Effects of floral resource quality on *Bombus vosnesenskii* foraging behavior

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ABSTRACT

Pollination is an important ecosystem service. Bumblebees are among the most effective native crop pollinators. This study examined the floral resource use of the native California bumblebee (*Bombus vosnesenskii)*. I conducted bee, pollen, and nectar collections from May 15 - July 15, 2009 at 40 sites in northern California. To determine what resources the flowers produced, I analyzed pollen and nectar from the species found at each site. To determine bee visitation, I caught 25 bees at each site by netting and recorded the time and number of people netting. I identified pollen from 26 different plant species in the corbiculae of bees caught in the field. I did not find sufficient evidence to confirm my hypothesis that bumblebees would be most attracted to native flowers and flowers that produce high quality nectar and abundant pollen. There was no significant difference in visitation between semi-natural and managed sites. Overall, *B. vosnesenskii* were found to be suitable pollinators of crops on organic farms because they visit managed landscapes and will collect pollen from non-native plants.

KEYWORDS

pollination, agriculture, bumblebees, native species, ecosystem services

INTRODUCTION

Pollination is an important ecosystem service; an estimated one third of the world's diet is dependent on animal-pollinated crops, most of which are bee-pollinated (McGregor, 1976). This estimate has been confirmed by a more recent study by Klein, Vaissiere, Cane, Steffan-Dewenter, Cunningham, and Kremen (2007) that found 35% of global food production to come from crops that depend on pollinators. Pollination by honeybees, *Apis mellifera*, is estimated to be worth between $12.3 billion and $16.4 billion to the US economy alone (Losey & Vaughan, 2006).

Conventional farms hire commercial hives of honeybees to pollinate crops, but 100% of pollination could be provided by wild native bees on organic farms near bee habitat (Kremen, Williams, & Thorp, 2002) . In addition, wild bees have been shown to increase the efficiency of honeybees by making honeybees more likely to switch to flowers of different sex after interacting with wild bees (Greenleaf & Kremen, 2006). Furthermore, honeybee colonies have been facing drastic declines in recent years due to Colony Collapse Disorder (CCD; Johnson, 2007). Increased use of native pollinators could be one way to offset the damage done by CCD.

Despite the economic and ecological importance of native pollinators, wild pollinator populations face many threats, and evidence of a global pollination crisis is steadily growing (Biesmeijer et al., 2006). Declines in managed honeybee populations are cause for further concern (Johnson, 2007), and can make honeybee rental prohibitively costly. Native bees can fulfill the pollination requirements if adequate habitat is provided for them (Kremen, Williams, & Thorp, 2002). In order to promote native bee-mediated pollination, it is essential that we identify the habitat requirements and foraging preferences of native pollinators.

Bumblebees are important because they are among the most effective native crop pollinators. They are also among the first species to be lost as native habitat is destroyed (Kremen et al., 2002). Greenleaf and Kremen (2006) found that tomato production was increased by visits from native bees, and *Bombus vosnesenskii* was the second most frequent visitor to the farms. Recent studies have found correlation between flower density and native pollinator density. The number of tree species in flower was predictive of native bee diversity in a tropical shade-coffee plantation (Jha, 2010). Westphal et al. (2003) found a positive correlation between the amount of mass-flowering crops like oilseed rape and the number of bumblebees in a field.

However, few studies analyze how differences in resources produced by plants affect bumblebee visitation.

This study examined the nectar and pollen preferences of the native California bumblebee *B. vosnesenskii* in order to identify the plant species critical to bumblebee colony success. Specifically, I investigated the abundance of various flowering species and examined how *B. vosnesenskii* visitation is related to flower cover area, nectar concentration and quantity, and pollen quantity produced by each plant. I compared visitation between semi-natural areas and managed land (organic farms). I hypothesized that bee visitation would have a significant positive correlation with nectar concentration and pollen abundance. Also, I hypothesized that bumblebees would be attracted to sites with a larger proportion of native plants, and semi-natural areas will have a higher rate of visitation than managed areas.

METHODS

Study site

I conducted bee, pollen, and nectar collections from May 15 - July 15, 2009 at 40 sites in northern California in Napa and Yolo counties. The region is characterized by a Mediterranean climate and chaparral woodland vegetation. I sampled from eight different transects, each transect having five sample sites. Four transects were located in semi-natural areas and four were on organic farms or pastures, henceforth referred to as managed areas. Some sites did not receive sufficient bee visitation (e.g., no bees were caught after an hour) and were excluded. Each transect was three km long, and each site was at least 500 m from any other site.

Pollen and nectar measurements

To determine what resources the flowers produced, I analyzed pollen and nectar from the species found at each site. I collected sample flowers from each species recorded in the vegetation surveys, and identified the plant species. I centrifuged six flowers from each species collected to extract nectar. I measured the volume of nectar with a calibrated micro pipette and the sugar concentration with a refractometer (Kearns & Inouye, 1993). I collected pollen from flowers that were taken as buds and opened in lab in order to ensure they had not been visited by pollinators. I suspended pollen grains in 50 mL ethanol solution, made slides from the suspension, and counted the grains using a light microscope.

Field measurements and observations

To determine bee visitation, I caught 25 bees at each site by netting and recorded the time and number of people netting. If a bee was carrying a pollen load, I removed the pollen and placed it in a separate tube labeled with its corresponding bee number. I later analyzed pollen under a microscope to determine what plant species it came from. Vegetation surveys were done at each site using thirty 1 m^2 quadrants per site. The quadrants were arranged in a regular grid. Only opened flowers were counted in each quadrant to get a representation of the floral resources available to bees at that point in time.

Data analysis

I analyzed the data using R software. I conducted a multiple regression analysis of bee visitation vs. flower species richness and proportion native flowers (Quinn & Keough, 2002). The proportion data was transformed using arcsine square root to normalize it. I used a Welch Two Sample t-test to compare visitation to semi-natural and managed sites.

RESULTS

Pollen and nectar measurements

I identified pollen from 26 different plant species in the corbiculae of bees caught in the field. Most pollen grains were identified to species but a few were left at genus level and "sp#" used as a placeholder. The abundance of each species is summarized in Figure 1. The predominant plant species were the natives *Heteromeles arbutifolia* and *Eschscholzia californica.* There were also a large number of non-native species in the corbiculae, most notably *Lotus corniculatus, Achillea millefolium, and Convolvulus sp1.*

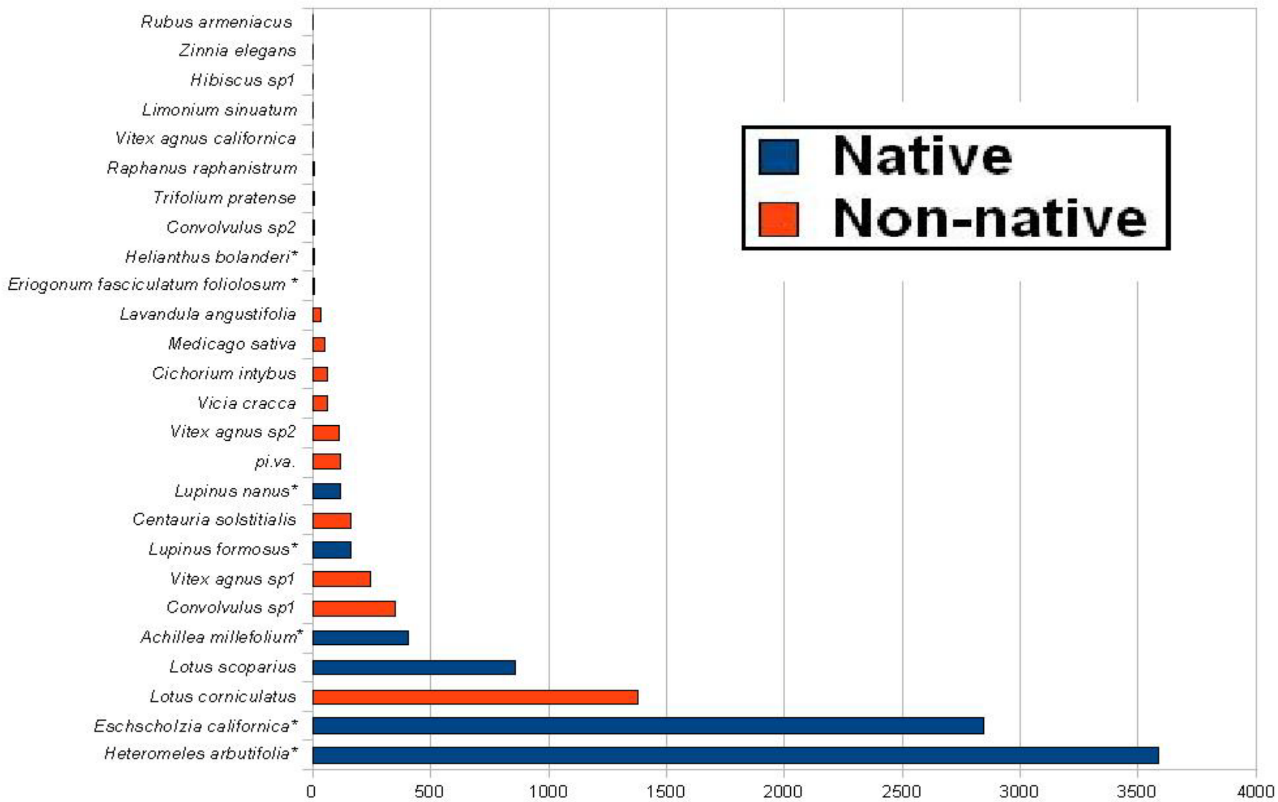

Figure 1. Abundance of different species of pollen collected from the corbicula of bumble bees. The number of grains is a total from all field sites.

I recorded sugar concentrations between 12-50% and volumes between 0.02 mL per flower and 1 mL per flower for all nectar samples (Table 1). Nectar quality did not fluctuate with bee preference, as measured by which species of pollen was found most often on the bees. The most common pollen was from *H. arbutifolia*, which produced only an average volume of nectar with average sugar concentration (32% sugar and 0.17 mL per flower compared to a max of 1 mL per flower in *Calendula arvensis* and 50% in *Salvia leucophila*). Conversely, I found that the most nectar-rich flowers such as *C. arvensis*, *S. leucophila,* and *Aster novibelgi* had no presence in the pollen load of bees.

Table 1. Nectar concentration and volume. Flowers collected in Yolo County, CA summer of 2010. Concentration is sugar concentration of nectar measured with hand-held refractometer.

Plant Species	flowers	Concentration %	volume (mL)	vol by flower (mL/flower)	vol times con
Centauria Solstitialis	6	21.5	3	0.5	10.75
Cichorium intybus	15	47	1.5	0.1	4.7
Calendula arvensis	2	38	2	1	38
Lotus Scoparius	24	29	0.5	0.02	0.6
Eriognum fasciculatum	22	46.5	0.4	0.02	0.85
Heteromeles Arbutifolia	12	32	2	0.17	5.33
Lotus Purshianus	24	28	0.4	0.02	0.47
Lavandula angustifolia	12	-	0.9	0.08	0
mi.au	4	22	2.5	0.63	13.75
Salvia Leucophila	12	50	3.5	0.29	14.58
Aster Novibelgi	13	-	-	-	0
Aster sp	20	19	1.7	0.09	1.62
Vicia cracca	6	12	-	-	0
Brassica sp	24	39.5	-	-	0

Field measurements and observations

Bumble bee visitation varied between field sites from 3.05 bees per hour to a maximum of 12.19 bees per hour. I performed a linear regression on visitation with proportion of native flower cover at a site as the explanatory variable (Figure 2). Proportion was used because field sites had drastically different total flower cover. The bee visitation data was approximately normally distributed: the Shapiro-Wilk test for normality had a p-value of 0.1277. The native flower cover data was not normally distributed with the Shapiro-Wilk test for normality giving a p-value of 2.639e-06. The flower cover data was transformed by arcsin squareroot. Proportion of native flower cover was not significantly correlated to visitation (p-value = 0.1411). I used a t-test to compare the difference in visitation between managed and semi-natural sites (Figure 3). There was no significant difference in visitation (p-value = 0.5357). There was likewise no significant correlation between visitation and flower species richness at a site (Figure 4).

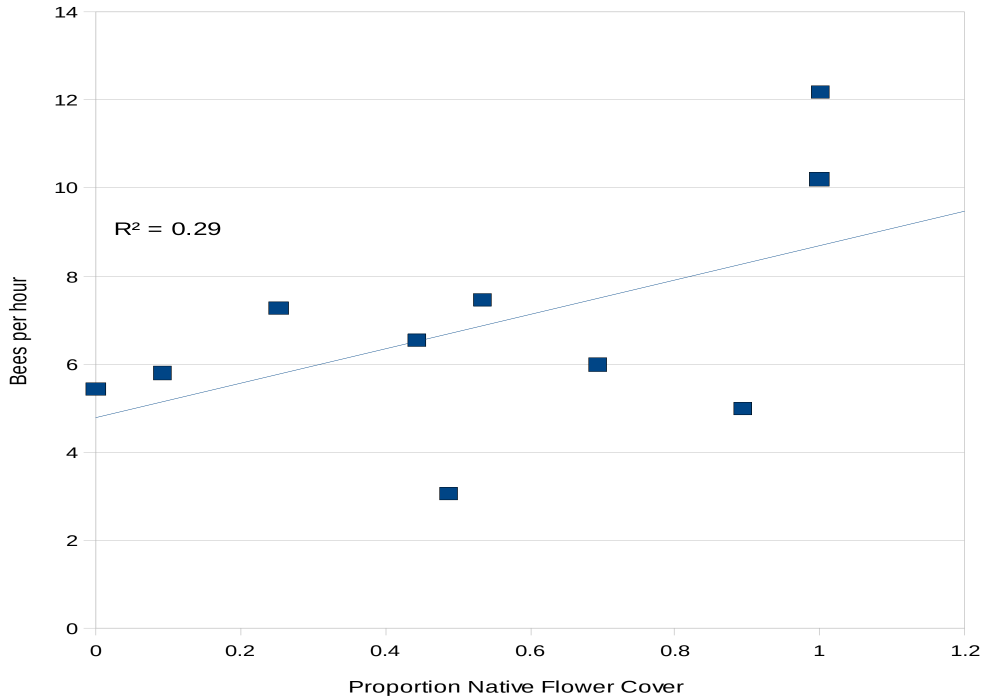

Figure 2. Correlation between bee visitation and proportion of native flower cover. P-value = 0.1411

Figure 3. Visitation to semi-natural and managed sites. P-value = 0.5357

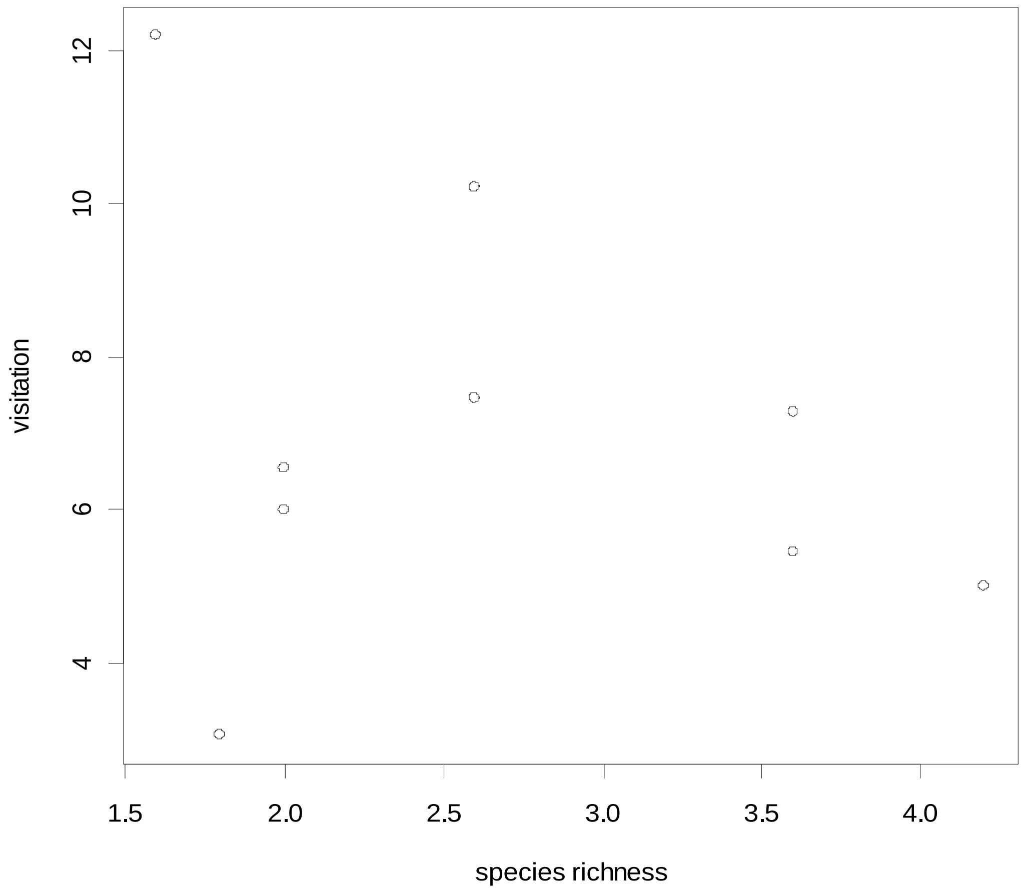

Figure 4. Correlation between bee visitation and flower species richness. Species richness is total number of different flowering species present at a site. P-value = 0.4690

DISCUSSION

In this study I aimed to explore the floral resources used by *B. vosnesenskii* and to determine what factors aid in attracting the bumblebees to a site. I did not find sufficient evidence to confirm my hypothesis bumblebees would be most attracted to native flowers and flowers that produce high quality nectar and abundant pollen. There was also no significant difference in visitation between semi-natural and managed sites.

Field observations

Field observations indicated that *B. vosnesenskii* visitation to managed sites was not significantly different from visitation to semi-natural sites. This is a good indication that *B. vosnesenskii* can be relied upon to provide pollination services to farms. There might have been a large number of colonies present within foraging distance of the farms. Nesting resources can be scarce in managed landscapes (Kells & Goulson, 2003). The fact that visitation to managed sites was not significantly different than visitation to semi-natural areas is an indication that *B. vosnesenskii* has sufficient nesting resources near the organic farms sampled in this study. Other researchers have also found that ground nesting species like *B. vosnesenskii* are less severely affected by isolation from natural habitat (Williams et al., 2010).

Floral resources

I observed that *B. vosnesenskii* preferred sites that had greater native plant cover, but this trend was not statistically significant. Sites with less native plants received less forager visits, but even some sites with no native plants had non-zero visitation. The pollen data showed that bees were collecting non-native species, including some crop plants like alfalfa (*Medicago stativa).* Bees collected only a few species of pollen each trip (mean 3, max 6). Even though *B. vosnesenskii* are generalists, they will focus on a few plants every foraging trip. This increases fertilization rates, and is important to address when considering the benefit provided to agriculture.

I did not find any reason for bees to prefer native plants in terms of quality of resources. Native plants were not found to produce more nectar than non-natives. The native California Poppy *E. californica* did produce more pollen, but *H. arbutifolia,* another native plant that was highly preferred by *B. vosnesenskii* produced less nectar than average.

Limitations

The conclusions from this study are limited to one species of bumble bee in one particular environment. Sampling more species might reveal interesting trends, but would require more collecting hours. If more data was gathered perhaps some of the trends seen in this study might turn out to be statistically significant. The methods I used for extracting nectar were not optimal as I had to centrifuge the flowers to get enough volume of nectar, and that may contaminate the sample with other fluids from the plant tissues. With better pollen and nectar sampling procedures, a correlation between floral resource quality and bumblebee preference may be revealed.

Future directions

Future studies should focus on applying similar methods to more species. *B. vosnesenskii* is just one of many native bee species that provide a pollination service to farms in California. (Greenleaf & Kremen, 2006). Researchers should also explore landscape-scale interactions between habitat quality and bumblebee abundance. This study focused on a fairly small scale looking at field sites and the floral resources in the immediate area. More studies on the availability of nesting resources also need to be conducted. Such studies are hard to undertake as bumblebee nests are difficult to locate. The farms examined in this study were organic farms, so the results may not hold for more conventional agricultural landscapes. It would be beneficial to conduct a study sampling different organic and conventional farms to find if visitation decreases with increasing agricultural intensity.

Conclusions

B. vosnesenskii were found to have characteristics suitable for pollinators of agricultural crops. They visit managed sites and pollinate flowers from foreign species. Other research has found that organic farms can rely entirely on native pollinators (Kremen et al., 2002). Farmers can increase bee visitation by providing some native plants. A study by Rands and Whitney (2010) found that when the density of wild flowers in a habitat was low, even a small increase would result in a large effect on attracting pollinators. With just a small investment in planting native vegetation on field margins, farmers can get an increase in free pollination services from native bees while providing more natural habitat for bees and other native insects.

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