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Research Article

Diversity of Social Wasps on Semideciduous Seasonal Forest Fragments with Different Surrounding Matrix in Brazil

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We surveyed social wasps (Polistinae) present in forest fragments of northwest of São Paulo state with different surroundings composed of a matrix of citrus crops and sugarcane in the expectation that the former matrix would be more diverse than the latter. We collected specimens actively using attractive liquids. We obtained 20 species in Magda, 13 in Bebedouro, 13 in Matão, and 19 in Barretos. The most common genus was *Agelaia* in all of the areas. The greatest Shannon-Wiener index of diversity was obtained in Magda ($H' = 2.12$). Species such as *Brachygastra moebiana*, *Metapolybia docilis*, *Mischocyttarus ignotus*, *M. paulistanus* and *M. consimilis* had not been recorded on recent surveys in the state. Furthermore *M. consimilis* is a new record for the state. We concluded that, with our data, a relation between the occurrence of social wasps and the surrounding matrix was not detected.

1. Introduction

Forest fragments may be treated as islands, and the surrounding area, the matrix, is treated as an ocean. The matrix area is considered to be ecologically uniform, exerting little influence on populations inside the fragments [1, 2]. More recently, some studies have demonstrated that the surrounding matrix can exert neutral, positive, or negative influences on the populations [3–5].

The replacement of natural areas by monocultures and pastures is one of the main causes of reduction of local and global diversity [6]. Besides habitat fragmentation, the use of pesticides and insecticides reduces the diversity of pollinators [7]. However, Durigan et al. [8] state that some crops have less impact on the natural vegetation than cattle. The majority of crops depend on or benefit from, the action of pollinators [9]. Pimentel et al. [10] show a great richness of arthropod species on many crops. Survey works are important because the survey of species in an area is the first step to its conservation and rational use. Without the knowledge of what species are present in an area, it is very difficult to take action aimed at conservation [11]. Pimentel et al. [10] assert that, as important as it is to conserve the biodiversity of national parks, it is important to conserve biological diversity in agricultural ecosystems, which, together with human settlements, cover approximately 95% of terrestrial environment [12].

Two of the most important monocultures in São Paulo state are sugarcane (*Saccharum* spp) and citrus (*Citrus* spp). Sugarcane is the main crop of São Paulo state with about 5.5 million hectares in 2007/2008 [13]. Regular use of burning facilitates manual harvest and repels venomous animals [14], but causes serious damage to the ecosystem [15] while the use of fertilizers may pollute watercourses and cause salinization of the soil [16]. Organic fertilization systems that can shelter a great biodiversity have been recommended [17]. Brazil is the world's greatest producer of oranges with about 18.5 million tons, and São Paulo State contributes about 15 million tons [18], grown on about 750 thousand hectares in 2007/2008 [13]. During the bloom, oranges offer a great production of pollen and nectar that can attract pollinators [19]. It would be useful to know if a survey of insects at a high trophic level reflects the matrix nearby with respect to the sterility (or toxicity) of some crops, such as sugarcane, and the productivity of others, such as oranges.

There are few data comparing areas with these two surrounding matrices and their possible effects to the biota. Rinaldi et al. [20] found a surprisingly high richness of spiders on sugarcane plantations. Ott et al. [21] sampled spiders on herbaceous vegetation in two different citrus orchards, "traditional" and "ecological," and despite the differences in cultivation practices, they found a lower richness than Rinaldi et al. [20]. Ott et al. [21] also did a survey on citrus trees of the "ecological" orchard, and there they found a greater richness of spiders species than Rinaldi et al. [20].

Andena et al. [22] did a survey of bees on an area that was previously surveyed by Campos [23] and found a lower richness of species. There were some changes in the surrounding matrix due to the replacement of the natural vegetation by sugarcane crops and pasture. The most common pollinator of *Citrus* in Brazil is *Apis mellifera*, but *Tetragonisca angustula* and *Trigona spinipes* are also frequent floral visitors [24, 25]. Other Hymenoptera and some Coleoptera, Diptera, Lepidoptera and Neuroptera also are floral visitors of *Citrus* [25]. A study in Rio Grande do Sul state observed five orders of predatory insects (Coleoptera, Hymenoptera, Neuroptera, Thysanoptera and Hemiptera) in canopies of *C. deliciosa* under organic management [26].

Social wasps have little importance with respect to pollination, but they are frequent floral visitors. Some of them collect nectar for colony's energy supply [27]. These insects show great ability to forage and collect other materials they need such as water, carbohydrates, prey and pulp [28–30], and are being used to control some pests [31]. After Richards [32], many surveying works have been done in different areas in Brazil using various methodologies [11, 33–55]. Here we compare four fragments of semideciduous seasonal forest of northwest of São Paulo state with a surrounding matrix composed of crops of citrus or sugarcane. Moreover, we compare those results to other surveys done in the same region.

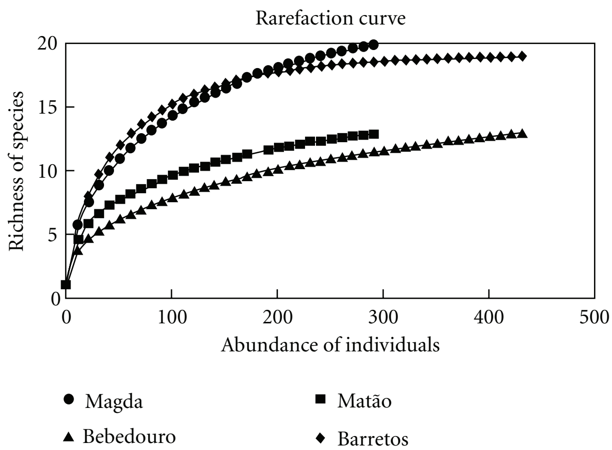

Figure 1: Rarefaction curve for the social wasps collected in the four studied areas.

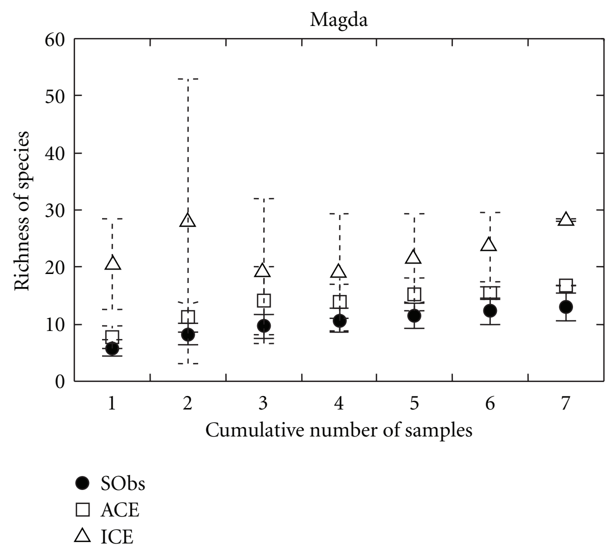

Figure 2: Richness of species observed and estimated using ACE (Abundance-based Coverage Estimator) and ICE (Incidence-based Coverage Estimator) indexes to the area of Magda.

2. Material and Methods

2.1. Study Area. Northwest of São Paulo state is the most deforested area of the state and with the lowest concentration of conservation units [56]. The natural vegetation of the region is characterized as semideciduous seasonal forest and cerrado (or brazilian savanna).

The study was conducted on fragments from the municipalities of Magda (20°30′ S 50°13′ W, 1656.20 ha), Bebedouro (20°53′ S 48°32′ W, 393.94 ha), Matão (21°37′ S 48°32′ W, 2189.58 ha) and Barretos (20°29′ S 48°49′ W, 597.33 ha). The first two had sugarcane crops as the surrounding matrix and the last two had citrus crops as the surrounding matrix.

2.2. Methods. The methodology used was based on active collection using an attractive liquid [57]. This methodology uses a 200 m transect in the vegetation on which is sprayed a solution of sucrose (1 : 5, commercial sugar : water) with 2 cm^3 of salt for each liter of solution. Using a costal sprayer, about 500 mL of solution was sprayed on each point of collection, in an area of approximately 3 m^2. Ten points were defined, 20 m distant from each other along the transect. The attracted wasps were captured with an entomological net, from 11:00 AM to 3:00 PM, during five minutes at each collecting point, with a spray interval of approximately 1 : 30 h. Collections were made in one transect in the interior of the forest fragment (at least 100 m of the edge), and one at the edge of the forest fragment, near the surrounding matrix.

Eight monthly collections were made in Magda (24 h of field work in the interior and 32 h at the edge), ten in Bebedouro (24 h of field work on the interior and 40 h on the edge), seven in Matão (24 h of field work in the interior and 28 h at the edge) and eight in Barretos (28 h of field work in the interior and 32 h at the edge) during the period of December 2007 to December 2009. The specimens collected

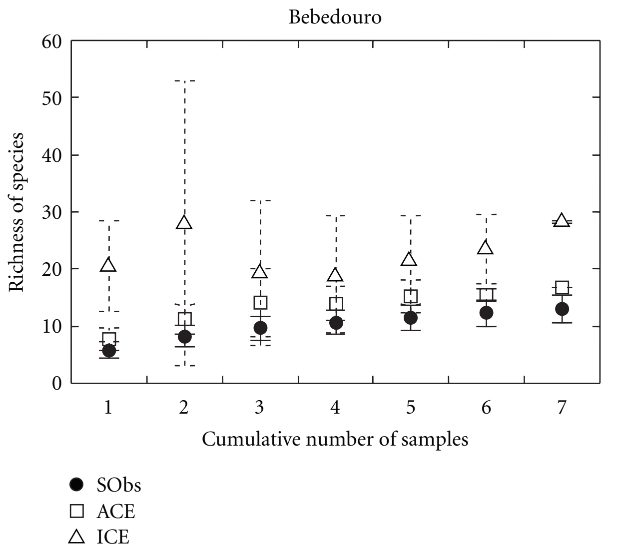

Figure 3: Richness of species observed and estimated using ACE (Abundance-based Coverage Estimator) and ICE (Incidence-based Coverage Estimator) indexes to the area of Bebedouro.

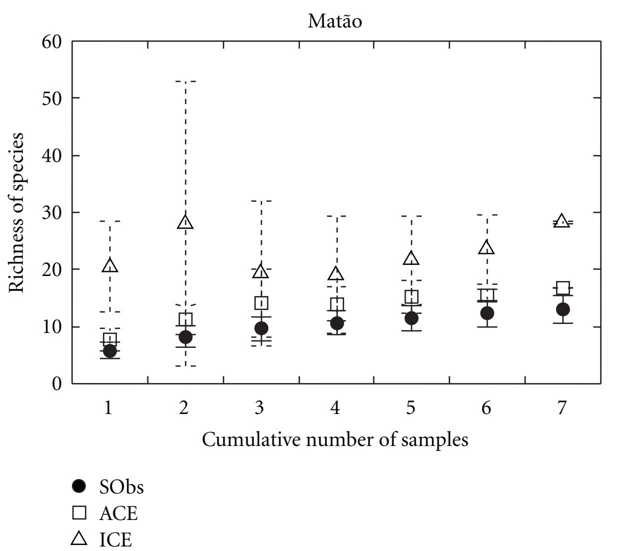

Figure 4: Richness of species observed and estimated using ACE (Abundance-based Coverage Estimator) and ICE (Incidence-based Coverage Estimator) indexes to the area of Matão.

were identified and deposited in the Hymenoptera Collection at the Department of Zoology and Botany, São Paulo state University, São Jose do Rio Preto, Sao Paulo, Brazil.

2.3. Statistical Analysis. Shannon-Wiener index of diversity, Berger-Parker index of dominance, Pielou index of evenness, and similarity analysis of Jaccard and Morisita-Horn were done using the software PAST, version 1.37 [58]. ACE (Abundance Coverage Estimator) and ICE (Incidence Coverage Estimator) indexes were used to estimate the richness using the software Estimates version 7 [59]. A rarefaction curve

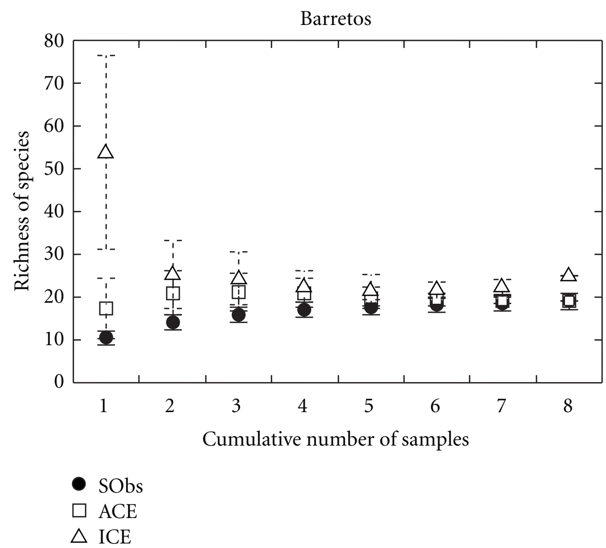

Figure 5: Richness of species observed and estimated using ACE (Abundance-based Coverage Estimator) and ICE (Incidence-based Coverage Estimator) indexes to the area of Barretos.

model of Hulbert was done on Biodiversity Professional Beta [60].

3. Results and Discussion

Twenty-nine species of social wasps belonging to 10 genera were collected in the four areas of study totalling 1460 individuals (Table 1).

Matão was the well-preserved area of study, the largest one, and was surrounded by citrus crops. It was expected to be the richest, but it was the poorest in number of species along with Bebedouro, the poorly preserved site, and it was surrounded by sugarcane crops. Also, Barretos, with a small area and citrus crops on its surrounding, had almost many species as Magda, the second largest area and the fragment that showed the greatest richness of social wasps.

In terms of surrounding matrix, it was expected that the fragments located on sugarcane matrix should have lower diversity because of the effects of the fire on the local fauna and the lack of flowers that could attract some wasps (unlike citrus crops), but this was not verified in our work. That null difference between diversity in those surrounding matrices could be supposedly explained by the fast recovery of an area after a burning event (as observed by Araújo et al. [15]) or a possible more intensive use of insecticides on citrus crops [61].

Our collections include species that merit particular notice. We collected species that represent significant records: *Brachygastra moebiana, Metapolybia docilis, Mischocyttarus ignotus, M. paulistanus,* and *M. consimilis* had not been recorded by recent surveys in São Paulo State; furthermore *M. consimilis* is a new record to the state. *Polybia jurinei* was the most abundant species in Magda, *Agelaia multipicta* was most abundant in Matão, and *A. pallipes* was most abundant in Bebedouro and Barretos. The genus *Agelaia* has species

Figure 6: Map showing the localization of the areas of São Paulo state where surveys of social wasps were done.

Table 1: List of social wasps species collected on the four areas studied. E: edge; I: interior; T: total. Magda and Bebedouro: sugarcane crops. Matão and Barretos: citrus crops.

Species	Areas											
	Magda			Bebedouro			Matão			Barretos		
	E	I	T	E	I	T	E	I	T	E	I	T
Agelaia multipicta	33	28	61	—	—	—	45	89	134	—	—	—
Agelaia pallipes	30	29	59	100	161	261	1	—	1	101	94	195
Agelaia vicina	20	25	45	21	44	65	40	18	58	—	—	—
Brachygastra moebiana	4	—	4	—	—	—	—	—	—	21	—	21
Brachygastra augusti	—	—	—	1	—	1	2	—	2	9	—	9
Brachygastra lecheguana	1	1	2	4	—	4	4	—	4	11	—	11
Brachygastra mouleae	1	—	1	—	—	—	1	—	1	3	—	3
Metapolybia docilis	1	—	1	—	—	—	—	—	—	1	—	1
Mischocyttarus cerberus styx	6	3	9	—	—	—	—	—	—	—	—	—
Mischocyttarus ignotus	2	—	2	—	—	—	—	—	—	—	—	—
Mischocyttarus paulistanus	2	—	2	1	—	1	—	—	—	—	—	—
Mischocyttarus rotundicollis	—	—	—	—	—	—	2	—	2	—	—	—
Mischocyttarus consimilis	1	—	1	—	—	—	—	—	—	—	—	—
Parachartergus smithii	1	—	1	—	—	—	—	—	—	2	1	3
Polistes simillimus	4	4	8	2	—	2	—	—	—	8	1	9
Polistes versicolor	3	1	4	—	—	—	38	2	40	3	1	4
Polistes geminatus	—	2	2	—	—	—	—	—	—	—	—	—
Polybia jurinei	40	30	70	—	1	1	2	3	5	20	29	49
Polybia dimidiata	—	—	—	35	21	56	—	—	—	3	—	3
Polybia fastidiosuscula	—	—	—	—	—	—	—	—	—	6	—	6
Polybia occidentalis	5	1	6	7	—	7	23	—	23	36	3	39
Polybia paulista	—	—	—	—	—	—	—	—	—	22	9	31
Polybia ruficeps xanthops	—	—	—	—	—	—	—	—	—	—	4	4
Polybia chrysothorax	—	—	—	—	—	—	14	8	22	—	—	—
Polybia ignobilis	14	3	17	20	6	26	1	—	1	15	8	23
Polybia sericea	3	—	3	2	—	2	—	—	—	5	—	5
Protonectarina sylveirae	—	—	—	4	—	4	4	—	4	7	—	7
Protopolybia exigua	—	—	—	1	—	1	—	—	—	—	—	—
Synoeca surinama	2	—	2	—	—	—	—	—	—	9	—	9
Total	173	127	300	198	233	431	177	120	297	282	150	432

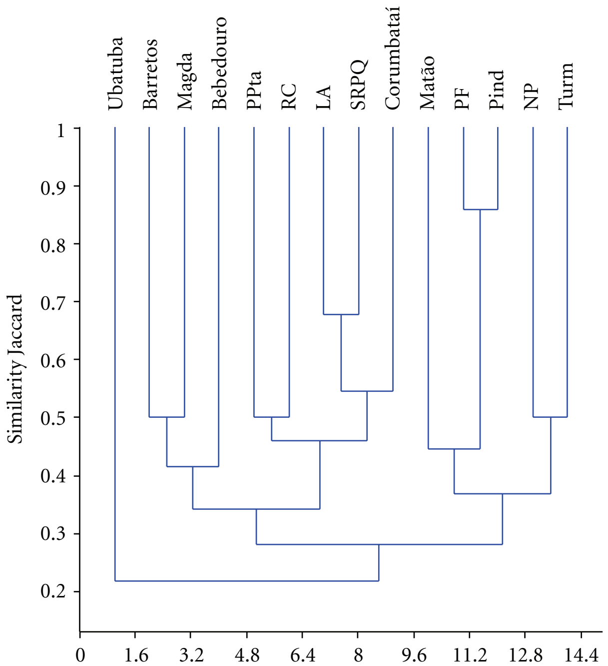

Figure 7: Similarity between the areas of São Paulo state where surveys of social wasps were done, using Jaccard index. PPta: Patrocínio Paulista, RC: Rio Claro, LA: Luiz Antônio, SRPQ: Santa Rita do Passa Quatro, PF: Paulo de Faria, Pind: Pindorama, NP: Neves Paulista, Turm: Turmalina.

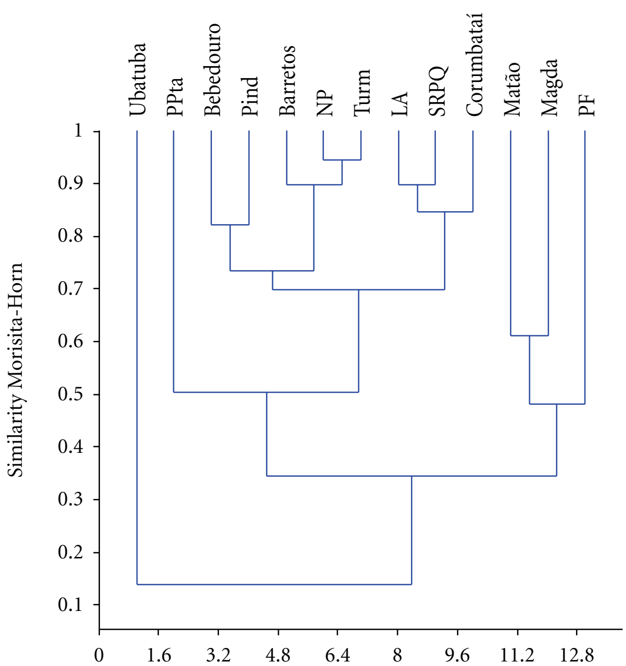

Figure 8: Similarity between the areas of São Paulo state where surveys of social wasps were done, using Morisita-Horn index. PPta: Patrocínio Paulista, Pind: Pindorama, NP: Neves Paulista, Turm: Turmalina, LA: Luiz Antônio, SRPQ: Santa Rita do Passa Quatro, PF: Paulo de Faria.

Table 2: Diversity, dominance and evenness indexes of the four areas studied.

Indexes	Magda	Bebedouro	Matão	Barretos
Diversity Shannon-Wiener	2.12	1.28	1.65	2.03
Dominance Berger-Parker	0.23	0.61	0.45	0.45
Evenness Pielou	0.71	0.50	0.64	0.69

with enormous colonies with great capacity of foraging, and they can establish their colonies in natural cavities [62–64], which may explain their success. Only *Mischocyttarus paulistanus* was collected exclusively in the fragments surrounded by sugarcane. No species was collected exclusively in the fragments surrounded by citrus.

According to the Shannon-Wiener index, the most diverse area was Magda, followed by Barretos, Matão and Bebedouro (Table 2). Magda had more species and did not show one dominant species. This is confirmed by the low value of Berger-Parker index and high value of Pielou index. The Pielou index also shows high values for Magda, followed by Barretos, Matão and Bebedouro. The higher value of Berger-Parker index in Bebedouro is because *A. pallipes* represented 60.57% of the individuals collected in this area. This species has little habitat specificity in nesting because it builds nests in soil cavities.

Based on the rarefaction curve (Figure 1), it is possible to see that the curves tended to stabilize showing that the collections were sufficient to sample the areas. However, regarding the indexes ACE and ICEs only in Barretos the curve is stabilized showing that all the species of this area were sampled (Figures 2–5).

Comparing our data with those of other authors that had sampled social wasps in São Paulo state [33, 35, 36, 52, 54, 65, 66] (Figure 6), the Jaccard similarity analysis (Figure 7) demonstrated that Barretos, Magda, and Bebedouro form a cluster, but Matão is more similar to Paulo de Faria and Pindorama. Jaccard coefficient groups localities based on the presence or absence of species.

The similarity analysis of Morisita-Horn (Figure 8), that groups localities based on the relative abundance of species, forms a big cluster with Bebedouro, Pindorama, Barretos, Neves Paulista, Turmalina, Luiz Antônio, Santa Rita do Passa Quatro and Corumbataí. The dominance of *A. pallipes* in all of these areas explains this group. Matão and Magda form another group with Paulo de Faria mainly because of the similar abundance of *A. multipicta* and *A. vicina*.

In comparison with recent surveys of social wasps in São Paulo state, it can be observed that the areas sampled in the present work have less richness than the areas on the central-eastern region of the state (Table 3). Besides the geographic distance and differences on conservation status of the areas and vegetation type, differences in methodologies can explain this fact. The areas on central-western region were sampled with the same methodologies, and, in comparison with these areas, the present study showed a greater richness.

Diniz and Kitayama [38], Silva-Pereira and Santos [46] and Santos et al. [45] noted that some species can set their nests in one environment and forage in others. In this work

Table 3: Comparison of the richness of social wasps species of the present work (marked with a*) with recent surveys done in São Paulo state.

Surveys	Genera	Species	Methodologies
Rodrigues and Machado [33]—Rio Claro	10	33	Search for colonies
Lima et al. [54]—Patrocínio Paulista	10	29**	Attractive solution, collection on flowers and search for colonies
Mechi [35]—Luiz Antônio	9	26	Collection on flowers
Mechi [36]—Santa Rita do Passa Quatro	8	26	Collection on flowers
Mechi [35]—Corumbataí	9	25	Collection on flowers
Togni [65]—Ubatuba	8	21	Bottle-traps, active search
Gomes and Noll [52]—Neves Paulista	7	12	Attractive solution
Gomes and Noll [52]—Paulo de Faria	4	7	Attractive solution, Malaise trap, meat bait, bottle traps
Gomes and Noll [52]—Pindorama	4	6	Attractive solution
Lima [66]—Turmalina	4	6	Attractive solution
Magda*	8	20	Attractive solution
Barretos*	8	19**	Attractive solution
Bebedouro*	7	13	Attractive solution
Matão*	6	13	Attractive solution

** Two *morphs* of *Polybia fastidiosuscula*, but for statistical analysis it was considered only one species.

we noted a greater richness of social wasps in the transect at the edge of the fragments. Lima et al. [54] also found more species at the edge. Santos et al. [43] observed a greater richness of species in environments that were more heterogeneous and that offer more resources than agricultural environments, such as nectar, prey, and water during the year supporting many social wasps [45]. Besides the intense replacement of the natural vegetation in urban areas and agroecosystems, the forest fragments can support social wasps that are important predators of some pests [31, 40], benefiting either the natural ecosystem or agrosystems [45].

4. Conclusions

We found no correspondence between the occurrence of social wasps and the area of the fragment or the surrounding agricultural matrix. It can be partially explained by the generalist habits of the social wasps. Other factors, such as the interactions between populations and historical aspects, may explain the richness of species on the remnant fragments.

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