

Chapter 6

Bee–Plant Interactions: Competition and Phenology of Flowers Visited by Bees

Rogel Villanueva-Gutiérrez, David W. Roubik, and Luciana Porter-Bolland

Abstract We present results of the flowering phenology of most plant species visited by European and Africanized honey bee (*Apis mellifera ligustica* and *A. mellifera scutellata*, respectively) in the Yucatán Peninsula. Colonies from both bee types visited the largest number of plant species at the end of the wet season (September and October) and the beginning of the dry season (November). A calendar is presented to indicate the community phenology of the floral resources of *Apis mellifera*. Comparisons were made in order to assess potential competition between both honey bee groups and between honey bees and native bees in relation to their food resources. Trees were also a constant pollen resource for *Apis mellifera* and *Melipona beecheii*, a native stingless bee. Solitary bees and *M. beecheii* bee seemed to change their floral resource use, both show ‘**resource partitioning**’ to avoid competition. For example, two important plant families, Anacardiaceae and Euphorbiaceae, were lost to competing honey bees, but compensated for by greater use of Fabaceae, Rubiaceae, and Sapotaceae among solitary bees. Invasive generalist pollinators may, however, cause specialized competitors to fail, especially in less biodiverse environments. Deforestation, hurricanes, and fires are three factors that affect the habitat and food resources for bee colonies. Within agricultural areas, having large areas of natural vegetation, corridors, or strips of vegetation between the crop fields is important to favor adequate diversity of natural pollinators for pollination of crop plants.

R. Villanueva-Gutiérrez (✉)

Conservación de la Biodiversidad, El Colegio de la Frontera Sur, Apdo. Postal 424, Av. Centenario km 5.5, CP 77014 Chetumal, Quintana Roo, Mexico
e-mail: rvillanu@ecosur.mx

D.W. Roubik

Smithsonian Tropical Research Institute, Balboa, Republic of Panama

Smithsonian Tropical Research Institute, Unit 9100, DPO, AA 34002, USA
e-mail: roubikd@si.edu

L. Porter-Bolland

Instituto de Ecología, A.C., Red de Ecología Funcional, Carretera Antigua a Coatepec 351, CP 91070 Xalapa, Veracruz, Mexico
e-mail: luciana.porter@inecol.mx

Keywords Solitary bees • *Melipona beecheii* • *Apis mellifera* • Flowering phenology • Melissopalynology • Competition • Nectar sources • Pollen sources • Foraging behavior

6.1 Introduction

Plants offer bees the resources they utilize to grow and reproduce, and plants benefit in turn from bee pollination, which enhances or facilitates sexual reproduction and genetic recombination. The interactions between any given plant and one or more of its pollinators may be intricate, but most obey certain general rules or performance standards. Obviously, in the Yucatán Peninsula there is no evolutionary history between the honey bee *Apis mellifera* and any native plant. However, many of their interrelationships allow one to investigate the behavioral and ecological adjustments of bees to the appearance and abundance of their resources. Here we explore some of those interactions in depth by including the most significant pollinating organism on earth, which has now become a separate biological entity in all of tropical America: the Africanized variety of *Apis mellifera*, here termed AHB.

From an economic point of view, pollination represents an important ecological service for wild and cultivated plants (Klein et al. 2007). Up to 90 % of terrestrial vascular plants potentially benefit from animal pollination (Ashworth et al. 2009; Ollerton et al. 2011). Insects in general, but particularly bees, represent one of the most important groups for pollination. An estimated 30 % of all crop species and as much as 75 % of major crop species, need or benefit from bee pollination (Roubik 1995; Meléndez-Ramírez et al. 2002; Klein et al. 2007). Managed bees are also important since not only can they be directed for enhancing pollination in agricultural systems, but also because of the economic importance of bee products.

To understand the interactions between plants and bees, information on flowering phenologies is of great importance. Phenology refers to the timing of recurring biological events in the animal and plant world, and its study pertains to causes of their timing with regard to biotic and abiotic factors. In relation to plants, phenology is the study of the periodicity mainly of leafing, flowering and fruiting of individual species, while at the community level, flowering phenology trends are also often considered (Lieth 1974; Roubik et al. 2005; Kuswaha et al. 2013).

From the bee's perspective, the phenology of plants determines resource availability in time and space. From the human perspective, knowing such information is important not only for bee management but for understanding how bee communities face current challenges brought about by environmental change. Changes that have been identified as threats to bee diversity and pollination services relate to effects of habitat destruction, climate change, biological invasions, biocides or chemical agents used to control other organisms (Burkle and Alarcón 2011; Roubik 2014), and the impact these products have on bee management (Villanueva-Gutiérrez et al. 2014). More information is urgently needed in order to establish the

relationship between the availability of resources to bees and their interactions with the aforementioned environmental factors.

The Yucatán Peninsula presents an interesting setting for studying flowering phenology of plants visited by bees, including the effects of challenges for pollinators. Bee management in the area has been an economic activity of historical importance, although exotic honey bees were used frequently only after the 1950s (Labougle-Rentería and Zozaya-Rubio 1986; Calkins 1975). This may be seen as the result of a combination of a rich flora available for bees and the Mayan tradition of beekeeping (Rico-Gray et al. 1991). Although until recently beekeeping was conducted with native bees, today the use of the Old World and now primarily African descendants of that primarily African *Apis* (Africanized honeybee hybrid) species, frequently mislabeled as “the European honey bee”, is managed throughout the Yucatán Peninsula.

The African honey bee *Apis mellifera scutellata* was introduced in Brazil in 1956 for honey production improvement. It quickly gave rise to the AHB, which is still much like its African progenitors in behavior and ecology. The replacement of European *Apis mellifera ligustica* with an African subspecies, their hybridization, and the current predominance of Africanized bees in most Neotropical habitats has been extensively reviewed in many journals and books, and will not be further reviewed here.

The arrival of Africanized honey bees in the Yucatán Peninsula was reported in September 1987 (Barrios-Delgado et al. 1990). The Africanization process took around 5 years in the area. This represents a longer period, by 2 years, than was reported in other places, probably because of the large number of European honey bee colonies that were present in the region. When there are very few Africanized honey bees compared to numbers of the European honeybees in an area, as occurred on the island of Puerto Rico (Galindo-Cardona et al. 2013), the Africanization process results in fewer behavioral or ecological changes among wild or naturalized honey bees. A key factor in the Neotropics is that there were almost no feral or naturalized honey bees in tropical America, before AHB arrival (Roubik 1989).

Here we present information on flowering phenology of plants visited by bees. The information is drawn from several studies conducted in the Yucatán Peninsula regarding flower visits by European and Africanized honey bees. One objective of these studies was to assess the impact of Africanization, both on European honey bees and native bees. The studies took place when the Africanized bees were just arriving to the Yucatán Peninsula (1988–1991). Comparisons were made in order to assess competition between both honey bee groups in relation to their food resources (Villanueva-Gutiérrez 1994, 1999, 2002; Villanueva-Gutiérrez and Roubik 2004).

6.2 Flowering Phenology Studies

A handful of studies have been conducted in the southeast of Mexico in relation to bee resources and flowering phenology. Villanueva-Gutiérrez (1984) related the flowering phenology of a low tropical deciduous forest in Veracruz with the flowering periods in which European honey bees visited the flora. Gentry (1995) focused on how different dry forest plant communities differ from each other. He found that differences in the severity of the dry season as well as rainfall patterns cause differing leafing patterns. Borchert et al. (2004) also found a relation between flowering periodicity and soil humidity, comparing flowering times of similar species in different areas. Porter-Bolland (2003) determined the important melliferous and polliniferous species in relation to their flowering phenology and beekeeping management in La Montaña, north of the Calakmul Biosphere Reserve in the state of Campeche, Mexico. Parra-Tabla and Vargas (2004) found that, as in other food deceit orchids (Roubik 2014), natural selection in *Myrmecophila christinae* favors individuals that flower early or late in relation to the population's flowering peak. However, results also suggest that a fluctuating regime of selective events act on flowering time of this species. Salinas-Peba and Parra-Tabla (2007) described the reproductive phenology, breeding system and pollination of *Manilkara zapota* in two contrasting environments: medium-height, subdeciduous forest, and homegardens or “solares” in a Mayan community in the state of Yucatán. Significant differences were found between environments both in the temporal distribution of flower and mature fruit production, as well as in the proportion of mature fruits.

The data were obtained by registering the pollen species identified in pollen load samples of honey bees. We also made a calendar to indicate the community phenology of the floral resources during our two-year study. It is part of a long-term study on bees to determine the most important honey and pollen sources for European and Africanized honey bees in the Sian Ka'an Biosphere Reserve (Villanueva-Gutiérrez 1994, 1999, 2002; Roubik and Villanueva-Gutiérrez 2009; Villanueva-Gutiérrez and Roubik 2004). Here we also discuss the competition that took place between the two *A. mellifera* subspecies, as well as between Africanized honeybees and native bees.

6.3 A Case Study

6.3.1 Study Area

Field work began in June 1989 and was completed in May 1991. Two sites were chosen to conduct fieldwork in the area of the Sian Ka'an Biosphere Reserve (SKBR). The first one, Palmas (site 1), is located bordering the reserve (33 km

south of Felipe Carrillo Puerto) while the second one, Santa Teresa (site 2), is located within the reserve (13 km northeast of Felipe Carrillo Puerto).

Vegetation was medium stature tropical forest (*selva mediana subperennifolia*), low stature forest (*selva baja subcaducifolia*) and low inundated tropical forest (*selva baja inundable*) (according to the classification of Miranda and Hernández-X 1963), and included patches of secondary vegetation. The area surrounding Palmas were more disturbed than those in the immediate vicinity of St. Teresa. This was because the first site was near a road and there was more agricultural activity. According to the classification of Koeppen (1936), the type of climate that exists in the study area is Aw, which is defined as hot subhumid, with a mean annual temperature over 22 °C and annual precipitation between 700 and 1500 mm.

The area foraged often by honey bees has a mean range of 1.7 km, with most foraging occurring within 6 km of the nest or hive (Levin and Glowska-Konopacka 1963; Winston 1987). In some cases, European and Africanized honey bees have been observed foraging at a range of 10 km from their colonies (Visscher and Seeley 1982; Vergara 1983; Roubik 1989). The mean range of 8 km that usually applies to Africanized honey bees implies that each colony could have access to at least 20,000 ha, or 200 km².

6.3.2 Pollen Analysis

At both study sites, Palmas and St. Teresa, 15 hives containing colonies headed by mated European honey bee queens, and 15 hives containing Africanized colonies derived from Africanized wild colonies [identified morphometrically by the method of Daly and Balling (1978)] were selected. The Africanized colonies were collected from the study areas. Modified Ontario Agricultural College (O.A.C.) pollen traps (Smith and Adie 1963; Waller 1980) were placed at the base of the hives to sample the pollen loads that the honey bees carry on their hind legs. Pollen load samples were obtained from these hives for determination and quantification of food sources for these two bee types.

Pollen loads were collected for 48 h each month during a period of 2 years. A total of 204 pollen load samples were obtained in both sites (102 from European honey bees and 102 from Africanized honey bees). The pollen grains from each sample were homogenized using a Sonicator cell disrupter (O'Rourke and Buchmann 1991), then acetolyzed using the Erdtman technique (1943) and mounted on slides with glycerin jelly. During the 2 years, we registered the flowering period of the flora and collected plant specimens. A pollen atlas (Palacios Chávez et al. 1991) was consulted for the identification of pollen grains from the honey and pollen load samples. In order to have a complete calendar of the identified pollen resources used by honeybees, we also used data obtained from honey samples (Villanueva-Gutiérrez 1994). In this way, sample composition could be analyzed in terms of species richness, pollen percentage frequency and mean percentage frequency per total number of samples.

6.3.3 *Species Visited by Honey Bees and Their Timing*

A total of 168 different pollen species were identified, belonging to 41 different plant families. Those that contributed the largest number of pollen species were Fabaceae, Asteraceae, Boraginaceae, Convolvulaceae, Euphorbiaceae, Sapindaceae, Poaceae, Myrtaceae, Sapotaceae and Tiliaceae. Fabaceae and Asteraceae families are very important in the bee diet; both families were represented in the pollen load samples, with 12 % and 11 % of the total number of pollen species respectively. The most frequent pollen species in the European bee samples for years 1 and 2 were *Cecropia peltata*, *Metopium brownei*, *Lonchocarpus* sp. 2, *Viguiera dentata*, *Eragrostis* sp. 1, *Panicum* sp. 1, *Bursera simaruba*, *Trema micrantha*, *Eupatorium albicaule*, *Eugenia* sp. 1 and *Pluchea* sp. 1. For the Africanized honey bee samples the most frequent pollen species during both years were *Cecropia peltata*, *Metopium brownei*, *Lonchocarpus* sp. 2, *Eragrostis* sp. 1, *Eupatorium albicaule*, *Viguiera dentata*, *Mimosa bahamensis*, *Rinchospora microcarpa*, *Eugenia* sp. 1, *Panicum* sp. 1, *Eupatorium albicaule* and *Bidens* sp. 1 (see also Villanueva-Gutiérrez 1999).

The pattern in which pollen species were identified in pollen load samples lets us understand their availability through time. We separated the plant species identified according to their habit: (1) trees, (2) shrubs, (3) herbs, (4) woody vines and (5) trees or shrubs. Group (5) refers to taxa (family, genus or species level) that have been described as either trees or bushes. Arranging the data according to the total number of pollen species found monthly in the pollen load samples, two graphs were made showing the annual flowering phenology of the community of plants used by honey bees both by total and according to the species' habit (Figs. 6.1 and 6.2).

A table was made in the form of a calendar, indicating the periods in which the different pollen species were collected by European and Africanized bees (Appendix). Some species provide pollen to the honey bees for short periods of 1 month or less, and others for longer periods. Species that are present in sampled pollen loads for long periods of time include *Buxus bartletti*, *Cordia* sp. 4, *Melanthera aspera*, *Mimosa bahamensis*, *Pluchea* sp. 1, *Psidium sartorianum* (9 months), *Eupatorium* sp. 2, *Pouteria* sp. 1 (10 months), *Bursera simaruba*, *Metopium brownei*, *Parthenium hysterophorus*, *Trema micrantha*, *Thouinia canescens* (11 months), and *Cecropia peltata* and *Eugenia* sp. 1 (12 months).

The distribution of flowering periods according to species habit reveals a small fluctuation in the number of tree species visited by both honey bees (combined data) during the year. The largest number of tree species was visited in September (18) and November (20), and the smallest in January (11). Shrubs had the largest number of species visited in January (10), July (9), September (10) and November (13), and the smallest number in May (1). Herbs' contribution to pollen had a large peaked sharply in October (25 species) and dropped in June (4). Woody vine species were not much visited by the honey bees. The largest number of species was found in November (8), while from January to June and in October, bees visited

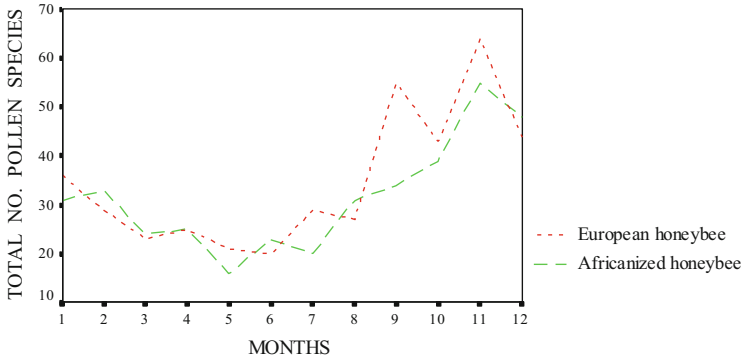


Fig. 6.1 Total number of pollen species found in European and Africanized honeybee pollen load samples (January to December)

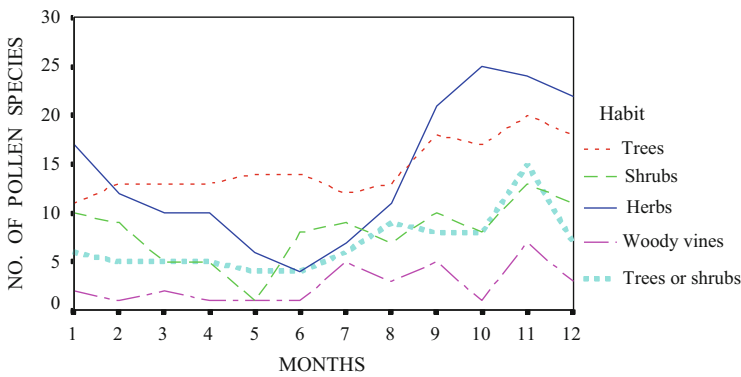


Fig. 6.2 Distribution of the pollen species according to their habit: trees, shrubs, herbs, woody vines and trees or shrubs (January to December)

only one or two species. The fifth group of plants, which includes either trees or shrubs, has the largest number of species visits in November (15) and the smaller ones in May and June (3 in both months).

Colonies of both bee types visited the largest number of plant species at the end of the wet season (September and October) and beginning of the dry season (November). The species visited included herbs, shrubs and trees. Considering only the number of pollen species per colony from both bee types, the largest number of plants visited by honey bees ranged from 10 to 31 species. The smallest number of plant species (per colony) visited by both bee types was in May and June, at the beginning of the wet season, and the species were mainly trees and shrubs. Colonies visited from 3 to 11 species per colony at that time.

Of the 168 total plant species visited by both subspecies of *A. mellifera* in this study, European bees visited 84 % and Africanized bees visited 64 %. Perhaps surprisingly, only 48 % of the plants visited by bees were common to both honey

bee types. Only 10 species (6 %) of those shared by both bee types were used intensively (Villanueva-Gutiérrez 1999; Villanueva-Gutiérrez and Roubik 2004).

6.4 Phenology of Plants Visited for Pollen Collection

The pattern followed by the total number of plant species that were visited by both European and Africanized honey bees was very similar to the one followed by the mean number of species visited per colony. European and Africanized bees visited the largest number of species at the end of the wet season and early dry season (September to January), showing a small drop on the number of species visited during October. The same pattern has been observed during this period by Ceballos-Martínez (1987) in Sian Ka'an Reserve in areas of similar vegetation types.

According to Villanueva-Gutiérrez (1999, 2002) the most frequent pollen species in both European and Africanized bee pollen load samples were *Cecropia peltata*, *Metopium brownei*, *Lonchocarpus* sp. 2, *Viguiera dentata*, *Bursera simaruba*, *Eragrostis* sp. 1, *Eupatorium albicaule*, *Panicum* sp. 1 and *Eugenia* sp. 1. These represent 71 % of all the mean percentage frequencies in the samples. Although using more plant species, the European bees specialize much more heavily on a few plants than do Africanized honey bees (Villanueva-Gutiérrez and Roubik 2004). European bees in the Yucatán Peninsula may have responded to exotic Africanized honey bee competition in two ways, by shifting flower choice and by increasing resource specialization. Interestingly, when competition is most intense, solitary native bees with no food reserves or colonies, seem specialize more on fewer resource species—the same as European honey bees, when faced with competition from feral Africanized honey bees (Roubik and Villanueva-Gutiérrez 2009; Roubik 2009).

As with the honey samples, competition might also occur if one or more of the most frequent pollen species become increasingly scarce, unless honey bees can switch to other abundant pollen sources (Villanueva-Gutiérrez and Roubik 2004; Roubik 2009). Competition often increases during part of a long drought period or when there is very high precipitation.

6.5 Nectar Competition Between European and Africanized Honey Bees

The major period of honey production at the sites in this study began in January and ended in May. According to our results, the most important nectar sources for bees during January and February are herbs, while trees comprise their main nectar source from March to May—the driest months of the dry season. Pollen of *Gynopodium floribundum*, *Viguiera dentata*, *Metopium brownei*, *Bursera*

simaruba, *Lonchocarpus* spp. *Piscidia piscipula*, and *Samyda yucatanensis* were the most common in honey samples (Villanueva-Gutiérrez 1994).

In flowering phenology studies of plants visited by honey bees at La Montaña area in Hopelchen, Campeche (Porter-Bolland 2003; Porter-Bolland et al. 2009), honey production began a little later, in mid February, and also ended in May (at the beginning of the rainy season). The difference may be that the forested area of La Montaña honey bees mostly rely on arboreal resources, rather than herbs.

Porter-Bolland (2010) identified plant species visited by honey bee according to beekeeper observations. She identified 146 species, belonging to 101 genera and representing 35 families. The latter is slightly less than the 168 species (from 41 different families) identified in the study presented in this chapter using a more precise method (the identification of plant sources through pollen loads on bees). The most important families identified by Porter-Bolland also included Fabaceae, Euphorbiaceae, Sapindaceae, and Sapotaceae (mostly trees), and Asteraceae and Convolvulaceae (mostly herbs and vines), as in this study.

The number of tree species visited by honey bees was constant during the year except for two small peaks in September and November. Trees represent a constant resource of nectar and pollen, even during periods in which there is not much nectar flow or pollen collection (Fig. 6.1 and Appendix). Trees were also found to be a constant pollen resource for *Apis mellifera* in a study in low deciduous forest in Veracruz, Mexico (Villanueva-Gutiérrez 1984). Porter-Bolland (2003) also found trees to be of great importance as bee resources in the study conducted in La Montaña area cited above, in an area covered by medium- and low-stature tropical forest located not far from Sian Ka'an, but inland of the peninsula in the state of Campeche.

Trees represent the most important pollen and nectar sources during the latter half of the dry period of the year (March to May); herbs are the most important nectar and pollen sources during the end of the wet period (October) and the first half of the dry period (November to February). The total number of plant species visited by the honey bees represented around 20 % of all the Angiospermae present at the Sian Ka'an area study sites (Villanueva-Gutiérrez 1994, 1999, 2002).

Between eight and ten species of shrubs were visited during the year, except at the end of the dry season (May) when sharp decline occurred. The group of species categorized as either trees or shrubs in habit presents a pattern similar to that of trees. Woody vines were not much visited by bees, except during July, September and November, when bees visited most of the Bignoniaceae and Sapindaceae species.

For this study, the invasive Africanized honey bee was compared side by side with re-introduced European *Apis mellifera ligustica* in post-invasion experiments, including adequate bee colony density and replication, and to make comparisons to pre-invasion foraging ecology. We compared which of the plant species were visited by European and Africanized honey bees (the species they shared), and which ones were visited only by either of them. The volumes of pollen introduced to the colonies were also considered and compared to give a better measure of the real diet being used by both honey bee subspecies.

Almost half of all flowering species in the study areas were visited by both Africanized and European honey bee types. That is, only 44 % of the plants visited by honey bees were shared by both groups, indicating a differential utilization of available resources.

Pollen from flowering species that do not produce any nectar were found in the honey samples. This is the case with *Cecropia peltata* (one of the most abundant species in the European and Africanized honey samples during the wet and the dry seasons). Also, 11 Poaceae, 6 Cyperaceae, 2 *Mimosa*, 2 *Malpighia* and 1 Piperaceae were found (Villanueva-Gutiérrez 1994). The pollen of these nectarless plants was probably collected by the foraging bees and introduced to the hives where some of it became trapped in the honey. Many of the activities undertaken by honey bees within the colony (dancing, food transmission, food handling, cleaning and grooming) probably contribute to the dispersal “contamination” of honey by pollen.

6.6 Bee Competition for Pollen and Nectar Sources

6.6.1 Pollen Volumes Collected by European and Africanized Honey Bees

We also calculated the volume of pollen collected by European and Africanized honey bees (Villanueva-Gutiérrez and Roubik 2004), so we could provide detailed quantitative comparisons of the volume and kind of pollen used by the two honeybee subspecies, and also corroborate our findings with the flower species used by apiary European honey bees at the same sites, 2 years before the African honeybee invasion began. Although major resource species were similar, the richest diet was that of the European bees, while *quantitatively*, African bees were more generalized and European bees more specialized. Morisita-Horn similarities were 0.76 for pollen use by volume sp^{-1} , and 0.55 for taxon-specific intensity of use. European bees were evidently displaced from their previous floral resources, to the extent that their principal diet item was novel based on pre-invasion records, as was a maximum monthly diet breadth recorded for both bees. We suggest resident European bees that compete with invasive honeybees may increase both diet breadth and quantitative specialization.

Frequency differences may also be influenced by factors such as the amount of pollen and nectar produced by each species, the availability of pollen and nectar from each plant species on days when pollen loads and honey were sampled, and the distance of those resources from the hives. These factors, together with the color, odor, and morphology of flowers, determine the preference of honeybees for particular nectar and pollen sources. It can be observed that there is a high reliance on only a few species: the first five, for example, comprise almost 50 % of all the mean percentage frequencies (Villanueva-Gutiérrez 1994, 1999; Villanueva-Gutiérrez and Roubik 2004). These polliniferous species represent an important

resource for beekeeping, considering that the Yucatán Peninsula is one of the most important honey production regions of the world, with over 10 hives per square kilometer), due to the large number of colonies managed mostly by the Mayan people (Paxton et al. 1991; Echazarreta et al. 1997).

6.6.2 *Ecological Studies on Solitary Bees in the Yucatán Peninsula*

A population dynamics study was conducted with solitary bees, Megachilidae and *Centris*, in the Sian Ka'an Biosphere Reserve from 1988 to 2005. Wooden traps were used to collect these bees and the pollen they store within their nest for feeding their brood (Roubik and Villanueva-Gutiérrez 2009). We found that drought and heavy rain or hurricane damage had severe effects on bee populations. Honeybee competition, and ostensibly pollination of native plants, caused changes in local pollination ecology. Natural disasters made a large negative impact on native bee populations, but sustained presence of Africanized honey bees were not affected.

Shifts in floral hosts by native bees were common. Two important plant families, Anacardiaceae and Euphorbiaceae, were lost to competing honeybees, but compensated for by greater use of Fabaceae, Rubiaceae, and Sapotaceae among native bees (Roubik and Villanueva-Gutiérrez 2009). Invasive generalist pollinators may, however, cause specialized competitors to fail, especially in less biodiverse environments.

6.6.3 *Conservation and Food Resources of the Stingless Bee *Melipona beecheii**

Melipona bees visit the flora of mature vegetation or low disturbed vegetation. The plants that have been reported as important nectar or pollen sources for this bee, (some based on beekeeper reports, are *Gymnopodium floribundum* ('dzidzilche'), *Piscidia piscipula* ('jabín'), *Lysiloma latisiliquum* ('tzalám'), *Eugenia buxifolia* ('pichi che'), *Eugenia axilaris* ('ich juju'), *Guazuma ulmifolia* ('pixoy'), *Swartzia cubensis* ('k'ataloox'), *Lonchocarpus longystilus* ('balché'), *Coccoloba cozumelensis* ('boob'), *Vitex gaumeri* ('ya axnik'), *Solanum lanceifolium* ('silclimuch'), *Senna* sp and *Solanum* sp. (Villanueva-Gutiérrez et al. 2005a; Parra-Romero 2015). This bee also seems to switch their food sources after the arrival of Africanized honey bee in order to avoid competition (Villanueva-Gutiérrez 1994; Villanueva-Gutiérrez and Colli Ucán 2005; Parra-Romero 2015). In the Yucatán Peninsula there is a low number of *Melipona* bee populations in the wild (Cairns et al. 2005) but a number of colonies are kept in hives of some type. Deforestation, hurricanes, and fires are three factors that affect food resources for

bee colonies. Many *Melipona* beekeepers report that they think their bees are dying from lack of food. They have witnessed, over time, that colonies produce less honey and that the population is diminishing in size to the point where the *Melipona* cannot defend against their natural enemies (Villanueva-Gutiérrez et al. 2005b).

6.7 Strategies for the Conservation of the Forest and Pollinators in the Yucatán Peninsula

Because of certain competitive advantages shown by Africanized honey bees, bee management programs should be prioritized. Bee management should be encouraged with a strong component of genetic improvement to lower Africanization rates and control feral populations. Bee management with native bees should also be promoted since the activity has been decreasing in most of the Yucatán Peninsula.

On the other hand, forest protection is important for the conservation of bee floral resources, as well as the regulation of agricultural activities. For this, legislation to protect forested areas from complete destruction, especially near villages and cultivated areas should be made more effective, including the encouragement of different conservation strategies, such as both Natural Protected Areas and community conservation initiatives. Other strategies can be the development of projects at the local level for reforestation and restoration. Within agricultural areas, having large natural vegetation areas, corridors, or strips of vegetation between the crop fields favor adequate diversity of natural pollinators for the pollination of crop plants. It is also important to allow the growth of herbs, shrubs, and trees that will be important sources of food for stingless bees. At the same time, planting native trees around meliponaries will provide important sources of food for stingless bees when they are located in backyards of the homes of local residents.

Mechanized agriculture is becoming a common practice in the contemporary Yucatán Peninsula, so the control of herbicides and pesticides is important. It has been demonstrated that honey bees do visit the flowers of genetically modified (GM) soybean, and there is a high risk of contamination not only of the honeys produced in the Yucatán Peninsula, but also the honeys produced throughout Mexico (Villanueva-Gutiérrez et al. 2014). The aforementioned strategies are vital for the conservation of pollinators of many native plants and crops. Native stingless bee colonies as well as many other foragers are vital to sustain plant communities.

6.8 Acknowledgements

We want to thank to Wilberto Colli-Ucán, Victor Ceballos-Martínez, and Margarito Tuz-Novelo for help in the fieldwork and Rodrigo Villanueva-Ceballos for his help in making the graphs.

Appendix

Calendar of Plants Visited for Honey and Pollen Collection by Honey Bees (Sampling Period of 2 Years)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Acanthaceae												
<i>Bravaisia tubiflora</i>											+	
<i>Justicia campechiana</i>	+		+			+	+	+	+	+	+	+
Amaranthaceae												
<i>Amaranthus</i> sp. 1	+											
<i>Iresine celosia</i>					+							
Anacardiaceae												
<i>Metopium brownei</i>	+	+	+	+	+	+	+		+	+	+	+
<i>Spondias</i> sp. 1						+	+					
Annonaceae												
<i>Annona</i> sp. 1										+		
Apocynaceae												
<i>Mandevilla</i> sp. 1					+							
Araliaceae												
<i>Dendropanax arboreus</i>									+	+	+	
Arecaceae												
<i>Chamaedorea</i> sp. 1								+	+		+	
<i>Cocos nucifera</i>	+	+							+	+	+	+
<i>Thrinax radiata</i>				+								
Arecaceae 1		+	+					+	+			
Arecaceae 2		+						+				
Asteraceae												
<i>Baccharis heterophylla</i>	+											

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Bidens squarrosa</i>	+	+					+					
<i>Bidens</i> sp. 1	+							+	+	+	+	+
<i>Eupatorium albicaule</i>	+	+	+						+	+	+	+
<i>Eupatorium campechense</i>	+											
<i>Eupatorium</i> sp. 1								+	+	+	+	
<i>Eupatorium</i> sp. 2	+	+	+	+		+	+	+	+	+	+	
<i>Melanthera aspera</i>		+		+	+	+		+	+	+	+	+
<i>Melanthera nivea</i>								+	+		+	
<i>Mikania</i> sp. 1			+									
<i>Parthenium hysterophorus</i>	+	+	+	+	+	+	+		+	+	+	+
<i>Pluchea</i> sp. 1	+		+	+			+	+	+	+	+	+
<i>Vernonia cinerea</i>	+	+										
<i>Viguiera dentata</i>	+	+	+	+							+	
Asteraceae 1	+											
Asteraceae 3				+								
Asteraceae 4			+									
Asteraceae 5										+		
Bignoniaceae												
<i>Amphilophium paniculatum</i>		+					+		+	+	+	
<i>Arrabidaea floribunda</i>									+		+	
<i>Cydista</i> sp. 1								+			+	
<i>Cydista</i> sp. 2								+	+			
Bignoniaceae 1										+	+	
Bombacaceae												
<i>Ceiba aesculifolia</i>									+	+	+	
<i>Ceiba pentandra</i>					+							
<i>Pseudobombax ellipticum</i>	+		+	+	+		+			+	+	+
Boraginaceae												
<i>Cordia alliodora</i>						+						
<i>Cordia curassavica</i>								+	+			
<i>Cordia dodecandra</i>	+											+
<i>Cordia gerascanthus</i>											+	

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Cordia</i> sp. 1							+				+	
<i>Cordia</i> sp. 3					+			+	+			
<i>Cordia</i> sp. 4	+	+	+	+		+		+	+	+	+	
<i>Cordia</i> sp. 5											+	
<i>Heliotropium</i> sp. 1		+		+								
<i>Heliotropium</i> sp. 2											+	
Bursaceae												
<i>Bursera simaruba</i>	+	+	+	+	+	+		+	+	+	+	+
<i>Bursera</i> sp. 1	+		+	+	+	+	+		+		+	
Buxaceae												
<i>Buxus bartlettii</i>	+	+		+		+	+	+		+	+	+
Cecropiaceae												
<i>Cecropia peltata</i>	+	+	+	+	+	+	+	+	+	+	+	+
Combretaceae												
<i>Bucida spinosa</i>					+							
<i>Conocarpus erecta</i>							+					
Convolvulaceae												
<i>Evolvulus alsinoides</i>										+	+	+
<i>Ipomoea</i> sp. 1											+	
<i>Ipomoea</i> sp. 2	+										+	+
<i>Ipomoea</i> sp. 3	+										+	
<i>Ipomoea</i> sp. 4	+											
<i>Jacquemontia nodiflora</i>											+	
<i>Jacquemontia</i> aff. <i>pentantha</i>	+											
<i>Merremia cisoides</i>									+			+
<i>Merremia tuberosa</i>	+	+										
<i>Operculina pinnatifida</i>											+	+
Cucurbitaceae												
<i>Cayaponia</i> sp. 1								+	+	+	+	
<i>Cucurbita maxima</i>									+			
Cyperaceae												
<i>Rhynchospora microcarpa</i>		+					+	+	+	+	+	+
Cyperaceae 1									+	+	+	

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cyperaceae 3										+		
Euphorbiaceae												
<i>Croton campechianus</i>										+		
<i>Croton chichenensis</i>							+				+	+
<i>Croton</i> sp. 1	+	+					+				+	+
<i>Croton</i> sp. 2				+					+			
<i>Euphorbia</i> sp. 1						+	+					
<i>Euphorbia</i> sp. 2							+	+	+		+	+
<i>Euphorbia</i> sp. 3								+				
Euphorbiaceae 1							+					
Fabaceae												
<i>Bauhinia divaricata</i>											+	
<i>Bauhinia herrerae</i>											+	+
<i>Caesalpinia gaumeri</i>		+	+		+							
<i>Caesalpinia</i> sp. 1		+									+	
<i>Caesalpinia</i> sp. 3								+				
<i>Gliricidia sepium</i>						+						
<i>Leucaena leucocephala</i>	+	+	+	+					+	+	+	+
<i>Lonchocarpus rugosus</i>	+							+	+	+	+	
<i>Lonchocarpus</i> sp. 1			+	+								
<i>Lonchocarpus</i> sp. 2		+	+	+	+	+					+	
<i>Lysiloma latisiliquum</i>					+	+						
<i>Mimosa bahamensis</i>	+	+	+	+	+				+	+	+	+
<i>Mimosa pudica</i>	+	+		+					+	+	+	+
<i>Nissolia fruticosa</i>			+	+						+	+	
<i>Piscidia piscipula</i>					+	+						
<i>Pithecellobium albicans</i>							+					
<i>Pithecellobium dulce</i>								+				
<i>Stylosanthes humilis</i>												+

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fabaceae 1						+						
Fabaceae 2											+	
Flacourtiaceae												
<i>Casearia nitida</i>						+						
<i>Laetia thamnia</i>							+					
<i>Samyda yucatanensis</i>	+		+	+	+				+		+	+
Labiatae												
<i>Hyptis pectinata</i>									+			
<i>Hyptis</i> sp. 1												+
<i>Leonotis nepetaefolia</i>												+
<i>Ocimum micranthum</i>					+							
Labiatae 1									+			
Lauraceae												
<i>Nectandra coriacea</i>										+		
Loranthaceae												
<i>Psittacanthus mayanus</i>										+		
Malpighiaceae												
<i>Malpighia emarginata</i>										+	+	
<i>Malpighia glabra</i>										+		
Malvaceae												
<i>Abutilon permolle</i>	+	+							+	+	+	+
<i>Hampea trilobata</i>									+			
<i>Hibiscus</i> sp. 1								+	+	+	+	
<i>Hibiscus</i> sp. 2								+	+	+	+	+
Malvaceae 2									+			+
Moraceae												
<i>Chlorophora tinctoria</i>	+	+	+							+	+	+
Moraceae 1								+	+			
Myrtaceae												
<i>Calypttranthes millspaughii</i>	+											
<i>Eugenia mayana</i>										+	+	
<i>Eugenia</i> sp. 1	+	+	+	+	+	+	+	+	+	+	+	+
<i>Eugenia</i> sp. 2										+	+	
<i>Eugenia</i> sp. 3							+	+			+	

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Myrcianthes fragans</i>		+						+	+		+	+
<i>Psidium sartorianum</i>			+	+	+	+	+		+	+	+	+
Poaceae												
<i>Chloris</i> sp. 1								+	+	+	+	
<i>Eragrostis</i> sp. 1		+	+	+								
<i>Panicum</i> sp. 1	+	+							+	+	+	+
<i>Panicum</i> sp. 2										+	+	
<i>Panicum</i> sp. 3												+
<i>Paspalum</i> sp. 1								+	+	+	+	
<i>Zea mays</i>									+	+		
Polygonaceae												
<i>Coccoloba</i> sp. 1							+	+	+	+	+	
<i>Coccoloba</i> sp. 2							+	+			+	+
<i>Gymnopodium floribundum</i>							+	+	+	+	+	+
Ranunculaceae												
<i>Clematis dioica</i>			+	+	+	+						
Rhamnaceae												
<i>Colubrina arborescens</i>											+	
Rubiaceae												
<i>Asemnanthe pubescens</i>							+	+				
<i>Chiococca alba</i>							+					+
<i>Exostema caribaeum</i>								+				
<i>Guettarda combsii</i>				+								
Rutaceae												
<i>Esenbeckia berlandieri</i>								+				+
Sapindaceae												
<i>Exothea diphylla</i>												+
<i>Paullinia</i> sp. 1	+		+		+		+	+	+		+	+
<i>Serjania racemosa</i>	+											
<i>Serjania yucatanensis</i>		+	+	+						+	+	+
<i>Serjania</i> sp. 2							+					
<i>Serjania</i> sp. 4											+	
<i>Thouinia canescens</i>	+	+	+	+		+	+	+	+	+	+	+
Sapindaceae 1								+				

(continued)

Angiospermae	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sapotaceae												
<i>Bumelia</i> sp. 1											+	
<i>Pouteria mammosa</i>												+
<i>Pouteria</i> sp. 1	+	+	+	+	+	+			+	+	+	+
<i>Pouteria</i> sp. 2			+	+	+				+	+	+	
Sapotaceae 1	+						+				+	
Sapotaceae 2												+
Sapotaceae 3										+		
Scrophulariaceae												
<i>Capraria biflora</i>									+			
Smilacaceae												
<i>Smilax spinosa</i>		+	+									
Tiliaceae												
<i>Corchorus</i> sp. 1												+
<i>Heliocarpus donnell-smithii</i>												+
<i>Heliocarpus</i> sp. 1	+										+	
<i>Heliocarpus</i> sp. 2												+
<i>Luehea speciosa</i>												+
<i>Triumfetta dumetorum</i>	+	+										
Ulmaceae												
<i>Trema micrantha</i>	+	+	+	+		+	+	+	+	+	+	+
Vernaceae												
Verbenaceae 1								+				

References

- Ashworth L, Quesada M, Casas A, Aguilar R, Oyama K. Pollinator-dependent food production in Mexico. *Biol Conserv.* 2009;142:1050–7.
- Barrios-Delgado C, Pérez-Dominguez E, Sánchez-Navarro LM. Efectos y repercusiones de la abeja africana en la Península de Yucatán. In: Proceedings of the IV American Seminar on beekeeping, Mazatlán, Sinaloa. Secretaría de Agricultura y Recursos Hidráulicos and Gobierno del estado de Sinaloa, Mexico; 1990, p. 15–33.
- Borchert R, Meyer SA, Felger RS, Porter-Bolland L. Environmental control of flowering periodicity in Costa Rican and Mexican tropical dry forests. *Glob Ecol Biogeogr.* 2004;13:409–25.
- Burkle LA, Alarcón R. The future of plant—pollinator diversity: understanding interaction networks across time, space, and global change. *Am J Bot.* 2011;98(3):1–11.
- Cairns CE, Villanueva-Gutiérrez R, Koptur S, Bray DB. Bee populations, forest disturbance, and Africanization in Mexico. *Biotropica.* 2005;37(4):686–92.

- Calkins CF. The introduction of *A. mellifera* to the Yucatán Peninsula of Mexico. *Gleanings in Bee Culture*. 1975;103:202–3.
- Ceballos-Martínez VM. Evaluación del polen recolectado por la abeja *Apis mellifera ligustica* Spinola en la Reserva de la Biósfera de Sian Ka'an, Quintana Roo, México. Bch thesis. University of Veracruz; Córdoba, Ver., Mexico; 1987, p. 24.
- Daly HV, Balling SS. Identification of Africanized honeybees in the Western Hemisphere by discriminant analysis. *J Kansas Entomol Soc*. 1978;5:857–69.
- Echazarreta CM, Quezada-Euan JGG, Medina LM, Pasteur KL. Beekeeping in the Yucatán Peninsula: development and current status. *Bee World*. 1997;78(3):115–27.
- Erdtman G. An introduction to pollen analysis. Waltham, MA: Chronica Botánica Co.;1943. 239p.
- Galindo-Cardona A, Acevedo-Gonzalez JP, Rivera-Marchard B, Giray T. Genetic structure of the gentle Africanized honey bee population (gAHB) in Puerto Rico. *BMC Genet*. 2013;14:65.
- Gentry AH. Diversity and floristic composition of neotropical dry forests. In: Bullock SH, Mooney HA, Medina F, editors. *Seasonally dry tropical forests*. Cambridge: Cambridge University Press; 1995.
- Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T. Importance of pollinators in changing landscapes for world crops. *Proc R Soc B Biol Sci*. 2007;274(1608):303–13.
- Koeppen W. *Das geographische system der klimare in handbuch der klimatologie*. Band I, Teil C; Berlin, Germany; 1936. p. 44.
- Kuswaha CP, Tripathi SK, Tripathi BD, Singh KP. Patterns of tree phenological diversity in dry tropics. *Acta Ecol Sin*. 2013;31:179–85.
- Labougle-Rentería JM, Zozaya- Rubio JA. La apicultura en México. *Ciencia y Desarrollo*. 1986;69:17–35.
- Levin MD, Glowska-Konopacka S. Responses of foraging honeybees in alfalfa to increasing competition from other colonies. *J Apic Res*. 1963;2(1):33–42.
- Lieth H. Phenology and seasonality modeling. *Ecological studies*, vol. 8. New York: Springer; 1974.
- Meléndez-Ramírez V, Magaña-Rueda S, Parra-Tabla V, Ayala R, Navarro J. Diversity of native bee visitors of cucurbit crops (Cucurbitaceae) in Yucatán México. *J Insect Conserv*. 2002;6(135–147):2002.
- Miranda F, Hernández-X J. Los tipos de vegetación de México y su clasificación. *Bol Soc Bot Méx*. 1963;28:29–179.
- Ollerton J, Winfree R, Tarrant S. How many flowering plants are pollinated by animals? *Oikos*. 2011;120(3):321–6.
- O'Rourke MK, Buchmann SL. Standardized analytical techniques for bee-collected pollen. *Entomol Soc Am*. 1991;20:507–13.
- Palacios Chávez R, Ludlow-Wiechers B, Villanueva-Gutiérrez R. Flora palinológica de la Reserva de la Biosfera de Sian Ka'an, Quintana Roo, México. Mexico: Centro de Investigaciones de Quintana Roo;1991. 321 pp.
- Parra-Romero HI. Recursos poliníferos de importancia para la abeja *Melipona beecheii* durante el período húmedo en el campus de ECOSUR, Chetumal. Bch. thesis. Instituto Tecnológico de Chetumal. Chetumal, Quintana Roo, Mexico; 2015.
- Parra-Tabla V, Vargas CF. Phenology and phenotypic natural selection on the flowering time of a deceit-pollinated tropical orchid, *Myrmecophila christinae*. *Ann Bot*. 2004;94:243–50.
- Paxton RJ, Echazarreta-González C, García M. Africanized honey bees in Yucatán, Mexico: a detailed survey. *Am Bee J*. 1991;131:646–8.
- Porter-Bolland L. La apicultura y el paisaje maya. Estudio sobre la fenología de floración de las especies melíferas y su relación con el ciclo apícola en La Montaña, Campeche, México. JSTOR. University of California Press, Mexican Studies-Estudios mexicanos. 2003;19(2):303–30.

- Porter-Bolland L. Estudio de caso: flora melífera de Campeche. En: Villalobos-Zapata, GJ, Mendoza Vega J. (Coord.), 2010. La Biodiversidad de Campeche: Estudio de Estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Gobierno del Estado de Campeche, Universidad Autónoma de Campeche, El Colegio de la Frontera Sur. Mexico. Pg; 2010.
- Porter-Bolland L, Medina Abreo ME, Montoy-Koh P, Martín-Ek G, May Pacheco G. Flora Melífera de la Montaña, Campeche: su importancia para la apicultura y la vida diaria. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad e Instituto de Ecología, A. C., Xalapa, Ver. México; 2009, p. 322 ISBN: 978-607-7579-11-3.
- Rico-Gray V, Chemas A, Mardujano S. Uses of tropical deciduous forest species by the Yucatecan Maya. *Agr Syst.* 1991;14:149–61.
- Roubik DW. Ecology and natural history of tropical bees. Cambridge: Cambridge University Press; 1989.
- Roubik DW. Pollination of cultivated plants in the tropics. *Agricultural Services Bulletin* 1118. Rome: FAO; 1995.
- Roubik DW. Ecological impact on native bees by the invasive Africanized honey bee. *Acta Biol Colombiana.* 2009;14(2):114–24.
- Roubik DW, Villanueva-Gutiérrez R. Invasive Africanized honey bee impact on native solitary bees: a pollen resource and trap nest analysis. *Biol J Linn Soc.* 2009;98:152–60.
- Roubik D W, Sakai S, Hamid AA, editors. Pollination ecology and the rain forest. *Ecological studies* 174. Sarawak Studies. New York: Springer; 2005.
- Roubik DW, editor. Pollinator safety in agriculture. Rome: FAO and UNEP; 2014.
- Roubik DW, Bernhardt P, Meier S. Orchids and Neotropical tropical pollinators, since Darwin's time. In: Darwin's orchids: then and now. Chicago: University of Chicago Press; 2014. p. 229–61.
- Salinas-Peba L, Parra-Tabla V. Phenology and pollination of *Manilkara zapota* in forest and homegardens. *Forest Ecol Manage.* 2007;248:136–42.
- Smith MV, Adie A. A new design in pollen traps. *Can Bee J.* 1963; 74: 4,5,8.
- Vergara C. Rango de vuelo y cuantificación de los recursos colectados por abejas africanizadas en un bosque tropical de Panamá. Unpublished data report. Balboa, Panama: Smithsonian Tropical Research Institute; 1983.
- Villanueva-Gutiérrez R. Plantas de importancia apícola en el ejido de Plan del Río, Veracruz, México. *Biotica.* 1984;9(3):279–340.
- Villanueva-Gutiérrez R. Nectar sources of European and Africanized honeybees (*Apis mellifera* L.) in the Yucatán Peninsula, Mexico. *J Apic Res.* 1994;33(1):44–58.
- Villanueva-Gutiérrez R. Pollen resources used by European and Africanized honey bees in the Yucatán Peninsula, Mexico. *J Apic Res.* 1999;38(1–2):105–11.
- Villanueva-Gutiérrez R. Polliniferous plants and foraging strategies of *Apis mellifera* in the Yucatán Peninsula, Mexico. *Rev Biol Trop.* 2002;50(3/4):1035–44.
- Villanueva-Gutiérrez R, Roubik DW. Why are African honey bees and not European bees invasive? Pollen diet diversity in community experiments. *Apidologie.* 2004;35:481–91.
- Villanueva-Gutiérrez R, Colli Ucán W. Plantas nectaríferas visitadas por la abeja maya Xunancab (*Melipona beecheii*) en Quintana Roo. Proceedings of the XIX American Seminario of Beekeeping, Campeche, Campeche. SAGARPA, Unión Nacional de Apicultores and Gobierno del Estado de Campeche; 2005.
- Villanueva-Gutiérrez R, Buchamann S, Donovan AJ, Roubik DW. Crianza y manejo de la abeja xunancab en la Península de Yucatán. Tucson Arizona: ECOSUR-The BEE Works; 2005a.
- Villanueva-Gutiérrez R, Roubik WD, Colli-Ucán W. Extinction of *Melipona beecheii* and traditional beekeeping in the Yucatán Peninsula. *Bee World.* 2005b;86(2):35–41

- Villanueva-Gutiérrez R, Echazarreta González C, Roubik DW, Moguel-Ordoñez Y. Transgenic soybean pollen (*Glycine max* L.) in honey from the Yucatán Peninsula, Mexico. *Scientific Rep.* 2014; 4: 4002.
- Visscher PK, Seeley TD. Foraging strategy of honey bee colonies in a temperate deciduous forest. *Ecology.* 1982;63:1790–801.
- Waller GD. A modification of the O.A.C. pollen trap. *Am Bee J.* 1980;120:119–21.
- Winston M. *The biology of the honey bee.* Cambridge, MA: Harvard University Press;1987. 281p.