General Entomology

Checklist of bee species (Hymenoptera: Apoidea: Anthophila) in the urban areas of Cerrado biome in Barreiras, Bahia, Brazil

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Abstract. In a global context, few studies have investigated the effects of urbanization on apifauna, as well as the importance of green areas in urban centers for the conservation of local bee fauna. In Brazil, this line of research is still quite recent, with most studies carried out in regions with a predominance of the Atlantic Rainforest phytogeographic domain. For the Brazilian state of Bahia, such research is still scarce and, especially, if we consider the large territorial dimension that this state denotes. In the area that covers the Cerrado, few studies have been carried out that inventory the urban apifauna. In this paper we present a list of bee species recorded in urban areas of the city of Barreiras, Bahia, Brazil, which represent the first apifauna inventory in the Western region of Bahia. Specimens were collected fortnightly from November 2019 to April 2020, using two sampling methods: colored water traps (ARCAS/pantraps) and entomological net. A total of 749 specimens were sampled, distributed in four families, 18 tribes, 29 genera, and 45 species. A total of 369 (49.3%) specimens were collected using the entomological net and 380 specimens (50.7%) by using the ARCAS. Our results showed that the area with the highest level of urbanization had bioindicator species of degraded environments, which benefit from urbanization, and despite the urban growth, the fragments found in the matrix can serve as a refuge for bee fauna, as long as they are well planned.

Keywords: ARCAS; Biodiversity; Inventory; Neotropical; Urban fauna.

O ver time, bees have developed an intrinsic relationship with the phanerogam flora, from which they obtain the resources necessary for the survival of their populations (e.g., nectar, oils, resins, and pollen). In addition to obtaining shelter from predators and environmental weather. The main ecological importance of these insects is the performance of cross-pollination, thus, ensuring the reproduction of angiosperms, maintenance of gene flow, and plant genetic diversity (Aizen et al. 2009; Sántagi et al. 2009; dos Santos et al. 2020; Pires & Maués 2021).

Despite the accumulated knowledge about the importance of bees and other insects as pollinators (Klein et al. 2007; Kremen et al. 2007; Aizen et al. 2009; Kwapong et al. 2010; Potts et al. 2010, 2016), these animals are enduring strong environmental pressure, especially due to the loss of their habitats and various other misuses of the soil, which poses a serious threat (Beringer et al. 2019; Sánchez-Bayo & Wyckhuys 2019). The combination of several factors contribute to the threat that bees face, causing progressive decline. These factors include inadequate management of soil, climatic variations, the advance of agriculture, excessive use of agrochemicals, indiscriminately and/or without criteria to protect pollinators, the action of pathogens and habitat destruction by deforestation, and fires and urbanization intensified by population increase, causing the loss of large forest areas, places that previously served as shelter for these pollinators (Cham et al. 2019; Sánchez-Bayo & Wyckhuys 2019).

The process of urbanization, as one of the many anthropomorphic activities, changes the landscape drastically and irreversibly, increasing the proportion of buildings and decreasing areas of forest remnants (Fortel et al. 2014). Urbanization has a tendency to modify the space and thus threaten biodiversity and the ecosystem services it provides (Fortel et al. 2014; Aráujo et al. 2016; dos Santos et al. 2020).

In a global context, few studies have investigated the effects of urbanization on apifauna, as well as the importance of green areas in urban centers for the conservation of local bee fauna (Grandolfo et al. 2013; Aráujo et al. 2016; Cardoso & Gonçalves 2018; de Santos & Chacoff 2020). In Brazil, this line of research is still quite recent, with most studies carried out in regions with a predominance of the Atlantic Rainforest phytogeographic domain (Aidar et al. 2013; Aráujo et al. 2016; Cardoso & Gonçalves 2018; Santana & Oliveira 2010). For the State of Bahia, such research is still scarce and, especially, if we consider the large territorial dimension that this state denotes, which encompasses the convergence of three phytogeographic domains (Atlantic Rainforest, Caatinga, and Cerrado). In the area that covers the Cerrado, few studies have been carried out that inventory the urban apifauna (Antonini et al. 2006; Sántagi et al. 2009; Aidar et al. 2013; Grandolfo et al. 2013; Leão-Gomes & Nemésio 2020). Despite the great anthropomorphic pressure exerted by agribusiness
and considering the real geographic gap in relation to its biodiversity, it is still possible to find fragments of natural vegetation that can play a key role in maintaining regional biodiversity in Cerrado (Joner 2012; Grandolfo et al. 2013).

It is known that urbanization causes the loss of natural habitats, as well as promoting the reduction of food sources, nesting sites, number of floral visitors and, therefore, of pollinators. To minimize these impacts on fauna and flora, as well as promoting human well-being, urban environments must provide the configuration of green patches within the urban matrix. This needs to be done in order to conserve the biodiversity of the pollinators, as well as allowing the mobility of individuals between the fragments of forest areas in the urban matrix and adjacent natural fragments (Martins et al. 2017; De Santis & Chacof 2020).

With the increase in urbanization, more studies are needed to understand the dynamics of the bee communities that inhabit this perimeter so that we can contribute to the preservation and/or conservation of Brazilian apifauna (Sirghi et al. 2015). Given this context cited above, the purpose of this paper is to know the species of bees residing in the urban perimeter of Barreiras, Bahia, Brazil.

**MATERIAL AND METHODS**

The study was carried out in the municipality of Barreiras, Bahia, located in the extreme west of Bahia state, Brazil, at an altitude of 454 m. For the development of the research, two sampling points were chosen within the municipality to carry out the collections which have typical Cerrado vegetation, and subhumid tropical climate according to the Köppen classification (Pina et al. 2016). The first collection point was the Exhibitions Park Engenheiro Geraldo Rocha (Area I) (12°08'34'' S; 45°00'10'' W) with a total area of 44 ha (Sematur 2020), and the second study site was at Mimo Mountain range (Area II) (12°08'48" S; 44°57'40" W) (Figure 1), with a total area of 5.900 ha, which were equidistant at approximately 4.5 km.

The two collection points are within the limits of the city's urban perimeter and have different use of occupations. Area I, despite being an environmental protection area, has undergone several changes over time in its natural vegetation with some unsuccessful recovery attempts (Sematur 2020). Area II is in a better state of conservation than the first area, but it suffers from fires during dry periods, which changes the original configuration of the flora.

The bees were collected fortnightly, from November 2019 to April 2020, in climatic conditions suitable for bee activity (minimum of 15 °C, light wind and no rain).

Two sampling methods were used: I) actively using entomological nets along the established area, and II) through passive collection using Colored Water Traps (ARCAs or pantraps) in the following colors: blue, white, and yellow (Santana & Oliveira 2010; Moreira et al. 2016). Having a grand total of 24 collections over the sampling period.

Afterwards, the bees were sorted, mounted on entomological pins, and sent to the Laboratory of Bionomy, Biogeography and Insect Systematics (BIOSIS-UFBA), located in the Institute of Biology, Universidade Federal da Bahia (IBIO-UFBA), where the insects were identified by a taxonomist (FFO) and later deposited in the BIOSIS reference collection. The classification used in this work follows the proposal by Michener (2007), with small modifications according to Moure et al. (2012) (e.g., Oxaeini).

**RESULTS AND DISCUSSION**

The bee community was represented by 45 species, 29 genera, 18 tribes, and four families, with a total of 749 individuals sampled. A total of 369 (49.3%) specimens were collected using the entomological nets and 380 specimens (50.7%) by using the ARCAs (Table 1).

Among the five families with occurrence registered in Brazil, four of them were sampled in the present study, namely Andrenidae, Apidae, Halictidae, and Megachilidae. In Andrenidae, two tribes were found: Calliopsini and Oxaeini. For Apidae, a larger number of tribes were present: Apini, Bombini, Centridini, Ceratinini, Emphorini, Eucricidiini, Eucerini, Euglossini, Exomalopsini, Meliponini,
Table 1. List of bee species, collection methods and number of individuals sampled in two areas in the municipality of Barreiras, Bahia, Brazil.

| TÁXON | Area I Method | Area II Method | TOTAL | RA* (%) |
|-------|---------------|----------------|-------|---------|
|       | Passive       | Active         | Passive | Active |       |
| Andrenidae |               |                |        |         |       |
| Calliopsini |               |                |        |         |       |
| Acamptopoeum prinii (Holmberg) | - | - | - | 1 | 1 | 0.13 |
| Callonychium (Callonychium) brasiliense (Ducke) | 1 | - | - | - | 1 | 0.13 |
| Oxaeini |               |                |        |         |       |
| Oxaea flavescens Klug | - | - | - | 1 | 1 | 0.13 |
| Apidae |               |                |        |         |       |
| Apini |               |                |        |         |       |
| Apis mellifera Linnaeus | 21 | 120 | 78 | 99 | 318 | 42.47 |
| Bombini |               |                |        |         |       |
| Bombus (Thoracobombus) brevivillus Franklin | - | 1 | - | - | 1 | 0.13 |
| Centridini |               |                |        |         |       |
| Centris (Centris) aenea Lepeletier | - | - | - | 3 | 3 | 0.40 |
| Centris (Hemisiella) tarsata Smith | - | - | - | 1 | 1 | 0.13 |
| Centris (Hemisiella) trigonoides Lepeletier | - | - | - | 2 | 2 | 0.27 |
| Centris (Melacentris) obsoleta Lepeletier | - | 1 | - | - | 1 | 0.3 |
| Ceratinini |               |                |        |         |       |
| Ceratina (Crewella) sp. 1 | 2 | 2 | - | - | 4 | 0.53 |
| Emphorini |               |                |        |         |       |
| Ancyloscelis aff. apiformis (Fabricius) | 20 | - | - | - | 20 | 2.67 |
| Diadasina riparia (Ducke) | 15 | 4 | - | 1 | 20 | 2.67 |
| Melitoma segmentaria (Fabricius) | 7 | 1 | - | - | 8 | 1.07 |
| Melitoma sp. 1 | 1 | - | - | - | 1 | 0.13 |
| Melitomella murihirta (Cockerell) | 75 | 1 | - | - | 76 | 10.16 |
| Ptithrix plumata Smith | 1 | - | - | - | 1 | 0.13 |
| Eucerini |               |                |        |         |       |
| Mesoplia sp. 1 | 1 | - | - | - | 1 | 0.13 |
| Euglossini |               |                |        |         |       |
| Eulaema (Apeulaema) nigrita Lepeletier | - | 1 | - | 1 | 2 | 0.27 |
| Exomalopsis (Exomalopsis) auropilosa Spinola | - | - | 1 | 1 | 2 | 0.27 |
| Meliponini |               |                |        |         |       |
| Frieseomelitta varia (Lepeletier) | - | - | 3 | 14 | 17 | 2.27 |
| Geotrigna mombuca (Smith) | - | - | - | 4 | 4 | 0.53 |
| Oxytrigna sp. 1 | 1 | 2 | 6 | 5 | 14 | 1.88 |
| Scaptotrigona aff. deplis (Moure) | - | 3 | - | - | 3 | 0.40 |
| Scaptotrigona postica (Latreille) | 4 | 3 | 12 | 1 | 20 | 2.67 |
| Scaptotrigona sp. 1 | - | 2 | - | - | 2 | 0.27 |
| Tetragonisca angustula (Latreille) | 1 | 6 | 2 | 7 | 16 | 2.14 |
| Trigona sp. 1 | 8 | 8 | 13 | 28 | 57 | 7.62 |
| Trigona sp. 2 | - | - | 2 | 5 | 7 | 0.93 |
| Trigona spinipes (Fabricius) | 17 | 5 | 39 | 19 | 80 | 10.69 |
| Tapinotaspidini |               |                |        |         |       |
| Paratetrapedia sp. 1 | - | - | 1 | - | 1 | 0.13 |
| Xylocopini |               |                |        |         |       |

*to be continued*
The findings of this research reveal that urban growth is a serious threat to biodiversity, impacting the loss of habitats and reducing the number of pollinators, which can generate long-term effects such as increased temperature, soil compaction, and soil and air pollution (Geslin et al. 2016). However, these effects are felt by bees in different ways depending on the group, where some can be strongly benefited by the effects of urbanization, to the detriment of others (e.g., Fortel et al. 2014; Sirohi et al. 2015; Martins et al. 2017; Normandin et al. 2017).

Apidae is the most present family in several studies, both nationally and internationally. It is coherent to highlight it as the most represented in this study as well, what corresponds to the normal biodiversity of this family (Santiago et al. 2009; Martins et al. 2013; Fortel et al. 2014; Sirohi et al. 2015; Normandin et al. 2017; Desantis & Chacoff 2020).

The sampling of the Euglossini tribe was not satisfactory compared to other studies performed in Brazil. Only two individuals were collected (Table 1), possibly because the method of collection using scent baits that commonly attract males from this tribe was not used, which justifies its low representativeness in the present study (Grandolfo et al. 2013). As for the habits of bees, a greater richness of solitary species was found (approximately 73%), reinforcing the scientific findings of studies carried out around the world (e.g., Normandin et al. 2017; De Santis & Chacoff 2020). However, more richness is expected for solitary bees, as around 85% of the bee fauna corresponds to solitary bees (Batra 1984).

As for the Meliponini tribe, with social habits, greater abundance was recorded for the place with the lowest degree of urbanization, not corroborating the findings of Araújo et al. (2016) for urban areas in Minas Gerais (Atlantic Rainforest area). Most of the work on urban apifauna inventories has focused its efforts on the Meliponini tribe due to its high adaptability to areas with intermediate and high degrees of anthropization (Aidar et al. 2013; Araújo et al. 2016; de Araújo & Witt 2020).

The use of more than one sampling method together is indicated by the literature for a more complete sampling, enabling the sampling of rarer species or species that are difficult to collect with an entomological net (Sakagami et al. 1967; Krug & Alves-dos-Santos 2008; Santana & Oliveira 2010; Têixeira 2012). The use of the entomological net in synergy with the ARCA is already a routine methodology in apifauna inventories, a methodology also used for the present study (Fortel et al. 2014; Sirohi et al. 2015; Normandin et al. 2017), although the ARCA are more efficient in collecting small to medium sized bees, which have greater difficulty escaping the trap. The use of ARCA has gained notoriety for the inventory of bee fauna in Brazil, but for the Cerrado, specifically for the western region of Bahia, there is still no record of inventories using this type of trap (Santana & Oliveira 2010; Moreira et al. 2016).
The effect of urbanization can generate negative impacts leading to the loss of natural habitats, as well as the reduction of food sources and nesting sites, so it is important to have urban planning in order to mitigate these effects (Martins et al. 2017; De Santis & Chacoff 2020). Thus, as noted by Fortel et al. (2014) and Araújo et al. (2016), the place with the highest level of urbanization was characterized by less biodiversity.

Bearing in mind the configuration and characteristics of urban spaces, the overlapping of permeable and impermeable areas, decrease in the supply of foraging resources, and habitat fragmentation subject bee populations to anthropogenic pressure, what together corresponds the serious consequences generated by urbanization. Urban centers can serve as a refuge for certain groups of pollinators, disfavoring species that nest in the soil and favoring those that nest in pre-existing cavities, as is the case of Euolaema (Apuleaema) nigrita Lepeletier. In Fortel et al. (2014), which used the same methodology we adopted (ARCAs and entomological nets), and in Cardoso & Gonçalves (2018) and Nelson et al. (2021) which used only one of the methods, being the entomological nets and ARCA, indicated different bee species can function as bioindicators of disturbed areas, as observed also for Euolaema (Apuleaema) nigrita by Grandolfo et al. (2013). However, in the present study, only two females of Euolaema (Apuleaema) nigrita were sampled (Table 1), despite the majority of species of this tribe have the characteristic of flying long distances and being widely distributed in the Americas from the south of the United States of America (Texas) to Argentina, with greater diversity in the Neotropical region (Michener 2007; Mourê et al. 2012).

The Halictidae bees also has a wide distribution worldwide, having different levels of sociability and collected in the urban areas of South America, North America, Canada, and France (Santiago et al. 2009; Martins et al. 2013; Fortel et al. 2014; Normandin et al. 2017; De Santis & Chacoff 2020). This family was poorly represented in the present study, with few specimens from the Augochlorini and Halictini tribes. In our case, the occurrence of these tribes has been related to more preserved habitats, even in studies related to the effects of anthropogenic pressure, what together corresponds the first step in the construction of an instrument for understanding the urban bee fauna for the far west of Bahia, another gap identified during the review of literature.

The results showed that, despite the urban growth, the fragments found in the matrix can serve as a refuge for bee fauna, as long as they are well planned. Our results support research in the field of urban bee ecology in Cerrado, filling a gap in knowledge, which may be the first step in the construction of an instrument for understanding the urban bee fauna for the far west of Bahia, another gap identified during the review of literature.

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REFERENCES

Aidar, IF, AOR Santos, BF Bartelli, GA Martins & FH Nogueira-Ferreira, 2013. Nesting ecology of stingless bees (Hymenoptera, Meliponina) in urban areas: the importance of afforestation. Bioscience Journal, 29: 1361-1369.

Aizen, MA, LA Garibaldi, SA Cunningham & AM Klein, 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. Annals of Botany, 103: 1579-1588. DOI: https://doi.org/10.1093/aob/mcp076

Antonini, Y, RG Costa & RP Martins, 2006. Floral preferences of a neotropical stingless bee Melipona quadrifasciata Lepeletier (Apidae: Meliponina) in an urban forest fragment. Brazilian Journal of Biology, 66: 463-471. DOI: https://doi.org/10.1590/S1519-69842006000300012

Araújo, GJ, Y Antonini, LS Silva & GM Faria-Mucci, 2016. Onde os mais adaptados permanecem: comunidade de abelhas sem ferrão (Hymenoptera: Apidae, Meliponini) em áreas urbanas do município de Ubá, Minas Gerais, Brasil. EntomoBrasilis, 9: 175-179. DOI: https://doi.org/10.12741/embrasilis.v9i9.640

Batra, SW, 1984. Solitary bees. Scientific American, 250: 120-127. DOI: https://doi.org/10.1038/scientificamerican0284-120

Beringer, J, FL Maciel & FF Tramontina, 2019. O declínio populacional das abelhas: causas, potenciais soluções e perspectivas futuras. Revista Eletrônica Científica Da UERGS, 5: 18-27. DOI: https://doi.org/10.21674/2448-0479.51.18-27

Cardoso, MC & RB Gonçalves, 2018. Reduction by half: the impact on bees of 34 years of urbanization. Urban Ecosystems, 21: 943-949. DOI: https://doi.org/10.1007/...
pollinator turnover and increasing diversity associated with urban habitats. Urban Ecosystems, 20: 1359-1371. DOI: https://doi.org/10.1007/s11252-017-0688-8

Michener, CD, 2007. The Bees of the World. 2nd. Ed. Baltimore: Johns Hopkins University Press, Baltimore.

Moreira, EF, RL da S Santos, UL Penna, C Angel-Coca, FF de Oliveira & BF Viana, 2016. Are pan traps colors complementary to sample community of potential pollinator insects? Journal of Insect Conservation, 20: 583-596. DOI: https://doi.org/10.1007/s10841-016-9899-x

Moure, JS, D Urban & GAR Melo, 2012. Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region - online version. Available in: <http://www.moure.cria.org.br/catalogue> [Access: 08.1.2021].

Nelson, CJ, CM Frost & SE Nielsen, 2021. Narrow anthropogenic linear corridors increase the abundance, diversity, and movement of bees in boreal forests. Forest Ecology and Management, 489: 1-13. DOI: https://doi.org/10.1016/j.foreco.2021.119044

Normandin, É, NJ Vereecken, CM Buddle & V Fournier, 2017. Taxonomic and functional trait diversity of wild bees in different urban settings. PeerJ, 5: 3-35 DOI: https://doi.org/10.7717/peerj.3051

Pina, NVM, DH Costa & GB dos Santos, 2016. Geomorphological characterization and anthropic occupation at Serra do Mimo slope in the district of Morada do Laú, Barreiras city - Bahia State. Caminhos de Geografia, 17: 197-210.

Pires, CSS & MM Maués, 2020. Insect Pollinators, Major Threats and Mitigation Measures. Neotropical Entomology, 49: 469-471. DOI: https://doi.org/10.1007/s13744-020-00805-3

Potts, SG, JC Biesmeijer, C Kremen, P Neumann & WE Kunin, 2010. Global pollinator declines: trends, impacts and drivers. Trends in ecology & Evolution, 25: 345-353. DOI: https://doi.org/10.1016/j.tree.2010.01.007

Potts, SG, V Imperatriz-Fonseca, HT Ngo, MA Aizen, JC Biesmeijer, TD Breeze, LV Dicks, LA Garibaldi, R Hill, J Settele & AJ Vanbergen, 2016. Safeguarding pollinators and their values to human well-being. Nature, 540: 220-229. DOI: https://doi.org/10.1038/nature20588

Sakagami, SF, S Carocho & JS Moure, 1967. Wild Bee Biocenotics in São José dos Pinhais (PR), South Brazil.: Preliminary Report (With 3 Text-figures and 7 Tables). Journal of the Faculty of Science, Hokkaido University Series VI. Zoology, 16: 253-291.

Sánchez-Bayo, F & KAG Wyckhuys, 2019. Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232: 8-27. DOI: https://doi.org/10.1016/j.biocon.2019.01.020

Santana, ÁVC & FF de Oliveira, 2010. Inventário das Espécies de Abelhas (Hymenoptera, Apoidea) do Campus da UFBA (Ondina), Salvador, BA: Dados Preliminares III. Cândomdb Revista Virtual, 6: 28-51.

Santiago, LR, RM Brito, TMVL Muniz, FF de Oliveira & FDO Francisco, 2009. The bee fauna from Parque Municipal da Cachoeirinha (Iporã, Goiás state, Brazil). Biota Neotropica, 9: 393-397. DOI: https://doi.org/10.1590/S1676-06032009000300034

SEMATUR (Secretaria Municipal de Meio Ambiente e Turismo de Barreiras), 2020. Estudo Final para Proposta de Implantação do Parque Municipal Natural de Barreiras-BA. Bahia, Barreiras. Relatório. Available in: <https://barreiras.ba.gov.br/wp-content/uploads/2020/10/estudo-final-parque-municipal-atualizado-29-10-20.pdf> [Access: 22.iv.2021].

Sirohi, MH, J Jackson, M Edwards & J Ollerton, 2015. Diversity and abundance of solitary and primitively eusocial bees in an urban centre: a case study from Northampton (England). Journal of Insect Conservation, 19: 487-500. DOI: https://doi.org/10.1007/s10841-015-9769-2
Teixeira, FM, 2012. Técnicas de captura de Hymenoptera (Insecta). Revista Vértices, 14: 169-198. DOI: https://doi.org/10.19180/1809-2667.v14n12012p169-198