



## BIOLOGICAL SCIENCES

# Stingless bee (Apidae, Meliponini) guilds occurring in the immediate edges of forest fragments of the Baturité Massif, State of Ceará, Brazil

LUIZ WILSON LIMA-VERDE, ALÍPIO JOSÉ S. PACHECO FILHO & BRENO M. FREITAS

**Abstract:** This study investigated the occurrence of individuals of stingless bees attracted by the trophic resources existing in four edge areas of forest fragments located in the Baturité Massif, State of Ceará. In this sense, the study evaluated the species richness in the areas; the absolute abundance of species; the similarity of species between edges; and the affinity of bees for the same plant species. The sampling of bees compiled a total of 20 species distributed in 12 genera. Seven species stood out for abundance and two (*Trigona spinipes* and *Trigona fulviventris*) showed dominance. The results also showed that the fragments present a similar stingless bee fauna and the affinity of the bee species for the same plant species revealed the formation of five distinct bee groups in foraging preferences involving 15 (75%) out of the 20 species of bees studied.

**Key words:** foraging, meliponini bees, species richness, trophic resources.

## INTRODUCTION

In the neotropics, researchers have faced difficulties in bee census procedures due to the degradation of natural environments (Brosi et al. 2008). This process is characterized mainly by the fragmentation of habitats caused almost always by anthropogenic actions carried out over the centuries (Viana & Pinheiro 1998, Cerqueira et al. 2003, Brown & Lomolino 2006). At the immediate edges of these fragments, the dynamics of biological interactions are altered by new established physical conditions (Bierregaard et al. 1992, Murcia 1995).

Gene flow between animal and plant populations is the factor most drastically affected in space and time. In this case, the elements that contribute most to these genetic alterations are the fragment sizes, the distances between them and the permeability of the

established matrix (Viana et al. 1992, Scariot et al. 2003, Schneider et al. 2003). In the group of Meliponini and other Apoidea, this critical limit is perceived through the emergence of diploid males, due to the lack of alleles for the proper genetic combinations (Kerr & Vencovsky 1982).

Although these immediate edges of forest fragments are marked by the effects of human interference, they develop a flora, partly exotic, perfectly adapted and whose dynamics is directly related to the structural modification of the matrix (Cane 2001, López-Barrera 2004, Ewers & Didham 2006, Maciel et al. 2011). In these sites, a considerable richness of bee species, including of meliponini, has been observed using the trophic resources made available by this flora (Antonini et al. 2003, Gonçalves & Melo 2005, Gonçalves et al. 2009). However, the pattern of occurrence of meliponini bees in these environments is also characterized

by other factors such as the conservation of the fragments, the lack, the quality and the seasonality of trophic resources and the levels of relative humidity (Heithaus 1979, Antonini et al. 2003, Brosi et al. 2008, Brosi 2009).

Bee census studies carried out in anthropic areas of different Brazilian regions have shown a relatively large variation, mainly in the richness and abundance of stingless bee species, both as a function of the region and the plant typology (Locatelli et al. 2004, Aguiar & Zanella 2005, Batalha Filho et al. 2007, Milet-Pinheiro & Schindwein 2008, in the Northeast region; Wilms et al. 1996, Faria-Mucci et al. 2003, Anacleto & Marchini 2005, Andena et al. 2005 in the Southeast region; Krug & Alves-dos-Santos 2008, in the South region; Santos et al. 2004 in the Central-West region). Outside Brazil, similar research was also carried out in environments affected by human activities, in the vicinity of fragments of ombrophilous forests, such as those of Heithaus (1979) and Samejima et al. (2004) in Costa Rica (Central America), and Brosi et al. (2008) and Brosi (2009) in Malaysia (Southeast Asia).

In the State of Ceará, research on the Meliponini group and its trophic resources has not been carried out frequently on fragments of Atlantic forest such as those occurring in the Baturité Massif, Brazilian semi-arid. Recently, Lima-Verde et al. (2014) carried out a floristic survey in these same areas selected for this research to relate the plant species with the meliponini species.

In this sense, areas of immediate edges of forest fragments of this massif were selected to investigate the occurrence of species of these bees attracted by the trophic resources therein. In order to ecologically evaluate the behavior of this group of bees, four edges of four distinct forest fragments were used to answer the following questions: i) how is the richness of

bee species represented in these areas?; ii) how is the abundance of individuals per species characterized in these environments?; (iii) how similar are the forest edges in bee species?; iv) how do bees relate to environmental variables? v) how does the sharing of floral resources occur among bees?

## MATERIALS AND METHODS

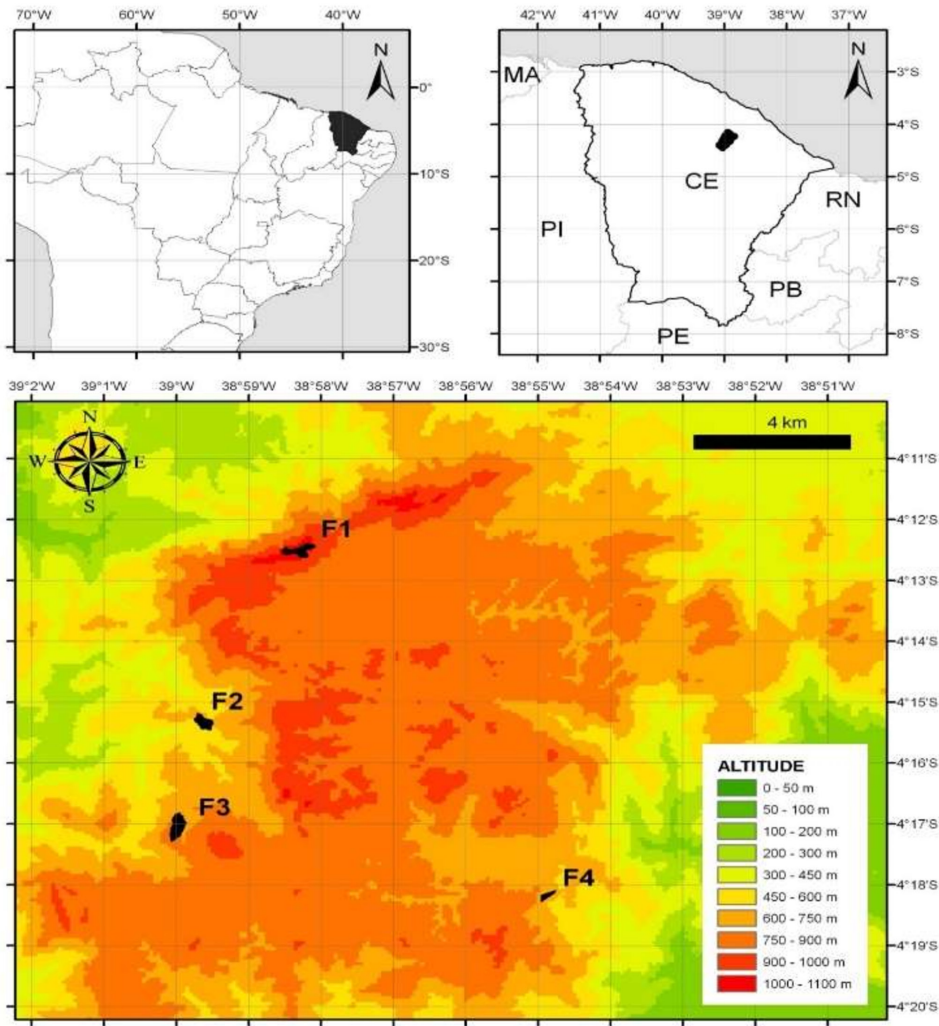
### Study area

Field work was conducted in areas of the municipalities of Baturité, Guaramiranga and Mulungu located on the Baturité Massif (4° to 4° 30' S and 38° 45' to 39° 15' W), northeast of the State of Ceará (Gomes 1978, Souza et al. 1994, Souza 1997) (Fig. 1).

The other geoenvironmental aspects are in agreement with the literature cited in Lima-Verde et al. (2014). In this context, it is worth mentioning that the field work was carried out exclusively at the immediate edges of the forest fragments, the edges receiving the designations F1, F2, F3 and F4. F1 and F2 (municipality of Guaramiranga); F3 (municipality of Mulungu); and F4 (municipality of Baturité). In Table 1, the denominations of local forest types were abbreviated to fodm (dense ombrophilous forest) and fedm (seasonal deciduous montane forest).

### Bee sampling

The procedure for bee sampling was based on the standardized methodology of Sakagami et al. (1967), with modifications according to local circumstances. Bee samplings were performed once in a month during 18 months, from March 2008 to August 2009 in all four forest fragment edges. Bees were sampled from 7:00 am to 5:00 pm, with the transects inspected in two directions, twice in the morning and twice in the afternoon, totaling 40 hours per month of



**Figure 1.** Location of sampling sites (F1, F2, F3, F4) in the Baturité Massif, State of Ceará, Brazil. Source: SRTM/ NASA.

collection effort in the four areas and 640 hours in the period. The collection of bees was carried out using entomological nets and occurred predominantly in herbaceous and shrubby plants and, more rarely, in arboreal specimens up to six meters high, as well as in entrances of the nests. In groups of herbaceous species and in shrub specimens, the collection time of the bees was about five minutes for each group and for each specimen. In the trees, this procedure occurred during 20 minutes, and the entomological net, in this case, was equipped with an extensible pole to reach the tree’s canopy.

The bees captured were killed in lethal vials containing ethyl acetate and then transferred to suitably labeled individual vials. In the laboratory, they were selected by morphospecies and identified according to Silveira et al. (2002) and Michener (2007), and part of the material was sent to experts for confirmation and identification. Material representative of the collections is deposited in the collection of the Bee Laboratory, Department of Animal Sciences, in the Federal University of Ceará.

**Table I.** List of meliponini bees associated to the sampling sites F (Edge), to the number of species of plants visited (Nepv) and to the respective vegetation typology (Vegetation) in the Baturité Massif, State of Ceará. M01-M20 (meliponini from 01 to 20), # (collection in the nest), \* (new records), fodm (dense ombrophilous forest), fedm (seasonal deciduous montane forest).

Species	Edge	Nepv	Vegetation
M01. <i>Cephalotrigona capitata</i> (Smith, 1874)	F1, F4	3	fodm, fodm
M02. <i>Frieseomelitta doederleini</i> (Friese, 1900)	F2	3	fedm
M03. <i>Frieseomelitta francoi</i> (Moure, 1946) *	F3	1	fedm
M04. <i>Frieseomelitta varia</i> (Lepeletier, 1836)	F1, F3	5	fodm, fedm
M05. <i>Geotrigona</i> sp.	F4	1	Fodm
M06. <i>Lestrimelitta</i> cf. <i>tropica</i> Marchi & Melo, 2006 *	F2	#	fedm
M07. <i>Leurotrigona</i> sp.	F3	1	fedm
M08. <i>Melipona</i> ( <i>Mechmelia</i> ) aff. <i>rufiventris</i> Lepeletier, 1836	F1, F3	8	fodm, fedm
M09. <i>Nannotrigona</i> sp.	F1, F2, F3, F4	9	fodm, fedm, fedm, fodm
M10. <i>Oxytrigona tataira</i> Smith, 1863 *	F3, F4	5	fedm, fodm
M11. <i>Partamona ailyae</i> Camargo, 1980 *	F1, F2, F3, F4	2	fodm, fedm, fedm, fodm
M12. <i>Plebeia</i> aff. <i>flavocincta</i> (Cockerell, 1912) *	F3	2	fedm
M13. <i>Plebeia</i> sp.	F1, F2	1	fodm, fedm
M14. <i>Scaptotrigona</i> sp. 1	F1, F2, F3, F4	15	fodm, fedm, fedm, fodm
M15. <i>Scaptotrigona</i> sp. 2 *	F4	1	fodm
M16. <i>Scaptotrigona</i> sp. 3 (sp. nov.) *	F1, F3	1	fodm, fedm
M17. <i>Trigona fulviventris</i> Guérin, 1837	F1, F3, F4	39	fodm, fedm, fodm
M18. <i>Trigona fuscipennis</i> Friese, 1900	F2, F3, F4	3	fedm, fedm, fodm
M19. <i>Trigona spinipes</i> (Fabricius, 1793) *	F1, F2, F3, F4	51	fodm, fedm, fedm, fodm
M20. <i>Trigonisca pediculana</i> (Fabricius, 1804)	F2	1	fedm

## Data analysis

Data were organized in matrices of abundance in which the columns corresponded to the species of bees and the rows to the monthly collections. For each edge, a matrix was constructed to evaluate the parameters to be studied. The species richness in the four edges was estimated through the calculations of the species accumulation curve (collector curve), according to Gotelli & Colwell (2001). In this case,

we used the Chao 2 and first order Jackknife richness estimators.

Similarity in meliponini species between edges was evaluated using the Bray-Curtis similarity coefficient and the grouping analysis (Unweighted Pair Group Method with Average - UPGMA) (Magurran 2011). These data were also used for an evaluation of the effects that the distances between edges, relief slopes, plant typologies and altitudes between edges can have in the approximation or distancing of these areas,

regarding the similarity of the melipofauna. The Bray-Curtis coefficient of similarity and UPGMA were also used to investigate the sharing of floral resources among bees.

## RESULTS

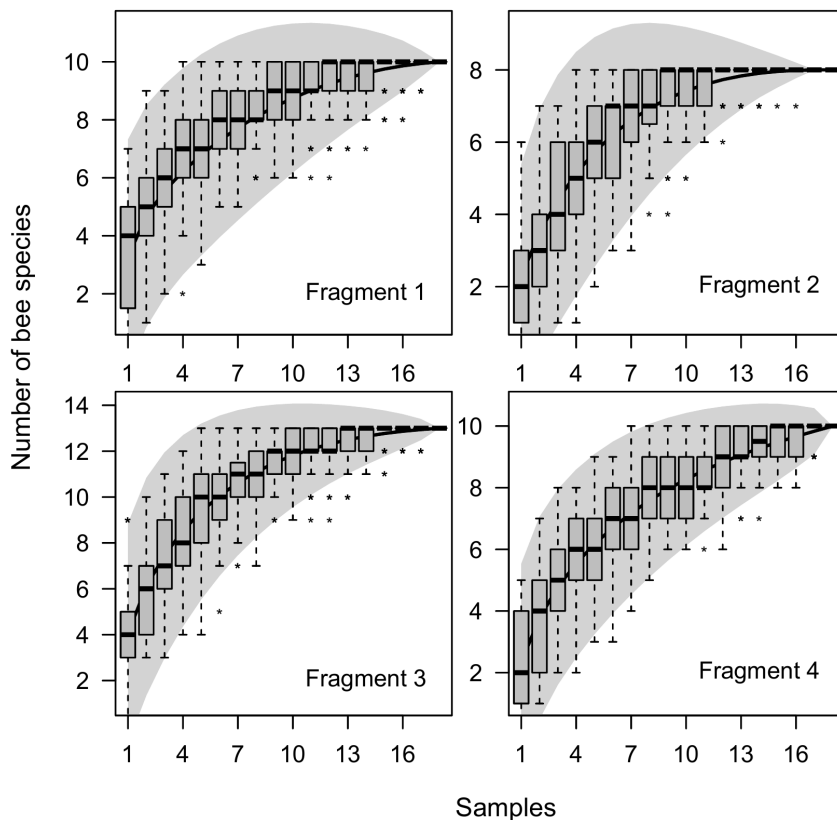
### Bee species richness

Sampling of stingless bees collected 1,346 specimens of 20 species distributed in 12 generic taxa (Table I). The most species-rich genera were *Frieseomelitta*, *Scaptotrigona* and *Trigona*, each with three species.

Samplings per edge corresponded in F1 to 350 individuals, ten species and eight genera; in F2, to 256 individuals, nine species and eight genera; in F3, 436 individuals, 13 species and nine genera; and in F4, to 304 individuals, ten species and seven genera (Table I). The analysis of the collector curve suggests that, with the

exception of the F4 edge, the other areas reached sampling sufficiency (Fig. 2). In this case, the estimation of the number of bee species of the richness estimators did not show a discrepancy between the number of species collected and the estimated number of species for F1 (Chao = 10.12, Jackknife 1 = 10.94), F2 (Chao = 8, Jackknife 1 = 8) and F3 (Chao = 13.16, Jackknife 1 = 13.94), therefore, there was sampling sufficiency for these edges. However, there was discrepancy between these data for F4 (Chao = 14.25, Jackknife 1 = 12.83).

In addition to the 12 species of meliponini bees recorded by Ducke (1908, 1911), eight new records (*Frieseomelitta francoi*, *Lestrimelitta* cf. *tropica*, *Oxytrigona tataira*, *Partamona ailyae*, *Plebeia* aff. *flavocincta*, *Scaptotrigona* sp. 2, *Scaptotrigona* sp. 3, sp. nov., *Trigona spinipes*) were made for the Baturité Massif. Among these species, as a new species, *Scaptotrigona* sp. 3 (sp. nov.) (Table I).



**Figure 2.** Monthly accumulation curve representing the effort of collecting meliponini bees in the edges of four forest fragments located in the Baturité Massif, State of Ceará.



### Abundance of bees

In the evaluation of the absolute abundance of the stingless bees studied (Fig. 3), six species stood out M19 (M19 (*Trigona spinipes*), M17 (*Trigona fulviventris*), M14 (*Scaptotrigona* sp. 1), M18 (*Trigona fuscipennis*), M09 (*Nannotrigona* sp.) and M11 (*Partamona ailyae*), the first two considered the dominant species.

### Similarity of bees

All the areas presented similarities above 30% in the composition of bee species. The edges F3 x F4 were the most similar, with a similarity of 64.15%, also emphasizing the edges F1 x F2 with a lower limit value of 31.14% (Table II). The edge F2 (Fig. 4) was the most distinct in relation to its fauna of meliponini bees.

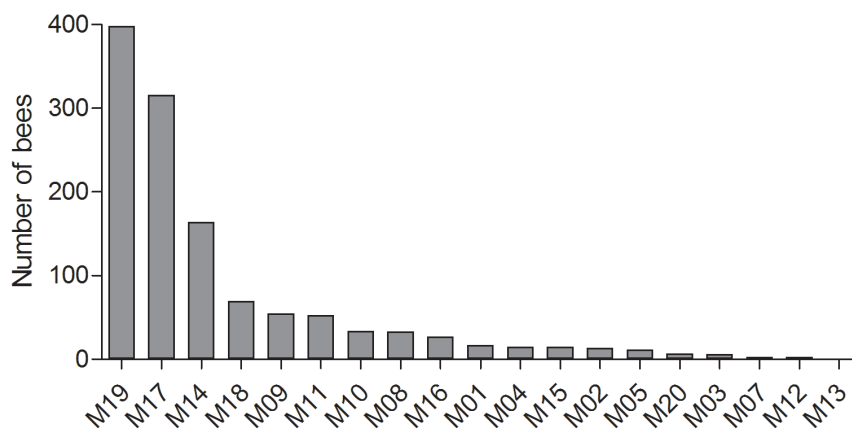
### Sharing floral resources between bee species

The similarity analysis representing the affinity of the meliponini bee species for the same plant species (niche overlapping) revealed the formation of five distinct groups, considering a minimum similarity of 30% (Fig. 5). These groups involved 15 (75%) out of the 20 species of bees studied, where it was possible to distinguish clusters whose similarity ranged from 0 to 93.75%. The most representative affinity was between

M01 and M15 (*C. capitata* and *Scaptotrigona* sp. 2), involving the latter percentage value.

## DISCUSSION

The results of the collector curve showed that the collected material had a good representativeness in meliponini bee species for the conditions of the Baturité massif. Generally, in the inventories of Apoidea in Brazil the number of occurrence of species of stingless bees has been considered low in several ecosystems. In areas of savannah-steppe (caatinga of the arid region, *sensu* IBGE 2012), for example, this number has not exceeded 11 species (Martins 1994, Aguiar & Martins 1997, Viana 1999, Zanella 2000, 2003, Aguiar 2003, Aguiar & Zanella 2005, Batalha Filho et al. 2007). In different types of savanna (cerrado), grassy-woody steppe (clean field), semi-deciduous seasonal lowland forest (restinga) and ombrophilous forest (Atlantic forest), bee surveys recorded a maximum of only six species (Faria-Mucci et al. 2003, Locatelli et al. 2004, Gonçalves & Melo 2005, Viana & Kleinert 2006, Milet-Pinheiro & Schlindwein 2008, Siqueira et al. 2012). However, in the savanna (cerrado), Nogueira-Ferreira & Augusto (2007) recorded 18 species and, in the cerrado-Amazon transition



**Figure 3. Absolute abundance of meliponini bee species registered in the Baturité Massif, State of Ceará. M01-M20 (meliponini from 01 to 20) see Table I.**

**Table II. Similarities (Bray-Curtis Coefficient) of the meliponini fauna between edges (F) related to distances between edges (Distance), mountain slopes (Slope), vegetation typologies (Vegetation) and altitudes (Altitude), in the Baturité Massif, State of Ceará. Win (Windward), Lee (Leeward), fodm (dense ombrophilous forest), fedm (seasonal deciduous montane forest).**

Edge	Similarity (%)	Distance (km)	Slope	Vegetation	Altitude (m)
F1 x F2	31.14	3.23	Win x Lee	fodm x fedm	1015-1114 x 670-690
F1 x F3	57.35	9.01	Win x Lee	fodm x fedm	1015-1114 x 780-790
F1 x F4	62.81	3.96	Win x Win	fodm x Fodm	1015-1114 x 660-680
F2 x F3	46.96	5.79	Lee x Lee	fedm x fedm	670-690 x 780-790
F2 x F4	41.73	10.27	Lee x Win	fedm x fodm	670-690 x 660-680
F3 x F4	64.15	12.36	Lee x Win	fedm x fodm	780-790 x 660-680

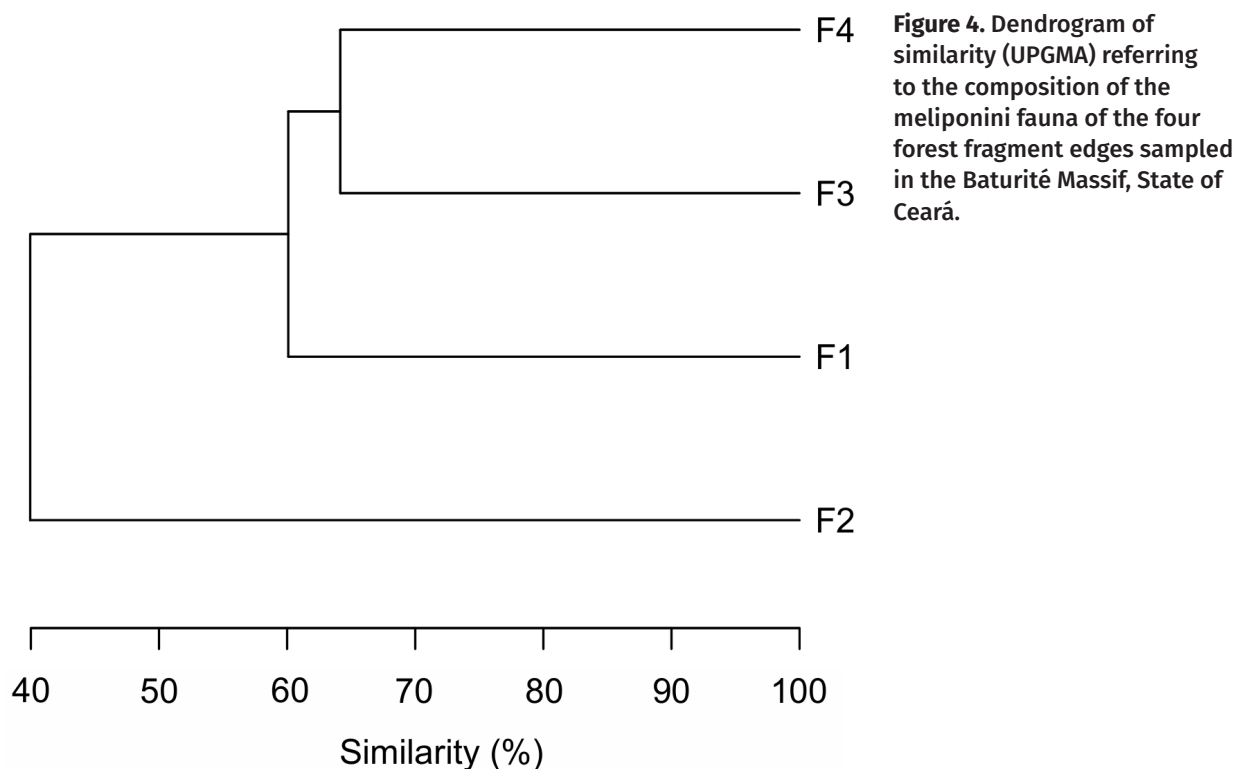
area, Santos et al. (2004) recorded 20 species. Outside the Brazilian territory, in an altitude tropical forest in Costa Rica, Brosi (2009) also recorded 20 species of meliponini bees.

According to Zanella & Martins (2003), in the group Apiformes, the number of species per genus is almost always low, mainly in the caatinga, and this characteristic for the meliponini also does not escape the rule. These authors also argue that the low species richness of stingless bees found in these censuses may be associated with the local extinction of several species, as a consequence of the effects of habitat fragmentation. Some factors may contribute to this situation, among which are: reduced genetic diversity, caused by population reduction (Kerr & Vencovsky 1982); the lack of trophic resources in general, and especially those that “stimulate” the food and storage dynamics of these products by the colonies, as would be the case of plant species with mass flowering (Bawa 1980, 1990, 1994, Ramalho 1998, Monteiro & Ramalho 2010); and the lack of substrate for nesting, especially those related to arboreal

cavities, where most species of meliponini bees establish their colonies (Samejima et al. 2004).

The results of absolute abundance revealed the importance, in order of magnitude, of the species *Trigona spinipes*, *Trigona fulviventris*, *Scaptotrigona* sp. 1, *Trigona fuscipennis*, *Nannotrigona* sp. and *Partamona ailyae*. The dominant group, *T. spinipes* and *T. fulviventris*, is common in the Baturité Massif. The first species has a wide geographical distribution in this mountainous area and the second one occupies only the most humid environments at altitudes generally above 600 m. Both present colonies with large numbers of individuals that are generalists in the use of local trophic resources. In generic groups, such as *Trigona* and *Scaptotrigona*, some species generally present populous colonies that stand out for their ability in food collection and storage procedures. These species therefore have a generalist behavior and are widely distributed in their nesting environments (Roubik 1982, Pacheco Filho et al. 2015).

The activity of *T. spinipes* in flowers of the various types of the Brazilian vegetation and its



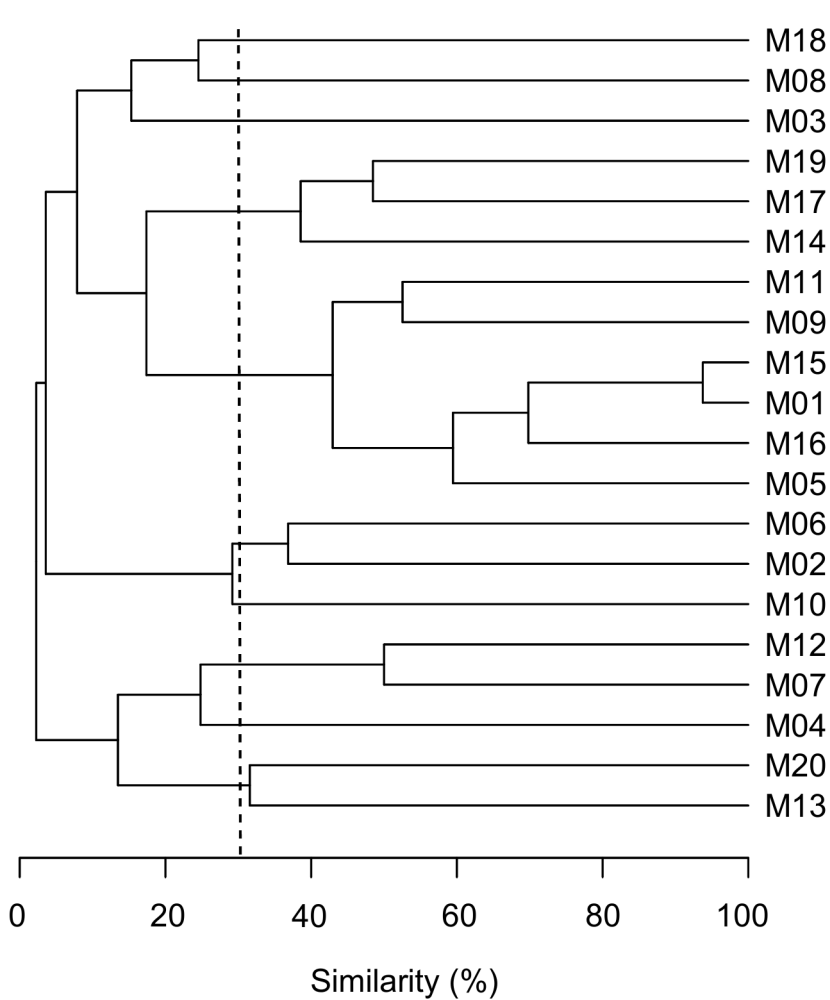
participation as a species of generalist preference for these resources has already been evaluated by authors such as Laroca (1970), Cortopassi-Laurino & Ramalho (1988), Wilms et al. (1996) and Pacheco Filho et al. (2015). As for the abundance, the importance of this species has been observed in bee censuses in ecosystems such as savanna, savannah-steppe, ombrophilous forest and semideciduous seasonal lowland forest (Viana et al. 1997, Lorenzon et al. 2003, Locatelli et al. 2004, Aguiar & Zanella 2005, Viana & Kleinert 2006, Milet-Pinheiro & Schlindwein 2008). Likewise, research with *T. fulviventris* also revealed its generalist habit in the use of food resources and its abundance in more humid environments (Sierra & Pardo 2008, Oliveira et al. 2009, Pacheco Filho et al. 2015).

The conditions of habitat degradation in immediate edges of fragments of various types of vegetation have particular environmental characteristics and were poorly evaluated until now, both in relation to fauna and flora. This fact

has made it difficult, in particular, to investigate bees (Brosi et al. 2008). In this sense, the whole dynamics of biological interactions undergoes deep changes that mainly affect the presence of stingless bees. In particular, this group of Apoidea depends on well-preserved fragments with abundant and seasonal trophic resources, as well as environments with adequate levels of relative humidity (Heithaus 1979, Bierregaard et al. 1992, Murcia 1995, Antonini et al. 2003, Brosi et al. 2008, Brosi 2009).

The similarity between species of bees in these areas can therefore generate different interpretations due to these multiple influences. In this case, the preference that these species have for a given habitat is one of the preponderant factors, although several species have a ample spectrum of occupation in different environments, especially when these are connected by almost imperceptible *continuum* in the geographic space. In this context, the results suggest that the high similarity of the bee





**Figure 5.** Dendrogram of similarity (UPGMA) representing the affinity of the meliponini bee species for the same plant species found in the Baturité Massif, State of Ceará. M01-M20 (meliponini from 01 to 20) see Table I.

fauna between the different fragments studied, according to the environmental parameters listed in Table II, can be a consequence of the high plasticity that these bees present in the occupation of the different local environments and where they use, as source of resources, various plant species. In fact, Meliponini bees were already registered as a group capable of using floral resources of many species of different botanical families (Pacheco Filho et al. 2015).

Several factors are associated with the sharing of floral resources by stingless bees. In this sense, one major factor for the performance

of this group of bees in the foraging processes is the presence of plant species with differentiated flowering strategies, especially those species that show mass flowering (Heithaus 1979, Mantovani & Martins 1988, Ramalho 1998, 2004). A second reference directly includes the trophic habits of these bees, where the generalist feeding behavior is highlighted (Laroca 1970, Roubik 1982, Cortopassi-Laurino & Ramalho 1988, Wilms et al. 1996). Some plant species of the Baturité Massif are classified according to the flowering strategies outlined above, thus standing out for the importance in the supply of food resources to the local Meliponini species (Lima-Verde

et al. 2014, *op cit.*). Among these, *Spermacoce verticillata* (Rubiaceae), *Libidibia ferrea* (Fabaceae), *Serjania lethalis* (Sapindaceae), *Vernonanthura brasiliensis* (Asteraceae), *Cynophalla flexuosa* (Capparaceae), *Senna splendida* (Fabaceae) and *Wedelia scaberrima* (Asteraceae) were highlighted, some of which present the flowering strategies discussed above.

*S. verticillata*, for example, was the species that most attracted bees, 12 (60%) out of the 20 species of meliponini bees, possibly presenting a great adaptive plasticity in the four edge areas (Lima-Verde et al. 2014, *op cit.*). This species is arranged in concentrated patches of individuals as representing, on the whole, an individual with massive flowering. Studies such as Wilms et al. (1996), Gonçalves & Melo (2005) and Viana et al. (2006) refer to this species as one of the resources sought by several species of bees in different ecosystems in Brazil.

## CONCLUSIONS

The record of 20 species of meliponini bees for the Baturité Massif, with some species highly abundant, evidences to some extent the existence of forest fragments and areas of temporary matrix edges with conditions to maintain this rich bee fauna, both biologically and ecologically active.

The results show that the two plant typologies are generally important for the different species of local Meliponini bees, both informing the exclusiveness of a vegetation type for a particular species and relating the use of both environments to individual species. This allows, in a way, the understanding of part of the ecology of this group of bees in this mountain range.

In the current conditions of these remaining forest fragments, their immediate edges are relevant as environments that guarantee, temporally and spatially, complementary food resources for the local meliponini fauna. However, this situation suggests that inside these fragments there is a lack of floral resources, mainly from tree species, which are characterized by attractive blooms for these bees.

Otherwise, as biological indicators, this knowledge helps in the necessary decision-making, when managing these environments as a function of these bees, as well as facilitating the most appropriate management of colonies under a rational exploitation regime by beekeepers.

## REFERENCES

- AGUIAR CML. 2003. Utilização de recursos florais por abelhas (Hymenoptera, Apoidea) em uma área de caatinga (Itatim, Bahia). *Rev Bras Zool* 20(3): 457-467.
- AGUIAR CMI & MARTINS CF. 1997. Abundância relativa, diversidade e fenologia de abelhas (Hymenoptera, Apoidea) na caatinga, São João do Cariri, Paraíba, Brasil. *Iheringia, Ser Zool* 83: 151-163.
- AGUIAR CML & ZANELLA FCV. 2005. Estrutura da comunidade de abelhas (Hymenoptera: Apoidea: Apiformis) de uma área na margem do domínio da caatinga (Itatim, Bahia). *Neotrop Entomol* 34(1): 15-24.
- ANACLETO DA & MARCHINI LC. 2005. Análise faunística de abelhas (Hymenoptera, Apoidea) coletadas no cerrado do estado de São Paulo. *Acta Sci Biol Sci* 27(3): 277-284.
- ANDENA SR, BEGO LR & MECCHI MR. 2005. A comunidade de abelhas (Hymenoptera, Apoidea) de uma área de cerrado (Corumbataí, SP) e suas visitas às flores. *Revi Bras Zool* 7(1): 55-91.
- ANTONINI Y, ACCACIO GM, BRANT A, CABRAL BC, FONTENELLE JCR, NASCIMENTO MT, THOMAZINI APBW & THOMAZINI MJ. 2003. Efeitos da fragmentação sobre a biodiversidade – insetos. In: Rambaldi DM & Oliveira DAS (Eds), *Fragmentação de ecossistemas: causas, efeitos sobre a biodiversidade e recomendações de políticas públicas*, Ministério do Meio Ambiente, Brasília: MMA/SBF, Brasília-DF, p. 239-273.

- BATALHA FILHO H, NUNES LA, PEREIRA DG & WALDSCHMIDT AM. 2007. Inventário da fauna de abelhas (Hymenoptera, Apoidea) em uma área de caatinga da região de Jequié, Bahia. *Biosci J* 23(1): 24-29.
- BAWA KS. 1980. Evolution of dioecy in flowering plants. *Ann Ver Ecol Syst* 11: 15-39.
- BAWA KS. 1990. Plant-pollinator interactions in tropical rainforest. *Annu Ver Ecol Syst* 21: 399-422.
- BAWA KS. 1994. Pollinators of tropical dioecious angiosperms: a reassessment? No, not yet. *Am J Bot* 81: 456-460.
- BIERREGARD RO, LOVEJOY TE, KAPOV V, SANTOS AA & HUTCHINGS RW. 1992. The biological dynamics of tropical rainforest fragments. *Bioscience* 42: 859-866.
- BROSI BJ. 2009. The complex of social stingless bees (Apidae: Meliponini) to tropical deforestation. *For Ecol Manage* 258: 1830-1837.
- BROSI BJ, DAILY GC, SHIH TM, OVIEDO F & DURAN G. 2008. The effects of forest fragmentation on bee communities in tropical country side. *J Appl Ecol* 45: 773-783.
- BROWN JH & LOMOLINO MV. 2006. Biogeografia. Ribeirão Preto: FUNPEC Editora, 691 p.
- CANE JH. 2001. Habitat fragmentation and native bees: a premature verdict? *Conserv Ecol* 5(1): 3.
- CERQUEIRA R, BRANT A, NASCIMENTO MT & PARDINI R. 2003. Fragmentação: alguns conceitos, In: Rambaldi DM & Oliveira DAS (Eds), Fragmentação de ecossistemas: causas, efeitos sobre a biodiversidade e recomendações de políticas públicas, Ministério do Meio Ambiente, Brasília: MMA/SBF, Brasília-DF, p. 23-40.
- CORTOPASSI-LAURINO M & RAMALHO M. 1988. Pollen harvest by africanized *Apis mellifera* and *Trigona spinipes* em São Paulo: botanical and ecological views. *Apidologie* 19: 1-24.
- DUCKE A. 1908. Contribution à la connaissance de la faune hyménoptérologique du Nord-Est du Bresil – II. Hyménoptères récolté dans l'Etat de Ceara en 1908. *Rev Fr Entomol* 27: 57-81.
- DUCKE A. 1911. Contribution à la connaissance de la faune hyménoptérologique du Nord-Est du Bresil – III. Hyménoptères récolté dans l'Etat de Ceara en 1909 et supplements aux deux listes antérieures. *Rev Fr Entomol* 28: 78-122.
- EWERS RM & DIDHAM RK. 2006. Confounding factors in the detection of species responses to habitat fragmentation. *Biol Rev* 81: 117-142.
- FARIA-MUCCI GM, MEL MA & CAMPOS LAO. 2003. A fauna de abelhas (Hymenoptera, Apoidea) e plantas utilizada como fontes de recursos florais, em um ecossistema de campos rupestres em Lavras Novas, Minas Gerais, Brasil. In: Melo GAR & Santos IA (Eds), Apoidea Neotropica – Homenagem aos 90 anos de Jesus Santiago Moure, Criciúma: UNESC Edições, Criciúma-SC, p. 241-256.
- GOMES MAF. 1978. O maciço de Baturité – uma abordagem ecológica. In: Anonymous (Eds), Anais do III Encontro Nacional de Geógrafos, Fortaleza. Fortaleza: AGB/UFC, p. 39-59.
- GONÇALVES RB & MELO GAR. 2005. A comunidade de abelhas (Hymenoptera, Apidae) em uma área restrita de campo natural no Parque Estadual de Vila Velha, Paraná: diversidade, fenologia e fontes florais de alimento. *Rev Bras Entomol* 49(4): 557-571.
- GONÇALVES RB, MELO GAR & AGUIAR AJC. 2009. A assembleia de abelhas (Hymenoptera, Apidae) de uma área de campos naturais do Parque Estadual de Vila Velha, Paraná e comparações com áreas de campos e cerrados. *Pap Avulsos Zool (São Paulo)* 49(14): 163-181.
- GOTELLI NJ & COLWELL RK. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement comparison of species richness. *Ecol Lett* 4: 379-391.
- HEITHAUS ER. 1979. Community structure of neotropical flower visiting bees and wasps: diversity and phenology. *Ecology (N Y)* 60: 675-691.
- KERR WE & VENCOSKY R. 1982. Melhoramento genético em abelhas I. Efeito do número de colônias sobre o melhoramento. *Brazil J Genet* 5: 279-285.
- KRUG C & ALVES-DOS-SANTOS I. 2008. O uso de diferentes métodos para amostragem da fauna de abelhas (Hymenoptera: Apoidea), um estudo em Floresta Ombrófila Mista em Santa Catarina. *Neotrop Entomol* 37(3): 265-278.
- IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. 2012. Manual técnico da vegetação brasileira: sistema fitogeográfico, inventário das formações florestais campestres, técnicas e manejo das coleções botânicas, procedimentos para mapeamentos, 2ª ed., Rio de Janeiro: CDDI, 276 p.
- LAROCA S. 1970. Contribuição para o conhecimento das relações entre abelhas e flores: coleta de pólen das anteras tubulares de certas Melastomataceae. *Rev Flo* 2: 69-74.
- LIMA-VERDE LW, LOIOLA MIB & FREITAS BM. 2014. Angiosperm flora used by meliponine guilds (Apidae, Meliponina)

occurring at rainforest edges in the state of Ceará, Brazil. *An Acad Bras Cienc* 86: 1395-1409.

LOCATELLI E, MACHADO ICS & MEDEIROS P. 2004. Riqueza de abelhas e a flora apícola em um fragmento da mata serrana (Brejo de Altitude) em Pernambuco, Nordeste do Brasil. In: Pôrto KC, Cabral JJP & Tabarelli M (Eds), Brejos de altitude em Pernambuco e Paraíba – História Natural, Ecologia e Conservação, Ministério do Meio Ambiente, Brasília: MMA/CID Ambiental, Brasília-DF, p. 153-177.

LÓPEZ-BARRERA F. 2004. Estructura y función en bordes de bosques. *Ecosistemas* 13(1): 67-77.

LORENZON MCA, MATRANGOLO CAR & SCHOEREDER JH. 2003. Flora visitada pelas abelhas eussociais (Hymenoptera, Apidae) na serra da Capivara, em caatinga do sul do Piauí. *Neotrop Entomol* 32(1): 27-36.

MACIEL LA, SILES MFR & BITENCOURT MD. 2011. Alterações na vegetação herbácea de floresta ombrófila densa decorrentes do uso em uma trilha turística na Serra do Mar em São Paulo, Brasil. *Acta Bot Bras* 25(3): 628-632.

MAGURRAN AE. 2011. Medindo a Diversidade Biológica. Curitiba: UFPR, 261 p.

MANTOVANI W & MARTINS FR. 1988. Variações fenológicas das espécies do cerrado da Reserva Biológica de Mogi Guaçu, estado de São Paulo. *Rev Bras Bot* 11: 101-112.

MARTINS CF. 1994. Comunidade de abelhas (Hymenoptera, Apoidea) da caatinga e do cerrado com elementos de campo rupestre do estado da Bahia, Brasil. *Rev Nord Biol* 9(2): 225-257.

MICHENER CD. 2007. The bees of the world. Washington DC: The John Hopkins University Press, 970 p.

MILET-PINHEIRO P & SCHLINDWEIN C. 2008. Comunidade de abelhas (Hymenoptera, Apoidea) e plantas em uma área do agreste pernambucano, Brasil. *Rev Bras Entomol* 52(4): 625-636.

MONTEIRO D & RAMALHO M. 2010. Abelhas generalistas (Meliponina) e o sucesso reprodutivo de *Stryphnodendron pulcherrimum* (Fabales: Mimosaceae) com florada em massa na Mata Atlântica, BA. *Neotrop Entomol* 39(4): 519-526.

MURCIA C. 1995. Edge effects in fragmented forests: implication for conservation. *Trends Ecol Evol* 10: 58-62.

NOGUEIRA-FERREIRA FH & AUGUSTO SC. 2007. Amplitude de nicho e similaridade no uso de recursos florais por abelhas eussociais em uma área de cerrado. *Biosci J* 23(1): 45-51.

OLIVEIRA FPM, ABSY ML & MIRANDA IS. 2009. Recurso polínico coletado por abelhas sem ferrão (Apidae, Meliponinae)

em um fragmento de floresta na região de Manaus – Amazonas. *Acta Amazonica* 39(3): 505-518.

PACHECO FILHO AJS, VEROLA CF, LIMA-VERDE LW & FREITAS BM. 2015. Bee-flower association in the Neotropics: implications to bee conservation and plant pollination. *Apidologie* 46: 530-541.

RAMALHO M. 1998. Os meliponíneos na floresta atlântica: efeitos potenciais da pressão de forrageio sobre sistemas reprodutivos de árvores com floradas maciças. In: Anais do III Encontro sobre Abelhas, Ribeirão Preto. Ribeirão Preto: USP, p. 75-81.

RAMALHO M. 2004. Stingless bees and mass flowering trees in the canopy of Atlantic Forest: a tight relationship. *Acta Bot Bras* 18(1): 37-47.

ROUBIK DW. 1982. Ecological impact of africanized honeybees on native neotropical pollinators. In: Jaisson P (Eds), Social insects in the tropics, Paris: Université Paris- Nord, Paris, France, p. 233-247.

SAKAGAMI SF, LAROCA S & MOURE JS. 1967. Wild bees biocenotics in São José dos Pinhais- PR, South Brazil – preliminary report. *J Fac Sci Hokkaido Univ (Ser 6 Zool)* 19: 253-291.

SAMEJIMA H, MARZUKI M, NAGAMITSU T & NAKASIZUKA T. 2004. The effects of human disturbance on a stingless bees community in a tropical rainforest. *Biol Conserv* 120: 577-587.

SANTOS FM, CARVALHO CAL & SILVA RF. 2004. Diversidade de abelhas (Hymenoptera: Apoidea) em uma área de transição Cerrado-Amazônia. *Acta Amazonica* 34(2): 319-328.

SCARIOT A, FREITAS SR, NETO EM, NASCIMENTO MT, OLIVEIRA LC, SANAIOTTI T, SEVILHA AC & VILLELA DM. 2003. Efeitos da fragmentação sobre a biodiversidade-vegetação e flora. In: Rambaldi DM & Oliveira DAS (Eds), Fragmentação de ecossistemas – causas, efeitos sobre a biodiversidade e recomendações de políticas públicas, Ministério do Meio Ambiente, Brasília: MMA/SBF, Brasília-DF, p. 103-123.

SCHNEIDER MPC ET AL. 2003. Efeitos da fragmentação sobre a biodiversidade – genética de populações naturais. In: Rambaldi DM & Oliveira DAS (Eds), Fragmentação de ecossistemas – causas, efeitos sobre a biodiversidade e recomendações de políticas públicas, Ministério do Meio Ambiente, Brasília: MMA/SBF, Brasília-DF, p. 297-315.

SIERRA CIA & PARDO AHS. 2008. Abejas visitantes de *Aspilia tenella* (Kunth) S. F. Blake (Asteraceae): comportamiento de forrajeo y cargas polínicas. *Rev Fac Nac Agr Medellín* 61(2): 4576-4587.

SILVEIRA FA, MELO GAR & ALMEIDA EAB. 2002. Abelhas brasileiras – sistemática e identificação. Belo Horizonte: Fundação Araucária, 253 p.

SIQUEIRA ENL, BARTELLI BF, NASCIMENTO ART & NOGUEIRA-FERREIRA FH. 2012. Diversity and Nesting Substrates of Stingless Bees (Hymenoptera, Meliponina) in a Forest Remnant. *Psyche* 2012: 1-9.

SOUZA MJN. 1997. Geomorfologia. In: IPLANCE (Eds), Fortaleza: Atlas do Ceará, Fortaleza-CE, p. 18-19.

SOUZA MJN, SOARES AML, CARVALHO GMS, SOARES ZML & CRUZ MLB. 1994. Geossistemas e potencialidades dos recursos naturais – serra de Baturité e áreas sertanejas periféricas (Ceará). Fortaleza: FNMA/UFC/FUNCEME, Fortaleza-CE, 102 p.

VIANA BF. 1999. A comunidade de abelhas (Hymenoptera: Apoidea) das dunas interiores do rio São Francisco, Bahia, Brasil. *An Soc Entomol Bras* 28(4): 635-645.

VIANA BF & KLEINERT AMP. 2006. Structure of bee-flower in the coastal sand dune of Abaeté, northeastern Brazil. *Rev Bras Entomol* 50(1): 53-63.

VIANA BF, KLEINERT AMP & IMPERATRIZ-FONSECA VL. 1997. Abundance and flower visits of bees in cerrado of Bahia, tropical Brazil. *Stud Neotrop Fauna Environ* 32(4): 212-219.

VIANA BF, SILVA FO & KLEINERT AMP. 2006. A flora apícola de uma área restrita de dunas litorâneas, Abaeté, Salvador, Bahia. *Rev Bras Bot* 29(1): 13-25.

VIANA VM & PINHEIRO AFV. 1998. Conservação da biodiversidade em fragmentos florestais. *Série Téc IPEF* 12(32): 25-42.

VIANA VM, TABANEZ AJA & MARTINEZ JLA. 1992. Restauração e manejo de fragmentos florestais. In: Anais do II Congresso Nacional sobre Essências Nativas- Conservação da biodiversidade, São Paulo. São Paulo: Instituto Florestal, p. 400-406.

WILMS W, IMPERATRIZ-FONSECA VL & ENGELS W. 1996. Resource partitioning between highly eusocial bees and possible impact of the introduced africanized honey bee on native stingless bees in the brazilian atlantic rainforest. *Stud Neotrop Fauna Environ* 31: 137-151.

ZANELLA FCV. 2000. The bees of the Caatinga (Hymenoptera, Apoidea, Apiformes): a species list and comparative notes regarding their distribution. *Apidologie* 31: 579-592.

ZANELLA FCV. 2003. Abelhas da Estação Ecológica do Seridó (Serra Negra, RN): aportes ao conhecimento da diversidade, abundância e distribuição espacial das espécies da caatinga, In: Melo GAR & Santos IA (Eds), Apoidea Neotropical – Homenagem aos 90 anos de Jesus

Santiago Moure, Criciúma: UNESC Edições, Criciúma-SC, p. 231-240.

ZANELLA FCV & MARTINS CF. 2003. Abelhas da caatinga: biogeografia, ecologia e conservação, In: Leal IR, Tabarelli M & Silva JMC (Eds), Ecologia e conservação da caatinga, Recife: Editora Universitária (UFPE), Recife-PE, p. 75-134.

#### How to cite

LIMA-VERDE LW, PACHECO FILHO AJS & FREITAS BM. 2020. Stingless bee (Apidae, Meliponini) guilds occurring in the immediate edges of forest fragments of the Baturité Massif, State of Ceará, Brazil. *An Acad Bras Cienc* 92: e20181303. DOI 10.1590/0001-3765202020181303.

*Manuscript received on December 11, 2018;  
accepted for publication on January 31, 2019*

#### LUIZ WILSON LIMA-VERDE<sup>1</sup>

<https://orcid.org/0000-0002-6908-1692>

#### ALÍPIO JOSÉ S. PACHECO FILHO<sup>1</sup>

<https://orcid.org/0000-0003-2865-2142>

#### BRENO M. FREITAS<sup>2</sup>

<https://orcid.org/0000-0002-9932-2207>

<sup>1</sup>Universidade Federal do Ceará, Departamento de Biologia, Bloco 906, Av. Humberto Monte s/n, Campus do Pici, 60455-760 Fortaleza, CE, Brazil

<sup>2</sup>Programa de Pós-Graduação em Zootecnia, Universidade Federal do Ceará, Bloco 808, Av. Humberto Monte s/n, Campus do Pici, 60021-970 Fortaleza, CE, Brazil

Correspondence to: **Luiz Wilson Lima Verde**

E-mail: [limaverdelw@yahoo.com.br](mailto:limaverdelw@yahoo.com.br)

#### Author contributions

LWLV and BMF prepared the study design and performer data collection, AJSF carried out the data analysis and the three authors wrote and reviewed the manuscript.

