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Pollination by Native Bee Communities in Berkeley, California

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ABSTRACT

Urban agriculture is on the rise in many areas throughout California. Native bees are a viable option to satisfy the growing demand for sustainable pollination services. Nevertheless, little is known about native bee ecology. This study examines native bee pollination in two urban agricultural sites that differ in their proximity to natural habitat. Squash, tomato, strawberry and sunflower plants were observed at the Oxford track and Berkeley Youth Alternative garden in Berkeley, California. Data collected from both sites include; distance from natural habitat, diversity of native bee pollinators and their visitation rates. I hypothesized that the Oxford Tract would have higher native bee diversity and visitation rates than the Berkeley Youth Alternative garden, because the Oxford Tract was closer to native bee habitat. The community statistics gave mixed results for genus richness and evenness. The t-test indicated no significance of visitation rates for each plant type between each site. Results indicated that close proximity to natural habitat had no effect on native bee visitation rates to crops. The factors expected to contribute to a healthy native bee population are: common floral resources between native and non-native habitats, habitat fragmentation and age variability of gardens. City planners and conservationists should be cognizant of these factors when developing an urban agricultural site that can provide food and sustain biodiversity.

INTRODUCTION

Urban agriculture utilizes sustainable agricultural techniques in order to produce food for inner city communities which often lack access to healthy foods and local retailers (McClintock 2008). Urban agriculture has been on the rise in many urban areas including Oakland, California, where the city council has mandated that thirty percent of all food in Oakland must come from a local source such as urban agriculture by 2015 (Green 2007). As agriculture becomes more prominent in urban settings, the demand for pollination services also increases (Green 2007). One way to meet the pollination demand is to utilize existing native bee populations. Incorporating resources for native bees into urban agriculture will promote urban ecosystem health by providing viable seeds and fruits for insects, birds, and other wildlife (Delaplane & Mayer 2000) in addition to providing urban neighborhoods with sustainable produce.

Little is known about native bee ecology as new studies are only beginning to surface (Hernandez et al. 2009). Current studies show that native bees are a rich natural resource in urban California gardens (Frankie et al. 2009a), have preferences for certain plants (Frankie et al 2005), and are found in small residential gardens (Frankie et al. 2009b). Furthermore, native bees are generally more numerous and diverse near natural habitats where they provide pollination services to various crops (Kremen et al. 2002, Klein et al. 2003, Ricketts et al. 2004). Native bees are just as effective at large scale-pollination as commercial honey bees and thus gaining more popularity amongst researchers and the agricultural industry (Kremen et al. 2004, Kremen et al. 2007, Williams & Kremen 2007).

Studies in agricultural landscapes have shown

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that native pollinators are more effective when they are close to natural habitats. Ricketts et al. (2004) found that native bee diversity and visitation rates are significantly greater in coffee fields that are near tropical forests than other fields that are further away. Kremen et al. (2004) found that farms that were within a 2.4 km radius of areas with forty percent or more natural habitat were able to rely solely on native bee communities for pollination. Additionally, Ricketts et al. (2008) found strong evidence that increased isolation from natural habitat results in a decline of native bee visitation rates. There are many studies showing the relationship between distance and pollination in commercial agriculture, but not in urban agriculture. Ultimately, there is the potential for native pollinators to play a large role in urban agriculture, but we don't know how effective they will be in this very different landscape – one with presumably less native habitat nearby. In order to gain further knowledge of how the pollination services works, it is important to understand the relationship between the distance of the native bee habitat from the site of pollination and the rate of pollination in these urban settings.

The purpose of this study is to examine native bee pollination in two urban agricultural sites that differ in their proximity to natural habitat. The objectives of this study are to 1) calculate native bee diversity for each plant type per site, and 2) compare visitation rates between the two sites for each plant type . I hypothesize that the Oxford study site will have higher native bee diversity and visitation rates than the Berkeley Youth Alternative study site because the Oxford study site is closer to natural habitat. Using distance from natural habitat and metrics of pollinator diversity, I hope to further the understanding of the pollination services, by native bees for urban agriculture.

METHODS

Site Description

The study assessed two urban agricultural gardens located in Berkeley, California (Fig. 1). The two gardens are: Berkeley Youth Alternative (BYA) Community Garden located at 1260 Bancroft Way, Berkeley, CA and the Oxford Track located at Oxford at 1751 Walnut Street, Berkeley CA. The size of the Oxford garden is 2.74 kilometers, while the BYA Garden is 7.62 kilometers. The Oxford Track is closer to natural habitat than the BYA garden. Both gardens are functional throughout summer and fall. This ensures that some flowers are always available for pollination, regardless of the season. In each garden I found sufficient quantities of sunflowers, strawberries, squash, and tomatoes for my study. The length of the beds in the Oxford garden was roughly 2 by 1 meter. The length of the beds in the BYA garden was roughly 3.5 by 1 meter. The BYA Garden contains three European honey bee hives. The Oxford garden is next to a native bee garden. Both are organic; they do not use pesticides, nor do they use synthetic fertilizers.

Figure 1. Location of sites in Berkeley, California. A represents Oxford Garden and B represents Berkeley Youth Alternative Garden (BYA).

Natural Habitat Classification

I used Google Earth to locate the nearest natural habitat to each garden. In an urban setting, natural habitats were designated as vacant/fallow land or gardens specifically designed for native bee attraction. The Oxford garden borders a native bee garden located to the southeast. The BYA garden is located roughly two miles away from the nearest natural habitat.

Bee Visitation

To measure bee visitation rates at each garden, I observed a 1 by 1 square meter quadrat for three minutes. This size quadrat and observation time worked well in other urban bee studies (Frankie et al. 2009b). A visitation was recorded when the bee touches the pollen produced by the flower. To ensure equal representation among the visitations observed, each quadrat was examined between 0700h and 1400h. Each quadrat was observed for 3 minutes at a time. Each visit was conducted under sunny or scattered clouds with temperatures between 21 and 38 degrees Celsius and wind speeds that are less than 4 m s-1.

Data Analysis

For my data analysis I compared 3 independent variables with visitation rates. To test my hypothesis I used the following independent variables:

1. Distance to native habitat: This has been measured and is a fixed number. The Oxford garden will be represented by 0 and the BYA garden will be represented by 1. This is a binary approach to represent two categories.

2. Bee taxa: This is a total count of all native bee taxa found at each garden. This will be comprised of 8 categories: Bombus spp., Ceratina sp., Megachile spp., Anthophora sp., Melissodes spp., Peponapis pruinosa, Apis Mellifera, and Small bee. The following abbreviations

are given to the bee taxa in figure 1 and figure 2: Antho (Anthophora sp.), Bomb (Bombus spp.), Cera (Ceratina sp.), HB (Apis Mellifera), Mega (Megachile spp.), Melis (Melissodes spp.), (Peponapis pruinosa) and SB (Small bee)

3. Plant type: This will be comprised of 4 categories: tomatoes (S. lycopersicum), squash (C. pepo), sunflowers (H. annuus) and strawberries (F. ananassa).
I then compared them to visitation rates which will be continuous.

Community Statistics

I examined the community statistics by using three diversity indices to see if there is a difference in diversity and evenness between the Oxford garden and the BYA garden. The values will be examined to see if visitation rates for each plant were dominated by some genera over others. To quantify the community statistics three indices were used: the Berger Parker index, $d = \frac{N}{N_{max}}$, where N is the total number of indivudals of all genera and Nmas is the number of indivudals in the most common genus. A larger d value means more diveristy in the system. The Simpons's Index, $D = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{N(N-1)}$, where there are S speices and n_i is the number of indivuals of the ith genus and N is the total number of indivuals. I expressed Simpson's index as 1/D so that the index will increase as diveristy increases. Simpon's Index used infromation from each genus, unlike Berger Parket, and so it is more accurate, but very insenstive to the addition of rare speices to the sample. The Shannon index, $H' = -\sum_{i=1}^{S} p_i \ln p_i$ where p_i is the proportion of indivudals (from the sample total) of speices i. Using the Shannon index, I calculated the eveness, $E = \frac{H'}{H_{max}}$, where H_{max} is attained when the number of individuals in every speices is equal.

Statistical Analysis

I used R commander in R, Office Excel 2007, Microsoft Access 2007 for organizing and analyzing my data. I used a Welch Two Sample t-test to compare visition rates at the garden sites per plant type. I used this type of t-test because I had unequal variances in my data. This will tell me if there is a difference between weeks in terms of average visitition between the two study sites for the given plant type.

RESULTS

Community Statistics

From late June through July I observed 372 bee visits (203 at BYA and 169 at OXF), and of these visitations eight genera were observed. The average combined visitation rates of each garden are given in table 1. At both BYA and OXF, squash was visited the most by Pepon (P. pruinosa), Strawberry was visited the most by HB (A. mellifera),

Plant Type	Average Visitation
Squash	9
Strawberry	3
Sunflower	7
Tomato	2

Table 1. The table provides the combined average visitation rates of each garden for each plant

Sunflower was visited the most by HB (A. mellifera), and tomato was visited the most by Bomb (Bombus) (Fig. 2 and Fig. 3).

In comparing diversity indices between the two study sites, I found that BYA had more native bee diversity than OXF when I used the Berger Parker index and the Simpson's index (Table 2). The percent difference between the sites and the Berger Parker index is 9% while the percent difference for the Simpson's index and the sites was 3%. Using the Shannon index for diversity and evenness I found that OXF was more diverse and more even than BYA (Table 2). The difference between the two sites as determined by the Shannon index for diversity and evenness is 1%.

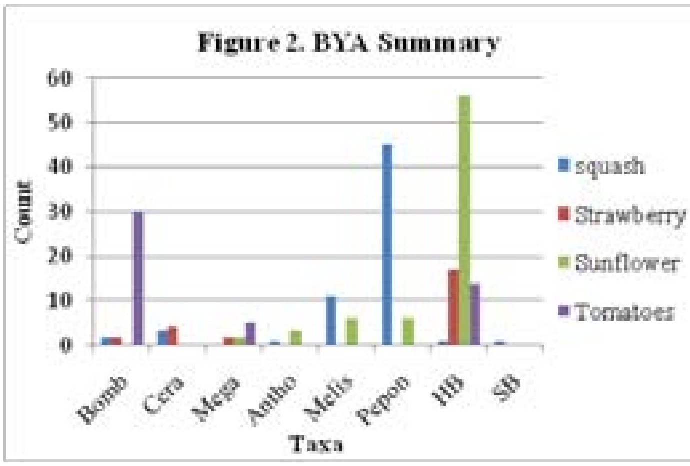
Visitation Statistics

There was no significant difference in visitation by native bees between the two gardens for squash (Welch Two Sample t-test with df = 33, t = 1.33, P = 0.19), tomatoes (Welch Two Sample t-test with df = 36, t = -0.38, P = 0.71), sunflower (Welch Two Sample t-test with df = 28, t = 0.37, P = 0.72), and strawberries (Welch Two Sample t-test with df = 8.6, t = 0.84, P = 0.42).

DISCUSSION

In my study I compared visitation rates to four plant types, squash, strawberry, sunflower and tomato at two gardens, BYA and OXF. OXF was closer to natural habitat than BYA. Using community statistics and t-tests I was able to test my hypothesis that OXF will have higher native bee diversity and visitation rates than BYA because OXF is closer to natural habitat. My community statistics gave mixed diversity and evenness readings for the two gardens while my t-test showed no significance between visitation rates to the four plant types at each study site. The results indicate that proximity to natural habitat is not the only variable that governs native bee visitation rates and diversity and evenness within urban garden sites.

I hypothesized that OXF have higher native bee diversity and visitation rates than BYA because OXF is closer to a natural habitat. The diversity indices from OXF and BYA did not produce consistent results which may be a result of how each diversity index is calculated. Both the Berger-Parker index and the Simpsons index indicated that BYA is more diverse than OXF. The Shannon



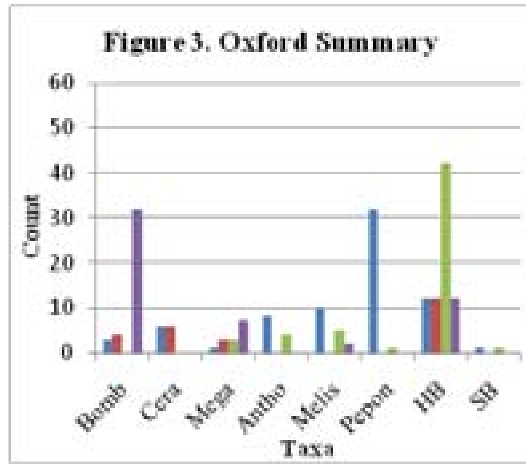


Figure 2. and Figure 3. Count of Genera by site. This graph shows the number of visits of each genus to the plant type at the Oxford Tract Garden in Berkeley, Ca.

index contradicted this finding, instead resulted in OXF as more diverse than BYA. The mixed diversity and evenness findings were due to both study sites sharing the same number of taxa. The three diversity indices may vary due to the abundance of single taxa or the different sample sizes collected (Walda 1983, Caruso et al 2006). The Shannon index can increase through additional unique genera, or greater species evenness (Walda 1983). When comparing the evenness of Fig. 2 and Fig. 3, OXF displayed more evenness than BYA since the Pepon numbers are closer in magnitude to the other genera counts. Overall the number of each genus that visited each plant type was more even in the Fig. 2 than in Fig. 1. The difference in the Shannon index can be attributed to OXF having a small sample size of 169, versus BYA having a sample size of 206. The Berger-Parker index and the Simpsons index both indicated that BYA was more diverse. A reason for the differences in indices could be that both weigh heavily towards the most abundant genera in the sample while being less sensitive to species richness (Caruso et al 2006, Walda 1983). Although BYA and OXF have the same amount of genera, BYA had higher numbers of a select few genera than OXF. The mixed results from the diversity indices indicated that both study sites showed no difference in their diversity or evenness.

	Berger Parker Index	Simp-son's Index	Shannon Index	Even-ness
BYA	2.64	3.95	1.57	0.76
OXF	2.22	3.74	1.63	0.78

Table 2. Summary of diversity indices for BYA and OXF. The Bold numbers correspond to a higher diversity. For all indices, the greater the number the more diverse the system is.

Contrary to my hypothesis that OXF will have higher native bee diversity and visitation rates than BYA; I found no strong association between distance from natural habitat to native bee visitation and diversity. The diversity indices gave mixed diversity results and the t-test showed no significance between the visitation rates at each site for each plant type. My findings indicate that BYA is no different from OXF in terms of native bee visitation or diversity. This suggests that native bee visitation and diversity is not governed by distance from natural habitat alone. Indeed, studies have shown that natural habitat is one of many governing factors for native bee visitation and diversity in a garden (Williams & Kremen 2007, Winfree et al 2008). I suggest four possible reasons as to why proximity to natural habitat may not be the primary governing factor for native bee visitation rates and diversity in urban agriculture.

Native bees may have switched to floral resources found in the urban habitats that share similar characteristics as the floral resources found in natural habitats (Williams & Kremen 2007, Winfree et al 2008). Studies have shown that females nesting in organic farms were buffered to isolation effects by switching to floral resources growing at the farm site when seminatural habitat was too distant (Williams & Kremen 2007). This could be the case with BYA and OXF. While BYA did not have natural habitat in close proximity, the females may have been able to feed off of floral resources already existing in BYA or around the residential area. Another study has shown that gardens with sufficient weedy or floral resources year around could mimic the utility of natural resources for native bees (Winfree et al 2008). BYA does not have any natural habitat in close proximity; nevertheless, there were plenty of bee attracting plants in and around the residential area. These floral resources could have sustained the bee population found at BYA.

High dispersion of natural habitat fragments throughout my study sites may have improved native bee visitation and diversity (Holzschuh et al 2008, Frankie et al 2009a). Organic gardens can support higher pollinator diversity if there are fallow strips of land located within the garden (Holzschuh et al 2008). OXF is closer to natural habitat. However, most land is either covered with crops or has groundcover/mulch. This makes it difficult to for bees to nest. BYA has fallow strips of land that allow for nesting habitat. The fallow land may provide the year round nesting but it may not provide enough floral resources to sustain a diverse native bee population. The floral resources needed to sustain a year round population could be found in urban residential gardens (Frankie et al 2009a). These residential gardens could also provide more nesting habitat for the native bees (Frankie et al 2009a, Frankie et al 2009b).

The variability in the age of the study sites may also be a factor in visitation rates (Frankie et al. 2009b, Pawelek et al. 2009). Older gardens tend to have more biodiversity BYA is 17 years old while OXF is only six years old. Studies have shown that older gardens tend to have more established native bee populations (Frankie et al 2009b, Pawelek et al 2009). OXF is not as old however; it is located close to natural habitat. The close proximity to natural habitat could account for the variability in visitation and diversity due to the age difference.

The lack of significance may have been due to the fact that I was unable to detect the true effects of natural habitat distance to the study sites because my data sets were too small and/or variable (Williams, Minckley & Silveira 2001, Winfree et al 2008). This may have been true for my smaller data sets such as tomato. However, the statistical model for the more extensive squash data set showed no significance between site and visitation rates. This indicates that the sites show no difference in visitation rates.

CONCLUSIONS

Contrary to related studies of crop pollination by native bees, I found that close proximity to natural habitat did not affect native bee visitation rates. I expect that there is no difference in native bee visitation rates or diversity between the two study sites because of the effects of common floral resources between native and non-native habitat, habitat fragmentation and the age of the gardens. These factors might explain why native bees are abundant and diverse, even in areas with low proportion of natural habitat

I have identified two factors, in addition to proximity of natural habitat, which may affect native bee visitation and diversity. These factors should be explicitly examined in future studies. The first factor that may affect native bee visitation and diversity is the amount and the size of fallow land on or around the study sites. Fallow land may provide unexpected floral resources and nesting habitat that normally would not exist if cultivated by a food crop. Studies have shown plants that we often identify as weeds can provide ample pollen and nectar to attract new native bees and sustain an existing native bee population in between crops cycles (Frankie et al. 2005).

The second factor is the amount of diverse floral resources that are not food crops, of which natives bees can utilize as a food source and habitat. A 3-year survey of bee pollinators in seven cities from Northern California to Southern California concluded that a predictable group of native bee species can be expected to visit certain ornamental plants (Frankie et al. 2009a). Utilizing these certain ornamental plants may increase native bee richness and diversity in urban agriculture.

Future Directions

My study has provided areas of inquiry for future research on native bee ecology and pollination service. I suggest three questions for further inquiry. First, how do varieties of floral resources influence the amount of food crop visitation? Second, what affect does fallow land have on the amount of food crop visitation? Third, is there more native bee visitation and diversity on food crops located in urban areas versus areas near conventional farms? These questions will grant greater insight into native bee ecology and urban ecology. Nevertheless, my study indicates that close proximity to natural habitat is not the only requirement for native bee attraction. By incorporating common floral resources between native and non-native habitats, habitat fragmentation and the age of the gardens one could expect native bees to be found in urban agricultural.

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LITERATURE CITED

1. Caruso, T., Pigino, G., Bernini, F., Gargagli, R., Migliorini, M. (2007). The Berger-Parker index as an effective tool for monitoring the biodiversity of disturbed soils: a case study on Mediterranean oribatid (Acari: Oribatida) assemblages, Italy. Biodivers Conserv 16:3277-3285
2. Delaplane, K.S., & Mayer, D.F. (2000). Crop Pollination by Bees. CABI Publishing, New York
3. Fox, J., Andronic, L., Ash, M., Boye, T., Calza, S., Chang, A., Grosjean,P., Heiberger, R., Kerns, J.G., Lancelot, R., Lesnoff, M., Ligges, U., Messad,S., Maechler, M., Muenchen, R., Murdoch, D., Neuwirth, E., Putler, D., Ripley, B., Ristic, M., Wolf P. (2009). Rcmdr: R Commander. R package version 1.5-4. http://CRAN.R-project.org/package=Rcmdr

4. Frankie, G. W., R. W. Thorp, J. Hernandez, M. Rizzardi, B. Ertter, J. C. Pawelek, S. L.
5. Witt, M. Schindler, and V. Wojcik. 2009a. Native bees are a rich natural resource in urban California gardens. California Agriculture 63(3):113-120.
6. Frankie, G. W., R.W. Thorp, J.C. Pawelek, J. Hernandez, and R. Coville. 2009b. Urban Bee Diversity in a Small Residential Garden in Northern California. Journal of Hymenoptera Research 18(2):368-379.
7. Frankie, G. W., R. W. Thorp, M. Schindler, J. Hernandez, B. Ertter, and M. Rizzardi. 2005. Ecological Patterns of Bees and Their Host Ornamental Flowers in Two Northern California Cities. Journal of the Kansas Entomological Society 78(3):227-246.
8. Green, Matthew. (2007) Oakland Looks towards greener pastures: The Oakland Food Policy Council. Edible East Bay, Spring 2007, 36-37.
9. Hernandez,J. L., Frankie, G.W., Throp, R. W. 2009. Ecology of Urban Bees: A Review of Current Knowledge and Directions for Future study. Cities and the Environment. 2(1):article 3, 15pp. Http://escholarship.bc.edu/cate/vol2/iss1/3 .
10. Holzschuh, A., I. Steffan-Dewenter and T. Tscharntke. 2008. Agricultural landscapes with organic crops support higher pollinator diversity. Oikos. 117:354-361.
11. Kremen, C. Williams, N.M.& Thorp, R.W. (2002) Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Science of the United States of America. 99:16812-16816.
12. Kremen, C. (2004) The area requirement of an ecosystem service: crop pollination by native bee communities in California. Ecology Letters. 7:1109-1119.
13. Kremen, C., N. M. Williams, M. A. Aizen, B. Gemmill-Herren, G. LeBuhn, R. L. Minckley, L. Packer, S. G. Potts, T. Roulson, I. Steffian-Dewenter, D. P. Vasquez, R. Winfree, L. Adams, E. E. Crone, S. S. Greenleaf, T. H. Keitt, A.-M Kleind, J. Regetz, and T. H. Ricketts. 2007. Pollination and other ecosystem services provided by mobile organisms: a conceptual framework for the effects of land-use change. Ecology Letters. 10:299-314.
14. Klein, A.M. Steffan-Dewenter, I. & Tscharntke, T. (2003) Fruit set of highland coffee increases with the diversity of pollinating bees. Proceedings from the Royal Society, Biological Sciences. 270:955-961.
15. McClintock, N. (2008) From Industrial Garden to Food Desert: Unearthing the Root Structure of Urban Agriculture in Oakland, California. Institute for the study of Social Change. ISSC Fellows Working Papers. Paper ISSC_WP_32. <http://repositories.cdlib.org/issc/fwp/ISSC_WP_32> Accessed 2009 Mar 12.
16. Pawelek, J. C., G. W. Frankie, R. W. Thorp, and M. Przybylaski. 2009. Modification of a community garden to attract native bee pollinators in urban San Luis Obispo, California.Cities and the Environment 2(1):article7. http://escholarship.bc.edu/cate/vol2/iss2/7 (accessed 2/08/2010).
17. R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.
18. Ricketts, T.H. Daily, G.C. Ehrlich, P.R. & Michener, C.D. (2004) Economic value of tropical forest to coffee production. Proceedings from the national academy of Science of the United States of America. 101:12579-12582.
19. Ricketts, T.H. Regetz, J. Steffan-Dewenter, I. Cunningham, Saul A. Kremen, C. Bogdanski, A. et al. (2008) Landscape effects on crop pollination services: are there general patterns? Ecology Letters. 11:499-515.
20. Williams, N.M. & Kremen, C. (2007) Resource distributions among habitats determine solitary bee offspring production in a mosaic landscape. Ecology Letters. 10:1105-1113.
21. Winfree, R., N. M. Williams, H. Gaines, J. S. Ascher and C. Kremen. 2008. Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. Journal of Applied Ecology. 45(3):793-802.
22. Williams, N. M., C. Kremen. 2007. Resource distributions among habitats determine solitary bee offspring production in a mosaic landscape. Ecological Applications. 17:910-921.
23. Wolda, H. 1983. Diversity indices and tropical cockroaches, Germany. Oecologia. 58:290-298