Seasonal primary pollinator abundance and resource use in a subalpine meadow, San Juan Mountains, CO

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ABSTRACT

Pollination plays a huge ecological and economic role in nature and in civilization. The agriculture industry relies heavily on insect-driven pollination for fruit production. Likewise, many angiosperms depend on insect pollination for fertilization and reproduction. This study outlines bee and fly pollination habits in a subalpine meadow near Molas Pass in the San Juan Mountains, Colorado, which is an undersampled region for pollinators. The objectives of this study were to determine the seasonal abundance of bees and flies, as well as to examine their pollination habits focusing on flower species and resource preferences. In the meadow, 40 $1m^2$ plots were established. Within each plot, pollinator visitation and resource collection were recorded over a 5-minute period every 3-4 days between June and September. Bees and flies not identified in the field were collected for later lab identification. Flies visited twice as many different flower species as bees, were present in much greater numbers, and were consistently observed solely collecting nectar. In response to increases in precipitation mid-season, bee prevalence decreased significantly while fly visitation rates were unchanged. Differing pollination strategies between bees and flies, along with changes in weather patterns leading to shifts in mid-season flowering time, could have consequences for future pollination patterns, especially at higher elevations.

INTRODUCTION

The pollination of flowering plants, though often unseen, is considered to be of high economic importance. Pollination systems are required for fruiting success, an industry that was estimated at being worth $217 billion dollars worldwide in 2005 (Settele et al. 2009). A study in Egypt addressing the recent decline in pollinators projected an annual loss of approximately $2.4 billion dollars for the country if pollinators were to suddenly disappear (Brading et al. 2009).

Additionally, the mutualistic process of pollination is essential for reproduction for many plants, and provides a critical source of food for pollinators. Bees in particular are directly dependent on flowers, with pollen required for larval growth and nectar used as a main source of energy (Forrest and Thomson, 2011).

Factors including freezing temperatures, increased wind, and increases in precipitation all can negatively affect the presence of flying insects as well as the structure of the vegetative community. However, while both plant and pollinator phenology is regulated by temperature, plants have been found to be more likely to advance phenology in response to springtime warming. This can be partially explained by the tendency of bee pollinators to overwinter aboveground, and therefore be less affected by snow cover (Forrest and Thomson, 2011).

Subalpine meadow ecosystems present a fantastic opportunity for the observation of intricate and dynamic pollination systems that can be affected by anything from changes in flowering time to fluctuations in climate patterns. This observational study focused on the principal diurnal pollinators in a high-altitude setting, namely bees and flies, although other pollinator groups were observed less frequently including butterflies, moths, and beetles.

In order to better understand the underlying patterns driving the pollination process, the following objectives were reached:

1. To determine the seasonal abundance of bees (Order Hymenoptera) and flies (Order Diptera) in a subalpine meadow, San Juan Mountains, CO.

2. To monitor the pollination habits of bees and flies, focusing on preferences in species and flower resources such as pollen and nectar.

METHODS

Study Site

This study was carried out in the San Juan Mountains near Silverton (37.8°N, 107.6° W), Colorado, in a subalpine meadow landscape below West Turkshead Peak, just north of Molas Pass (Fig. 1.1). The location for this study was chosen based on vegetative composition and an elevation of approximately 3500 m (11,500 ft). Vegetation observed in the meadow included various *Salix* species, several all-season species including *Achillea lanulosa* and *Fragaria vesca,* generalist species like *Erigeron coulteri,* and several dandelion species including *Taraxacum officianale, Agoseris glauca,* and *Agoseris aurantiaca.* Several pollinator types were observed throughout the growing season including bees (Hymenoptera), flies (Diptera), butterflies (Lepidoptera) and beetles (Coleoptera).

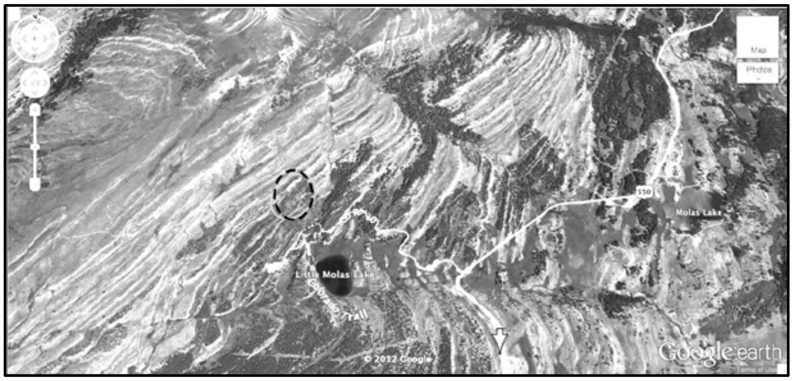

Figure 1.1. Subalpine meadow location (dashed black circle) in relation to Little Molas Lake and Hwy 550, San Juan County, CO. Google Earth, 2012.

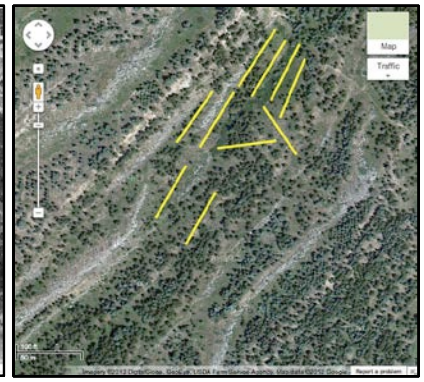

Figure 1.2. Meadow transect layout. Google Maps, 2012.

Experimental Design

The meadow was divided into ten 50-m long belt transects spatially arranged to best incorporate the unusual shape of the meadow (see Figure 1.2). Along each transect, four 1m^2 plots were designated every 10 meters for a total of 40 observation points. Transects were located at least 20 meters apart to avoid potential overlap. Each plot was analyzed for pollinator composition and general flowering phenology.

Climate

Climate data were obtained from the Natural Resources Conservation Service's SNOTEL site located at Molas Lake, San Juan County, CO (37º45'N 107º 41'W).

Phenology

Every 3-4 days throughout the growing season, all pollinator visitation was noted, focusing specifically on bee and fly abundance in each 1m^2 plot for a 5-minute period. Pollinators observed within the plot but not in contact with a flower were also noted when possible.

The flowering period was quantified as the duration of first flower in several plants to the end of flowering for most (>90%) individuals (Kudo et al. 2008). A flower was considered open if floral parts were open enough for pollinators to get nectar and pollen and if they hadn't lost petals or were dry (Inouye et al. 2003). Any flowers were noted that showed frost or grazing damage.

Resource Utilization

The resource type the pollinator was observed to be collecting (pollen, nectar or both) was recorded when possible. For bees, the presence of a corbicular pollen load determined whether the bee was collecting pollen. Bumblebees probing flowers for nectar and a pollen load were considered to be collecting for both nectar and pollen (Pleasants 1980).

Insect Abundance

Bees and flies not identified in the field were collected with a net to be properly mounted for later lab identification. Bumblebee species (*Bombus* spp.) were identified in the field by species through their distinctive abdominal and thoracic color patterns (Pleasants 1980). The most abundant species were identified with other species being identified based on available time, but voucher specimens of these species have been kept for future studies.

On pollination collection days, the net method was used to assist in creating a voucher collection of bees and flies for the study site by walking the entire length of the study site for 10 minutes back and forth west and east of the plots, for a total time period of 20 minutes.

Reference Collection
Bees and flies collected in the field were stored in an 80% ethyl alcohol, 20% water solution to inhibit rapid decomposition until specimens reached the laboratory. Pollinator specimens were then dried and mounted on pins, taking care to adequately dry out wings and antennae to aid in identification. Digital photos were taken of each pinned insect at a magnification of 100x in an effort to obtain further specimen identification. The completed collection resides in the Fort Lewis College Biology Department as a baseline collection for San Juan County, CO.

Data Analysis
Statistical analyses including a 2-tailed Pearson correlation and a Bonferroni post hoc test were performed using SPSS 18.0.0 (SPSS Inc., 2001). Additional statistical tests including a repeated-measures ANOVA and a Tukey post hoc were performed using SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

This year proved to be an unusual climate year, as snow melted early and precipitation was low during the first two months of the 2012 subalpine growing season (Fig. 2). Temperatures were not documented below freezing during the span of this study, but a series of precipitation events occurred after July 8, 2012 (DOY 190).

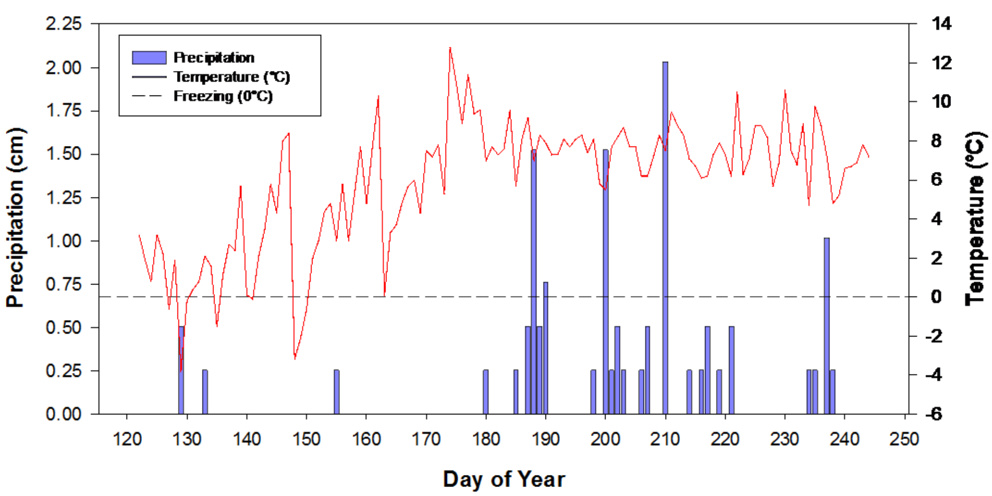

Figure 2. Climate profile of Molas Pass, San Juan County, CO during the summer growing season from May 1, 2012 (DOY 122) to Aug. 31, 2012 (DOY 244). Data were obtained from the SNOTEL station located at Molas Lake (37º45'N 107º 41'W) at an elevation of 3200 m. Blue bars represent individual precipitation events.

The presence of bees and flies varied as the season progressed. The number of flies observed across all meadow plots increased significantly by July 18, 2012 (DOY 200) while bee presence appeared to decline slightly. The average of bee and fly visits observed after this point appear to peak at the same intervals, however flies were consistently present at least twice as often as bees (Fig. 3).

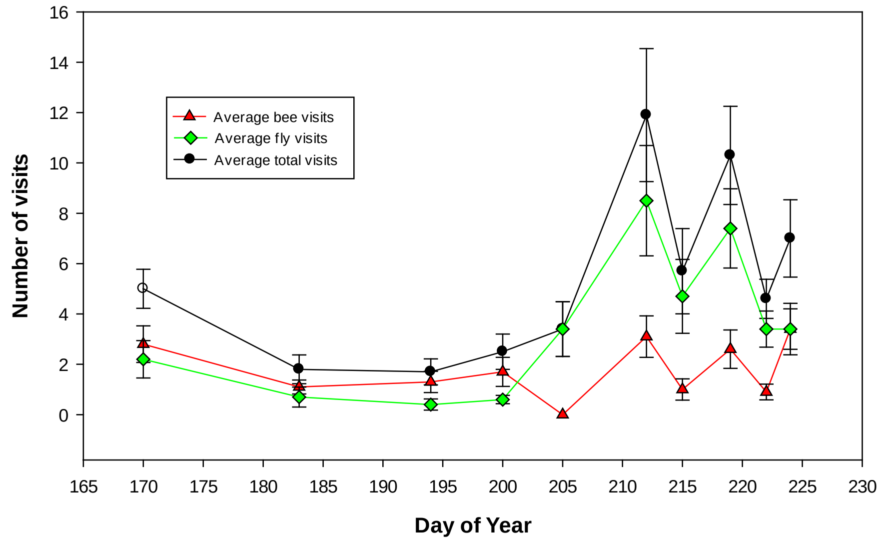

Figure 3. Average number of pollinators observed per $1m^2$ plot, specifically bees and flies, across ten transects at 40 $1m^2$ sampling points. The black line represents total average pollinator visits while red and green lines represent bee and fly visits respectively. Error bars were calculated using the standard error of the mean.

Using a repeated measures analysis of variance (ANOVA) with insect type and time as main effects, flies were significantly more abundant than bees over the entire time period, $F(1,141) = 7.59$, $p = 0.013$. Moreover, time of year had a significant effect on insect presence, $F(9,290) = 4.62$, $p < 0.0001$. While the Bonferroni post hoc test revealed days 212 and 219 to be most different in terms of overall insect abundance ($p < 0.05$), the Tukey post hoc test showed a significant difference in bees and flies during the following days: Day 205 ($p = 0.0058$), day 212 ($p = 0.0332$), day 215 ($p = 0.0262$), day 219 ($p = 0.0133$) and day 222 ($p = 0.0051$).

Across all ten transects and sampling dates, fly visitations were twice as frequent as bee visits, with the average amount of fly visits at about 3.47 while the average amount of bee visitations was approximately 1.79. For all plots over all sampling dates, 335 individual flies were observed while 148 individual bees were observed in direct contact with a flowering plant (Fig. 4).

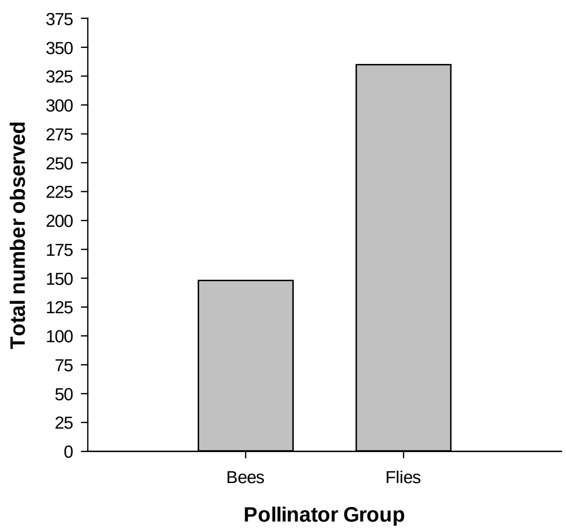

Figure 4. Total number of bees and flies observed at 40 sampling points across ten transects within a subalpine meadow. Observations lasted for 5 minutes per sampling point over ten different sampling dates.

The number of flowers and species visited varied between bees and flies. Across both pollinator groups, the most-visited flowering plants included *Taraxacum officianale* (common dandelion), *Potentilla gracilis*, *Heterotheca pumila*, and *Erigeron coulteri* (Coulter's daisy) (Fig. 5).

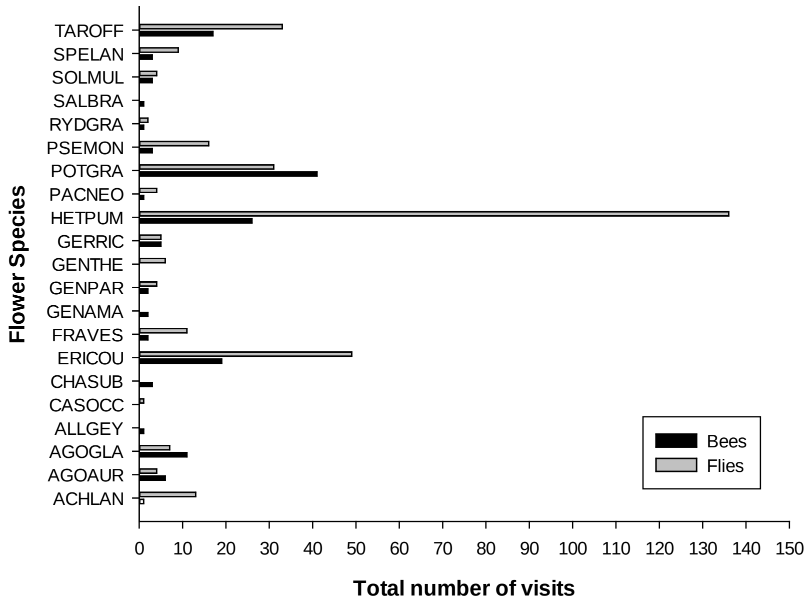

Figure 5. Total number of bees and flies observed on each flower at 40 sampling points across ten transects within a subalpine meadow. Observations lasted for 5 minutes per sampling point over ten different sampling dates. A flower species code can be found on the following page.

Resource utilization also varied between bees and flies. Of the insect individuals directly observed gathering flower resources, bees were found to most often forage for both pollen and nectar, while flies were generally more concerned with collecting only nectar (Fig. 6). To examine the relationship between pollinator type and flower resources gathered, a two-tailed Pearson correlation test was used. The presence of flies was found to be positively correlated with nectar gathering, r=0.375, p=0.000. The presence of bees was found to be positively correlated with gathering both pollen and nectar, r=0.291, p=0.003.

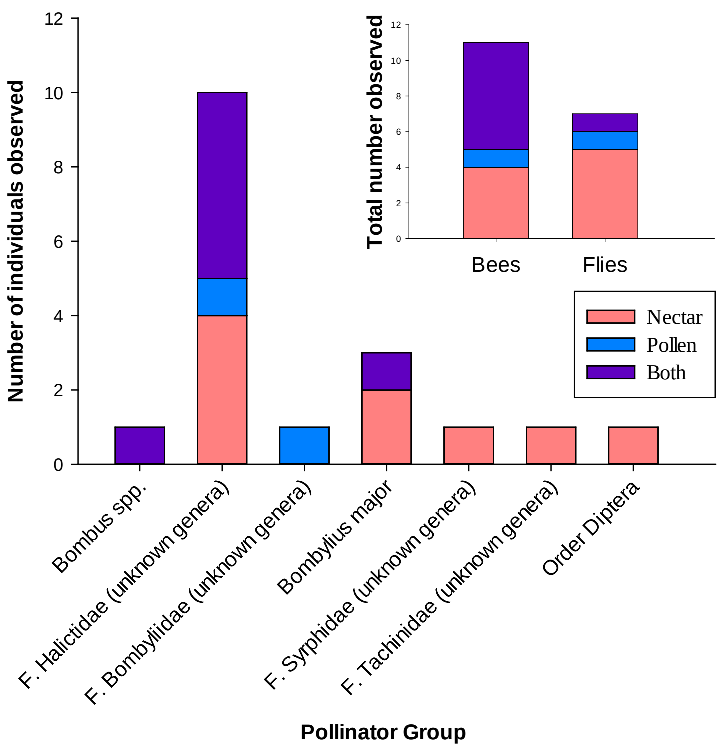

Figure 6. Pollen and nectar gathering across multiple bee and fly groups, observed across ten transects at four sampling points per transect. Red = nectar, blue = pollen and purple = both nectar and pollen. The presence or absence of a corbicular pollen load determined whether the bee was collecting pollen.

Flower species code: ACHLAN = *Achillea lanulosa*, ALLGEY = *Allium geyeri*, AGOAUR = *Agoseris aurantiaca*, AGOGLA = *Agoseris glauca*, CASOCC = *Castilleja occidentalis*, CHASUB = *Chamerion subdentatum*, ERICOU = *Erigeron coulteri*, FRAVES = *Fragaria vesca*, GENAMA = *Gentianella amarella*, GENPAR = *Gentiana parryi*, GENTHE = *Gentiana thermalis*, GERRIC = *Geranium richardsonii*, HETPUM = *Heterotheca pumila*, PACNEO = *Packera neomexicana*, POTGRA = *Potentilla gracilis*, PSEMON = *Pseudocymopteris montanus*, RYDGRA = *Rydbergia grandiflora*, SALBRA = *Salix brachycarpa*, SOLMUL = *Solidago multiradiata*, SPELAN = *Spergulastrum lanuginosum*, TAROFF = *Taraxacum officianale.*

DISCUSSION

For the Molas Pass region of San Juan County, the climate pattern largely determined the presence and abundance of flying pollinators during the 2012 growing season (DOY 120 – 240). Exposure of the subalpine to increased precipitation beginning around July 8, 2012 (DOY 190) significantly increased the prevalence of fly pollinators by July 18, 2012 (DOY 200) within the meadow plots, while bee presence declined slightly. Because both pollinator functional groups peaked in abundance at the same intervals after the monsoonal rains began, it can be inferred that both groups responded similarly to changes in climate.

Climate change has been suggested to contribute to the progressive deterioration of pollination systems, although this is thought to be primarily due to increased plant susceptibility to late frosts (Thomson, 2010; Saavedra et al. 2003) and freezing temperatures were not documented over the span of this study. Many climate change studies focus on the implications of earlier flowering, but mid-season flowering may be the most crucial time for pollinators due to the onset of monsoonal rains. Other recent studies have documented discrepancies between mid-season flowering and bee presence; one study showed that bumblebees visited a peak number of plant species in mid-summer, but total bumblebee abundance peaked later than the number of flowering plant species (Pyke et al. 2011). Shifts in flowering time could potentially result in further asynchronies between pollinators and flowering plants.

Foraging behavior and resource utilization varied significantly between pollinator groups. Bees were most often observed collecting both pollen and nectar, while flies were frequently observed collecting only nectar. These foraging behaviors hold several implications for pollination success, since only the transfer of pollen ensures fertilization. However, flies often inadvertently transfer pollen and their presence in large numbers could make up for their alternative pollination strategy.

Bee populations also face threats that are not directly related to climate change. *Volucella bombylans*, a predatory fly species, is potentially able to deposit parasitoidal larvae in underground bumblebee nests. This species closely resembles the bumblebee *Bombus huntii* and was frequently observed at the study site all season. Current research on this relationship is sparse, though other *Volucella* species are known to have parasitic relationships with specific species of bees and wasps.

An increase in fly prevalence, or a decrease in bee prevalence, carries the most implications for flower species that were observed to be predominantly visited by bees, including *Allium geyeri*, *Chamerion subdentatum*, *Gentianella amarella*, *Potentilla gracilis*, and *Salix* species. Bees are considered to hold a very important global role as pollinators, and are often the principle pollinators of subalpine and alpine regions. Bees also tend to prefer more complex flowers than flies (Thomson, 2010). Flies could not necessarily fill the niche left by bees in the event of a decline in bee populations.

Overall, three bee genera were observed over the duration of this study that are not yet officially reported in San Juan County, CO, including *Coelioxys*, *Lasioglossum* (Subgenus *Dialictus*), and *Megachile.* Currently there are 15 registered bee species for San Juan County, while most other CO counties list three times as many species.

The largest limitation encountered during the course of this study was the determination of resource gathering; bees do collect pollen in corbicular loads but this pollen is used to feed larvae, not for pollination. Further study over consecutive years is necessary to more accurately quantify the effects of changes in climate on flying pollinator populations, as well as to explore the potential shifts in flower populations in relation to changes in pollinator populations.

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