Effectiveness of pollination by wild bees as influenced by landscape composition and distance from natural habitat

Molly Waytes

On Site Supervisor:

Hannah Gaines, M.S. and Rachel Mallinger, M.S.
Department of Entomology, University of Wisconsin-Madison
Madison, WI

Faculty Supervisor:

Dr. Binney Girdler
Department of Biology, Kalamazoo College
Kalamazoo, MI

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Abstract

Bees are an animal pollinator often utilized by fruit growers. While honey bees have historically been used for crop pollination, they are currently facing a number of threats to their population. Wild bees present a potential source of pollination services for crops to supplement those provided by honey bees. However, landscape composition and the availability of foraging and nesting resources might affect wild bee abundance and therefore pollination services. We looked at wild bee pollination in cranberry marshes in Wisconsin. The objectives of this research were to determine (1) if wild bees could provide pollination services equivalent to those provided by honey bees, (2) if wild bee pollination varied with landscape composition and (3) if distance from edge of natural habitat affected pollination by wild bees. Sites were chosen so that the surrounding landscape varied from below 35% to above 60% of agriculture or wooded area within 2 km of sites. Pan traps were placed in cranberry marshes to measure wild bee abundance. Sentinel plants, including sunflower and buckwheat, were placed in cranberry fields and visitation rates and seed count were recorded to represent pollination success. Wild bee abundance was found to be positively correlated with surrounding woodland, but was not significantly correlated with surrounding agriculture. Seed number did not significantly vary in the presence or absence of honey bees or with surrounding agriculture or wooded area. It was, however, significantly affected by an interaction between honey bee presence and surrounding agriculture. Seed number did not significantly differ at increasing distances from natural habitat. Based on these observations, wild bees may be a viable alternative to honey bees depending on habitat composition.

Introduction

Animal pollinators are an essential component to food production. They contribute directly or indirectly to over one third of global crop production (Klein *et al.*, 2007). Some specialty crops, such as figs, have coevolved with their pollinators and are thus dependent on them for reproduction (Anstett *et al*., 1997; Shanahan *et al*., 2001). Almonds are another example of a self-incompatible crop that needs cross-pollination to produce fruit, a service often provided by bees (McGregor, 1976). These animal pollinated crops have been found to contribute greatly to human dietary health, supplying lipids and a number of vitamins and minerals (Eilers *et al.*, 2011).

Animal pollinators do not just aid in food production and diet; many non-agricultural plant species are dependent upon the presence of pollinators as well. In fact, 90% of all flowering plants worldwide depend on animal-mediated pollination (Kearns *et al.*, 1998). Studies in Britain and the Netherlands have shown a parallel decrease in wild plants and their animal pollinators, suggesting the two populations are mutually dependent (Biesmeijer *et al*., 2006).

One greatly utilized animal pollinator worldwide is the domesticated honey bee, *Apis mellifera* (Corbet *et al.*, 1992). Southwick and Southwick (1992) determined that honey bees contribute an annual $1.6 to $5.7 billion in social gains to the U.S. alone. The most obvious contribution of honey bees is in the production of honey and beeswax, but honey bees are also a key component to the production of many pollinator-dependent fruit and vegetable crops.

However, honey bees are not necessarily the most efficient pollinators due to their generalist foraging behavior, visiting many flower species in one foraging trip. Specialist pollinators may be more effective as they display loyal foraging to one plant species (Delaplane and Mayer, 2000). Also, honey bees prefer nectar rich plants and sometimes forage only for nectar, intentionally avoiding contact with pollen and therefore pollinating less efficiently. Because of this, wild bees have been found to be more efficient pollinators than honey bees for plants like cranberries, blueberries and alfalfa, which either have lower nectar content (as is the case of the cranberries) or require certain mechanisms for the maximum release of pollen (as is the case for blueberries and alfalfa) (Batra, 1995; Javorek *et al.*, 2002).

Relying solely on the honey bee for pollination is also dangerous, especially as their populations have declined due to a number of threats recently, including the varroa mite and Colony Collapse Disorder (vanEngelsdorp *et al.*, 2009, Le Conte *et al.*, 2010). Having a diversity of pollinators available not only provides insurance against declining honey bee numbers, but may also increase pollination and therefore fruit set (Klein *et al.*, 2003). Pollination services provided by wild bees alone was found to be sufficient for fruit production, and even exceeded pollination services provided by honey bees for fruit such as melons, peppers and tomatoes (Kremen *et al.*, 2002, Winfree *et al.*, 2007, Winfree *et al.,* 2008). Tomatoes require sonication, or strong vibrations to release the majority of the pollen from the anthers; honey bees lack the ability to sonicate, but bumble bees are able to, making them more efficient pollinators of tomatoes (Greenleaf and Kremen, 2006). A low number of wild pollinators in canola resulted in pollination deficits, illustrating their importance for full fruit set (Morandin and Winston, 2005).

Wild bees may be a possible alternative to honey bees; however, a challenge to incorporating wild bees in crop pollination is that agriculture often displaces natural habitats that provide essential foraging and nesting resources for these wild bees. The amount of agriculture in the landscape has thus been shown to be negatively correlated with pollinator abundance, diversity and pollination services (Kremen *et al.*, 2002; Klein *et al.*, 2006). On the other hand, Winfree *et al.* (2007) found that native bees in temperate forested regions benefited from the presence of agriculture, which provided mass floral resources, and that intermediate disturbance by human activities may also be beneficial to bees through the presence of more flowering plants. Though the floral resources available during the bloom of an agricultural crop might provide a dietary supplement, wild pollinators may suffer from a lack of resources before or after the bloom if there are few alternative resources available. Natural habitats, with a diversity of plants, can provide resources for bees during their entire foraging period. Therefore areas with a large amount of cropland would likely have reduced wild bee abundance and diversity, which would necessitate the renting of honey bees for supplemental pollination.

While landscape composition, such as the amount of agricultural or natural land in a given area, might affect wild bee presence, so too might the distance of a farm to natural habitat. Studies in California have shown that the amount of crop pollination services provided by native bees depended on the farm’s distance from upland, natural habitat (Kremen *et al.*, 2004). Another study on pollination found that wild bees were the dominant pollinators of small blueberry fields while honey bees were the dominant pollinators of large blueberry fields, possibly suggesting wild bees were capable of pollination but only in fields with centers closer to natural habitat (Isaacs and Kirk, 2010). Carvalheiro *et al.* (2010) found that pollination declines with distance from natural habitat and suggested that floral and nesting resources provided by natural habitat are more vital to bees, or preferred by bees, compared to the flowering crops. If natural habitat is the preferred nesting and foraging habitat, wild bees may avoid flying too far from the natural habitat into the crop. Large monoculture fields might therefore experience disparity in pollination as the edges, which are closer to natural habitat, are pollinated more regularly compared to plants in the center of the field.

Along with bee abundance and visitation rates, pollinator species richness has also been found to decline with increasing distance from natural habitats (Ricketts *et al.*, 2008). Lower bee species richness means less pollinator redundancy, resulting in pollination services that are more affected by the year-to-year variability of pollinator populations. Lower bee species richness may also result in the absence of efficient pollinator species in areas far from natural habitat. Differently sized bees may be distributed unequally with increasing distance from natural habitat. Larger bees forage over a larger spatial scale compared to smaller bees and fly further from their nests (Greenleaf *et al.*, 2007). Thus, the center of a large field, far from natural habitat, would be expected to have reduced bee species richness and fewer smaller bee species. The loss of pollination services provided by these smaller bee species could potentially hurt fruit production.

Cranberries are an economically valuable crop in Wisconsin that require animal pollination. Honey bees have not been found to be the most effective pollinators of cranberries (Delaplane and Mayer, 2000). Despite their comparative inefficiency, growers often rent honey bees as a safeguard to ensure pollination of their crop (Evans and Spivak, 2006). There are a number of wild bee species capable of pollinating agricultural crops found in Wisconsin, including those in the families of Andrenidae, Apidae, Halictidae, Megachilidae and Colletidae (Wolf and Ascher, 2008). It is possible that native bees could match or exceed honey bees in pollination services of cranberry plants. However, the abundance and diversity of wild bees might be low in areas with a high amount of agriculture, and cranberry plants located far from natural habitat, in the middle of large fields, might face pollination deficits.

Our research examined pollination services provided by wild bees in cranberry marshes and whether they could supplement or replace pollination by honey bees. The first objective was to determine whether plants in the absence of honey bees could be pollinated to the same degree as plants in the presence of honeybees, and whether this was determined by the amount of natural habitat surrounding a cranberry marsh. We hypothesized that pollination could be provided sufficiently by wild bees, at the same level or higher than pollination provided by honey bees. This would be affected negatively by increasing percentages of surrounding agriculture. The second objective of our research addressed whether distance from the edge of cranberry marshes, and therefore distance to natural habitat, affected wild bee visitation rates and therefore the pollination services provided to plants. We hypothesized that plants located farther away from natural habitat would see a decline in pollination services provided. To carry out these objectives, we examined visitation rates and seed set of sentinel plants placed in cranberry marshes 1) in the presence and absence of honey bees and 2) at varying distance to the edge of the marsh.

Methods

Site selection

All experiments were conducted in cranberry marshes in central Wisconsin (Jackson, Wood, Portage, Monroe and Juneau Counties) (Figure 1). To determine whether wild bees could provide pollination services equal to honey bees and whether this varied at sites with different amounts of natural habitat (Objective 1), sites were chosen on a landscape gradient. Sites were located on a gradient of low percentage woodland or agriculture (below 35%) to high percentage woodland or agriculture (above 60%) within 2 km of the site (Figure 2). Landscape gradients were identified using digital orthophotos and the Cropland Data Layer (CDL, USDA 2008). Previous research in the area has shown that native, wild bee species richness and abundance are negatively correlated with agriculture and positively correlated with woodland surrounding the cranberry marshes at a 2 km radius (Gaines unpublished data).

Sites that rented honeybees during the cranberry bloom were chosen for comparison with wild bees. Honey bees were rented by cranberry farmers during the cranberry bloom and then removed after the bloom, which allowed for the control of honey bee presence. Data were gathered both while the honey bees were present and after their removal.

To measure whether pollination services varied with distance to the edge of the field and natural habitat (Objective 2), four sites with a high wild bee abundance in 2010 (Gaines unpublished data) were chosen to ensure that pollination would occur to some extent and to allow for differences at varying distances from edge to be identified.

Figure 1. Map of Wisconsin with site location indicated by dots.

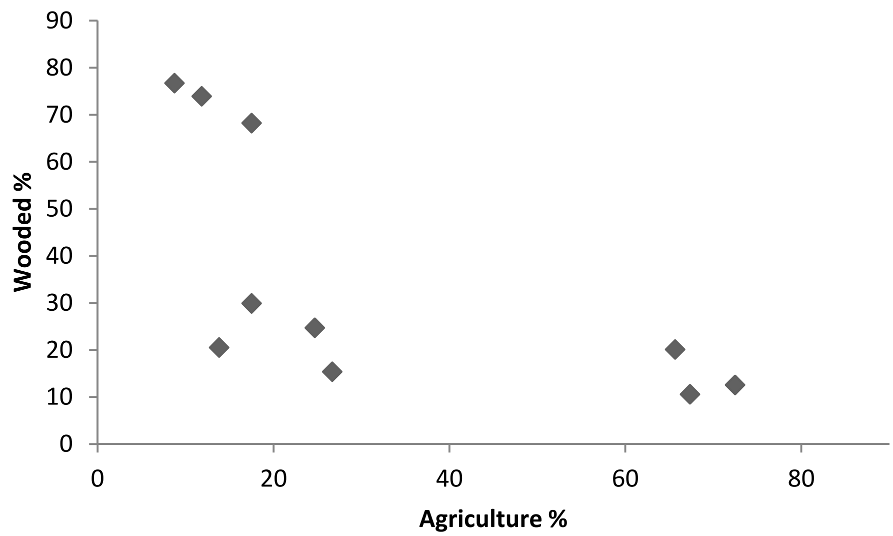


Figure 2. The percentage of wooded and agricultural land in a 2 km radius of objective 1 sites.

Wild bee abundance

To determine if wild bee abundance varied with different landscape composition, wild bee abundance was measured at all sites using pan traps. Traps were set along a 40m transect established in the cranberry bed in a corner of the marsh along a non-farm edge. Bees were collected before, during, and after cranberry bloom using white, florescent blue, and fluorescent yellow pan traps. The traps were filled with a dilute soapy water solution. Sets of three traps (one of each color) were placed 10 meters apart from each other along the transect. Traps were left in each marsh for 3 day intervals and all sites were visited within two days. Specimens were put into 70% alcohol upon collection.

Sentinel plants

Sentinel plants were used to measure pollination success instead of using cranberry directly. The plants were chosen for their short life cycle and to more easily control access to the plants by insects in a greenhouse setting. More importantly, the use of sentinel plants allowed for pollination to be examined during and after the cranberry bloom to control for the presence of honey bees.

Objective 1

To determine pollination services using seed count, sentinel sunflower plants were placed in each of the ten cranberry marshes identified along a landscape gradient. The experiment was conducted twice, once during cranberry bloom, when honeybees were present, and once after bloom, when honeybees were absent. Sunflowers were grown in a greenhouse until flowering. Six sunflowers were placed at each site, five of which were open to pollinators while one was bagged with fine mesh, excluding pollinators, to serve as a control. All plants were bagged when being transported to the field to equalize any negative effects bagging might have on the plants, as well as to prevent possible pollination while the plants were not in the field. Plants were placed at the corner of the cranberry marsh and left in the field for three days.

During the period that they were in the cranberry marsh, visitation rates by bees to the sunflowers were observed. Observations were taken three times while the plant was in the field for 10 minute intervals and each individual bee visit to the flowers was recorded. Bee type was recorded to morphospecies, which were later separated into three categories, honey bee, bumble bee and solitary bee. Based on the difficulty of visually identifying solitary bees outside of morphospecies, they were placed in one category; bumble bees and honey bees were more easily identifiable to genus and therefore were separated into their own categories. Observation took place on days with clear, partly cloudy or bright overcast weather, temperatures above 75 F and between 9 am and 5 pm. After three days, sunflowers were brought back to the greenhouse.

Seeds were harvested after the sunflowers reached maturity and were left to dry. Seed count was measured for each plant; only viable seeds were counted. All seeds were measured while still in the shell. Seed count was used as an indicator of pollination success at each site with and without honeybees.

Objective 2

To determine whether plants experienced a difference in pollination at further distances away from natural habitat, buckwheat was used as a sentinel plant. *Brassica rapa* and canola plants were also intended to be used as sentinel plants, but were lost to a pest infestation in the greenhouse. Buckwheat was grown in the greenhouse until flowering at which time it was placed at five cranberry marshes at 0 m, 33 m, 66 m and 99 m from the edge of the field going into the center of the field. As objective 2 was measuring the effect of distance to edge on wild bee pollinators and pollination rates, this experiment was conducted only after cranberry bloom when honey bees were absent.

Four pots of buckwheat plants were placed at each location at each of the four sites. Three pots were open to pollinators while one was covered and excluded from pollinators to serve as a control. Plants were left in the field for three days and were then brought back to the greenhouse. The process was completed twice at each site. After the plants were brought back to the greenhouse and seeds were set, the seed count was recorded to indicate pollination rate and success at each distance from the edge.

Analysis

To determine whether bee abundance was affected by landscape composition Analysis of Variance (ANOVA) and regression were used, where the number of morphospecies found per site was the response variable and the predictor variables were percent wooded land and percent agricultural land within 2 km of each site.

For both objectives 1 and 2, average seed count of the control plants were subtracted from the seed count of the open plants to eliminate the role of self-pollination (henceforth referred to as seed count). For objective 1 ANOVA was used to detect differences in pollination, where average seed count per site was treated as a response variable and the presence or absence of honeybees was the predictor variable. Due to the loss of some sentinel plants, only eight of the ten sites were compared. The regression between the averaged seed count per site and different landscape variables (percent wooded land and percent agricultural land within 2 km of each site) was also calculated and an ANOVA was used to test for significance.

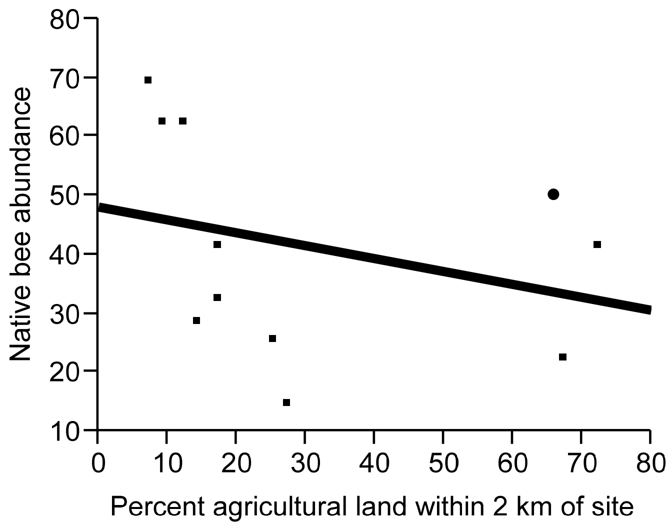
For objective 2, ANOVA was used to detect the differences between corrected seed count as affected by distance from natural habitat. Corrected seed count was the response variable and distance from natural habitat was the predictor variable.

Results

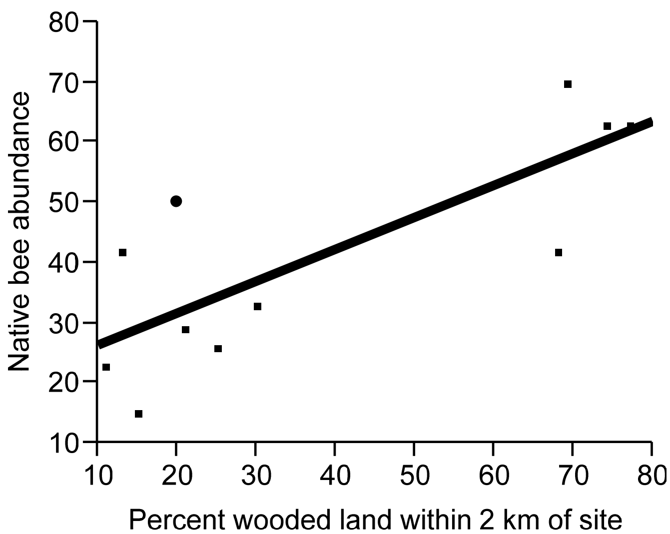
Wild bee abundance in a cranberry marsh was not found to be significantly correlated with percent agriculture at a 2 km radius surrounding the site (df=10, F=0.9077, *p*=0.3656) (Figure 3a) but was significantly correlated with percent woodland at a 2 km radius (df=10, F=15.3173, *p*=0.0035) (Figure 3b). The number of honey bee, bumble bee and solitary bee visits to sentinel plants were not found to vary significantly with percent agriculture or percent woodland at a 2 km radius (Tables I, II and III).

Though there was not a significant difference between the seed count of sunflower plants in the absence and presence of honey bees (df=1, F=0.5744, *p*=0.4611) (Figure 4), analysis revealed a significant correlation with seed count and an interaction between agriculture and the presence or absence of honey bees (df=1, F=4.7743, *p*=0.0494). A positive trend between seed count and percent agriculture in the absence of honey bees was found, though the interaction was not strongly significant (df=1, F=4.1594, *p*=0.0875) (Figure 5a). No significant effect of agriculture was found on pollination services provided in the presence of honey bees (df=1, F=2.1351, *p*=0.1943) (Figure 5a), as measured by seed count. There was also no significant effect of woodland on pollination services provided in the absence (df=1, F=0.0648, *p*=0.8076) or in the presence of honey bees (df=1, F=2.9995, *p*=0.1340) (Figure 5b).

Distance from the edge of natural habitat (0 m, 33 m, 66 m, and 99 m) did not significantly affect the number of buckwheat seeds per plant (df=71, F=0.8637, *p*=0.4643) (Figure 6). There was no significant correlation with seed count and an interaction between distance from edge and site (df=9, F=1.5612, *p*=0.1498).



a.



b.

Figure 3. Total wild bees captured in pan traps at sites with varying percent (a) agriculture (p=0.365 and R^2=0.0916) and (b) wooded area (p=0.003, R^2=0.6299) at a 2 km radius.

Table I. Honey bee visitation rate to sunflowers with varying percent wooded and agricultural land at a 2 km radius from site.

Source	DF	Sum of Squares	F Ratio	Prob > F
% Agriculture	1	0.4910	1.4187	0.2724
% Wooded	1	0.4635	1.3392	0.2851

Table II. Bumble bee visitation rate to sunflowers with varying percent wooded and agricultural land at a 2 km radius from site.

Source	DF	Sum of Squares	F Ratio	Prob > F
% Agriculture	1	0.004586	0.0737	0.7938
% Wooded	1	0.008853	0.1423	0.7171

Table III. Solitary bee visitation rate to sunflowers with varying percent wooded and agricultural land at a 2 km radius from site.

Source	DF	Sum of Squares	F Ratio	Prob > F
% Agriculture	1	0.3758	2.4822	0.1591
% Wooded	1	0.002020	0.0133	0.9113

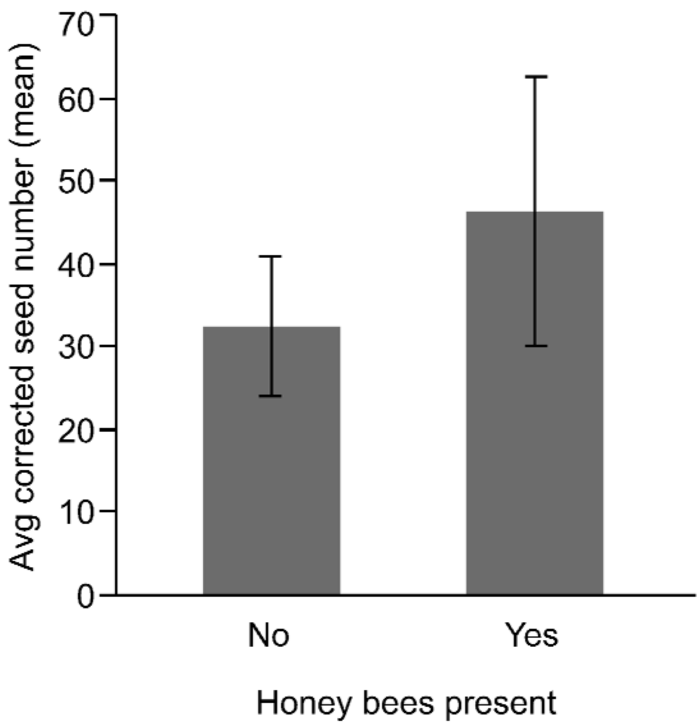
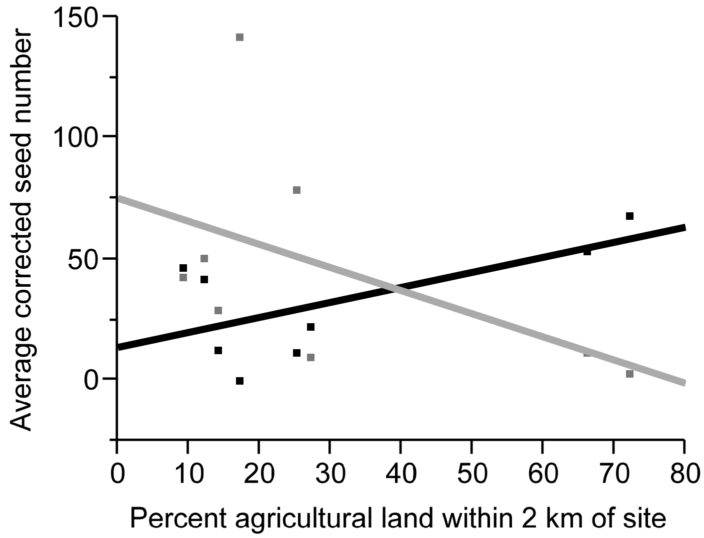
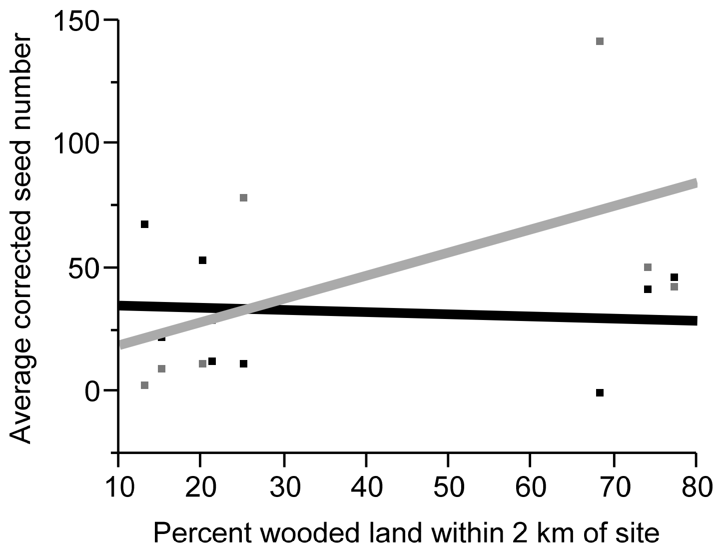


Figure 4. Mean (±1 SE) average sunflower seed count compared in the absence and presence of honey bees (p=0.4611).



a.



b.

Figure 5. Regression of corrected sunflower seed number with percent agricultural land (a) in the absence (p=0.0875, R^2=0.4094) and presence (p=0.1943, R^2=0.2625) of honey bees and percent wooded land (b) in the absence (p=0.8076, R^2=0.01068) and the presence (p=0.1340, R^2=0.3332) of honey bees within 2 km of the site. The black regression line corresponds to seed number when honey bees are not present and the grey regression line corresponds to seed number when honey bees are present.

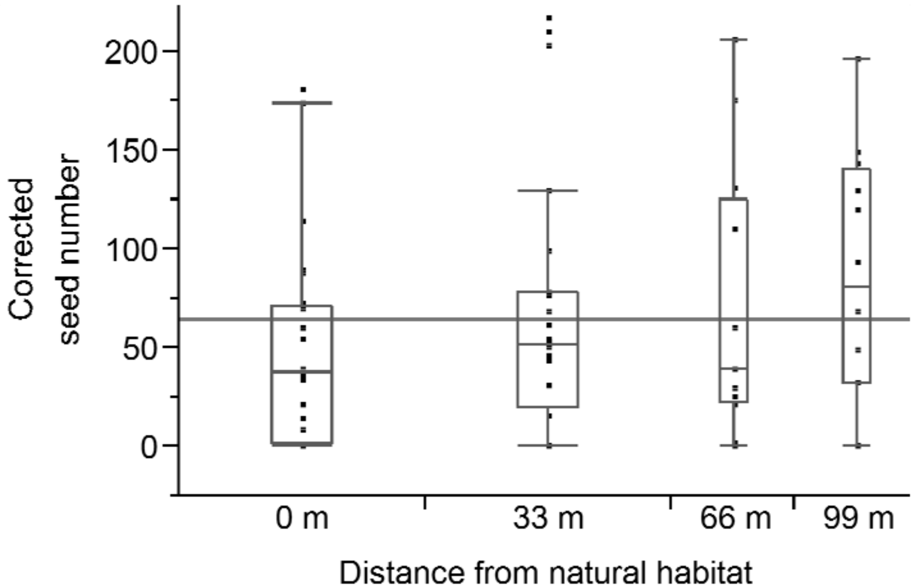


Figure 6. Corrected buckwheat seed number from plants placed at 0 m, 33 m, 66 m and 99 m away from natural habitat (p=0.4643).

Discussion

Wild bee abundance across different landscapes

Wild bee abundance was affected by landscape composition, with more bees in cranberry marshes with a higher percentage of surrounding woodland. Woodland may therefore offer more floral and nesting resources for wild bees. This is an important consideration for growers when creating new cranberry beds or when considering landscape changes to existing cranberry marshes. Cranberry marshes located in places with a higher percentage of surrounding woodland, or that have forested habitat incorporated into their managed land, would be more likely to have native bees and therefore possibly benefit more from the pollination services provided by these native bees.

One possible reason for why we did not see a significant effect of agricultural habitat on wild bee abundance is that all types of agriculture were grouped into one general category. The type of surrounding agriculture might differently influence wild bee abundance, as some types of agriculture, like cranberry, may be more beneficial to wild bees than others due to the differing availability of nesting and foraging resources. In general, annual non-flowering wind-pollinated crops like corn have a more detrimental effect on wild bees than animal-pollinated crops like berries. Kremen *et al* (2007) suggests that crops like berries, which provide large amounts of pollen and nectar, are a viable short-term food resource for bees. Along with offering a food supply, cranberry marshes may provide nesting resources as well. Some wild bee species, like members of the genus Megachile, may prefer to nest in dikes and other areas close to cranberry marshes (Cane *et al.* 1996). In future studies that take into account surrounding agriculture, the fact that some agriculture types are more attractive and beneficial to bees than others should be considered.

Another consideration is not just the type of agriculture, but the diversity of agriculture. A variety of agriculture could potentially be more beneficial for bees if the flowers of the crops bloom at different times of the year. Winfree *et al.* (2007) found that native pollinators could provide sufficient pollination even in areas of intensive land use. This is contrary to the expectation that agriculture is negatively correlated with pollinator abundance, diversity and pollination services (Kremen *et al.* 2002; Klein *et al.*2006). It may be that the types of agriculture and the diversity of agriculture effect whether the landscape encourages or discourages the presence of wild bees. Areas with a high diversity of agriculture may provide consistent floral resources for bees if the blooms of the crops are staggered; even as one resource becomes unavailable, another one would take its place throughout the season. In areas where agriculture increases habitat heterogeneity through a diversity of crops, agriculture may have a positive effect on bees (Kremen *et al.* 2007). Because this study classified agriculture into one category, the possible benefits of diversified agriculture may have been overlooked. Future studies may wish to not only concentrate on the type of agriculture present but also on agricultural diversity.

Visitation to sentinel plants on a landscape basis

While native, wild bee abundance was found to differ with landscape composition, wild bee visitation to sentinel plants did not vary significantly across sites and with landscape composition. These results may be influenced by the difficulties in quantifying bee visitation, as some bee species will repeatedly visit the same flower or spend long amounts of time flying on and off a flower. Additionally, despite precautions taken in regards to weather condition and time of observation, it was impossible to standardize weather and time across all sites and observation days. As some bees may be sensitive to weather and time of day, their visitation may have therefore varied.

Pollination of sentinel plants with and without honey bees on different landscape compositions

Seed count did not vary significantly with honey bee presence, suggesting that wild bees alone may be sufficient for the pollination of cranberries. While there was not a significant regression between either agriculture or wooded area and seed count, there was a positive trend between agriculture and seed count in the absence of honey bees. There was also a significant interaction between agriculture and honey bee presence that affected seed count. It was originally assumed that, based on previous findings, areas with higher agriculture would have a lower bee abundance and therefore might experience lower pollination rates (Gaines unpublished data). However, the regression trend suggests the opposite.

One possible explanation is that the relative attractiveness of the sentinel plants changed during and after the bloom, especially in areas of higher agriculture. During the cranberry bloom there was a large, concentrated floral resource available that might overshadow the attractiveness of sentinel plants. After the bloom, however, that resource was absent. In areas of high natural habitat, wild bees may have had floral resources available in the natural habitat and therefore the sentinel plants were not especially attractive. However, in areas with high agriculture, especially if the agriculture was cranberry, the loss of the cranberry bloom could cause available floral resources to greatly decline. Therefore the sentinel plants would be much more attractive to wild bees after the cranberry bloom in areas of high agriculture than in areas of high natural habitat. While it is possible that the agriculture in the sites that were researched was more attractive to wild bees than previously thought, abundance data suggests that woodland, not agriculture, had a positive correlation with bee abundance; all agricultural sites studied were similar in that they all had low surrounding woodland.

Pollination at increasing distances from natural habitat

We found that sentinel buckwheat plants placed up to 100 m away from natural habitat experienced the same pollination as those placed directly next to natural habitat. This finding illustrates that wild bees may venture to the middle of fields, which is contrary to the hypothesis that if enough floral resources are available within a short distance away from the nest (or natural habitat), then a wild bee might not venture out to its maximum foraging range. Findings may have been influenced by the fact that there was not a cranberry bloom during the time data was collected, meaning floral resources were scarcer in the area. Thus bees may be foraging at larger ranges than they would be with an abundance of resources. The scale of the study may have also affected results; a different study that measured distances did so at distances exceeding 100 m (Carvalheiro *et al.*, 2010). Since many cranberry fields do have centers more than 100 m away from natural habitat, future studies may wish to measure greater distances to find any differences. Nevertheless, results show that wild bees are capable of pollinating flowers at a significant distance away from natural habitat.

Conclusion

Results show that pollination by wild bees can match pollination done in the presence of honey bees, though there is some variation with landscape composition. They also show that within distances of around 100 m from adjacent natural habitat, plants will be evenly pollinated by wild bees. Wild bees can therefore provide levels of pollination similar to those provided by honey bees and can be depended upon for pollination even at distances away from natural habitat. However, this is contingent on a site supporting native, wild bees with adequate foraging and nesting resources. It was also found that bees are more abundant at sites surrounded by wood habitat, suggesting that woodland provides better resources for bees compared to agricultural habitat.

Type and diversity of agriculture should be considered when considering the potential negative influences of agriculture. There is a possibility that diversified agriculture may offer a more heterogeneous, and therefore more beneficial, landscape for bees. However, the negative consequences of the presence of agriculture, including the use of pesticides and herbicides, as well as the possibility of higher levels of disturbance, should still be considered.

The relative attractiveness of sentinel plants is an important consideration. While using sentinel plants was necessary for the research that took place after the cranberry bloom ended, some of the data may have been confounded because of differences in the relative attractiveness of sentinel plants.

Perhaps too much importance has been placed on pollination by honey bees. The recent decline of honey bees has been a cause for alarm. Threats to honey bee populations like Varroa mites and Colony Collapse Disorder are difficult to eliminate and will probably continue to affect honey bees in the future (Le Conte, Ellis and Ritter 2010, vanEngelsdorp *et al.* 2009). Moreover, as pollinators honey bees are generalists and more susceptible to weather conditions than wild bees (Vicens and Bosch 2000). Their effectiveness lies in the fact that growers can inundate fields with hives, therefore assuring that there will be more than enough bees for pollination.

Wild bees can be considered a viable alternative to honey bees. Simple landscape adjustments that include flowering plants that bloom at different times of the year and undisturbed areas for nesting may eventually sustain a sufficient population of wild bees in the area where honey bees will be less necessary. Perhaps entirely removing honey bees for pollination would not be wise in areas of low woodland or other natural habitat. With supportive habitat, though, wild bees may be a promising alternative for managed honey bees.

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