Sociobiology 66(2): 381-388 (June, 2019) DOI: 10.13102/sociobiology.v66i2.4303

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - WASPS

Occurrence and nesting behavior of social wasps in an anthropized environment

RC da Silva, AS Prato, DS Assis, FS Nascimento

Universidade de São Paulo (USP), Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Departamento de Biologia, Ribeirão Preto-SP, Brazil

Article History

Edited by
Marcel Hermes, UFLA, Brazil
Received 03 December 2018
Initial acceptance 26 February 2019
Final acceptance 29 March 2019
Publication date 20 August 2019

Keywords
Synanthropism; Biodiversity of wasps; Polistinae wasps; Nesting substrate.

Corresponding author
Rafael Carvalho da Silva
Universidade de São Paulo – USP
Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Departamento de Biologia
Av. Bandeirantes nº 3900, Vila Monte Alegre
CEP 14040-900, Ribeirão Preto-SP, Brasil.
E-Mail: rcswasp@gmail.com

Abstract

Some effort has been made concerning the measurement of the social biodiversity of wasps in Brazil. However, few approaches were made regarding how these taxa have adapted their nesting behavior to anthropic mixed environments. Thus, the present work aimed to survey the occurrence of social wasps in an anthropic area and their relationship with different types of nesting substrates. Increasing the knowledge of social wasps in anthropic areas may allow us to develop strategies for their conservation and management. Twenty long-term surveys were made at the Universidade de São Paulo, Ribeirão Preto campus, São Paulo State. During the searches, we collected information about wasp species and nesting substrate. A total of 20 species of eight genera were identified, and a total of 431 active colonies were registered. Epiponini was the tribe that expressed the most species richness. On the other hand, Mischocyttarini was represented by more active colonies. *Mischocyttarus cerberus* had a remarkable greater number of colonies, whether compared to the other species which agreed with the idea of preference of anthropic environments by independent founding wasps. Nesting behavior was associated with eight substrate categories. In general, we observed that some species may express certain plasticity regarding to their nesting substrate preference, whereas some expressed certain specificity. These findings may be related to the fact that some species are less sensitive to urban areas and then express a plastic behavior concerning to where they start their nests. Facing the increase of current urbanization process and, consequently, habitat loss, this type of study contributes toward a better understanding of how these insects are affected and behave in altered environment.

Introduction

Urban development can be classified as one of the main reasons for local extinction rates, which, consequently, eliminates a large number of native species (Czech et al., 2000; Marzluff, 2001), or, at least, implies in the decreasing of overall diversity (Faeth et al., 2011). The urbanization impact can be severe, causing losses on resource availability (both food and nesting sites), pollution increasing, microclimate alteration, affecting local biodiversity and pollination services (Grimm et al., 2008; Grab et al., 2019). Abundance, abundance, species richness and evenness are affected by urbanization (Shochat et al., 2010).

Even though insects are found to be spread worldwide, few approaches have analyzed the urbanization effect over them, especially in neotropical regions (Lima et al., 2000; McIntyre, 2000; de Barros Alvarenga et al., 2010; Detoni et al., 2018). Information concerning how wasps respond to urbanization is almost scarce, especially for the social species (Detoni et al., 2018), which perform different ecological roles over the environments where they live, acting as predators of different agricultural pests (Oliveira et al., 2017b; Barbosa et al., 2018), as detritivores of decaying fruits or animal carcasses (Barbosa et al., 2014; Clemente et al., 2012), as fruit damagers (De Souza et al., 2010a), as pollinators (Somavilla & Köhler, 2012), and even like environmental quality indicators (De Souza et al., 2010b).

Among studies that have been previously carried out, it was suggested that some social wasps belonging to Polistinae (Hymenoptera, Vespidae) seem to be well adapted to urban areas, and that they are able to nest in different types of human-made structures (de Barros Alvarenga et al., 2010; Oliveira et al., 2017a). This interaction can be understood based on the availability of structures in such areas, which enable wasps to get protection from unfavorable weather. In addition, any threat related to predation and competition for nesting substrates (Lima et al., 2000; Prezoto et al., 2007) is reduced. Metal, concrete, ceramic, stone, plastic, porcelain, asbestos, synthetic materials, and wood are highlighted as the substrates chosen by wasps in urban areas (Lima et al., 2000; Detoni et al., 2018). Interestingly, some species may stock their nests according to what is available in the environment. In summary, it is known that there are some species which are capable of nesting in both urban and natural areas, on the other hand, there are others which are limited to one or another (Lima et al., 2000; de Barros Alvarenga, 2010; Oliveira et al., 2017a).

These wasps are known because of their diversity in Neotropical regions, comprising almost a thousand of species described (Pickett & Carpenter, 2010). Basically, these wasps start building their nests by using two different strategies, which permit their classification in: independent founding wasps (*Polistes* and *Mischocyttarus*) or swarm-founding wasps (Epiponini) (Jeanne, 1980; Wenzel, 1998). Brazilian social wasp biodiversity is actually well known for several areas with different vegetal formation, such as Brazilian savanna and semideciduous mountain forest (de Souza & Prezoto, 2006), campos rupestres (Silva-Pereira & Santos, 2006), mangrove and resting (Santos et al., 2007), semideciduous seasonal forest (Gomes & Noll, 2009), dense and open upland forest, upland forest dense downland, closed and open flooded forest, high and low white-sand forest (Somavilla et al., 2015) and montane humid forest (Somavilla et al., 2017). Though, there are still few approaches regarding such types of study in anthropized and agricultural-urbanized places (Lima et al., 2000; de Barros Alvarenga et al., 2010; Oliveira et al., 2017a; Detoni et al., 2018). Consequently, biodiversity and nesting habits of Polistinae social wasps remain relatively little known in such areas (Oliveira et al., 2017a). Thus, to fill these gaps, we present here information regarding to surveys in an agricultural-urbanized mixed area in the interior of São Paulo State, Brazil. Understanding specific details about the social wasp's occurrence across mosaic-like environment may contribute for better knowledge about the particular ecological characteristics of wasps (De Souza et al., 2010b), in addition, and to develop different strategies of conservation and management of these insects.

Material and Methods

Study area

The present study was conducted at the University of São Paulo, USP, campus of Ribeirão Preto, Brazil. The city is situated in the northeast part of the State of São Paulo, Brazil (21° 05' S, 47° 50' W, 531 m altitude). The campus has an area of 574.75 ha, with more than the half of its area combined by buildings and a wooded area composed of exotic and native vegetation (Barth, 2006), characterized as Semideciduos Seasonal Forest (Fragoso & Varanda, 2010). It is surrounded in its northern border by a large sugarcane plantation (Fig 1). The weather regime is characterized by a strong seasonality, with a rainy summer and a dry winter. The major part of the rainfall (80%) occurs from October to March. On the other hand, the lower incidence of rainfall is registered from June to August (5%) (IPT, 2000).

Data collection

Nest recordings were obtained from April to September in 2016. We made 21 discontinuous surveys during the period (21 days of data collection), and we searched for nests in 108 building and surrounding gardens across the studied area (Fig 1). The searches were always performed in two periods: from 08:00h to 11:00h and from 14:00h to 17:00h. A total of 126 hours (six hours per day) of inspection effort based on active search method was carried out, which was commonly used in similar studies (de Souza & Prezoto, 2006; Oliveira et al., 2017a).

During the searches, we registered the name of species, the number of nests for each species and finally the types of substrate used by them for nesting. Once a nest was found, information was included in an Excel spreadsheet (see Supplementary material - doi: 10.13102/sociobiology.v66i2.4303.s2280). When necessary, samples were collected with an entomological net and then they were archived in the entomological collection of the Laboratório de Comportamento e Ecologia de Insetos Sociais from Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, University of São Paulo, USP, campus of Ribeirão Preto, SP, Brazil – SP.

Species identification was done by using taxonomic keys of Richards (1978) and Carpenter and Marques (2001). Comparisons were also made with identified specimens deposited in the entomological collection of the laboratory, and finally, some sampled material was confirmed by specialists.

Nesting substrate categories were based on eight types as follows: 1 – Glass; 2 – Masonry; 3 – Metal; 4 – Paper; 5 – Plant material; 6 – Plastic; 7 – Wood or lastly 8 – N/A (not applicable to others). We performed a compilation including wasp species and their substrates, and the results were then plotted in a network of interactions, which allowed us to verify for any substrate preference in general and also for each species.

Statistical analysis

Data analysis were performed in the R software v.3.4.3. First, for measuring the diversity of wasps in each substrate we used the Shannon-Wiener (H) index, and for evenness we used the Pielou index (J). We chose the Shannon-Wiener

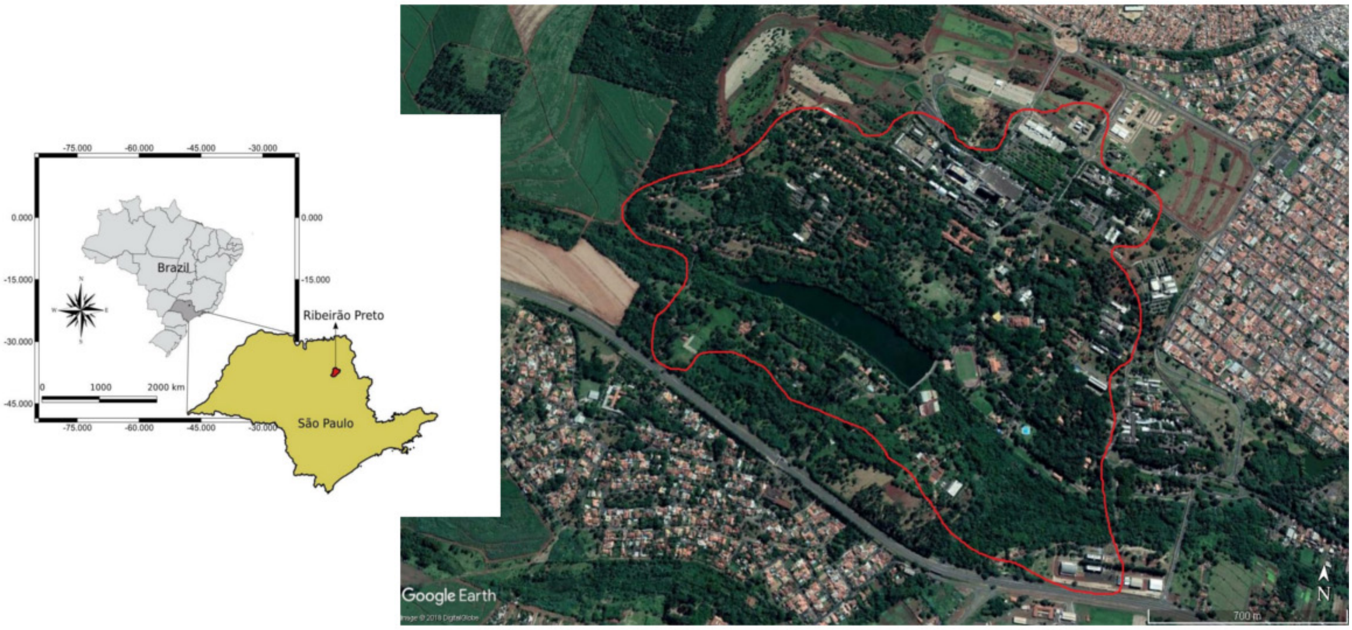

Fig 1. Geographic representation of the studied area through the campus of University of São Paulo – Ribeirão Preto.

index as a diversity measure because the index uses both abundance and evenness of species. Moreover, the Pielou index showed how equal the species are nesting in the substrate (Magurran, 2004). Both indexes were used for each substrate with sampled colonies. We used the package Vegan v.2.4.4 (Oksanen et al., 2007).

We analyzed the species specificity index with the package 'Bipartite' v.2.08. This index calculates the interactions between the parts, the value ranges from 0 to 1, where 0 is low specificity and 1 higher specificity. Furthermore, we used the values of proportional similarity as suggested by Feinsinger et al. (1981). These values are calculated in the interaction between the availability of resources and their use by the species (Dormann et al., 2008).

The differences among the richness in the substrates were tested with the G test. The G test was used to evaluate the values observed, and to test these values with the expected value.

Results and Discussion

A total of 431 active colonies were registered during the collection months and 20 species of social wasps were found, which were allocated in eight genera (Table 1). A similar results were also found by Oliveira et al. (2017a) and Lima and colleagues (2000) in previous surveys also performed in urban areas. The wasp richness data found in our study are partially in accordance with what was found in another area with similar anthropic characteristics. For instance, Detoni et al. (2018) studied an urban perimeter associated mainly to *Pinus ellioti* in Southestern Brazil and registered 13 species of wasps, distributed in five genera. Some species that we found along our survey were also sampled in a previous study, associated to sugarcane field (Barbosa et al., 2018), which reinforce the importance of social wasp conservation in such environments. Interestingly, although we had performed a survey in an urbanized area, we obtained relatively the same richness of species as Togni et al. (2014) who collected wasps in a nature reserve located in Atlantic Forest biome.

Mischocyttarus and *Polybia* highlighted as the most represented by species in the studied area, both with six species each, while in contrast, some genera were represented by only one species (Table 1). The fact that *Mischocyttarus* is the richest genus of social wasps (around 240 species), out of which 117 occur in Brazil and *Polybia* being the genus with most species described within Epiponini might support the high diversity of both genus in the present study. Results concerning richness of *Mischocyttarus* and *Polybia* had previously been presented in anthropized environments surrounded by Atlantic forest fragments and *Pinus elliotti* (Oliveira et al., 2017a; Detoni et al, 2018) and either in agricultural environments (de Castro Jacques et al., 2015). It has been proposed that this sinanthropism might be selected due to the lower rates of vertebrate predation and an interspecific dispute over sources (see McGlynn, 2012), although living in disturbed areas may affect colony performance (Michelutti et al., 2013). In our work, *Mischocyttarus cerberus* was the species with the highest number of nests found. Similar results were registered by Elpino-Campos et al. (2007) and Oliveira et al. (2017a), besides that, this species was found in six out of eight substrates; nevertheless, it seemed to prefer nesting over masonry substrate rather than other substrates.

In general, we registered more nests of independent founding wasps (*Mischocyttarus*) than swarming-founding wasps, which differs from studies performed in more preserved areas where Epiponini is more frequent (Togni et al., 2014). It should be understood considering that the studied place contains plenty of buildings and adjacent vegetation, which corroborates with the high degree of synanthropism proposed

Tabel 1. Species, number of colonies found of each species and relative frequency of nests sampled along the survey.

Species	Number of active colonies	%
Mischocyttarus cerberus Ducke, 1918	172	39.91
Mischocyttarus metathoracicus (de Saussure, 1854)	97	22.51
Mischocyttarus cassununga (R. vonIhering, 1903)	39	9.05
Polybia occidentalis (Olivier, 1792)	31	7.19
Polistes versicolor (Olivier, 1792)	28	6.50
Polybia paulista H. von. Ihering,1896	24	5.57
Mischocyttarus sp.1	9	2.09
Mischocyttarus montei Zikán 1949	7	1.62
Polybia ignobilis (Haliday, 1836)	4	0.93
Protopolybia exigua (de Saussure, 1854)	4	0.93
Polybia fastidiosuscula de Saussure, 1854	3	0.71
Metapolybia miltoni Andena & Carpenter, 2011	2	0.46
Protopolybia sedula (de Saussure, 1854)	2	0.47
Mischocyttarus sp.2	2	0.47
Metapolybia sp.1	1	0.23
Agelaia pallipes (Olivier, 1792)	1	0.23
Brachygastra augusti (de Saussure, 1854)	1	0.23
Protonectarina sylveirae (de Saussure, 1854)	1	0.23
Polybia sp.1	2	0.47
Polybia sp.2	1	0.23
Species richness 20	431	100

between the genus of independent founding wasps and urban areas (Lima et al., 2000; de Barros Alvarenga et al., 2010; Oliveira et al., 2017a). Moreover, nests of primitively eusocial wasps normally are smaller, which consequently attract less human attention (Smith, 2004, Elpino-Campos et al., 2007). Several nests of *Mischocyttarus* were found in places where they would not be easily noticed, for example, underneath air conditioners (personal observation). Curiously we sampled only one *Polistes* species in the studied area, which represents another group of wasp which is normally found associated to anthropized areas (Detoni et al., 2018; .Maciel et al., 2016).

Among the 431 colonies registered, the most used nesting substrate was masonry in 42% of the records, which may correlate with the greater availability of this substrate in the studied area. Secondly, metal substrate was represented with 32.71%, followed by wood substrate with 13.92% of nest found; the fourth position was occupied by plant material with 3.71%, followed by glass substrate with 3.25%, and by plastic substrate which was represented by 3.25% of the results, then by N/A category 0.7%, and lastly by paper substrate with 0.46% (Fig 2, Table 3). Our results agreed with those found by Detoni et al. (2018), regarding the most used nesting substrate by wasps in urban areas. On the other hand, this result might have been affected by each nesting substrate type availability rate in the area rather than preference, but it has not been directly verified.

The Shannon index ranged from 0.637 to 1.906, N/A and Plant Material, respectively. The plant material had the major diversity (Shannon Index = 1.906), followed by man-made buildings (Shannon Index = 1.857), in which the glass had lower Shannon diversity (0.657). The evenness of the paper substrate was 1, being more even than all substrates, and the lowest value was the glass substrate with 0.597. All the results are in Table 2.

Some species were all specific to their substrate and obtained specificity equal to 1 (*Agelaia pallipes*, *Brachygastra augusti*, *Metapolybia* sp.2, *Mischocyttarus montei*, *Polybia ignobilis*, *Polybia* sp.1, *Polybia* sp.2, *Protonectarina sylveirae*, *Protopolybia exigua* and *Protopolybia sedula*). However for some it may be related to the low number of nests registered and not specificity per se (Table1). Nevertheless, other species remain above 0.420 of specificity. *Mischocyttarus* sp.1 showed the lowest specificity with 0.426. The more common sampled species, *M. cerberus*, had a specificity of 0.52 (Fig 2).

Table 2. Diversity index to survey. S = Number of observed species, H' = Shannon-Wiener index and J' = Pielou Evenness index.

Substrate	S	H'	J'
Masonry	14	1.86	0.7
Wood	9	1.79	0.82
Plant Material	8	1.91	0.92
Metal	8	1.42	0.68
Plastic	6	1.74	0.97
Glass	3	0.66	0.6
Paper	2	0.69	1
N/A	2	0.64	0.92

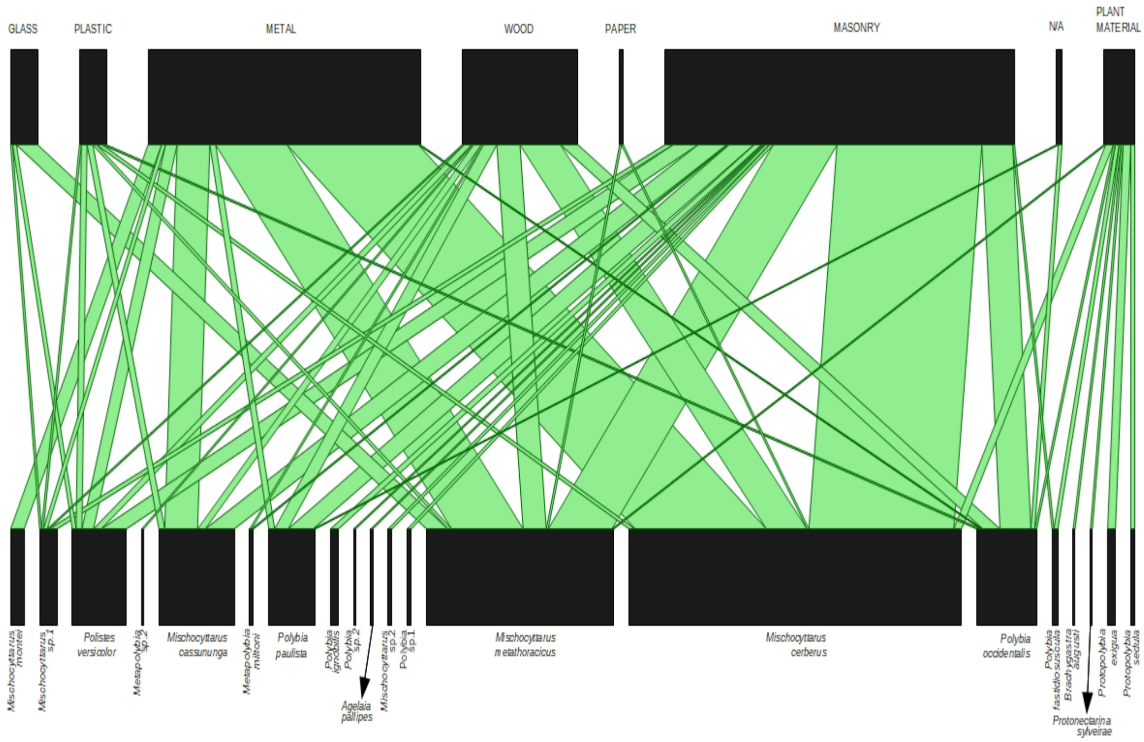

Fig 2. Relation between wasps and different nesting substrate, involving 20 wasp species and eight types of substrates on the University of São Paulo campus of Ribeirão Preto, Brazil.

Among the species found during the study, it was possible to notice that some of them showed a certain plasticity in relation to the substrate used (Figure 2). For instance, *M. cerberus*, *Mischocyttarus metathoracicus* and *Polybia occidentalis* were registered in almost all types of nesting substrate, but *Mischocyttarus montei* showed less plasticity in relation to the substrate chosen, being registered only in metal substrates. The apparent preference of the wasp for nesting in masonry might be related to the greater offer of this substrate in comparison to the others, and this fact reinforces the idea of a good adaptation of this species in urban environments (Virgínio et al., 2016).

In sequence, the second category most used by wasps was metal, this preference was probably related with a phenomenon known as "heat islands" (Lola et al., 2013), the accumulated heat over the metallic superficies provides suitable conditions for the colonies to develop, it was previously shown in studies with social insects (Virgínio et al., 2016).

We believe that collection method chosen for sampling the fauna did not affected the number of species found, because normally the active search method is the most used in similar studies, and according to Souza et al. (2016), depending on the situation, it is the most effective method to sample the richness of an area whether compared with others. On the other hand, some authors believe that the use of more than one collection method makes possible to get better information about the biodiversity (Auad et al., 2010, Souza et al., 2011). Even though we had not searched for social wasps in the surrounding areas, based on previous data from the same region, it is possible to suggest that some genera might be more tolerant to the urbanization process expressing a kind of behavior nesting plasticity (*Polybia*, *Mischocyttarus* and *Polistes*), because they have been previously sampled in natural areas and in ours, which is an anthropized one, whereas others were not registered in our study (Gomes & Noll, 2009; Locher et al., 2014).

Urban environments may contribute in a positive way to increase the chances of social wasps survival, since they provide suitable areas for nesting, and confer protection against bad weather. Moreover, they represent places where there is less competition for resources among many species, and even predation rates by natural enemies may be lower (Prezoto et al., 2007). Finally, considering the generalist diet of social wasps, it was suggested that their presence near sugarcane areas can be beneficial, because these insects may perform natural biological control against different sugarcane pests, such as *Diatraea saccharalis*, *Mocis latipes* and *Spodoptera frugiperda* (Barbosa et al., 2018).

Due to the increasing urbanization and reduction of natural vegetation in many environments, the elucidation through basic studies of how well adapted the species of social wasps are, and consequently their success to nest in altered spaces, contribute to help us to understand clearly the interactions between those insects and the environment. Thus, the present study represents one of the few attempts carried out up to this moment about the biodiversity of social wasp fauna in areas occupied almost exclusively by human activities. In this way, future studies gathering data for Polistinae wasps in this type of mixed areas may help us to understand how wasps adapt their behavior and lifestyle toward a changing environment.

Besides that, it would fill gaps about the distribution of species along Brazilian territory. Finally, they would be important for a better understand regarding how some species are being more affected by human disturbance over their natural nesting areas.

Table 3. Pairwise comparison regarding the richness of species found among substrates.

Pair of substrates	*G* value	*p-* value
masonry x paper	11.252	0.001
masonry x plastic	3.985	0.046
masonry x glass	8.733	0.003
masonry x N/A	11.252	0.001
wood x paper	4.818	0.028
wood x N/A	4.818	0.028
plant material x paper	3.854	0.049
plant material x N/A	3.854	0.049
metal x N/A	4.818	0.028
metal x paper	4.818	0.028

Acknowledgments

The authors would like to thank Dr. Alexandre Somavilla of the Instituto Nacional de Pesquisas da Amazônia for his suggestions and helpfull comments in the first version of this manuscript. Besides, we would like to thank Prof. Dr. Sergio Ricardo Andena of the Universidade Estadual de Feira de Santana for checking and confirming some samples. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001 (R.C.S.) Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) – A.P.S. [proc. nº 870320/1997-1] and Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP – A.P.S. [proc. nº 2016/11887-4], D.S.A. [proc. nº 2015/17358-0], R.C.S. [proc. nº 2016/08761-9] FAPESP: 2018/10996-0 to F.S.N. [proc. n° 2018/22461-3]).

References

Auad, A.M., Carvalho, C.A., Clemente, M.A., & Prezoto, F. (2010). Diversity of Social Wasps (Hymenoptera) in a Silvipastoral System. Sociobiology, 55: 627-636.

Barbosa, B.C., Paschoalini, M.F., & Prezoto, F. (2014). Temporal activity patterns and foraging behavior by social wasps (Hymenoptera, Polistinae) on fruits of *Mangifera indica* L. (Anacardiaceae). Sociobiology, 61: 239-242. doi: 10.13 102/sociobiology.v61i2.239-242

Barbosa, B.C., de Jesus Silva, N.J., Zanuncio, J.C., & Prezoto, F. (2018). Occurrence of Social Wasps (Hymenoptera: Vespidae) in a Sugarcane Culture. Sociobiology, 65: 320-324. doi: 10.13102/sociobiology.v65i2.2151

Barth, O.M. (2006). Palynological analysis of geopropolis samples obtained from six species of Meliponinae in the Campus of the Universidade de Ribeirão Preto, USP, Brazil. Apiacta, 41(2).

Clemente, M.A., Lange, D., Del-Claro, K., Prezoto, F., Campos, N.R. & Barbosa, B.C. (2012). Flower-visiting social wasps and plants interaction: Network pattern and environmental complexity. Psyche: A Journal of Entomology, 2012: 1-10. doi: doi: 10.1155/2012/478431

Czech, B., Krausman, P.R. & Devers, P.K. (2000). Economic associations among causes of species endangerment in the United States: associations among causes of species endangerment in the United States reflect the integration of economic sectors, supporting the theory and evidence that economic growth proceeds at the competitive exclusion of nonhuman species in the aggregate. BioScience, 50: 593-601.

de Barros Alvarenga, R., de Castro, M.M., Santos-Prezoto, H.H. & Prezoto, F. (2010). Nesting of social wasps (Hym., Vespidae) in urban gardens in Southeastern Brazil. Sociobiology, 55: 445-452.

de Castro Jacques, G., Souza, M.M., Coelho, H.J., Vicente, L.O. & Silveira, L.C.P. (2015). Diversity of social wasps (Hym.: Vespidae: Polistinae) in an agricultural environment in Bambuí, Minas Gerais, Brazil. Sociobiology, 62: 439-445. doi: 10.13102/sociobiology.v62i3.738

de Souza, M. M. & Prezoto, F. (2006). Diversity of social wasps (Hymenoptera: Vespidae) in semideciduous forest and cerrado (Savanna) regions in Brazil. Sociobiology, 47: 135-147.

de Souza, A.R., Venâncio, D.F. & Prezoto, F. (2010a). Social wasps (Hymenoptera: Vespidae: Polistinae) damaging fruits of *Myrciaria* sp. (Myrtaceae). Sociobiology, 55(1A and 1B): 297-300.

de Souza, M.M., Louzada, J., Eduardo Serrão, J. & Cola Zanuncio, J. (2010b). Social wasps (Hymenoptera: Vespidae) as indicators of conservation degree of riparian forests in Southeast Brazil. Sociobiology, 56: 387-396.

Detoni, M.F.D.F.S., Barbosa, B.C., Maciel, T.T., dos Santos, S.J.L., & Prezoto, F. (2018). Long-and short-term changes in social wasp community structure in an urban area. Sociobiology, 65: 305-311. doi: 10.13102/sociobiology. v65i2.2597

Dormann, C. F., Gruber, B., & Fründ, J. (2008). Introducing the bipartite package: analysing ecological networks. Interaction, 1(0.2413793)

Elpino-Campos, Á., Del-Claro, K. & Prezoto, F. (2007). Diversity of social wasps (Hymenoptera: Vespidae) in Cerrado fragments of Uberlândia, Minas Gerais State, Brazil. Neotropical Entomology, 36: 685-692.

Faeth, S. H., Bang, C., Saari, S. (2011). Urban biodiversity: patterns and mechanisms. Annals of the New York Academy of Sciences, 1223(1): 69-81. doi: 10.1111/j.1749-6632.2010. 05925.x

Feinsinger, P., Spears, E.E. & Poole, R.W. (1981). A simple measure of niche breadth. Ecology, 62: 27-32.

Fragoso, F.P. & Varanda, E.M. (2011). Flower-visiting insects of five tree species in a restored area of semideciduous seasonal forest. Neotropical Entomology, 40: 431-435.

Gomes, B. & Noll, F.B. (2009). Diversity of social wasps (Hymenoptera, Vespidae, Polistinae) in three fragments of semideciduous seasonal forest in the northwest of São Paulo State, Brazil. Revista Brasileira de Entomologia, 53: 428-431.

Grab, H., Branstetter, M.G., Amon, N., Urban-Mead, K.R., Park, M.G., Gibbs, J., Blitzer E.J., Poveda K., Loeb G. & Danforth, B.N. (2019). Agriculturally dominated landscapes reduce bee phylogenetic diversity and pollination services. Science, 363(6424), 282-284. Doi: 10.1126/science.aat6016

Grimm, N.B., Faeth, S., Golubiewski, N., Redman, C., Wu, J., Bai, X. & Briggs, J.M. (2008). Global change and the ecology of cities. Science, 319(5864): 756-760.

Jeanne R.L. (1980). Evolution of social behavior in the Vespidae. Annual Review of Entomology, 25: 371-396.

Lima, M. A. P., Lima, J. R. & Prezoto, F. (2000). Levantamento dos gêneros, flutuação das colônias e hábitos de nidificação de vespas sociais (Hymenoptera, Vespidae) no Campus da UFJF, Juiz de Fora, MG. Revista Brasileira de Zoociências, 2: 69-80.

Locher, G.A., Togni, O.C., Silveira, O.T. & Giannotti, E. (2014). The social wasp fauna of a riparian forest in southeastern Brazil (Hymenoptera, Vespidae). Sociobiology, 61: 225-233. doi: 10.13102/sociobiology.v61i2.225-233

Lola, A.C., Uchoa, P.W., Júnior, J.A.S., Cunha, A.C. & Feitosa, J.R.P. (2013). Variações termo-higrométricas e influências de processo de expansão urbana em cidade equatorial de médio porte. Brazilian Geographical Journal: Geosciences and Humanities Research Medium, 4: 615-632.

Maciel, T.T., Barbosa, B.C. & Prezoto, F. (2016). Armadilhas atrativas como ferramenta de amostragem de vespas sociais (Hymenoptera: Vespidae): Uma meta-análise. EntomoBrasilis, 9: 150-157. doi: doi:10.12741/ebrasilis.v9i3.644

Magurran, A.E. (2004). An index of diversity. Measuring Biological Diversity, 100-133.

Marzluff, J. M. (2001). Worldwide urbanization and its effects on birds. In *Avian ecology and conservation in an urbanizing world* (pp. 19-47). Springer, Boston, MA.

McGlynn, T.P. (2012). The ecology of nest movement in social insects. Annual Review of Entomology, 57: 291-308. doi: 10.1146/annurev-ento-120710-100708

McIntyre, N.E. (2000). Ecology of urban arthropods: a review and a call to action. Annals of the Entomological Society of America, 93: 825-835.

Michelutti, K.B., Montagna, T.S. & Antonialli-Jr, W.F. (2013). Effect of habitat disturbance on colony productivity of the social wasp *Mischocyttarus consimilis* Zikán (Hymenoptera, Vespidae). Sociobiology, 60: 96-100. doi: 10.13102/sociobiology.v60i1.96-100

Oksanen, J., Kindt, R., Legendre, P., O'Hara, B., Stevens, M. H. H., Oksanen, M. J. & Suggests, M. A. S. S. (2007). The vegan package. Community Ecology Package, 10: 631-637.

Oliveira, T.C.T., Souza, M.M. & Pires, E.P. (2017a). Nesting habits of social wasps (Hymenoptera: Vespidae) in forest fragments associated with anthropic areas in southeastern Brazil. Sociobiology, 64: 101-104. doi: 0.13102/sociobiology.v64i1.1073

Oliveira, M.M., Gomes, F.B., Somavilla, A. & Krug, C. (2017b). *Polistes canadensis* (Linnaeus, 1758) (Vespidae: Polistinae) in the Western Amazon: a Potential Biological Control Agent. Sociobiology, 64: 477-483. doi: 10.13102/sociobiology.v64i4.1936

Pickett, K.M. & Carpenter, J.M. (2010). Simultaneous analysis and the origin of eusociality in the Vespidae (Insecta: Hym.). Arthropod Systematics and Phylogeny, 68: 3-33.

Prezoto, F., Ribeiro-Júnior, C., Cortes, S.A.O. & Elisei, T. (2007). Manejo de vespas e marimbondos em ambiente urbano. Manejo de Pragas Urbanas, 1: 123-126.

Santos, G.M.D.M., Bichara Filho, C.C., Resende, J.J., Cruz, J.D.D. & Marques, O.M. (2007). Diversity and community structure of social wasps (Hymenoptera: Vespidae) in three ecosystems in Itaparica Island, Bahia State, Brazil. Neotropical Entomology, 36: 180-185.

Shochat, E., Lerman, S.B., Anderies, J.M., Warren, P.S., Faeth, S.H. & Nilon, C.H. (2010). Invasion, competition, and biodiversity loss in urban ecosystems. BioScience, 60: 199-208.

Silva-Pereira, V. & Santos, G.M.M. (2006). Diversity in bee (Hymenoptera: Apoidea) and social wasp (Hymenoptera: Vespidae, Polistinae) community in "Campos Rupestres", Bahia, Brazil. Neotropical Entomology, 35: 165-174.

Smith, E.F. (2004). Nest sites of the paper wasp *Mischocyttarus collarellus* (Hymenoptera: Vespidae: Polistinae) in a lowland tropical rain forest. Journal of the Kansas Entomological Society, 77: 457-469.

Somavilla, A. & Köhler, A. (2012). Preferência Floral de Vespas (Hymenoptera, Vespidae) no Rio Grande do Sul, Brasil. EntomoBrasilis, 5: 21-28.

Somavilla, A., Andena, S.R. & de Oliveira, M.L. (2015). Social Wasps (Hymenoptera: Vespidae: Polistinae) of the Jaú National Park, Amazonas, Brazil. EntomoBrasilis, 8: 45-50. doi: 10.12741/ebrasilis.v8i1.447

Somavilla, A., de Oliveira, M.L. & Rafael, J.A. (2017). Social wasps (Vespidae: Polistinae) from two National Parks of the

Caatinga Biome, in Brazil. Sociobiology, 64: 334-338. doi: 10.13102/sociobiology.v64i3.1593

Souza, A.D., Venâncio, D.F.A., Zanuncio, J.C. & Prezoto, F. (2011). Sampling methods for assessing social wasps species diversity in a eucalyptus plantation. Journal of Economic Entomology, 104: 1120-1123.

Souza, C.A.S., Vale A.C.G. & Barbosa, B.C.(2016). "Vespas Sociais (Vespidae: Polistinae) em Fitofisionomias Urbanas: um Checklist do Município de Barra Mansa, Rio de Janeiro, Brasil." EntomoBrasilis, 9: 169-174. doi: 10.12741/ebrasilis.v9i3.620

Togni, O.C., de Almeida Locher, G., Giannotti, E. & Silveira, O.T. (2014). The social wasp community (Hymenoptera, Vespidae) in an area of Atlantic Forest, Ubatuba, Brazil. Check List, 10: 10-17. doi: 10.15560/10.1.10

Virgínio, F., Maciel, T.T. & Barbosa, B.C. (2016). Hábitos de Nidificação de *Polistes canadensis* (Linnaeus) (Hymenoptera: Vespidae) em Área Urbana. EntomoBrasilis, 9: 81-83. doi: 10.12741/ebrasilis.v9i2.586

Wenzel J. (1998). A generic key to the nests of hornets, yellow jackets, and paper wasps worldwide (Vespidae: Vespinae, Polistinae). American Museum Novitates, 10024: 1-39.