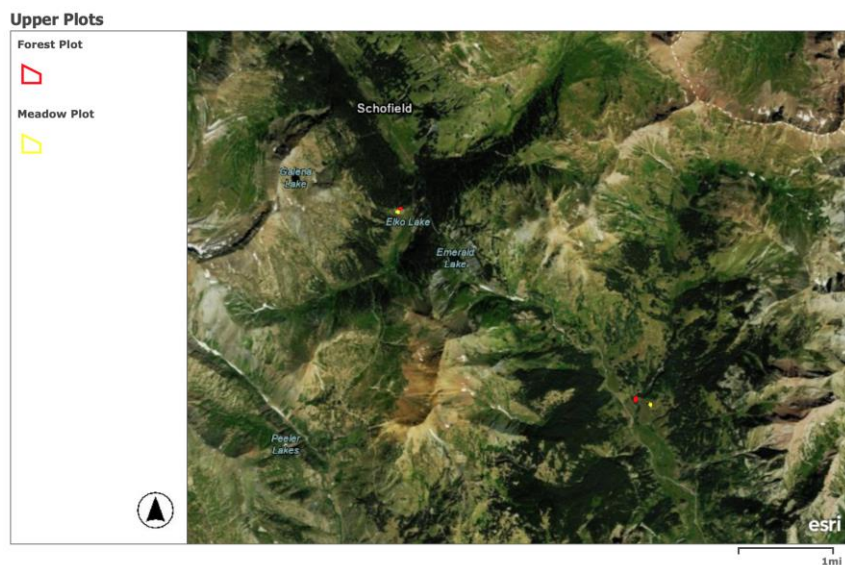


Figure 1. Upper plots in Gothic Valley (Top to bottom: North Elko Forest and Meadow, Rustlers Forest and Meadow)

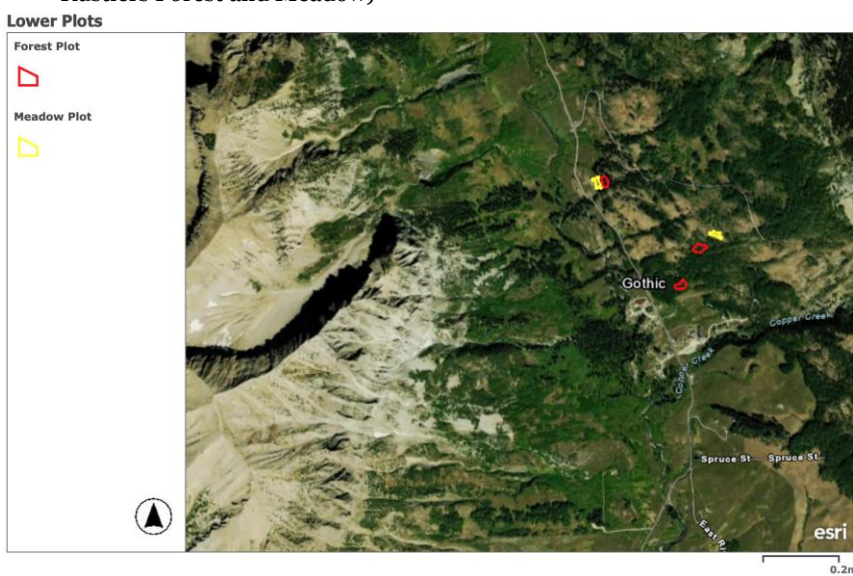


Figure 2. Lower plots in Gothic Valley (Top to bottom: Seans #1 Forest and Meadow, Davids Forest and Meadow, and Seans #2 Forest).

Commented [r1]: I am still working with Shannon to complete these as the GIS has some weird glitches.

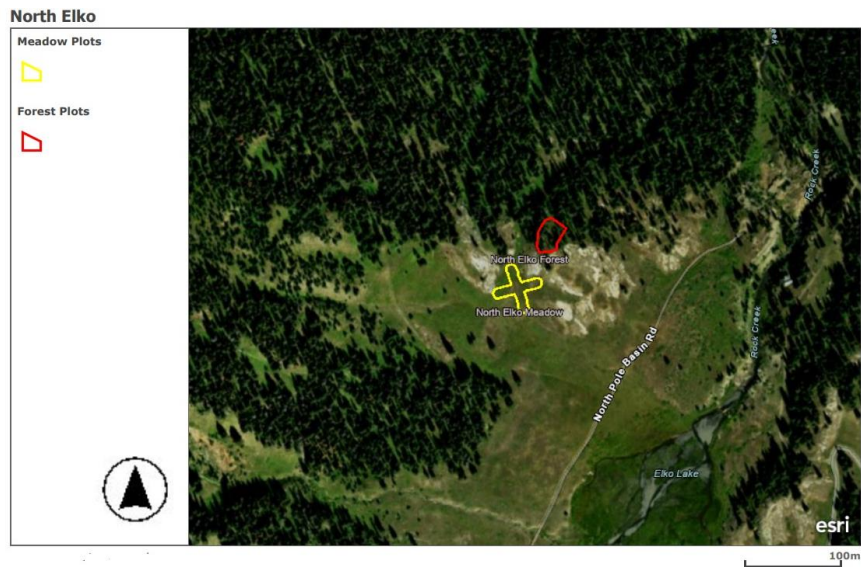


Figure 3. North Elko Forest and Meadow plots.



Figure 4. Rustlers Forest and Meadow plots.

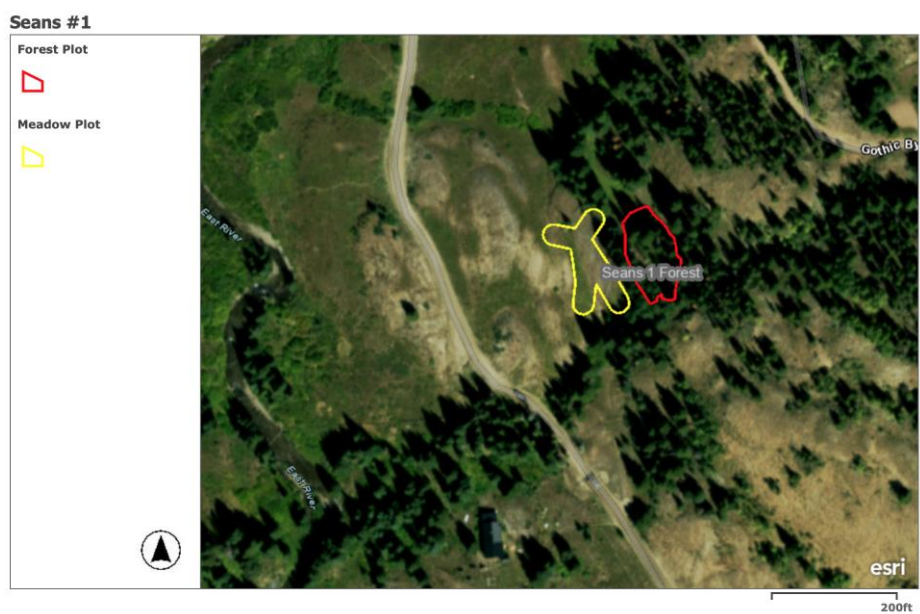


Figure 5. Seans #1 Forest and Meadow plots (Seans Meadow not labeled.)

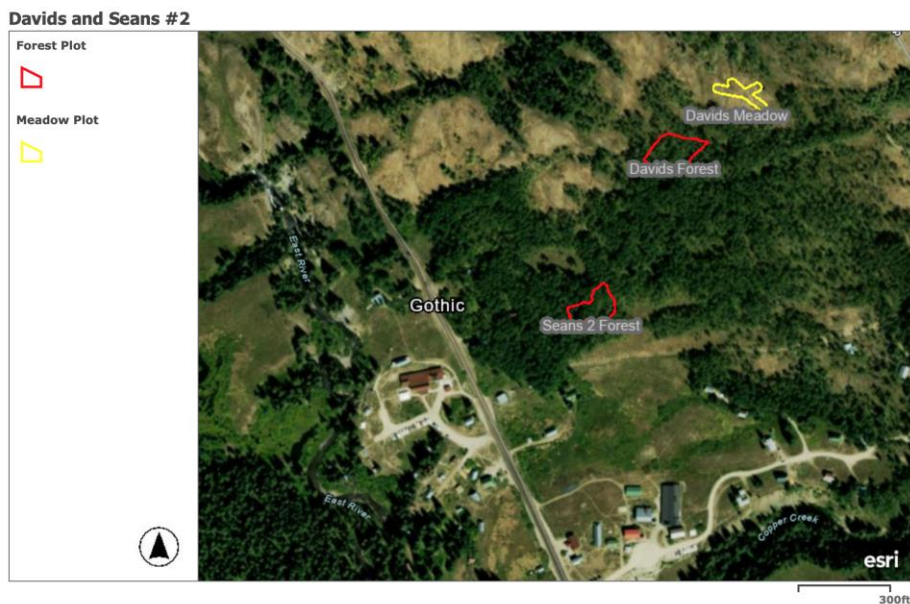


Figure 6. Davids Forest and Meadow and Seans #2 Forest plots.

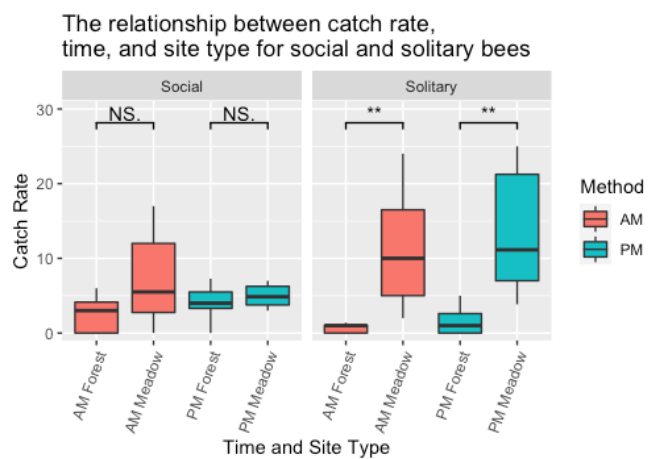


Figure 7. The relationship between catch rate, time, and site type for social and solitary bees.

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Table 1. Densiometer Table for Forest Sites

Forest Site	Forest Type	% Canopy Open
Rustlers	Fir-Spruce	20.28
North Elko	Fir-Spruce	32.76
Davids	Aspen	14.3
Seans #1	Fir-Spruce	9.1
Seans #2	Aspen	4.16