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A Critical View of Colony Losses in Managed Mayan Honey-Making Bees (Apidae: Meliponini) in the Heart of Zona Maya

Rogel Villanueva-Gutiérrez,[1] David W. Roubik,[2] Wilberto Colli-Ucán,[1] Francisco J. Güemez-Ricalde,[3] and Stephen L. Buchmann[4]

abstract: This research considered native Mayan stingless bees, *Melipona beecheii*, with special attention to decrease in their managed colonies. From a total of 155 beekeepers located in 60 communities, 58 were randomly selected to survey in 2011. Their experience ranged from less than one to 50 years, and initial colonies from one to 100. Both structured and open interviews were conducted. Participants generally reported they believed bees were obtaining less food, which could produce colony loss. The present and a previous survey in the Zona Maya show colony loss averages 4–5% each year. In this study, during an average of 10 years, 27 beekeepers lost none, 9 lost all, and the remainder lost 44% of their colonies. Further analysis revealed colony loss had no association with relative habitat disturbance, presumed Africanized honey bee abundance, or beekeeping experience. However, those initially with more colonies in a meliponary lost them at a greater rate, indicating competition for food. Initial colony number was near 11, but currently is near 4 per meliponary. Little colony propagation (husbandry) was the norm until recently, when initiatives including meliponiculture workshops stimulated more husbandry. Twenty-six percent of beekeepers had less than one year experience and they began meliponaries using wild colonies. Because established meliponicultors were found to very seldom rely on new wild colonies, increased husbandry efforts are necessary to offset natural mortality of managed colonies. Five meliponicultors increased their colonies over 300% in two years (40 to 123 colonies), whereas a 34% loss in nine years (480 to 206 colonies) was found among the individuals randomly surveyed.

key words: Colony loss, husbandry, *Melipona beecheii*, meliponiculture, Mexico, Quintana Roo, traditional knowledge

Breeding and handling of the 'xunan kab', the stingless bee *Melipona beecheii* Bennett, is part of traditional American meliponiculture or stingless beekeeping (Fig. 1). Its practice by the Maya predates Hispanic times by approximately 3500 years. Throughout history, *Melipona beecheii* has been the most extensively managed bee in Mesoamerica and Mexico. Today, meliponiculture centered on xunan kab continues nearly in traditional form, although the number of colonies has greatly diminished for those who practice the art (Quezada-Euán *et al.,* 2001; Villanueva-Gutiérrez *et al.,* 2005a,b). Not enough data had been presented when notable decline was interpreted to be due to habitat change, competition with invasive honey bees, or other variables (e.g., Cairns *et al.,* 2005; Villanueva *et al.,* 2005b). Our study is an attempt to correct this shortcoming in understanding the state of managed xunan kab in Yucatán.

[1] El Colegio de la Frontera Sur, Av. Centenario km 5.5, Apdo. Postal 424, Chetumal, Quintana Roo, C P 77014, Mexico. e-mail: rvillanu@ecosur.mx
[2] Smithsonian Tropical Research Institute, Balboa, Republic of Panama, and Unit 9100, DPO AA 34002-9998, USA. e-mail: roubikd@si.edu
[3] Universidad de Quintana Roo, Boulevard Bahía S/N esq. Comonfort, Col. del Bosque, Chetumal, Quintana Roo CP 77019, Mexico
[4] Departments of Entomology, and Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona 85721, USA

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Fig. 1. Meliponary of the authors in the Zona Maya, at ECOSUR, in Chetumal, Mexico.

Francisco Javier Clavijero (1824) reported that Mexican meliponicultors owned up to 500 colonies, similar to even older reports among civilizations in South America (Roubik, 2000). Honey was the sweetener used before sugar cane *Saccharum officinarum* (Poaceae) was known in the American tropics, and there were no Old World honey bees, genus *Apis*, thus honey came from native stingless bees, bumble bees and some wasps (Roubik, 1989, 2000). Honey also was used to pay tributes, perform various rituals, and in exchange for goods (Gonzalez-Acereto *et al.,* 2011; Ayala *et al.,* 2013). Today, in the Zona Maya region discussed here, it is extremely difficult to find a stingless bee-keeper—'meliponicultor'—with even 50 colonies. Our study species or, more likely, the only named species that represents a group of closely related Central American and Mexican bees (see Quezada-Euán *et al.,* 2007; Roubik and Camargo, 2012; Roubik, 2013) is widespread, and has populations in Jamaica and Cuba (Schwarz, 1932; Camargo and Pedro, 2007).

To initiate a meliponary (Fig. 1), Mayan people have traditionally cut logs of hard wood like *Manilkara* (Sapotaceae), containing the natural colony, and transported them to their home area, usually to a garden. Bee colonies are protected, or transferred to log hives or a box made of boards, or divided and propagated and even fed, but are always managed for honey. *Melipona beecheii* was the principal bee employed among all the local, native honey-producing stingless bees, approximately 15 species in the Yucatecan Mayan region (Ayala, 1999; Roubik *et al.,* 1991). Their regular colony division and husbandry, permitted by the bee's unusually mild behavior, relatively large (among stingless bees) honey storing capacity (1–2 L/y), and constant queen production, led to advanced meliponiculture known nowhere else in the world. To propagate a colony, some of the adults and brood with one or more queens soon to emerge are transferred to a new hive. If a virgin queen mates with a drone, then a new colony is formed (Nogueira-Neto, 1997).

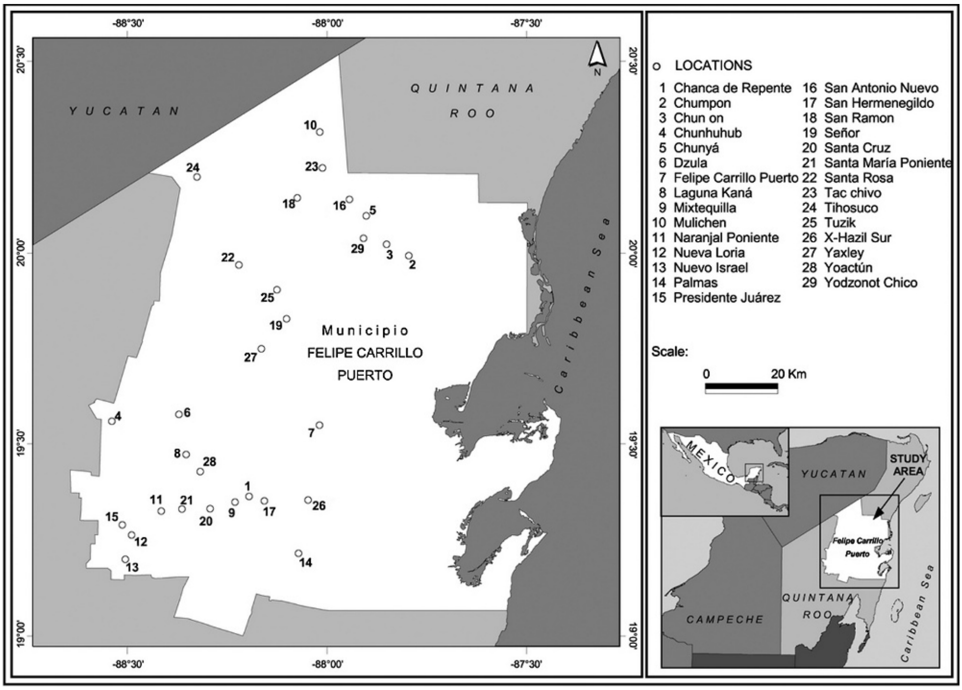

Fig. 2. Map showing the location of meliponaries studied within the Zona of Maya of Quintana Roo state, Mexico.

Villanueva-Gutiérrez *et al.* (2005b) present results from interviews with 23 meliponicultors from 30 communities within the Zona Maya of Quintana Roo. They detail procurement of 'hobones' or hollow tree sections with nesting bee colonies. We have observed a Mayan hamlet that had one colony from the wild for 27 years—the 'mother colony'—from which a meliponary of 27 colonies was gradually built (Villanueva-Gutiérrez, *op. cit.*), and one wild colony was procured during 1994—indicating colonies are seldom harvested to augment managed meliponaries. Further, between 1950 and 1981 at least 755 colonies domiciled in hobones were owned by the 23 meliponicultors we previously surveyed. By the end of 2004 they had 89 colonies, and 35% had lost all their colonies. The precise date and reasons for colony loss were not ascertained and, as in the present work, we attempt to interpret field data reported to us, including data gained by structured and open interviews (see Materials and Methods). All but four beekeepers maintained or demonstrated they had not successfully divided or propagated their colonies, or obtained more after initiating their meliponaries, up until and including the year 2011. Thus, colony number was established when their meliponicultural experience began, and a decline would be detectable, or its probable cause inferred, given the data we collected. More important, no statistical analysis of correlations or trends, leading to predictions, could be made from our first publication, due to lack of rigorous procedure and statistical testing, and small sample size (see Roubik, 1983, 2001, or LeBuhn *et al.*, 2012), which we redress herein.

Materials and Methods

The present research took place in 24 Maya communities located in the middle of Quintana Roo, officially designated 'Zona Maya' (Fig. 2). This region is thickly forested, with trees reaching a height of approximately 20–25 m, termed 'selva mediana', and much of the vegetation is of old growth, although frequently disturbed by hurricanes and fire (Whigham *et al.,* 1991; Roubik and Villanueva-Gutiérrez, 2009). Of nearly 200 communities we visited in the Zona Maya, a total of 60 had individuals actively practicing meliponiculture. Maya communities with populations greater than 50 were chosen and in those, 155 meliponicultors were found. In 2011 we interviewed a randomly selected sample of 58, representing one-third of the total meliponine beekeepers. Previous surveys dating to 2004 (Villanueva *et al.,* 2005b) included almost completely different individuals from the present study. However, some non-quantitative information from interviews was pooled for the entire study period, which covers over 30 years—1981 to 2011.

The data are rendered in categories, whereby each variable is divided into two possible states for statistical analysis in a 2×2 contingency table (see below). As a means of monitoring the habitat quality of vegetation that can support *Melipona beecheii* and meliponaries, satellite images (Google Earth, April, 2012) of vegetation, and our 'ground truth' observations, were combined to describe each meliponary (Fig. 2) and categorize surrounding land as either cleared of most the native vegetation and disturbed, or as relatively intact forest. We used an estimated maximum bee flight range of *Melipona beecheii* of 5 km (Roubik 1989: 85) to delimit foraging territory.

Variables for a standard questionnaire included meliponicultor age, sex, number of years keeping colonies, initial colony number, number kept now, total colonies lost in a meliponary, colony husbandry or division, colony feeding, colony transfer from natural nests, use of box hives, honey sales, reasons thought likely for colony losses or other problems, and meliponiculture courses attended. A standard set of questions in Spanish was asked—in Mayan for those who had difficulty with Spanish (Villanueva-Gutiérrez *et al.,* 2005b). No general bee biology was emphasized (e.g., flight range, longevity of a queen, number of workers in a colony), but rather, management practice. Most meliponicultors have meager resources, and along with many who practice apiculture, theirs is a secondary, not a primary, vocational activity. The categorical variables that were analyzed with colony loss are those summarized in Table 1. We did not insist meliponicultors recall exactly when they lost colonies, or other details. Thus, the oldest information includes events potentially dating from 1961, and particular events, such as hurricanes or droughts that tend to have an impact on bee colonies (Villanueva-Gutiérrez *et al.,* 2005a,b; Roubik and Villanueva-Gutiérrez, 2009) cannot be examined statistically. Furthermore, in 2011, a large proportion of the study subjects (15 of 58) had not even practiced meliponiculture for one year, and thus they are not included in the statistical analyses for colony loss, but were tabulated in general descriptive statistical results. 'Open' interviews about the main local and regional problems facing meliponicultors were also performed. We gave no suggestion or expectation as to assessing the state of meliponiculture during interviews. Our basic approach was to associate hard data with any possible trend or cause and effect relationship that beekeepers mentioned or that we deduced.

After tabulating the data, we applied a test of association between two categories, divided by their medians. This method maximizes the number of raw data counts in

Table 1. Categorical variables analyzed with colony loss.

Fisher's exact test (P)	Association found	Category 1	Category 2
1.000	none	annual loss	experience
0.758	none	initial colonies	age
0.744	none	total loss	experience
0.662	none	annual loss	habitat quality
0.112	little	initial colonies	total loss
0.122	little	current colonies	age
0.081	little	initial colonies	experience
0.056	positive	annual loss	gender
0.043	positive	annual loss	initial colonies
0.029	negative	annual loss	age
0.001	positive	experience	age
0.0001	positive	total loss	annual loss

each cell of the 2 × 2 tables we used to perform Fisher's exact tests (see Gotelli and Ellison, 2004).

Results

The mean annual colony loss was 3.9%, among the 56 meliponicultors that did not sell their colonies (only two did so, see below), and 3.8% among the experienced meliponicultors. Only eight persons in our study have been meliponicultors during more than 20 years (mean 11.4, SD 10.4 years), and mean beekeeper age was 50 years (maximum 90, minimum 23) among the 58 people. There were 20 female meliponicultors, and 25 beekeepers older than the mean. The 15 new meliponicultors began beekeeping with anywhere from one to 14 colonies, mostly with one. They obtained them from wild colonies nesting in trees, including also the one given to each of them, in the program headed by the first author. The maximum colonies kept among our surveyed meliponicultors was 100, inherited in 1966 by an individual 90 years of age in 2011, and one individual had kept colonies for 50 years. Average honey harvest was 3.63 liters per year, and those who sold honey ($N = 21$) received an average of 143 Pesos per liter, little more than $10.

Colony loss varied widely, because many of the experienced 43 meliponicultors lost all or no colonies. In a mean of 10 years, 27 beekeepers lost none, 9 lost all, and the remainder lost 44% their colonies. The mean average loss in one year was 4.4% for those who lost neither all nor none. Two more sold their 7 colonies to ecotourist concerns. More experienced meliponicultors averaged 44% loss of colonies since they began keeping the bees (an average of 11.4 years), or a loss of 3.8% per year. Among those more experienced meliponicultors, obvious, but trivial associations, existed between mean annual loss and total loss—because the later was divided by years, to obtain the former—and beekeeper age was closely correlated with years of experience (Table 1). More interesting, perhaps, is that the mean annual loss was positively associated with the initial number of colonies in the meliponary ($P = 0.043$). Larger meliponaries accrued more losses per year, although the initial number of colonies had little association with the total loss ($P = 0.112$). A larger meliponary lost colonies at a faster rate during at least part of its history. We further interpret this point below.

Our data for the 41 experienced meliponicultors (Table 1), 21 male and 20 female, indicate male meliponicultors experienced less loss ($P = 0.056$), but all female respondents began rather recently—traditional meliponiculture had been practiced only by men. Nonetheless, the results given in Table 1 show that greater beekeeper age was significantly related with lower colony loss ($P = 0.029$), but that experience in meliponiculture was, in general, not correlated with loss, considering the total loss since beginning ($P = 0.744$), or mean loss per year ($P = 1.00$). Another finding was that the rate of colony loss/year was not influenced by relative habitat modification or conversion from forest to more open or cultivated land ($P = 0.662$). The map given in Fig. 2 contains six sites having little or no forest within several km, as we saw in our direct observations; they are meliponary sites 6, 7, 12, 15, 22 and 27.

If past trends predict future realities (Table 1), considering mean time engaged in meliponiculture is about 11 years (for total meliponicultors it is slightly less than 9 years), the prediction of total colony loss tempo is not yet testable, given the 20 years of expected longevity for a meliponary (11 years in existence plus 9 years more if rate of loss, until 2011, continues). More important, the largest group of meliponicultors, regardless of their age, gender, initial number of colonies, or years of experience, have lost no colonies at all. Nonetheless, the main reasons expressed by respondents as probable causes for colony losses were the lack of food (pollen and nectar resources from native forest trees) for their bees, hurricanes, and prolonged drought, and a few maintained that beliefs or knowledge (of what, was not mentioned) had an influence on bee colony loss.

A small minority of meliponicultors made innovations. Four each used wooden box hives, or divided their colonies, or obtained new colonies from natural nests in living trees. A slightly larger minority of 11 stated that they had fed their colonies, between June and January. Although a total of 14 said they had divided colonies, only four reported which colonies had been used to make the divisions. The 10 that did not provide details were not successful in dividing colonies, and lost prospective new colonies. The likelihood that those 14 individuals in fact had average per capita colony loss differing from beekeepers who said they never divided a colony or brought in a new one is further evaluated in our discussion, below.

Discussion

The meliponicultors surveyed were relatively inexperienced by standards of Mayans through history, who we believe inherited their hives and practiced meliponiculture, after observing their elders, for most of their lives. We found that colony numbers had declined about as fast as those seen previously during recent decades, but not going back several decades (Villanueva-Gutiérrez *et al.,* 2005b). The main reason for decline appears to be simply management. The past records had included data from over a half century ago. But at 24 meliponaries, there had been a loss of 299 colonies out of 389, during 14 years (1990 to 2004), a mean of 5.5% per year. In the present study, for 56 beekeepers, 206 colonies, at the end of 2011, came from an initial 480 colonies, maintained between less than one to 50 years (mean = 8.55 years), a mean 6.6% loss per year. However, the experienced beekeepers, those with more than a year of experience, had lost an average of 3.8% of their colonies each year. Considerable variation was found among the three beekeepers previously interviewed, B. Kantún, P. Cahun Uh, and I. Peña Tuz (Villanueva-Gutiérrez *et al.,* 2005b). Since 2004, one had lost none, one had gained 10 by colony division, and one had lost all his colonies. After our 2011 data were taken, up to and including 2013 until August, five meliponicultors that both had and had not been interviewed in 2011 increased their total bee colonies by 308%, or 154% per year—greatly offsetting the over 6% per year loss experienced by the randomly sampled beekeepers. All of those 83 new colonies came from divisions made with existing stock.

In addition to replacing losses due to natural colony mortality, there is an economic incentive in what can be called ‘boutique honey’, which may sell for considerably more than the $10 per liter usually received by meliponicultors in Zona Maya. After care is taken in hygiene and preparation, small decorative bottles of Mayan honey with a fancy explanatory tag are sold to local tourists, or exported and, although most *Melipona* honey still is consumed locally in Mayan villages, some is sold to medical ‘doctors’ in Mexico City. It may be that meliponiculture can become a gainful activity if boutique meliponine honey acquires a market niche (Courtopassi-Laurino *et al.,* 2006, Vit *et al.,* 2013), but we see no evidence for that stage, as yet, in Mayan meliponiculture. The mean age of 50 years among Mayan meliponicultors in Quintana Roo was similar to findings by González-Acereto and Quezada-Euán (2010) in the neighboring state of Yucatán, where there is less natural forest or biodiversity in flowering vegetation. The average number of colonies/meliponicultor in Yucatán state was 12 (near the more heavily forested states of Campeche and Quintana Roo), while for the experienced meliponicultors we surveyed it was only four.

Meliponicultors with many years of experience, as well as those newly trained in meliponiculture, particularly the women, are motivated to explore this activity as one that can generate a certain income or benefit. Presumably related to honey sale seen as lucrative in tourism, two meliponicultors sold all seven of their colonies to ecotourist concerns in Yucatán. For this reason, although many have lost colonies without compensation other than honey sales, others receive $50–$100/colony. Are the sell-offs perhaps motivated by the certainty that colonies will be lost, whether an added benefit is derived, or are they motivated by short-term gain? The seven colonies were sold by meliponicultors of the same age, whereas one had kept colonies for 10 years and the other for only one year. Their colony sales are more profitable than honey sales, even at this low level, and we suggest may promote conservation of the Mayan honey bee, as a flagship species (Krüger, 2005). The honey produced by stingless bees is still used in Mayan traditional medicine for treatment of many ailments, and provides an incentive for meliponiculturists to adapt and continue. The motivation for honey production and sale is presumably not monetary, because the average sales amount to 500 Pesos a year, about $40.

Are colony numbers declining, and why? Many meliponicultors reported they believe their bees are dying from lack of food. They report witnessing, over time, less honey production and that the population is diminishing in size to the point colonies cannot repel natural enemies (Villanueva-Gutiérrez *et al.,* 2005b). We must consider other factors, one of which includes the rate of restocking colonies. We think there are two main reasons for decline that are validated by our data and analysis. First, the current owners seldom divide their colonies, and second, there are generally no new hobones coming in. A third reason is that colonies of the same species compete more often than before for food, when kept in meliponaries (see below). There are no census data for wild colonies of which we are aware, and there are no data of the kind required to detect a population decline in *Melipona beecheii* within Yucatecan forests (Roubik, 2001). Expressed concerns of biologists who study the meliponas of

Yucatán and wider areas (see Vit *et al.,* 2013, and Cairns *et al.,* 2005; Quezada Euán *et al.,* 2007; Ayala *et al.,* 2013) lack quantitative methodology or analysis. Our survey shows that there are no declines in managed colonies kept by roughly half of the meliponicultors, during a mean observation time of 11.4 years. Moreover, the predictive variables that we could identify included mainly the age and gender of the beekeeper, which have very little basis from which to propose a mechanistic explanation. The best predictor seems to be the management strategies of the beekeepers themselves. However, apparently only four male meliponicultors, of those in the planned study and interviews, propagated their colonies.

Because a sample of four is too small to analyze, and because 14 responded that they had in fact made colony divisions, we used the latter number and its mean success, in 2 × 2 contingency table tests to compare the colony loss experienced by those who say they did, and say they did not, divide their colonies. The results, both with Fisher's exact test ($P = 0.049$) and with a G-test with a correction for small samples (Yates correction, $P = 0.126$) show *less* colony loss for those who did not divide colonies. In contrast, the four persons who verified they had made successful divisions and stated how many colonies they had divided, experienced either no loss at all (three persons), or a loss of 14% their initial total, well below the expected loss of 33%. These men were 45 to 80 years in age and practiced meliponiculture for 1, 2, 10 and 25 years. It may be suggested that confidence in their husbandry technique, with no fear of losing their colonies from the attack of parasites like phorid flies after colony division (see Villanueva *et al.,* 2005a,b), made these individuals successful, while 10 of the respondents, new to meliponiculture, failed.

For colonies that do die, natural mortality of stingless bee colonies has been studied only a few times and they succumb both to starvation and natural enemies (Slaa, 2006; Roubik, 2006 and DWR, unpubl. data). Individual colonies also are drowned or their nests ripped asunder by hurricanes, such as Hurricane Sandy that struck the Caribbean region in 2013, and killed many native exposed solitary bees, and sheltering colonial bees (DWR, unpubl. data). Bees kept in hives should have lower mortality because they are protected. Predictions from studies just mentioned and data in Table 1 are surprisingly consistent, yet based on too few studies. *Melipona* colonies may be expected to survive for about 20 years, through a series of queen replacements and natural matings. If colony density is too low to provide males for outcrossing and mating, then populations will decline. This point does not seem to have been reached in Quintana Roo, in the Zona Maya, at least in meliponaries.

In our introduction, we cited an historical figure on meliponary size, and similar meliponaries have existed in contemporary times, the 1970's (Roubik, 2000). But such figures must derive in part from the rate of forest clearing for agriculture and cattle ranching, or the fences made with wooden posts, in which certain species, like *Melipona favosa*, can build their nests (DWR, pers. obs.). That is, the colonies brought to meliponaries are undoubtedly determined in part by the rate of tree felling and colony discovery by humans. During three decades of our study, only four individuals, among established beekeepers, reportedly took in wild colonies in sections of tree trunks. In contrast, those seeking to establish a meliponary readily found colonies or, as in the program to reinstate meliponiculture, a person able to find colonies in the wild was hired to procure them.

Those colonies of *Melipona beecheii* located in degraded habitats that surround Mayan villages compete relatively often with Africanized *Apis mellifera* for floral resources (Villanueva-Gutiérrez *et al.,* 2005b, 2013), but perhaps less for nesting sites. That is because nesting Africanized *Apis mellifera* readily use many sites besides tree cavities (Roubik and Boreham, 1990), and often use buildings, while such behavior is uncommon in *M. beecheii* (DWR and RGV, pers. obs., see also Baum *et al.,* 2008). Nonetheless, the greater number of honey bees presumed to be found in disturbed habitat, like the existence of more versus less disturbed vegetation near successful meliponaries, had no relation to the longevity of *Melipona* colonies kept—but in reality scarcely managed. In contrast, the faster decline in colonies in the largest meliponaries suggests intraspecific food competition is a more salient factor than interspecific competition with an invading honey bee, to which native species adapt via resource partitioning (Roubik and Villanueva, 2009).

Colony loss rate was higher in the initially larger meliponaries, which in our study were those handed down from the preceding generation, and contained as many as 100 colonies. Currently, meliponaries consist of far fewer colonies, usually less than 5, with the largest having 22 colonies. One possible explanation is that the intensity of competition for food between members of the same species has increased to the point that larger meliponaries are not productive or recommended, which is expected from the local reduction in forest and plant species diversity, including many preferred by *M. beecheii* (Villanueva-Gutiérrez *et al.,* 2005a), other unknown or undocumented factors, and intensification of agriculture and livestock rearing (Cairns *et al.,* 2005).

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