Native-Naturalized Plant Species for Pollinators in Agricultural Lands in the Caribbean Area

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Abstract

Conventional agricultural fields provide few non-crop plant species that are both capable of tolerating the intensive farming practices, and suitable resources for wild bees. In the southern plains of Puerto Rico and in Saint Croix, U.S. Virgin Islands, there are extensive acreages of land used for intensive conventional agriculture, yet, information focused on the conservation of wild bees in these regions is lacking. Herein, we determined pollinator abundance, diversity and distribution in agricultural lands in Santa Isabel, Puerto Rico and St-Croix, U.S. Virgin Islands. Contrary to our hypothesis, proximity to natural vegetation did not strongly affect bee diversity and abundance. Although, in Puerto Rico, we found the highest bee abundance and diversity in pumpkin fields located within a 1.6 Km radius of natural vegetation, this was not the case for watermelon, eggplant and pepper crops. This suggests that conventional agricultural practices have a stronger influence on wild bee populations than the landscape surrounding agricultural fields. Equally surprising, in St-Croix, where all four of our survey sites were located less than 1.6 Km from natural vegetation, we recorded the greatest bee diversity and abundance in the only conventional agricultural field surveyed on the island. We provide a list of crop plants and wildflowers used by foraging wild bees as well as review of relevant literature on each species to help farmers create natural agricultural field margins to enhance abundance and pollination services of wild bees in their fields.

1. *Introduction*

Bees are the main providers of pollination services in natural and agricultural environments (Michener 2007). Honey bees (*Apis mellifera*) and other managed bee species are often used to insure continuous pollination services, but many crops can also be effectively pollinated with wild bees (eg. Gemmill-Herren & Ochieng 2008; Kremen et al. 2008). Honeybees have been in decline over the past few decades due to factors that include the introduction of honeybee-specific pests such as *Varroa* and tracheal mites, poor nutrition, pesticide misuse, and agricultural practices (Allen-Wardell et al. 1998; Michener 2007; National Research Council 2007; CCD Steering Committee 2012). In contrast, most wild bees are not susceptible to these threats underscoring the importance and potential benefits of attracting and conserving their populations (but see Otterstatter & Thomson 2008 and Cameron et al. 2011). To promote pollination services of wild bees, it is important to meet their ecological requirements in agricultural landscapes. Bees require suitable nesting sites as well as a diversity and abundance of flowers (Vaughan et al. 2006). However, conventional agricultural fields (i.e., monocultures) provide few non-crop plant species capable of tolerating the intensive farming practices (e.g. tilling, herbicide and pesticide applications), and those that survive do not provide suitable resources for wild bees (Pywell et al. 2005, Rundlof et al. 2008). The lack of diverse and abundant resources for wild bees in monoculture fields requires that additional management actions be considered and implemented. Many studies have shown the benefits of increasing non-crop habitats for conserving bee populations in agricultural landscapes (e.g., Pywell et al. 2005; Hannon & Sisk 2009; Pywell et al. 2011). Those management practices are believed to be more important in the tropics than in temperate areas, where native pollinator richness and visitation rates display steeper decays with increasing distance from natural habitats (Ricketts et al. 2008).

In the southern plains of Puerto Rico and the U.S. Virgin Islands, there are extensive acreages of land used for intensive conventional agriculture, some of which have been cultivated for more than 150 years. Yet, to date, there has been a paucity of research efforts focused on pollinator conservation in these regions (Genaro & Franz 2008). In this study, we determined pollinator abundance, diversity and distribution in agricultural lands in Santa Isabel, Puerto Rico and St-Croix, U.S. Virgin Islands. We provide a list of crop plants and wildflowers used by foraging bees, and provide a review of relevant literature on each species to help farmers create natural agricultural field margins to enhance abundance and pollination services of wild bees in their fields.

2. Methods

2.1. Bee abundance and Diversity in Santa Isabel, Puerto Rico and St-Croix, USVI

2.1.1. Study System

To determine abundance and diversity in and around agricultural fields in Santa Isabel, Puerto Rico, we selected 6 agricultural fields and 3 'river sites' to survey (Fig. 1). Each agricultural field was separated by a distance of >1.6 Km (1 mile). Most large bees fly less than a mile from their nest (The Xerces Society 2011), hence, we assumed that fields separated by >1.6 km provided sampling independence. Three of the agricultural fields were within 1.6 Km of natural vegetation (e.g., river bank) and three were not. The sites near the river served as our reference sites, that is, those that reflected bee diversity and abundance in minimally disturbed habitat. All other sites were representative of conventional agricultural practices in Puerto Rico. In St-Croix, U.S.V.I., we surveyed three organic (not yet certified) and one conventional agriculture fields (Fig 2.). All fields were >1.6 km apart from each other.

Our surveys were conducted from January to May 2013. During this period the mean monthly temperature was 23.83°C and mean monthly precipitation was of 36.45mm, in Santa Isabel, Puerto Rico (NOAA's National Weather Service). In St-Croix, U.S.V.I., the mean monthly temperature between January and April was 25.90°C and mean monthly precipitation was of 38.86mm (NOAA's National Weather Service).

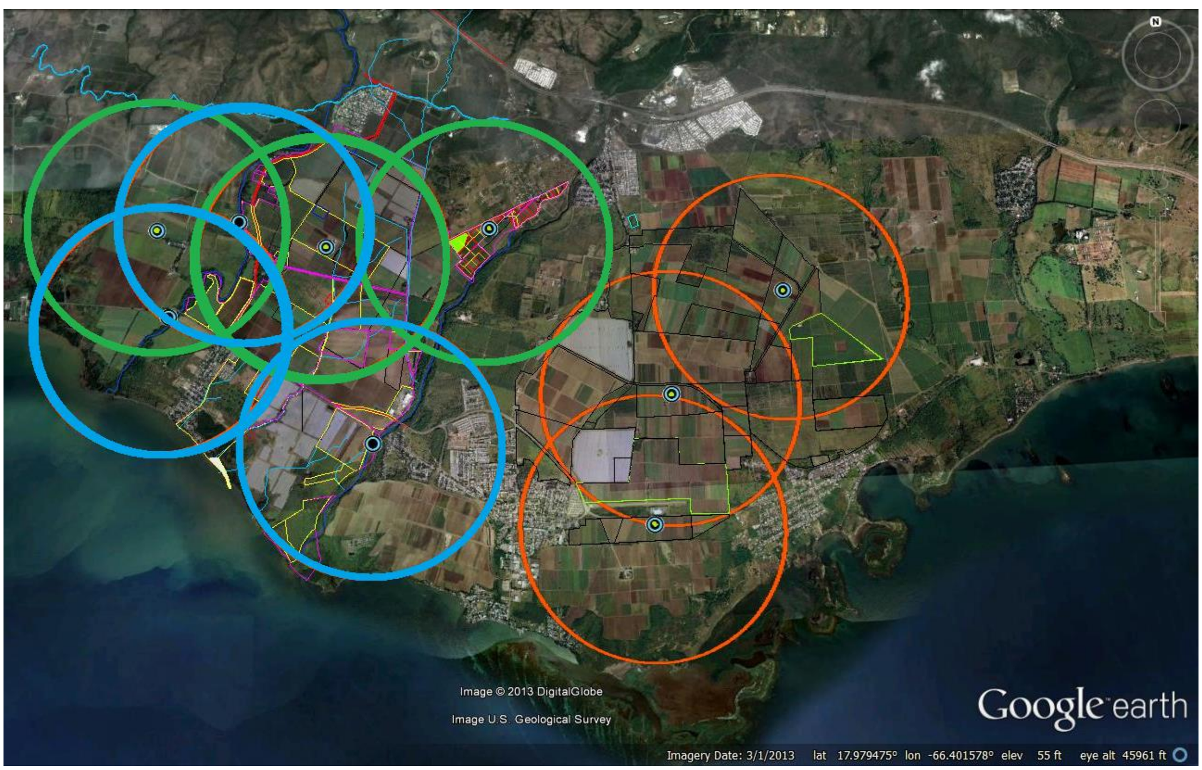


Figure 1. Points with green circles around them represent agricultural fields within 1.6 km (1 mile) of natural vegetation. Points with orange circles around them represent agricultural fields with no natural vegetation within a 1.6 km radius. Points with blue circles around them represent natural vegetation sites, which were located within <20 m of a river. All circles have a radius of 1 mile.

Figure 2. Markers represent the four farms surveyed in St-Croix, U.S. Virgin Island. All farms were >1.6 km (>1 mile) apart, as shown by the red line.

Four crops were surveyed in each field: pumpkin, eggplant, watermelon and pepper. Each crop field was surveyed three times, once a month between February and May. Not all crops were cultivated in all farms, so sample sizes vary for each crop. Surveys were conducted no earlier than two days after a field had been sprayed. We sampled these crops because both pumpkin and watermelon need to be pollinated for fruit set and can be effectively pollinated with honeybees (Agricultural Research Services, 2008). However, due to the short time-span the pumpkin flower is open, native bees may be better pollinators due to their early morning activity (Agricultural Research Services, 2008). When it comes to watermelon pollination, native bees are more effective on a bee-per-bee basis, than honeybees (Kremen et al. 2008). Eggplant needs to be buzz pollinated to release pollen, and since honeybees are not able to effectively buzz pollinated, native bees are best for eggplant pollination (Gemmill-Herren & Ochieng 2008). In fact, eggplant pollination by native bees results in larger fruit size (Gemmill-Herren & Ochieng 2008). Unlike the three aforementioned crop plants, pepper plants do not need to be pollinated for fruit production. Nonetheless, Cruz et al. (2005) have shown that when pollinated, pepper fruits are larger and fruits are less malformed than those that are not pollinated.

2.1.2. Data Collection

Surveys were performed using sweep nets and bee bowls. Bee bowls were placed in an “X” shaped transect, 30 paces (~15-20m) away from each other (Fig. 2). This ensured that bees on the edge and in the center of the fields were being surveyed. Bowls were placed between

8:00-10:00am. After placing bowls in each crop, we returned to the pumpkin crop first to sweep, and then continued with the remaining three crops. Pumpkin was surveyed first because of the limited time their flowers are open (Agricultural Research Services, 2008; Personal observations). Unlike pumpkin, watermelon pepper and eggplant flowers remained open the whole day. Two people swept for 30 minutes, starting where each of the 0 m bee bowls were placed. Only bees observed flying or foraging on flowers were swept. Sweep net sampling was done between 10:00am – 5:00pm on warm (≥25^{o}C), sunny (<60% cloud cover) days. Bowls were collected once sweep net sampling was completed, but no earlier than 4:00pm.

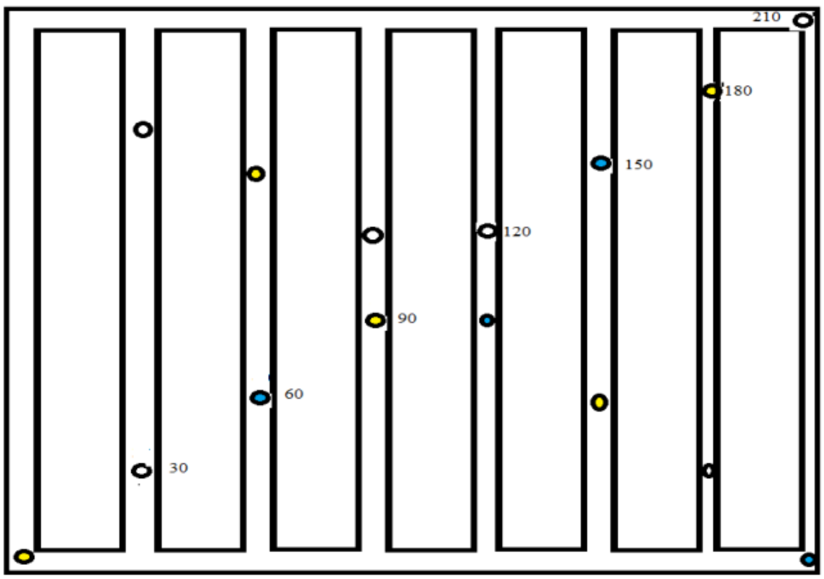


Figure 3. Aerial view of bee bowl placement in a crop field. Six rows of crops (3.65 m) usually separated each bowl from the next. Most often, the field was longer than 210 paces

2.1.3. Data Analysis

Bee diversity at each survey site was determined by tallying the presence or absence of each of the sixteen bee species collected in the Southeastern region of Puerto Rico. We plotted these data onto a map using ArcMap, to visually demonstrate the distance of farms from natural vegetation and their bee species diversity. To determine the effectiveness of our sampling techniques, we contrasted presence/absence data obtained from bee bowls and sweep nets. Lastly, to report the overall abundance of bees collected at each farm, we used the median and the maximum of each species collected in each crop. We used the median number of bees because sampling occasions for some crops were low (1-3 times/crop/farm, and 6 times/natural vegetation site), and likely not normally distributed. We also tabulated the total number of wild bees caught by calculating the sum of the median number of wild bees (excluding *A. mellifera*). This allowed us to determine whether distance from natural vegetation may have had an effect on the abundance of bees collected. The same analyses were done for the natural vegetation ('river sites') to determine what the bee species diversity and abundance may be at an 'undisturbed' site. The same method was used for the five bee species collected in St-Croix, U.S.V.I..

3. Results

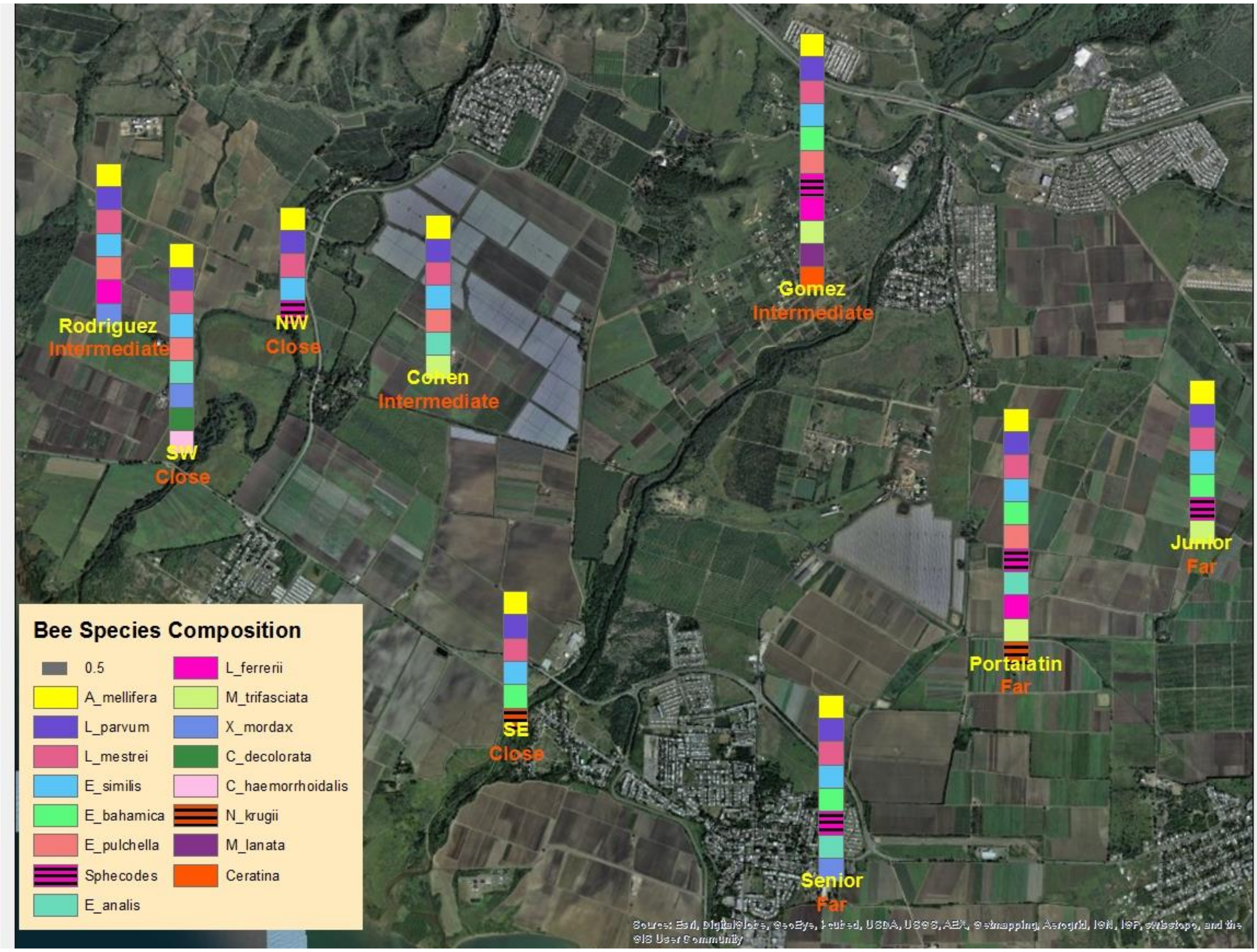


Figure 4. List of bees collected at each survey site in Santa Isabel, Puerto Rico. It can be seen that the distance to the natural vegetation does not affect species diversity. Species with striped colors (*Sphecodes* and *N. krugii*) are cleptoparasitic bees and thus not pollinators.

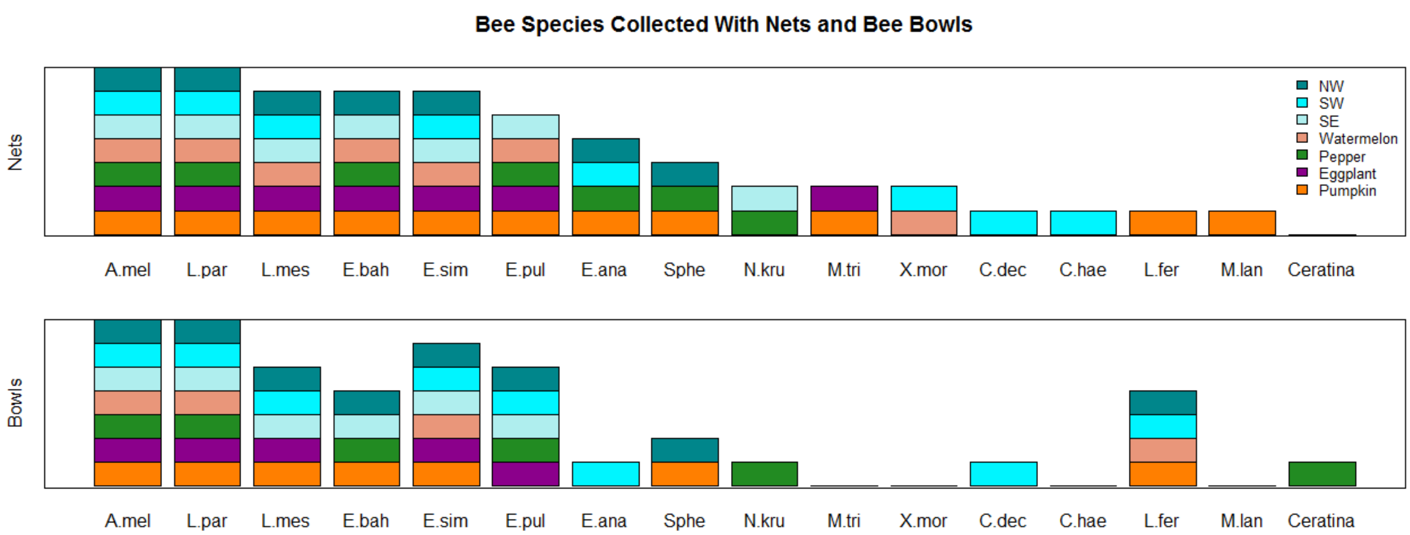
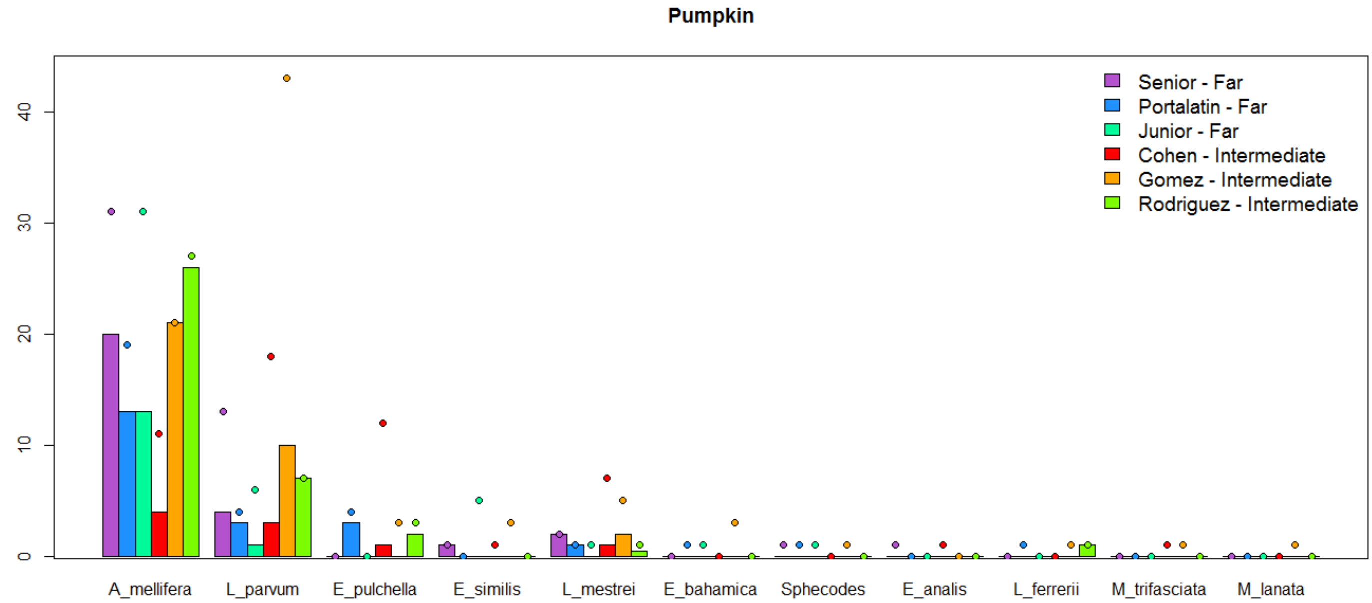
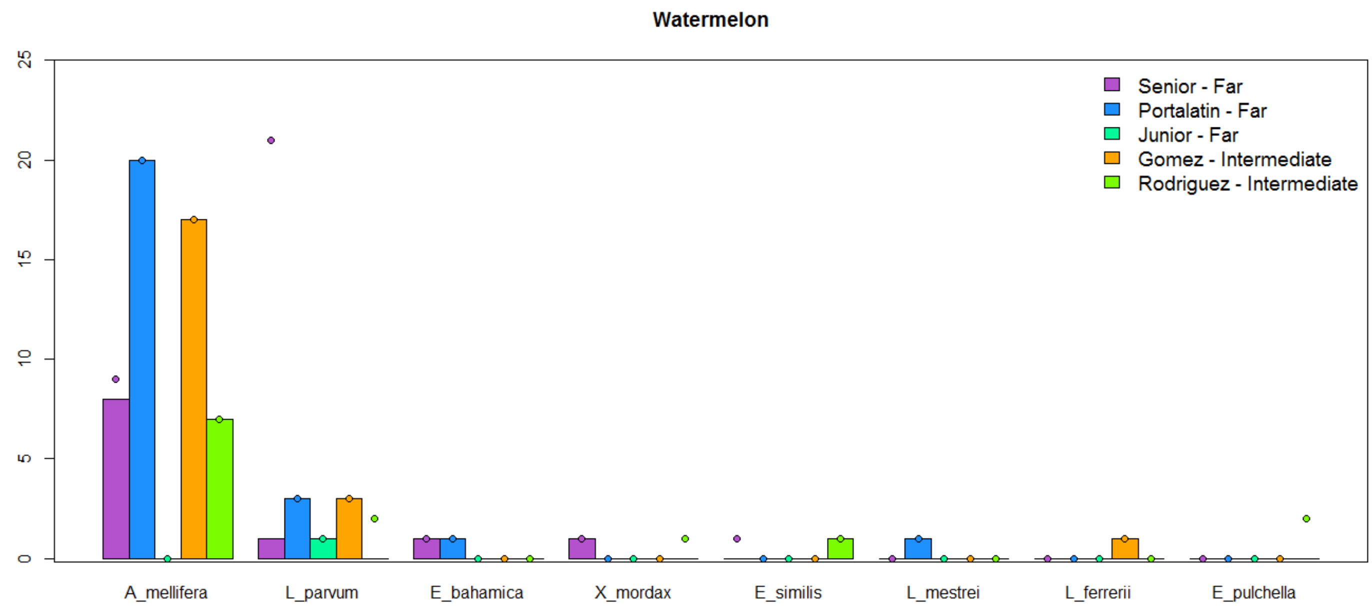
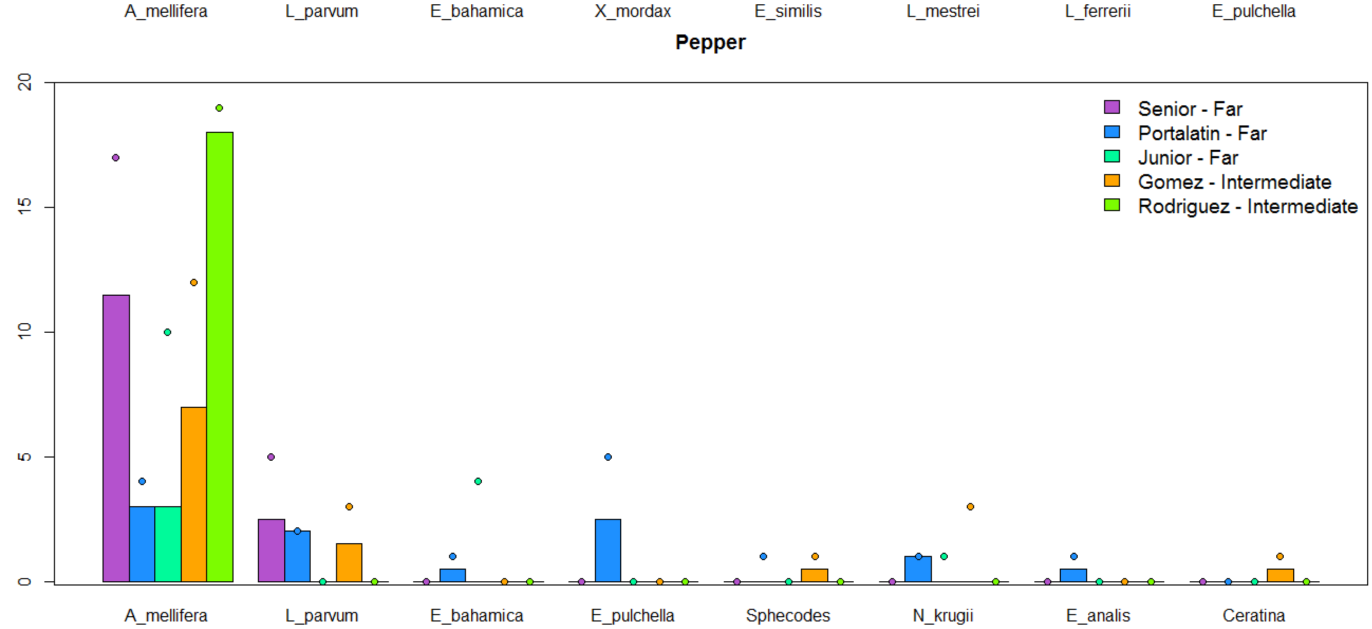


Figure 5. Bee species collected at least once using sweep nets or bee bowls in each surveyed crop (watermelon, pepper, eggplant, pumpkin) and natural vegetation site (NW, SW, SE).


Pumpkin
0
10
20
30
40
Senior - Far
Portalatin - Far
Junior - Far
Cohen - Intermediate
Gomez - Intermediate
Rodriguez - Intermediate
A_mellifera
L_parvum
E_pulchella
E_similis
L_mestrei
E_bahamica
Sphecodes
E_analis
L_ferrerii
M_trifasciata
M_lanata


Watermelon
0
5
10
15
20
25
Senior - Far
Portalatin - Far
Junior - Far
Gomez - Intermediate
Rodriguez - Intermediate
A_mellifera
L_parvum
E_bahamica
X_mordax
E_similis
L_mestrei
L_ferrerii
E_pulchella


Pepper
0
5
10
15
20
Senior - Far
Portalatin - Far
Junior - Far
Gomez - Intermediate
Rodriguez - Intermediate
A_mellifera
L_parvum
E_bahamica
E_pulchella
Sphecodes
N_krugii
E_analis
Ceratina

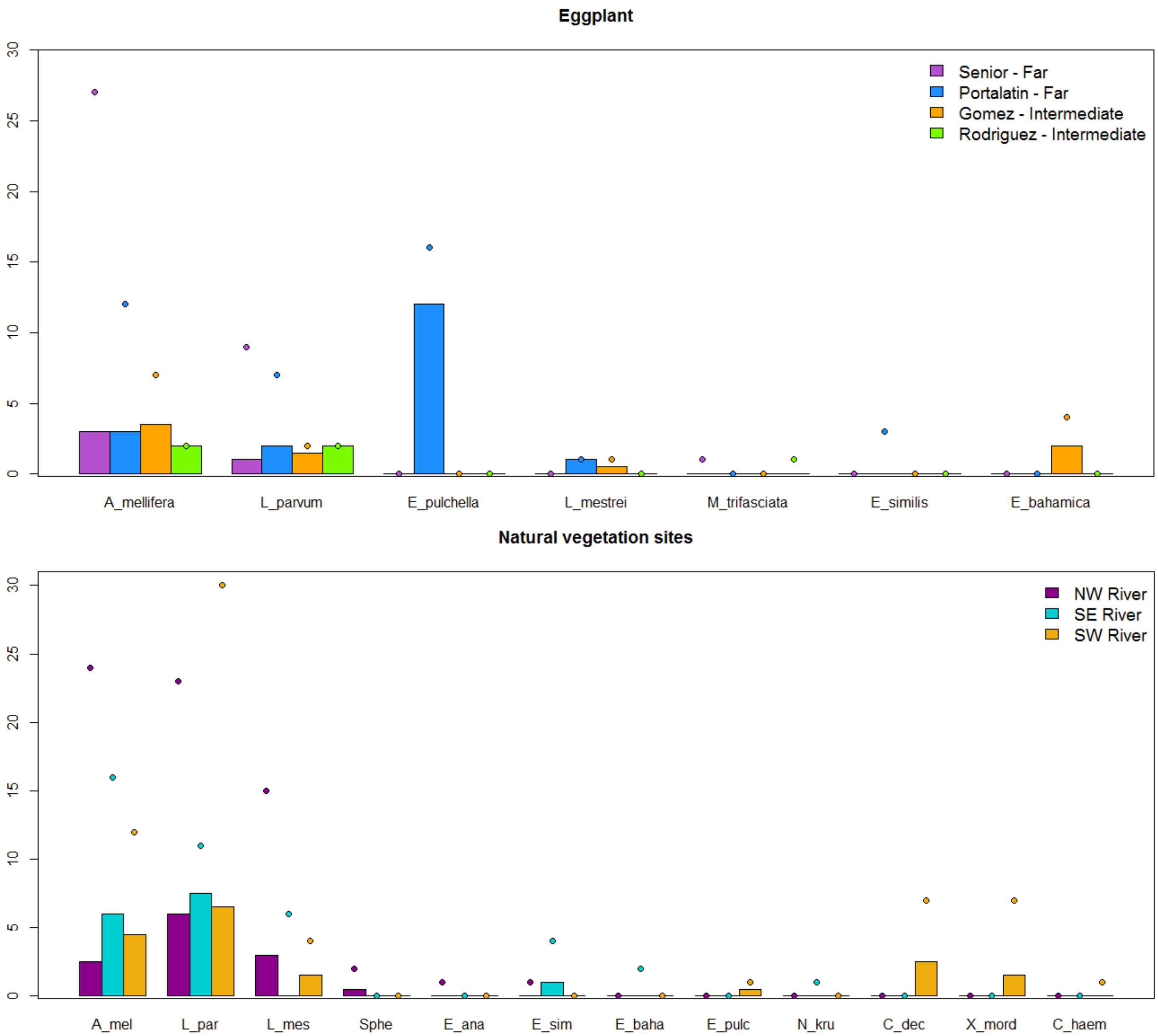


Figure 6. Median (bars) and maximum (points) number of bees collected per crop. Five bee species were collected in all crops in at least one field and one natural vegetation site. Three bee species (*Centris* spp.) were only collected in the SW river site, and one bee species (*Ceratina* spp.) was only collected in Gomez' pepper field.

3.1. Santa Isabel, Puerto Rico

Of the four crops surveyed in this study, pumpkin fields had the greatest wild bee species diversity, with ten wild bee species collected at least once. This is likely due to the reduced tilling and weeding that is done in pumpkin fields, which allows for a greater abundance of wildflowers interspersed within the field. As previously mentioned, the presence of wild bees may benefit pumpkin pollination as they may forage earlier and more efficiently than the managed honeybees. A greater diversity of wild bees were collected in pumpkin fields located at an intermediate distance from natural vegetation (4-8 species) compared to those located far from natural vegetation (5-6 species). Wild bee species abundance was also greater at fields located at an intermediate distance from natural vegetation (5, 10.5, 12) than those located far from natural vegetation (1, 7, 7).

As is the case for pumpkin, watermelon flowers are only open one day and close earlier in the day than other crop plants do. As such, an abundance of effective pollinators is essential for fruit production. Unlike our findings in pumpkin fields, watermelon fields located farm from natural vegetation did not greatly vary in abundance (3, 5, 1) and diversity (4, 3, 1) from those located at an intermediate distance from natural vegetation (4, 1 and 2, 4 respectively).

Unlike pumpkin and watermelon, eggplant flowers need to be buzz-pollinated to produce fruit. Thus, wild bees such as *Centris*, *Exomalopsis, Lasioglossum, Megachile, Melissodes and Xylocopa* are needed. Interestingly the eggplant field with the greatest wild bee species diversity (5 species) and abundance (15 bees) was located far from natural vegetation (Portalatin).

Lastly, though pepper plants do not need to be pollinated for fruit production, pollination can help fruits grow larger and mature faster than un-pollinated ones, and thus pollination can save land owners money. Our findings demonstrate that once again, a pepper field located far from natural vegetation (Portalatin) had the greatest wild bee species diversity (6 species) and abundance (6.5 bees).

Of the three natural vegetation sites we sampled, only one (SW) housed bee species that were not found in agricultural fields. This particular site was adjacent to what appeared to be an abandoned or unused field, and as such may have provided the ideal open habitat for bees. The two other river sites were within 20-30 meters of agricultural fields, and as such pesticides and/or herbicides may have drifted to the survey areas.

3.2. St-Croix, USVI

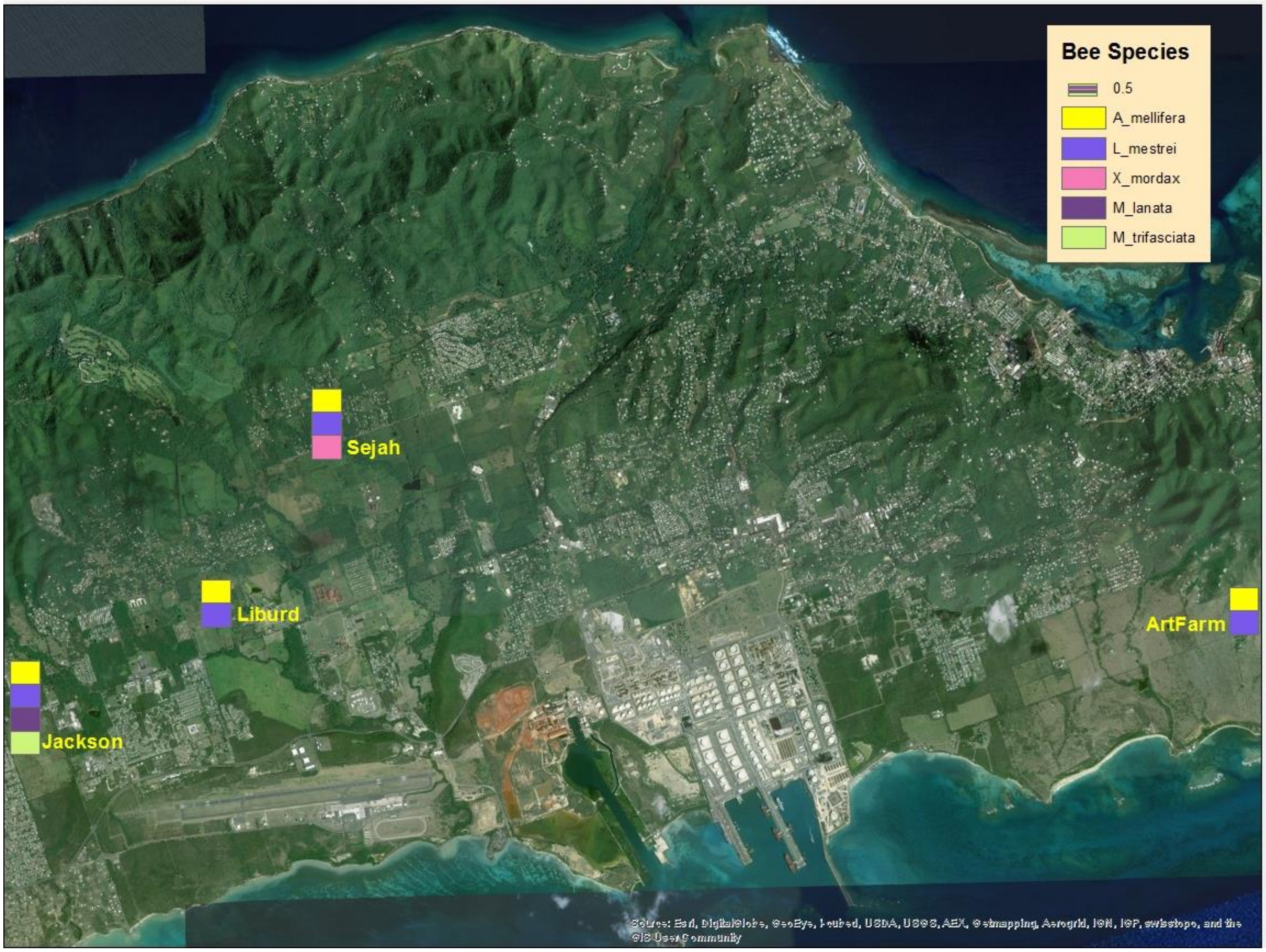


Figure 7. List of bees collected at least once each survey site. Jackson's farm, the only conventional agriculture farm, had the greatest bee species diversity.

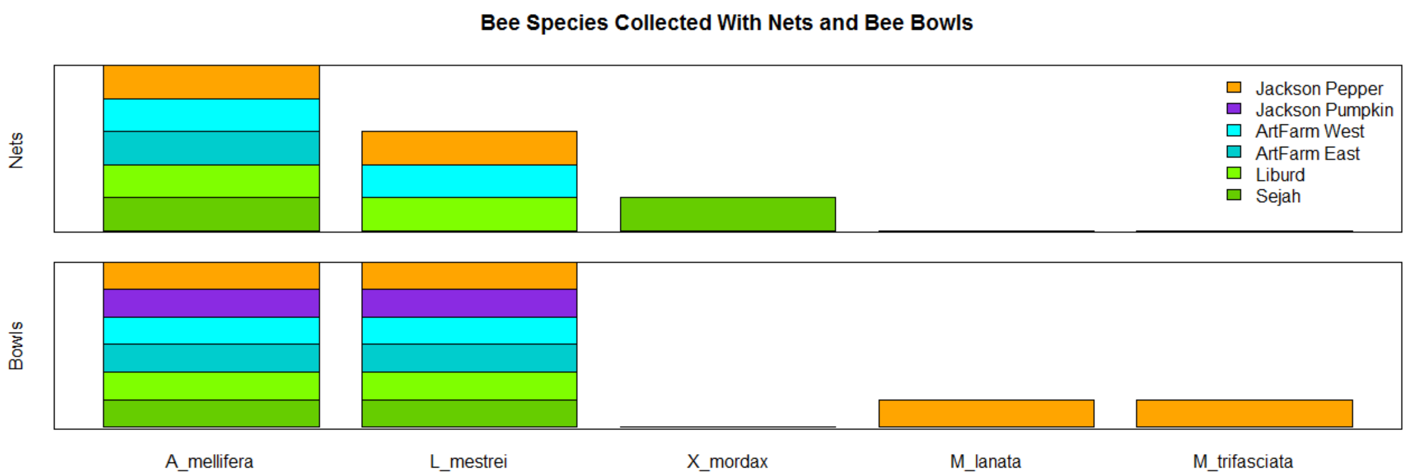


Figure 8. Bee species collected at least once using sweep nets or bee bowls in each agricultural field surveyed in St-Croix, USVI. Two crops were surveyed in Jackson's farm and two sites were surveyed in ArtFarm. Due to their small size, Liburd and Sejah's farms were entirely surveyed.

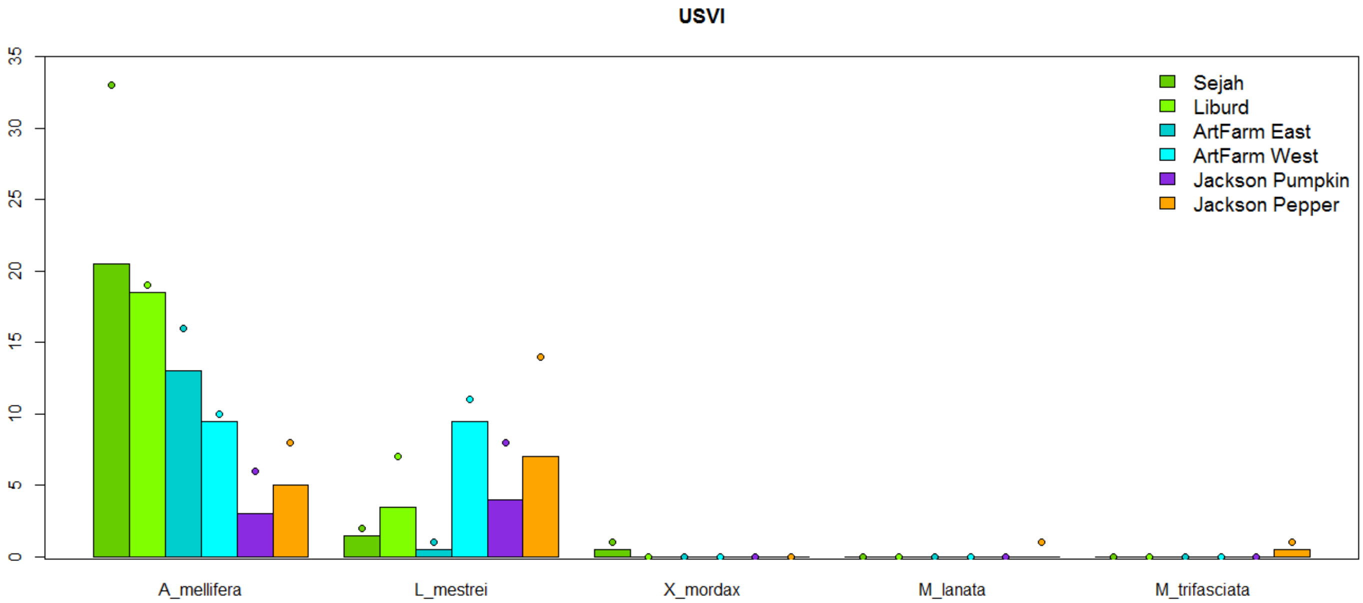


Figure 9. Median (bars) and maximum (points) number of bees collected at each survey site in St-Croix, USVI.

Of the six survey sites, Jackson's pepper fields had the greatest wild bee species diversity, with three of the four wild bee species collected at least once. His pepper fields also had the second highest abundance of wild bees collected. Interestingly, this is the only conventionally managed farm surveyed.

ArtFarm's west site had the highest abundance of wild bees collected, however only one wild bee was collected at this site (*L. mestrei*). ArtFarm has feral honeybee hives on site, and had the highest abundance of honeybees of all four farms surveyed. Though Sejah's farm did not have any honeybees hives on site, his farm had the second highest abundance of honeybees, and the second highest bee diversity of the four farms surveyed, with *L. mestrei* and *X. mordax* collected at least once. However, of the four farms surveyed, Liburd's farm had the lowest abundance of wild bees. We only collected one wild bee (*L. mestrei*) from Liburd's farm.

4. Discussion and overall conservation recommendations

Interestingly, bee species abundance and diversity was not directly dependent on proximity to natural vegetation. This leads us to believe that land management practices (e.g., application of herbicides and pesticides, tilling) have a stronger influence on wild bee populations and distribution at local levels (i.e., farms) than the landscape surrounding agricultural fields. Overall, we collected a maximum of eleven bee species in two farms, one located at an intermediate (Gomez) distance and one at a far distance from (Portalatin) natural vegetation. Though bee species diversity was highest in these fields, some wild bee species (*Centris* spp.) were only found at our river sites, suggesting that agricultural fields may provide unsuitable habitat and forage for these species. The majority of these *Centris* bees were collected on *Macroptilium lathyroides*, which we did not commonly observe in agricultural fields.

Agricultural practices and sizes of fields varied substantially between farms in Puerto Rico and those in St-Croix, U.S.V.I. Three of the four farms surveyed in St-Croix practices intercropping and companion planting, which allows for a great diversity of plants in a small area of land. This is mostly practiced to reduce the need for expensive herbicides and pesticides which most of the small-scale growers could not afford. We originally thought this diversity of crop plants would lead to a greater diversity and abundance of pollinators, however our study results show that this is not the case. In fact, the farm with the greatest diversity and abundance of wild pollinators was the only one that practices conventional agriculture. It's important to note that his conventional practices are different from those of the large scale growers in Puerto Rico. For example, his tilling depth is 12.7-15.24 cm compared to the 60.96-182.88 cm tilling depth of farms in Puerto Rico.

Ten of the sixteen and two of the five species we collected in Puerto Rico and St-Croix, respectively, nest in the soil. As such, we recommend that growers avoid tilling soils where nests may be present. In Puerto Rico, we observed a few nest entrances on the sloping soils on either side of the elevated crop rows, which appeared to be unharmed by agricultural practices due to their closeness to the crop. If these areas must be tilled, we recommend leaving an area of untilled, undisturbed soil, where *Centris, Exomalopsis, Lasioglossum and Melissodes* bees can safely nest year-round. If growers want to promote the presence of ground-nesting bees in their fields, we suggest creating an artificial nesting site for them. This can be achieved by piling soil removed from drainage ditches along selected areas of field margins. These nesting areas should be kept free of weeds as much as possible (The Xerces Society 2011).

To promote and sustain the population of tunnel nesting bees, such as *Megachile lanata* and *Xylocopa mordax* (found in Puerto Rico and St-Croix), we suggest constructing a 'man-made' nesting site. *Megachile lanata* has been observed accepting hollow tunnels of sarkandas (*Arundo* sp. and *Saccharum* sp.) and castor (*Ricinus communis*) (Sihag 1992). The tunnels must be between 6.5-11 mm in diameter and 10-20 cm long (Chaudhary & Jain 1978; Sihag 1992). Similarly, one can construct nesting sites for *X. mordax*. Instructions on how to build a nesting habitat for this bee can be found on p. 27-29 in Farming for Bees by Vaughan et al. (2007).

5. Species Accounts and Species-Specific Recommendations

Ceratina Ecology and Biology

Foraging activities:

Most species will forage on a wide variety of flowers (The Xerces Society 2011).

Nesting biology:

Little is known about Caribbean Ceratina (Genaro 1998). North American *Ceratina* are almost exclusively solitary and make their nests in dead stems, much like leafcutter bees *Megachile* (The Xerces Society 2011).

Conservation recommendations**:**

North American *Ceratina* make their nests in dead stems of elderberry, box elder, sumac and blackberry (The Xerces Society 2011). The materials of which tropical Ceratina make their nests is unknown.

***Ceratina guarnacciana* (New Record PR)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Pepper

Wildflowers Used (observations):

- *Unknown. Only one specimen collected using a bee bowl.*

Centris Ecology and Biology

Foraging activities:

Unlike other genus of bees, many *Centris* species collect plant oils instead of nectar. *Centris* have long tongues and are therefore able to extract nectar, or plant oils in some cases, from deep tubular flowers (The Xerces Society 2011). Adult *C. decolorata* are active year-round.

Nesting biology:

Although *Centris* are considered solitary nesting bees (The Xerces Society 2011). *Centris decolorata* nests in dense aggregations in sandy soils (Raw 1974). *Centris decolorata* nests are between 11-19cm deep and composed of a main tunnel that branches into three shorter ramifications, each one ending in a single cell (Raw 1984). *Centris decolorata* and *Centris haemorrhoidalis* are coastal species, nesting in sands near water sources (Ramos 1946; Raw 1984).

Conservation recommendations**:**

Though *Centris* bees were not collected in agricultural fields, likely due to the lack of adequate nesting sites, we suggest that land owners leave an area of soil untilled, where *Centris* species could establish nests. If nests were present in agricultural fields, tilling could destroy an entire generation of *Centris* bees due to the shallowness of their nests. We suggest creating an artificial nest site for these bees. For example, using soil removed from drainage ditches can be piled to create potential bee ground-nesting habitat. This can work for all ground nesting bees, not just *Centris* species. This area should be kept free of weeds (The Xerces Society 2011).

***Centris decolorata* (Lepeletier)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Not observed on any crop plant.

Wildflowers Used (observations):

- *Macroptilium lathyroides* (Native to Puerto Rico and USVI)
- *Centrosema virginianum* (Native to Puerto Rico and USVI)

Centris haemorrhoidalis **(Fabricius)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Not observed on any crop plant.

Wildflower used (observation):

- *Macroptilium lathyroides* (Native to Puerto Rico and USVI)

Exomalopsis *Ecology and Biology*

<u>Foraging activities</u>:

The average duration of a foraging trip is about 57 minutes (Raw 1976). *E. similis* is highly affected by rainfall, as they are not known to forage or leave their nests the day after a heavy rainfall. However, if rain begins while they are nester foraging, they can take shelter under leaves while waiting for the rain to stop (Raw 1976). In Jamaica, *E. similis* bees start foraging around 8:00-9:00am and return to their nest around 1:00pm (Raw 1976). In turn, *E. pulchella,* forages later in the day, leaving around 2:00pm and staying out until late afternoon. While *E. pulchella* and *E. similis* have similar flight patterns, *E. pulchella* can forage greater distances and spend a longer time foraging thant *E. similis.*

<u>Nesting biology</u>:

Exomalopsis are communal nesters, meaning that two or more bees share the same nest (Michener 2007). Younger generations return to the maternal nest, adding to the size (Norden et al. 1993; The Xerces Society 2011). They nest in dry soil that can vary in consistency from sand to coarse pebbles (Norden et al. 1993). Some species of *Exomalopsis* prefer nesting in sloping soils (Velez-Ruiz & Smith-Pardo 2013). Nest cells of South Western *Exomalopsis solani* appear at depths of 30-50 cm. Cells are arranged in horizontal linear series that radiate from the main vertical shaft (Norden et al. 1993). Nests of *E. pulchella* generally contain more bees than those of *E. similis* (Raw 1976).

During the course of this project, we have observed *Exomalopsis* nesting in the soils bordering the crop
rows.

<u>Conservation recommendations</u>**:**

In order to promote and maintain the presence of *Exomalopsis* bees, avoid tilling soils where nests may be present. We have observed a few nest entrances on the sloping soils on either side of the elevated crop rows, which appeared to be unharmed by agricultural practices due to their closeness to the crop. It appears as though these areas are infrequently tilled, and thus provide suitable nesting sites for these bees. However, as several generations of *Exomalopsis* can reside in a single nest, the destruction of one nest can substantially reduce the amount of *Exomalopsis* present in an agricultural field. As such, if these areas must be tilled, for instance between crop plantings, we recommend leaving an area of untilled, undisturbed soil, where *Exomalopsis* can safely nest year-round.

***Exomalopsis analis* (Spinola)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Watermelon
- Eggplant
- Pepper

Wildflower used (observation):

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Asystasia gangetica* (Introduced to Puerto Rico and USVI)
- *Chamaesyce prostrata* (Native to Puerto Rico and USVI)
- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- *Kallstroemia maxima* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- *Malvastrum coromandelianum* (Introduced to Puerto Rico and USVI)

- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Merremia quinquefolia* (Native to Puerto Rico and USVI)

Exomalopsis bahamica **(Timberlake)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Watermelon
- Eggplant
- Pepper

Wildflower used (observation):

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Asystasia gangetica* (Introduced to Puerto Rico and USVI)
- *Chamaesyce prostrata* (Native to Puerto Rico and USVI)
- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)

- *Kallstroemia maxima* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- *Malvastrum coromandelianum* (Introduced to Puerto Rico and USVI)
- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Merremia quinquefolia* (Native to Puerto Rico and USVI)

***Exomalopsis pulchella* (Cresson)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Watermelon
- Eggplant
- Pepper

Wildflower used (observation):

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Asystasia gangetica* (Introduced to Puerto Rico and USVI)

- *Chamaesyce prostrata* (Native to Puerto Rico and USVI)
- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- *Kallstroemia maxima* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- *Malvastrum coromandelianum* (Introduced to Puerto Rico and USVI)
- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Merremia quinquefolia* (Native to Puerto Rico and USVI)

***Exomalopsis similis* (Cresson)**

Collection Site: Santa Isabel, PR

Crop plants pollinated:

- Watermelon
- Eggplant
- Pepper

Wildflower used (observation):

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Asystasia gangetica* (Introduced to Puerto Rico and USVI)
- *Chamaesyce prostrata* (Native to Puerto Rico and USVI)
- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- *Kallstroemia maxima* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)

- *Malvastrum coromandelianum* (Introduced to Puerto Rico and USVI)
- ❖ *Melochia pyramidata* (Native to Puerto Rico and USVI)
- ❖ *Merremia quinquefolia* (Native to Puerto Rico and USVI)

Lasioglossum Ecology and Biology

Foraging activities:

Oligolectic.

Nesting biology:

Most *Lasioglossum* are ground nesters. They often choose areas with sandy soils. Nests of Puerto Rican *Lasioglossum* are similar in their basic structure and contents. Like the *Exomolopsis* nests, individual cells (~4/nest) radiate from the main vertical shaft via lateral burrows (Eickwort 1988). *L. parvum* nests in loose aggregations in coral sand and pulverized rock, with sparse low vegetation and in full sun (Eickwort 1988). *Lasioglossum gundlachi* and *L. ferrerii* nest in bare sandy soils (Eickwort 1988). Based on three dissected *L. gundlachi n*ests, we know that this species nests in small aggregations of 2-5 bees, with some mated females and sometimes some unmated, 'worker' bees. Based on three dissected *L. ferrerii* nests, we know that females are all mated and reproductive in the nest. It's been suggested that *L. parvum* and *L. gundlachi* are eusocial or semisocial, but can be communal. On the other hand, *L. ferrerii* is reported to be a communal nester only.

Conservation recommendations**:**

In order to promote and maintain the presence of *Lasioglossum* bees, avoid tilling soils where nests are present, or leave an area of soil untilled, thus allowing *Lasioglossum* to establish their nest there. As several broods of *Lasioglossum* can reside in a single nest, the destruction of one nest can substantially reduce the amount of *Lasioglossum* present in an agricultural field.

Lasioglossum parvum **(Cresson)**

Collection site: Santa Isabel, PR

Native to the Caribbean

Crop plants pollinated:

- Not observed on any crop plant

Wildflower used (observation):

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Bidens pilosa* (Introduced to Puerto Rico and USVI)
- *Boerhavia erecta* (Native to Puerto Rico and USVI)
- *Chamaesyce hirta* (Native to Puerto Rico and USVI)
- *Chamaesyce hyssopifolia* (Native to Puerto Rico and USVI)
- *Chamaesyce prostrata* (Native to Puerto Rico and USVI)

- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Pateneium hysterophorus* (Introduced to Puerto Rico and USVI)

***Lasioglossum ferrerii* (Baker)**

Collection site: Santa Isabel, PR

Native to the Caribbean

Crop plants pollinated:

- Not observed on any crop plant

Wildflower used (observation): May be

- *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Bidens pilosa* (Introduced to Puerto Rico and USVI)
- *Boerhavia erecta* (Native to Puerto Rico and USVI)

- ❖ *Chamaesyce hirta* (Native to Puerto Rico and USVI)
- ❖ *Chamaesyce hyssopifolia* (Native to Puerto Rico and USVI)
- ❖ *Chamaesyce prostrata* (Native to Puerto Rico and USVI)
- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- ❖ *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- ❖ *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- ❖ *Melochia pyramidata* (Native to Puerto Rico and USVI)
- ▪ *Pateneium hysterophorus* (Introduced to Puerto Rico and USVI)

Lasioglossum mestrei **(Baker) (*New Record USVI*)**

Collection site: Santa Isabel, PR and St-Croix, U.S.V.I

Native to the Caribbean

Crop plants pollinated:

- ▪ Not observed on any crop plant

Wildflower used (observation): May be

- ❖ *Amaranthus dubius* (Native to Puerto Rico and USVI)
- *Bidens pilosa* (Introduced to Puerto Rico and USVI)
- ❖ *Boerhavia erecta* (Native to Puerto Rico and USVI)
- ❖ *Chamaesyce hirta* (Native to Puerto Rico and USVI)
- ❖ *Chamaesyce hyssopifolia* (Native to Puerto Rico and USVI)
- ❖ *Chamaesyce prostrata* (Native to Puerto Rico and USVI)

- *Cleome gynandra* (Introduced to Puerto Rico and USVI)
- *Cleome viscosa* (Introduced to Puerto Rico and USVI)
- *Euphorbia heterophylla* (Native to Puerto Rico and USVI)
- *Ludwigia octovalvis* (Native to Puerto Rico and USVI)
- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Pateneium hysterophorus* (Introduced to Puerto Rico and USVI)

Megachile Ecology and Biology:

Foraging activities:

During the month of April in India, foraging activity starts between 8:00-10:00am depending on temperature, relative humidity and light penetration to the nest (Chaudhary & Jain 1978). Foraging activity reaches its peak around 10:00am-12:00pm, and stops around 6:00pm (Chaudhary & Jain 1978). In May, foraging started earlier, between 7:00-8:00am. In October, when average daytime temperatures ranged between 24-27°C and relative humidity was around 60%, bees left the nest around 9:00am and returned no later than 5:00-5:30pm (Chaudhary & Jain 1978). In December, the bees could leave the nest as late as 1:00pm to start foraging (Chaudhary & Jain 1978). On average, *M. lanata* prefers to forage when temperature reaches around 29°C, 34% RH and light reaching the nest is at 43.50 lux (Chaudhary & Jain 1978). Light intensity plays a very important role in determining when *M. lanata* will begin and end foraging activities (Chaudhary & Jain 1978). Bees spent between 18-85 minutes collecting a load of pollen.

Nesting biology:

In Jamaica, all nests are built of mud in cracks or in abandoned Sphecid wasp nests, which are often found on surfaces of buildings (Raw 2004).

Conservation recommendations**:**

As *M. lanata* can nest in the soil or in tunnels, we suggest providing them with a 'man-made' nesting site. *Megachile lanata* has been observed accepting hollow tunnels of sarkandas (*Arundo* sp. and *Saccharum* sp.) and castor (*Ricinus communis*) (Sihag 1992). The tunnels must be between 6.5-11 mm in diameter and 10-20 cm long (Chaudhary & Jain 1978; Sihag 1992). It may take time for the bees to accept these tunnels, so expect low tunnel acceptance at first, and it should increase over time (Sihag 1992). Three to four brood cells may be made in each tunnel

(Chaudhary & Jain 1978); providing longer tunnels does not result in more brood cells per tunnel.

Megachile lanata uses mud and leaf cuttings for nest construction (Chaudhary & Jain 1978).

Instructions on how to build a nesting habitat for this bee can be found on p. 28 in Farming for Bees by Vaughan et al. (2007)

Megachile lanata **(Fabricius) (New Record USVI)**

Collection site: Santa Isabel, PR and St-Croix, USVI

Introduced to the Caribbean from the India and Africa (Freitas 2004; Genaro & Franz 2008)

Crop plants pollinated:

- Pumpkin
- Pigeon pea (*Cajanus cajan*) (Abrol 2012)
- Alfalfa (*Medicago sativa*) (Abrol 2012)
- Pea (*Pisum sativum*) (Abrol 2012)
- Guava (*Psidium guajava*) (Abrol 2012)
- Sunhemp (*Crotolaria juncea*) (Abrol 2012)
- Mung beans (*Vigna radiate*) (Chaudhary & Jain 1978)
- Sunflower (*Helianthus annuus*) (Chaudhary & Jain 1978)
- Black gram (*Phaseolus mungo*) (Chaudhary & Jain 1978)

Wildflower used (observation):

- Plants in the pea family.
- *Prosopsis juliflora* (Chaudhary & Jain 1978)
- Jantar (*Sesbania aegyptica*) (Chaudhary & Jain 1978)

Melissodes Ecology and Biology:

<u>Foraging activities</u>:

Unknown

<u>Nesting biology</u>:

All *Melissodes* nest in the ground. Most are solitary, although a few species nest communally, with several individuals sharing a same underground tunnel system. Similarly to *Exomalopsis,* each female maintains its own separate brood cell.

<u>Conservation recommendations</u>**:**

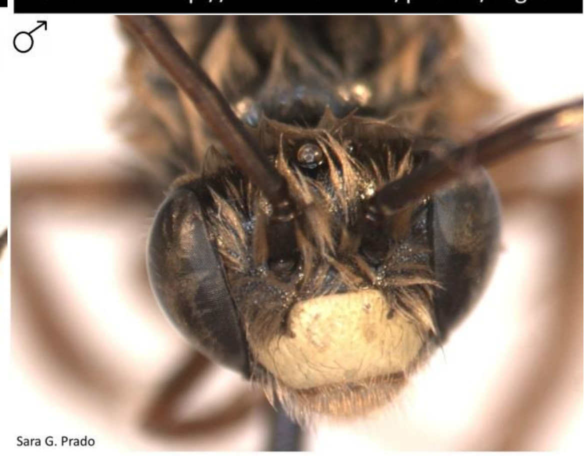
In order to promote and maintain the presence of *Melissodes* bees, leave an area of soil untilled, in order to allow the *Melissodes* to establish their nest there.

***Melissodes trifasciata* (Smith)**

Collection site: Santa Isabel, PR and St-Croix, USVI

Native to the Caribbean (Genaro & Franz 2008)

♂ ♂



Crop plants pollinated:

- Pumpkin
- Pepper

Wildflower used (observation): May be

- *Melochia pyramidata* (Native to Puerto Rico and USVI)
- *Macroptilium lathyroides* (Native to Puerto Rico and USVI)

Nomada Ecology and Biology:

Foraging activities:

Nomada females do not pollinate as they do not collect pollen. They lack pollen carrying structures because their offspring are being cared for by other bees, as they are cleptoparasites. Therefore *Nomada* feed on flower nectar but do not collect pollen (The Xerces Society 2011).

Nesting biology:

Most neotropical *Nomada* are cleptoparasites of *Exomlaopsis* species. More specifically, *Nomada pilipes* parasitizes *Exomalopsis pulchella and E. similis* nests (Alexander 1993). *Nomada krugii* has been documented to parasitize nests of *Agapostemon* (Alexander 1991).

Nomada can mimic the odors of their hosts in order to get into their hosts' nest without 'sounding the alarm' (The Xerces Society 2011).

Conservation recommendations**:**

No recommendations are made. Conserving *Exomalopsis* species indirectly conserves *Nomada* species.

***Nomada krugii* (Cresson)**

Native to the Caribbean (Genaro & Franz 2008)

Collection site: Santa Isabel, PR

Crop plants pollinated:

- Nothing. *Nomada* females do not pollinate as they do not collect pollen. They lack pollen carrying structures because their offspring are being cared for by other bees, as they are cleptoparasites. Therefore *Nomada* feed on flower nectar but do not collect pollen (The Xerces Society 2011).

Wildflower uses (observation)

- Collected while flying.

Sphecodes Ecology and Biology:

Foraging activities:

Sphecodes females do not pollinate as they do not collect pollen. They lack pollen carrying structures because their offspring are being cared for by other bees, as they are cleptoparasites. Therefore *Sphecodes* feed on flower nectar but do not collect pollen (The Xerces Society 2011).

Nesting biology:

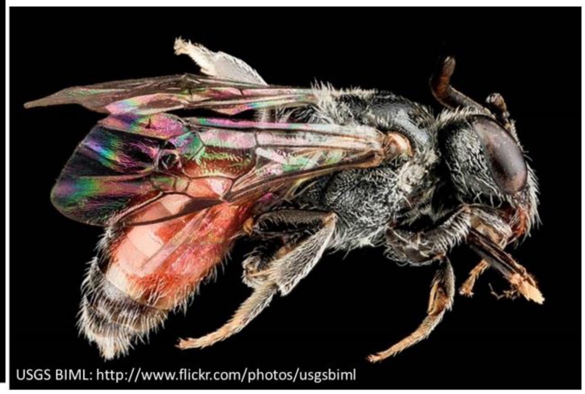
No *Sphecodes* construct their own nests (The Xerces Society 2011). Female *Sphecodes* enter the nests of *Lasioglossum* while the *Lasioglossum* are out foraging (The Xerces Society 2011). Once in the nest of *Lasioglossum*, *Sphecodes* females will destroy the eggs of its host before laying her own egg (The Xerces Society 2011). If the *Sphecodes* is a parasite of the semisocial *L. parvum* or *L. gundlachi,* then she will somehow replace the queen *Lasioglossum* and have the worker bees ten tend to and rear her offspring (The Xerces Society 2011).

Conservation recommendations**:**

No recommendations are made. Conserving *Lasioglossum* species indirectly conserves *Sphecodes* species.

Sphecodes tainoi (New Record PR)

Collection site: Santa Isabel, PR



Crop plants pollinated:

- None. This is not a pollinator

Wildflower uses (observation)

- *Partneium hysterophorus*

Xylocopa Ecology and Biology:

Foraging activities:

Unkown.

Nesting biology:

In Puerto Rico, *Xylocopa mordax* has been reported to nest in dead trunks or branches of:

- Hibiscus plants (*Hibiscus* spp.) (Jackson & Woodbury 1976)
- Tall albizia (*Albizia procera*) (Jackson & Woodbury 1976)
- *Ficus trigonata* (Jackson & Woodbury 1976; Hurd Jr. 1978)
- West Indian Mahogany (*Swietenia mahagoni*) (Jackson & Woodbury 1976)
- Treefern (*Alsophila* & *Cyathea* spp) (Jackson & Woodbury 1976)
- Redwood fencing (*Sequoia semperiverens*) (Jackson & Woodbury 1976)
- Poinsettia (*Euphorbia pulcherrima*) (Jackson & Woodbury 1976)
- Hog plum (*Spondia mombin*)
- Royal Poinciana (*Delonix regia*)
- Teak (*Tectona grandis*)
- Fence posts (*Erythrina* spp)
- West Indian Birch (*Bucera simaruba*)

Conservation recommendations**:**

Providing a nesting habitat for *X. mordax* can help maintain this excellent pollinator on the premises. Instructions on how to build a nesting habitat for this bee can be found on p. 27-29 in Farming for Bees by Vaughan et al. (2007)

***Xylocopa mordax* (Smith)**

Common name: Cigarron, Abejon, Avispon

Collection site: Santa Isabel, PR and St-Croix, USVI **(New Record** in Genaro and Franz, but reported in Hurd Jr. 1978)

Native to the Caribbean (Genaro & Franz 2008)

Crop plants pollinated:

- Pumpkin
- Eggplant
- Watermelon
- Avocado (*Persea Americana*) (Jackson & Woodbury 1976)
- Tamarind (*Tamarindus indica*) (Jackson & Woodbury 1976)
- Pigeon pea (*Cajanus cajan*) (Jackson & Woodbury 1976)
- Jicama (*Calopogonium coeruleum*) (Jackson & Woodbury 1976)
- Fava bean (*Canavalia gladiate*) (Jackson & Woodbury 1976)
- Sword bean (*Canavalia ensiformis*) (Jackson & Woodbury 1976)
- Cowpea (*Vigna luteola , V. vexillata*) (Jackson & Woodbury 1976)
- Barbados cheryy (*Malpighia glabra*) (Jackson & Woodbury 1976)
- Citron (*Citrus medica*) (Jackson & Woodbury 1976)
- Okra (*Abelmoschus esculentus*) (Jackson & Woodbury 1976)
- Water lemon, Jamaican honeysuckle (Pasiflora laurifolia) (Jackson & Woodbury 1976)
- Granada, pomegranate (*Punica granatum*) (Jackson & Woodbury 1976)
- Guava (*Psidium guajava*) (Jackson & Woodbury 1976)
- Sweet potato (*Ipomoea batatas*) (Jackson & Woodbury 1976)
- Basil (*Ocimum basilicum*) (Jackson & Woodbury 1976)

- Tomato (*Lycopersicon esclentum*) (Jackson & Woodbury 1976)
- Tobacco (*Nicotiana tabacum*) (Jackson & Woodbury 1976)
- Cucumber (C*ucumis sativus*) (Jackson & Woodbury 1976)
- Sunflower (*Helianthus annuus*) (Jackson & Woodbury 1976)
- Sorrel (*Rumex acetosa*) (Jackson & Woodbury 1976)
- Cashew (*Anacardium occidentale*) (Jackson & Woodbury 1976)

Wildflower used (observation) (Appendix of Documents from Jackson and Woodbury 1976):

- *Macroptilium lathyroides* (Native to Puerto Rico and USVI)
- *Centrosema virginianum* (Native to Puerto Rico and USVI)
- *Lantana* spp. (e.g. *Lantana camara*) (Jackson & Woodbury 1976)
- Sunflower (*Helianthus annuus*) (Jackson & Woodbury 1976)

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6. List of native and introduced plants

Number	Name	Status	Bees
1	Amaranthus dubius	Native	E_
			L_parvum
2	Argemone mexicanada	Native	A_mellifera
3	Asystasia gangetica	introduced	E_
4	Bidens pilosa	introduced	A_mellifera
			L_parvum
5	Boerhavia erecta	Native	L_parvum
			A_mellifera
6	Centrosema virginianum	Native	C_decolorata
			X_mordax

7	Chamaesyce hirta	Native	A_mellifera
			L_parvum
8	Chamaesyce hyssopifolia	Native	A_mellifera
			L_parvum
9	Chamaesyce prostrata	Native	A_mellifera
			L_parvum
			E_
10	Cleome gynandra	introduced	E_
			L_parvum
11	Cleome viscosa	introduced	E_
			L_parvum

12	Euphorbia heterophylla	Native	E_
			L_parvum
13	Kallstroemia maxima	Native	E_
			A_mellifera
14	Leucaena leucocephala	introduced	A_mellifera
15	Ludwigia octovalvis	Native	E_
			A_mellifera
			L_parvum
16	Macroptilium lathyroides	Native	A_mellifera
			C_haemorrhoidalis
			X_mordax

			C_decolorata
20	Merremia quinquefolia	Native	E_
21	Partneium hysterophorus	introduced	A_mellifera
			L_parvum
22	Physalis angulata	Native	A_mellifera
23	Tephrosia cinerea	Native	E_
24	Tridax procumbens	introduced	L_parvum
			A_mellifera