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RESEARCH ARTICLE - WASPS

Impacts of Fire in Social Wasps Community in an Area of Regenerating Brazilian Savanna

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Abstract

Fire is one of the most common natural harassments and it is characterized as an important component of the systems, although little studied regarding the influence of this event in social wasps communities. One month after the end of the collections, the area of Regenerating Brazilian Savanna of the present study undertook a fire in exactly half of the points sampled, which motivated one further year of sampling. The aim of this study was to compare the social wasps fauna collected before and after the fire, indicating a possible impact on their populations. In the first year of collection, before the fire, 21 species (seven genera) were sampled with a total amount of 297 individuals. In the second year, after the fire, 14 species were collected (reduction of 33,33% in richness) and six genera, with an abundance of 153 wasp individuals of Vespidae (loss of 48,48% of individuals). The area 1 in the first year, presented an abundance of 182 individuals (61,27%) and 16 species (76,19%) and the area 2, 115 (38,73%) and 19 species (90,47%). For the area 1 in the second year, 74 individuals (48,36%) and 12 species (85,71%) were captured and for the area 2 there were 79 individuals (51,64%) distributed among nine species (64,28%). However, we did not find significant values for both the abundance and for the richness among the areas and the years of sampling. Nine species were not registered in the second year, although two presented their registration only after the fire.

Introduction

In some ecosystems such as seasonally dry forest (Pinarda & Huffmana, 1997), mixed temperated forest (Abrams, 1992) and Brazilian Savanna (Miranda et al., 2002), fire is one of the most common natural perturbations and is an important element in the dynamics of these ecosystems (Hobbs & Huenneke, 1992). Fire occurrence is influenced by meteorological conditions and climatic changes; however, according to Mistry (1998), the principal cause of fire in the Brazilian Savanna is through agricultural activities.

Brazilian Savanna mostly occurs at tropical latitudes and have their existence directly linked to the rain cycle (Andrade, 2008) and fire (Miranda et al., 2002). The Savanna is a huge biome of South America and is considered a "hotspot" because of its biodiversity and its high degree of degradation (Mittermeier et al., 2005). In Brazil, the Savanna extends over the States of Mato Grosso, Mato Grosso do Sul, Goiás, Minas Gerais, Piauí, the Federal District, Tocantins and part of the States of Bahia, Ceará, Maranhão, Paraná, Rondônia and São Paulo. The main natural cause for burnings in the Savanna is lightning strikes occurring with higher intensity in the first rains, when vegetation is still dry (Ramos-Neto & Pivello, 2000).

Fires frequently alters the regeneration rate of many woody species, reduces their density through the mortality of small individuals (Hoffmann, 1996; 2000; Medeiros &

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Miranda, 2005) and favors the proliferation of herbs. Fires can also alter the pattern of flowering of some species (Prada et al., 1995), the tenacity of leaves (Vieira et al., 1996) and in general, fires increase the availability of food for the herbivores during the dry season (Rodrigues, 1996), due to these bloom after fire and tender leaves.

Insects are important in the colonization of the burned areas once fire can attract a wide range of arthropods through their perception of smoke and high temperatures; many of them use the burned trees for breeding and larvae that are born feed on dead wood (Lyon et al., 2000).

Insects are the most abundant and diverse group of animals in the terrestrial environment and particularly, the Hymenoptera is one of the largest orders with around 130 thousand species (Rafael et al., 2012). Among Hymenoptera, wasps are highlighted because they provide different environmental services as floral visitors (Heithaus, 1979; Barros, 1998; Silva-Pereira & Santos, 2006; Hermes & Köhler, 2006) and pollinators (Barros, 1998), being also important predators mainly of the larvae of Lepidoptera, thus being one of the main top-down drivers of herbivory. In other words wasps are important biological control agents (Prezoto, 1999).

Despite social wasps present a considerable share of the desirable characteristics of a bioindicator group little research has been conducted on this topic. As far as we are aware of, there are only three studies exploring the use of wasps as bioindicators: two studies investigated the concentration of heavy metals in larvae, pupae and adults of two species of wasps in Europe (Urbini et al., 2006), and the third one was conducted in Brazil by Souza et al. (2010) who investigated the use of wasps as bioindicators of conserved riparian woods of Rio das Mortes, City of Barroso, Minas Gerais. Of the thirty six species registered by Souza et al. (2010) *Pseudopolybia vespiceps* (Saussure) and *Polybia fastidiosuscula* (Saussure) were considered as indicators of conserved forest, while *Mischocyttarus drewseni* (Saussure) was an indicator of highly impacted areas.

In this study we explored the potential of the community of social wasps as bioindicators of perturbation by fire in the Brazilian Savanna. We took advantage of a fire that consumed roughly half of an area that was being surveyed to investigate the richness of social wasps. This unfortunate incident gave us the opportunity to investigate how the community of social wasps reutilize and recolonize burn down areas therefore proving an indication of ecosystem recovery. In particular we aimed to compare the community of social wasps before and after the fire.

Material and Methods

Study site

The studied site was an area of regenerating Brazilian Savanna about 25 ha limits at the South with the São Paulo State University (Universidade Estadual Paulista – UNESP) and at the Northeast with the State Forest Edmundo Navarro de Andrade – FEENA. The area presents a history of successive impacts, but it was observed a regeneration stage before the fire.

The climate in the region, according to the classification of Köppen, is of the Cwa type (tropical with two well defined seasons), characterized by drought in winter and average temperature in the hottest month above 22°C. The dominant vegetation at the study site is characterized by the dominance of grove species such as the Brazilian Savanna and herbaceous species such as from the families Poaceae, Fabaceae and Asteraceae (Personal Communication) and arboreous species such as from the families Myrtaceae, Asteraceae, Melastomataceae, Fabaceae (Potascheff et al., 2010), the site presents an aspect of woods, absence of sub-woods and trees of uniform size (Cardoso-Leite et al., 2004) being that the area of studies presents approximately 250.000 m^2 (Fig 1).

Initial survey was planned along 10 sampling points spaced at least 100 meters from each other. All points were visited every other month, from September 2012 to July 2013 and wasps were caught with attractive traps and by active search. Just after July 2013, approximately 140.000 m^2 area caught fire with a considerable loss of the vegetation community what motivated a further year of work to address the impact of fire on the wasp community. Thus, the study site was divided in two areas, area 1 (points from 1 to 5) that remained unaffected by fire and area 2 (points 6 to 10) that was burned (Fig 1). We resumed our sampling campaign 45 days after the end of the burning and kept the sampling campaign from September 2013 to July 2014.

Methods of sampling

Attractive Traps – 10 points were marked, being five at about 1.5 m above the soil and five in the level canopy (about 5-9 meters from the soil). Each trap was made of a 2 liters PET container, placed at 100 meters from each other. In each container there were made four circular openings with about 3 cm in diameter and baited with 200 ml of attractive juice (concentrated juice of passion fruit with sugar). The samples were collected with the aid of sieve and tweezers and fixed in 70% alcohol containers of the collection type (Locher et al., 2014).

Active Search – A team of three trained people in all collections applying the same effort. The search for wasps in through the area along existing trails and when found, wasps were collected with the help of an entomological net. Wasps were killed in a death chamber containing ether and latter fixed in 70% alcohol. Active search was conducted from 9:00 to 16:00 that covers the peak of foraging activity of most wasps.

Identification and destination of the collected material

Samples were identified by genders and species with the help of dichotomous keys (Richards, 1978; Carpenter & Marques, 2001) and comparison with reference material at the collection of social wasps of the Zoology Department. Voucher specimens were deposited in the collection of invertebrates of the Emilio Goeldi Museum of Pará (MPEG).

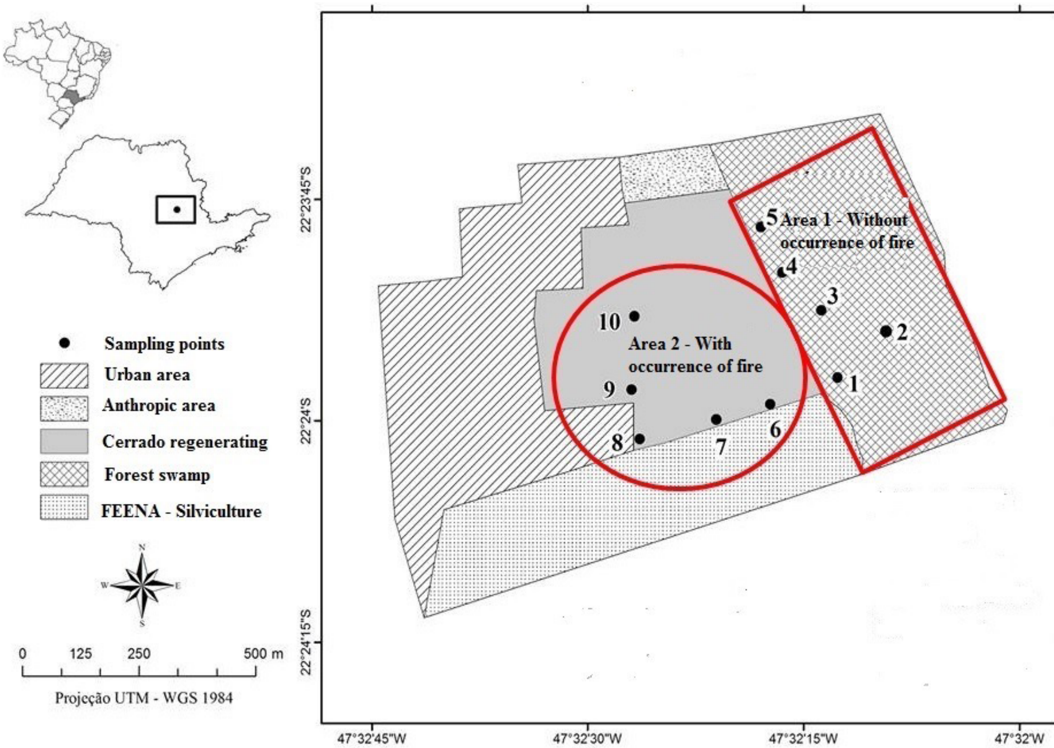

Fig 1. Map of distribution of collection points in the Regenerating Savanna in the Campus of Unesp Rio Claro and the respective areas in function of the fire event.

Data analysis

The programs used in the analysis were PAST – version 1.49 (Hammer et al., 2001), BioEstat - version 5.0 (Ayres et al., 2007) and resources of the free program R Development Core Team (2009).

In order to compare if there were significant differences in abundance and species richness between the pre and post fire period, we pooled by adding the abundance of each species in every collection point before and after the fire. We used the total abundance at each point and the species richness observed at each point as response variables to test if the fire had affected these community metrics. We used Generalized Linear Model on the program R, where abundance and richness were the response variables in separated models and fire with two levels (pre- and post-fire) was the explanatory variable. Both models were fitted with the gamma distribution and the inverse link function to meet model assumptions.

To verify if the number of collections was enough for a sampling of the social wasps community in the areas of this study and between the pre and post fire periods, the rarefaction method by the Program R was used. To estimate the number of species in the pre and post fire period, the Jackknife 1 and 2 estimators were used.

The non-metric multidimensional scale (MDS) was used for the evaluation of inter-local differences of area 1 (points from 1 to 5) without burning in the first year (A1/SQ), area 2 (points from 6 to 10) without burning in the first year (A2/SQ), area 1 without burning in the second year (A1/SQ), area 2 with burning in the second year (A2/Q). The aim was to verify the similarity among the points in these areas and the confection of the MDS figure was performed in the Program R using the MASS package. The MDS is a method that takes as basis the proximity of objects, subjected to stimulus used to produce a spatial representation of them (Härdle & Simar, 2007). In this case, the objects are the pre-defined points in each area and the stimulus was the fire that occurred in one of the sites. The proximity expresses the similarity among these points. The MDS is a technique of dimensional reduction, once its aim is to find a set of points in low dimension (usually two dimensions) which reflect the configuration of the data in high dimension.

Results

In the first year of collection, 21 species were sampled, distributed among seven genera and a total of 297 individuals. In the second year, after a case of fire, only 14 species were collected (33.3% reduction in species richness) and six genera, with a total abundance of 153 wasps (48.5% less than in previous year) (Table 1). The abundance of social wasps was reduced significantly by 48% after the fire ($X^2 = 8.1$, $df = 1$, $p = 0.005$). In the same way, species richness was reduced by 49% after the fire ($X^2 = 17$; $df = 1$; $p < 0.001$).

Rarefaction curves (Fig 2) showed that in the pre and post fire periods the sampling effort was sufficient to estimate accurately the composition of the wasp community in the study site. The Jackknife 1 and 2 estimators predicted 25.2 and 24.8 species respectively for the pre-fire period what means that we recorded between 83.4% and 84.8% of the actual species

Table 1. Abundance of social wasps in areas 1 (without burning) and 2 (without burning) in the first year and areas 1 (without burning) and 2 (with burning) in the second year in a fragment of Brazilian Savanna, Rio Claro, Brazil.

Species	1st Year			2nd Year			
	Area 1	Area 2	Total	Area 1	Area 2	Total	
	WO/burn	WO/burn		WO/burn	Burn	Area 1	Area 2
Agelaia multipicta	6	4	10	-	-	-	10
Agelaia pallipes	125	53	178	52	50	102	280
Agelaia vicina	8	8	16	-	-	-	16
Apoica pallida	1	1	2	-	-	-	2
Brachygastra lecheguana	-	-	-	1	3	4	4
Polybia chrysothorax	9	1	10	-	1	1	11
Polybia dimidiata	6	5	11	5	4	9	20
Polybia fastidiosuscula	1	2	3	3	-	3	6
Polybia ignobilis	10	14	24	1	2	3	27
Polybia minarum	-	1	1	-	-	-	1
Polybia occidentalis	3	-	3	2	2	4	7
Polybia paulista	-	5	5	1	-	1	6
Polybia sericea	2	1	3	2	1	3	6
Polybia jurinei	1	4	5	2	-	2	7
Protonectarina sylveirae	-	1	1	-	-	-	1
Synoeca cyanea	1	1	2	1	6	7	9
Mischocyttarus cassununga	-	-	-	1	-	1	1
Mischocyttarus drewseni	-	1	1	-	10	10	11
Mischocyttarus mattogrossoensis	4	6	10	-	-	-	10
Mischocyttarus rotundicollis	1	-	1	-	-	-	1
Mischocyttarus tricolor	1	1	2	-	-	-	2
Mischocyttarus montei	-	2	2	-	-	-	2
Polistes lanio	3	4	7	3	-	3	10
Total Abundance	182	115	297	74	79	153	450
Total Richness	16	19	21	12	9	14	23

composition of the wasp community in the study site. For the post-fire period, Jackknife1 and 2 estimators predicted 18.4 and 19.8 species respectively what means that we sampled between 76.2% and 70.1% of the actual species richness left after the burn, respectively.

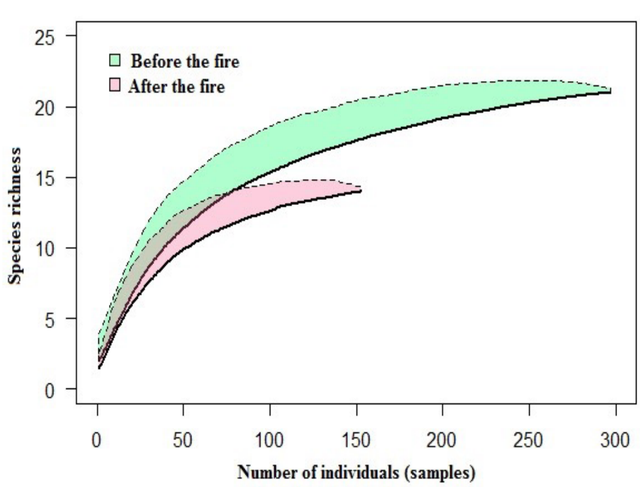

Fig 2. Rarefaction Curve based in the sampling (rarefaction calculated with the program R) for the periods before and after the fire.

When broken down by areas and years we observed in the first year, in area 1 total abundance of 182 individuals (61.3%) distributed in 16 species (76.2%) while in area 2 there were 115 individuals (38.7%) and 19 species (90.5%) and there were no significant differences between the two areas in year one in abundance and species richness (Table 2). Cross comparison of areas and years showed a significant 52.6% reduction in the species richness of area 2 after the burn,

Table 2. Summary of Kruskal-Wallis tests employed to compared species richness (upper triangle) and abundance (lower triangle).

	Area 1 Y1	Area 2 Y1	Area 1 Y2	Area 2 Y2
Area 1 Y1	- - -	H=0.1 P = 0.871	H = 1.7 P = 0.191	H = 1.7 P = 0.196
Area 2 Y1	H = 1.9 P = 0.172	- - -	**H = 3.5** **P = 0.062**	**H = 5.5** **P = 0.019**
Area 1 Y2	**H = 3.1** **P = 0.078**	H = 1.1 P = 0.297	- - -	H<0.1 P = 0.935
Area 2 Y2	**H = 3.7** **P = 0.054**	H = 0.2 P = 0.631	H=0.1 P = 0.809	- - -

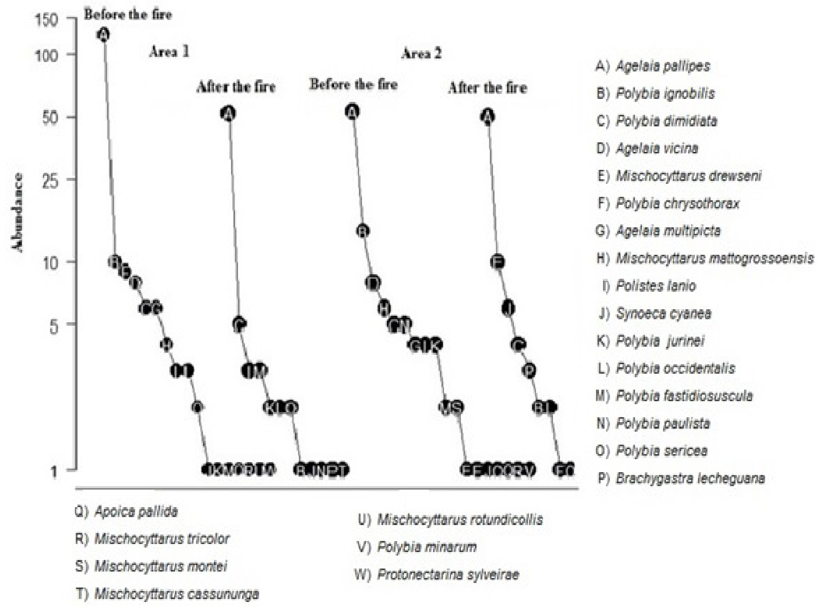

Fig 3. Distribution of the species of social wasps in areas 1 and 2 before and after the fire in a Brazilian Savanna fragment in Rio Claro.

and a marginally not significant 36.8% difference (p = 0.06) when comparing area 2 before the burn with area one after the fire. In abundance we observed a marginally not significant 36.8% difference between years in the unburned area, and a just marginally not significant 56.5% difference in abundance between area 1 before the fire and area two after the fire (Table 2 and Fig 3).

The non-metric multidimensional scaling (MDS) showed that area 1 and 2 before the fire had the wasps communities with the highest degree of resemblance in composition and structure as the polygons that define them greatly overlapped (Fig 4). In contrast area 2 before and after the burn represent the most distant polygons suggesting considerable differences in composition and structure of the recorded communities. This analysis also suggests either an indirect effect of fire on the wasp community of the non-burn area or simply caught the yearly variability in the community, since there a notorios spatial separation of the polygons define area 1 before and after the burn.

Agelaia pallipes (Olivier) represented 59.9% (178) of the individuals collected in the first inventory and 66.7% (102) in the second, being the most abundant species. The second most representative species was *Polybia ignobilis* (Olivier), with 24 individuals (8.1%) in the first inventory and *Mischocyttarus drewseni*, with 10 individuals (6.5%) in the second. The other species presented a frequency below 6.0% in the two years of sampling.

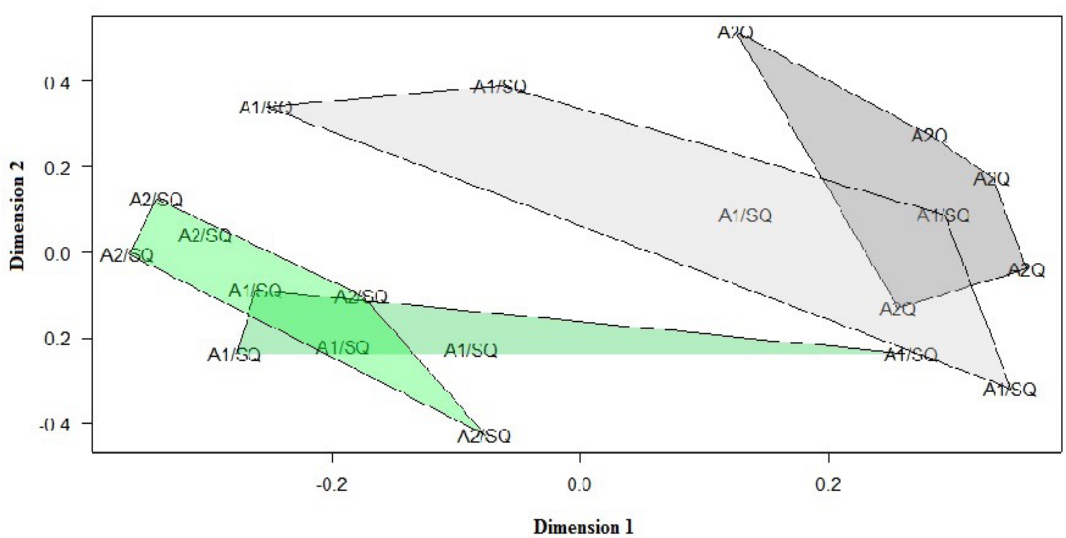

Fig 4. Multidimensional Scale (MDS) non metric for the evaluation of interlocal differences in area 1 without burning in the first year (A1/SQ), area 2 without burning in the first year (A2/SQ), area 1 without burning in the second year (A1/SQ), area 2 with burning in the second year (A2/Q).

A. multipicta (Haliday), *A. vicina* (Saussure), *Apoica pallida* (Olivier), *Poly. minarum* (Ducke), *Protonectarina sylveirae* (Saussure), *M. mattogrossoensis* (Zikán), *M. rotundicollis* (Cameron), *M. tricolor* (Richards) and *M. montei* (Zikán) were the species that were not observed after the fire, representing a loss of 42.8% of the species registered for the first year (Fig 5). However, two species (*Brachygastra lecheguana* (Latreille) and *M. cassununga* (R. Von Ihering) were not registered in the first year of collection, but were sampled after the fire in the area (Table 1 and Fig 5).

In the first month of collection after the fire (September 2013), we saw a nest of *B. lecheguana* still active, although affected by the burning. However, in the following five sampling campaigns the nest was observed to decline and there were no further capture of individuals of this specie. Regarding *M. cassununga,* only one individual was collected during all the collection period, in the month of November.

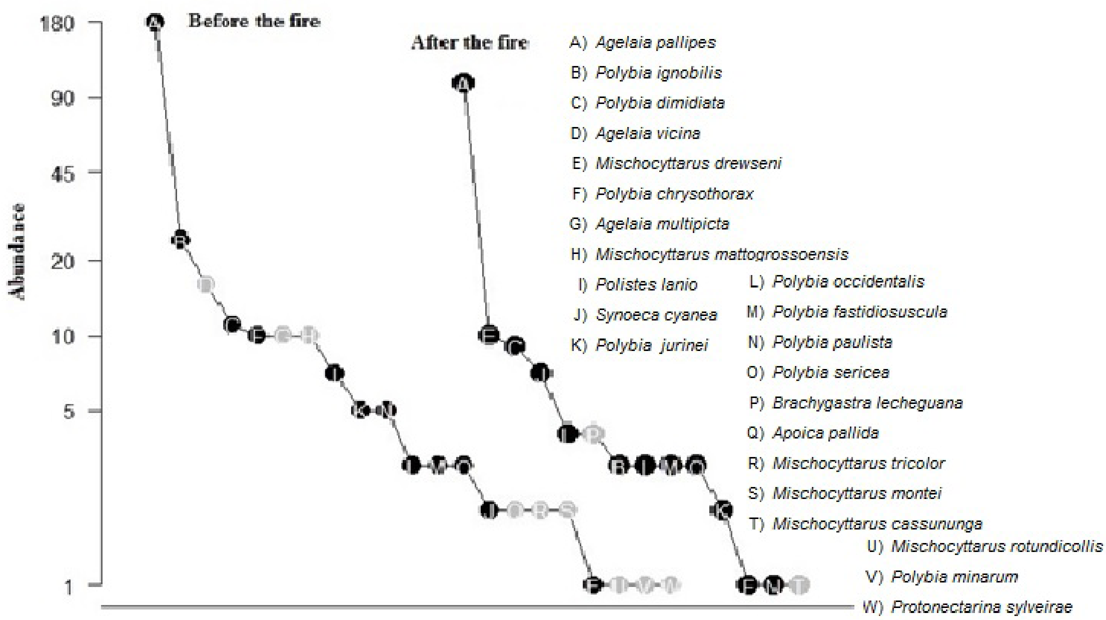

Fig 5. Distribution of species of social wasps in the Regenerating Savanna in Rio Claro. Gray letters in the first year indicate the species that disappeared in the post-fire period and those that are presented in gray for the second year were registered only in the post-fire.

Discussion

In the Brazilian literature, few studies emphasize the impact of fire on the community of social wasp, even when they had occurred during inventories and at most it is related only as an eventuality during the collection period. Thus, a deep discussion over this subject is very much limited by the lack of robust data on this issue.

A significant reduction in the number of species and abundance before and after fire in this study was observed. The losses of 33.3% species and 48.5% in abundance after the fire are similar to the data of Locher et al. (2014) in Ipeúna, São Paulo. In the cane field, where the burning of the straw occurred, there was a decrease of 31.4% in the abundance and 18.2% in the richness. In the riparian forest, where burning had not occurred, but closer to the sugar cane monoculture, there were 19.5% less records and 25% less species observed. Corroborating the present study we cannot distinguish between indirect fire effects and annual variation. This same relationship was observed by Locher et al. (2014) in a panel of riparian forest and plantation of sugar cane. The author reported that six months after the start of the collections there was the burning of sugarcane straw. When analyzing the abundances of captured species of the three previous months and the three months after the fire, it was observed that there was no significant difference among the samples of the riparian forest and those from the sugarcane plantation. However, after the burning of the straw of sugarcane, there were different species of social wasps, both at the edge of the riparian forest, as in the sugarcane plantation, despite the richness was less than three months after the fire. Which eliminating this environment, there was a decrease in the abundance of individuals from the second month after the firing, factor that according to the author can be correlated with the reduction of protected environments and trapped in the planting area, and therefore an increased migration into the woods, making it difficult to collect these, both in the sugarcane plantation, as in the edge of the riparian forest.

Rarefaction curves showed that in the pre and post fire periods the sampling effort was sufficient to estimate accurately the composition of the wasp community in the study site. However, it is important to outline that the collections were finalized in cold months (May and June 2014), what can explain the lower number of individuals and species sampled.

The air temperature during a fire can vary from 85°C to 840°C, while the soil temperatures range from 29°C to 55°C at 1 cm depth. For species of social wasps, nests can be built on the abaxial surface of leaves, in human constructions (*Polistes, Mischocyttarus, Apoica*, some species of *Polybia*), directly on the trunk of a tree (*Synoeca*), caught in vegetable branches (*Brachygastra* and *Polybia*), hidden in cavities, such as holes in the trunks of trees or soil (some species of *Agelaia* and *Polybia*) (Carpenter & Marques, 2001). All these genera present in this study were vulnerable in the area of the fire due to high temperatures in both the vegetation and on the ground.

The variation in soil temperature below 5 cm depth is almost zero, reaching a maximum of 3°C, without occurrence of fire (Miranda et al., 1993). Castro Neves & Miranda (1996) showed that after a fire in an off-course change of the albedo and heat flow in soil increased the amplitude of soil temperature of about 30°C to 1 cm deep, 10°C 5 cm deep, while the depth of 10 cm did not changed. Due to the *A. pallipes* nesting habit, it is possible that the burning did not reach their nests as they are found in such abandoned chambers of the genera ant nests *Atta*, in armadillo tunnels, among the roots of trees, hollow trunks and various artificial constructions, generating greater protection (Zucchi et al., 1995; Noll et al., 1997).

However, these effects are short-term, since the vegetation tends to recover quickly. The heat also influences altering the flowering pattern of some species (Prada et al., 1995), toughness of leaves (Vieira et al., 1996) and particularly enhancing the availability of food for herbivores during the dry season (Rodrigues, 1996). The feeding of social wasps is based on proteins from the capture of insects and other arthropods, nectar carbohydrates and exudates of Hemiptera, besides cellular contents and water (Gobbi & Machado, 1985). By using a range of features present in the environment, such as water, vegetable fiber, nectar and prey, social wasps reveal an opportunistic character, they return to places with large supply of resources or food, in search for the optimization of foraging and decrease in the search effort (Raveret-Richter, 2000). Thus, this change in food availability may favor the social wasps and maintain populations even after the fire.

As well as the organisms, resources are also affected differently by the fire. Consequently, specialist species (dependent on one or a few types of food) can be more subject to local extinction. As for generalist species, the limitation of some resources has few negative effects on populations, since they can be replaced by another (Frizzo et al., 2011). Clemente et al. (2013) in their study of interaction networks of social wasps and different species of plants, noted that the network was more complex in the riparian forests, presenting a higher number of species and individuals and a larger number of links between them. The degree of specialization of the network was more general in the riparian forests when compared to other phytophysiognomy studied, Rupestrian Field, which presents more strict vegetation characteristics. Interactions in the Rupestrian Field tended to specialization, with higher chances of local extinctions. An environment such as the one of the present study, after firing, can have considerably affected specialist species, which leads to decrease in abundance or even local extinction of these species.

Lawton (1983) and Santos et al. (2007) reported that environments with more complex structure enable the establishment and survival of more species of social wasps. The vegetation exerts considerable influence on the social wasps communities as it provides support for foundation of nests and food resources, and indirectly affects these communities by variations caused in temperature, air humidity and amount of ambient shadow. The species of social wasps that nest only on certain conditions, select the locations of their nests by the density and types of vegetation, whether open or closed, as well as the shape and arrangement of leaves and other plant structures (Machado, 1982; Santos & Gobbi, 1998). Thus, the alteration of the environment by the fire episode is a limiting factor for some species which explains the lower richness and abundance when compared to the first year.

The study performed by Chaibub (2013) aimed to compare the abundance, richness and diversity of social wasps with the work done by Elpino-Campos et al. (2007), in the same area from 2003 to 2004 where there were three fires during the collection period. The aim was to see whether the reduction of anthropic action (fire) over time would generate a significant increase in the diversity and abundance of social wasps. The diversity of species found in CCPIU (Itororó Ecological Reserve and Hunt and Fishing Club) before the fire was higher (1.063), compared to 10 years after (0.916). There was not the capture of unique species in this new study. Also, there was no difference in the abundance of individuals and the richness of species in the samples before and ten years after the fire (paired $t = 0.174$, $p = 0.872$, paired $t = 4.045$, $p = 0.027$, respectively), and between the different seasons of the year (paired $t = 0.174$, $p = 0.872$; paired $t = 4.045$, $p = 0.027$, respectively), although a greater abundance of individuals 10 years after the fire had been demonstrated.

Chaibub (2013) reports that with the current surveillance of the CCPIU Reserve, fires, frequent in the Savanna biome (Oliveira & Marquis, 2002), but not in an anthropic way, became rare or null. Even with this increased protection of the area and the rare burning events, the study Elpino-Campos et al. (2007) sampled ten species more than the ones in Chaibub (2013).

A. pallipes showed the highest abundance in Regenerating Savanna, with approximately 60% of individuals collected in the first year and more than 64% in the second, which corroborates in the study by Gomes and Noll (2009). The large representativity of *A. pallipes* in the Regenerating Savanna, an area with a high degree of degradation, possibly occurs because this species is less sensitive regarding the environmental degradation, since it nests in cavities in the soil (Noll et al., 1997). The same applies to the second year where the highest frequency is of this species over others.

A. vicina was not registered in the second year, which can be explained since this species needs hollow tree trunks or large natural cavities such as caves, since it is the species that builds the largest colonies, representatives of the subfamily Polistinae, with its population reaching more than one million individuals and a great capacity for foraging (Zucchi et al., 1995; Oliveira et al., 2010).

A. pallipes has wide distribution, from Costa Rica to Argentina and Paraguay (Richards, 1978). The great variety of habitats to its nest foundation gives *A. pallipes* greater plasticity, which explains the higher frequency in the Regenerating Savanna, an environment with high anthropogenic impact and degradation (Zucchi et al., 1995; Noll et al., 1997).

A. pallipes, is possibly less sensitive in relation to environmental degradation (Noll et al., 1997). In a study conducted in four cities in the Northwest of the State of São Paulo, *A. pallipes* was present in all study areas (Tanaka-Junior & Noll, 2011), also being representative in other studies such as Gomes and Noll (2009).

Species like *Poly. sericea* (Olivier), *Poly. paulista* (H. von Ihering), *B. lecheguana* and *Poly. ignobilis* (Haliday) present a wide range of ecological tolerance than other species and are usually dominant in open ecosystems, with strict environmental conditions (Santos et al., 2007). In this study, these species, even with less frequency, were able to hold on to the second year. Especially *B. lecheguana* that was observed in the first month of post-fire collection, but the nest had deceased due to fire and more individuals were not observed in the remaining months.

In the study by Souza et al. (2010), through multivariate analysis of indication value (*Species Indicator Value*), obtained through the Monte Carlo Test, in order to assess the ecological relationship between social wasps and the different faces in the area of study revealed that *Poly. fastidiosuscula* (Saussure), was present only in preserved areas, however, for *M. drewseni* the indication value was for degraded areas. In this study, *Poly. fastidiosuscula* presented the same abundance (n = 3) before and after the fire. But *M. drewseni*, corroborating Souza et al. (2010), presented only one individual in the first year and after the fire were ten where degradation was bigger.

Rodrigues (1996) and Vieira et al. (1996) report that resettlement may be of two types, endogenous or exogenous. Endogenous resettlement is carried out by individuals who survived the fire, either by taking refuge in shelters, nests, or move temporarily to adjacent areas and when resettling in the area their offspring spreads. Exogenous recolonization is characterized by the death of local individuals and establishment of immigrant individuals, usually coming from adjacent localities that were not affected by fire (Marini-Filho, 2000). This area of Regenerating Savanna is bordered on the south by the Universidade Estadual Paulista - UNESP and on the northeast by the State Forest Edmundo Navarro de Andrade (Cardoso-Leite et al., 2004). In the lower part of the area, there is a river that forms a Swampy Wood. (Plattineti-Júnior, 1979). These two vegetation areas may have served as a refuge for social wasp species or feeding the burned area with species.

However it is difficult to determine how long the animal community recovered from the impacts of fire. What the different studies seem to show is that apparently these recovery processes seem to be more rapid for the invertebrate fauna (Vasconcelos et al., 2008) than for the small vertebrates fauna (Fariaet al., 2004; Henriques et al., 2006). Once noted the considerable impact on the richness and abundance of social wasps after the fire, monitoring in the long term is important to verify that the restoration of fauna occurs. These aspects motivate most studies in this area in the long term.

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References

Abrams, M.D. (1992). Fire and the Development of Oak Forests. BioScience, 42: 346-353. doi: 10.2307/1311781.

Andrade, G.A.D. (2008). Savanas tropicais: dimensão, histórico e perspectivas. In F.G. Faleiro & A.L.D.F. Neto (Eds.), Savanas: Desafios e estratégias para o equilíbrio entre sociedade, agronegócio e recursos naturais (pp 48-77). Planaltina: Embrapa Cerrado.

Ayres, M., Ayres Junior, M., Ayres, D.L. & Santos, A.A. (2007). BioEstat 5.0 – Aplicações estatísticas nas áreas das ciências biológicas e médicas. Belém: MCT/IDSM/CNPq, 364 p.

Barros, M.A.G. (1998). Sistemas reprodutivos e polinização em espécies simpátricas de *Erythroxylum* P. Br. (Erythroxylaceae) do Brasil. Brazilian Journal of Botany, 21: 159-166. doi: 10.1590/S0100-84041998000200008.

Cardoso-Leite, E., Covre, T.B., Ometto, R.G., Cavalcanti, D.C. & Pagani, M.I. (2004). Fitossociologia e caracterização sucessional de um fragmento de Mata Ciliar, em Rio Claro, SP, como subsídio à recuperação da área. Revista do Instituto Florestal, São Paulo, 16: 31-41.

Castro Neves, B.M. & Miranda, H.S. (1996). Efeito do fogo no regime térmico do solo de um campo sujo de Cerrado. In H.S. Miranda, C.H. Saito & B.F.S. Dias (Eds.), Impactos de queimadas em áreas de Cerrado e Restinga (pp. 20-30). Brasília: ECL, Universidade de Brasília.

Carpenter, J.M. & Marques, O.M. (2001). Contribuição ao estudo dos vespídeos do Brasil (Insecta, Hymenoptera, Vespoidae, Vespidae). Série Publicações Digitais, v. 2. Cruz das Almas: Universidade Federal da Bahia, 147 p.

Chaibub, W.N. (2013). A comunidade de vespas sociais (Hymenoptera, Vespidae) de uma região de cerrado: variação temporal e espacial. Dissertação (Mestre em Ciências-Entomologia), Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto da Universiade de São Paulo, Ribeirão Preto, p 35.

Clemente, M.A., Lange, D., Dáttilo, W., Del-Claro, K. & Prezoto, F. (2013). Social wasp-flower visiting guild in less structurally complex habitats are more susceptible to local extinction. Sociobiology, 60: 337-344. doi: 10.13102/sociobiology.v60i3.337-344.

Faria, A.S., Lima, A.P. & Magnusson, W.E. (2004). The effects of fire on behavior and relative abundance of three lizard species in an Amazonian Savanna. Journal of Tropical Ecology, 20: 591-594. doi: 10.1017/SO266467404001798.

Frizzo, T.L.M., Bonizário, C., Borges, M.P. & Vasconcelos, H.L. (2011). Revisão dos efeitos do fogo sobre a fauna de formações savânicas do Brasil. Oecologia Australis, 15: 365-379. doi:10.4257/oeco.2011.1502.13.

Gobbi, N. & Machado, V.L.L. (1985). Material capturado e utilizado na alimentação de *Polybia (Myrapetra) paulista* Ihering, 1896 (Hymenoptera - Vespidae). Anais da Sociedade Entomológica do Brasil, 14: 189-195.

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. doi: 10.1590/S0085-56262009000300018.

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. (2001). PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica, 4(1): 9 p. Retrieved from: http://palaeo-electronica.org/2001_1/past/past.pdf.

Härdle, W. & Simar, E.L. (2007). Applied Multivariate Statistical Analysis, Berlin: Springer, 486 p.

Heithaus, E.R. (1979). Community structure of Neotropical flower visiting bees and wasps: diversity and phenology. Ecology, 60: 190-202. doi: 10.2307/1936480.

Henriques, R.P.B., Briani, D.C., Palma, A.R.T. & Vieira, E.M. (2006). A simple graphical model of small mammal succession after fire in the Brazilian Cerrado. Mammalia, 70: 226-230. doi: 10.1515/MAMM.2006.044.

Hermes, M.G. & Köhler, A. (2006). The flower-visiting social wasps (Hymenoptera, Vespidae, Polistinae) in two areas of Rio Grande do Sul State, Southern Brazil. Revista Brasileira de Entomologia, 50: 268-274. doi: 10.1590/S0085-56262006000200008.

Hobbs, R.J., & Huenneke, L.F. (1992). Disturbance, diversity, and invasion - implications for conservations. Conservation Biology, 6: 324-337. doi: 10.1046/j.1523-1739. 1992.06030324.x.

Hoffmann, W.A. (1996). The effects of fire and cover on seedling establishment in a neotropical savanna. Journal of Ecology, 84 :383-393. doi: 10.2307/2261200.

Hoffmann, W.A. (2000) Post-establishment seedling success in the Brazilian Cerrado: A comparison of savanna and forest species. Biotropica, 32: 62-69. doi: 10.1111/j.1744-7429.2000.tb00448.x.

Lawton, J.H. (1983). Plant architecture and the diversity of phytophagous insects. Annual Review of Entomology, 28: 23-39. doi: 10.1146/annurev.en.28.010183.000323.

Lyon, L.J., Huf, M.H., Hooper, R.G., Telfer, E.S., Schreiner, D.S. & Smith, J.K. (2000). Fire effects on wildlife food. In J.K. Smith (Ed.), Wildland fire in ecosystems: effects of fire on fauna (pp. 51-58). Ogden: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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.

Machado, V.L.L. (1982). Plants which supply “hair” material for nest building of *Protopolybia sedula* (Saussure, 1984). In P. Jaisson (Ed.), Social insects in tropics (pp. 189-192). Paris: University Paris-Nord.

Marini-Filho, O.J. (2000). Distance-limited recolonization of burned Cerrado by leaf-miners and gallers in central Brazil. Environmental Entomology, 29: 901-906. doi: 10.1603/0046-225X-29.5.901.

Medeiros, M.B. & Miranda, H.S. (2005). Mortalidade pós-fogo em espécies lenhosas de campo sujo submetido a três queimadas prescritas anuais. Acta Botanica Brasilica, 19: 493-500. doi: 10.1590/S0102-33062005000300009.

Miranda, A.C., Miranda, H.S., Dias, I.D.O. & Dias, B.F.D. (1993). Soil and air temperatures during prescribed Cerrado fires in Central Brazil. Journal of Tropical Ecology, 9: 313-320. doi: 10.1017/S0266467400007367.

Miranda, H.S., Bustamante, M.M.C. & Miranda, A.C. (2002). The fire factor. In P.S. Oliveira & R.J. Marquis (Eds.), The cerrados of Brazil: ecology and natural history of a neotropical savanna (pp. 51-68). New York: Columbia University Press.

Mistry, J. (1998). Fire in the Cerrado (savannas) of Brazil: an ecological review. Progress in Physical Geography, 22: 425-448. doi: 10.1177/030913339802200401.

Mittermeier, R.A., Da Fonseca, G.A.B., Rylands, A.B. & Brandon, K. (2005) A brief history of biodiversity conservation in Brazil. Conservation Biology, 19: 601-607. doi: 10.1111/j.1523-1739.2005.00709.x.

Noll, F.B., Simões, D., Zucchi, R. (1997). Morphological caste differences in the neotropical swarm-founding Polistinae wasps: *Agelaia m. A. multipicta* and *A. p. pallipes*

(Hymenoptera Vespidae). Ethology, Ecology and Evolution, 9: 361-372. doi: 10.1080/08927014.1997.9522878.

Oliveira, P.S. & Marquis, R.J. (Eds.) (2002). The cerrados of Brazil: ecology and natural history of a neotropical savanna. New York: Columbia University Press, 424 p.

Oliveira, O.A.L., Noll, F.B. & Wenzel, J.W. (2010). Foraging Behavior and Colony Cycle of *Agelaia vicina* (Hymenoptera: Vespidae; Epiponini). Journal of Hymenoptera Research, 19: 4-11.

Pinarda, M.A. & Huffmana, J. (1997). Fire resistance and bark properties of trees in a seasonally dry forest in eastern Bolivia. Journal of Tropical Ecology, 13: 727-740. doi: 10.1017/S0266467400010890.

Potascheff, C.M., Lombardi, J.A. & Lorenzi, H. (2010). Angiospermas arbóreas e arbustivas do campus da Universidade Estadual Paulista Júlio de Mesquita, Rio Claro (SP). Bioikos, 24(1): 21-30.

Prada, M., Marini-Filho, O.J. & Price, P.W. (1995). Insects in flower heads of *Aspilia foliacea* (Asteraceae) after a fire in a central Brazilian savanna: evidence for the vigor hypothesis. Biotropica, 27: 513-518. doi: 10.2307/2388965.

Prezoto, F. (1999). A importância das vespas como agentes no controle biológico de pragas. Revista Biotecnologia, Ciência & Desenvolvimento, 2: 24-26.

R Development Core Team. (2009). A language and environment for statistical computing. R Foundation for Statistical Computing. http://www.r-project.org. (accessed date: 23 June, 2014).

Ramos-Neto, M.B. & Pivello, V.R. (2000). Lightning fires in a Brazilian Savanna National Park: Rethinking management strategies. Environmental Management, 26: 675-684. doi: 10.1007/s002670010124

Raveret-Richter, M. (2000). Social wasp (Hymenoptera: Vespidae) foraging behavior. Annual Review of Entomology, 45: 121-150. doi: 10.1146/annurev.ento.45.1.121.

Rafael, J.A., Melo, G.A.R., De Carvalho, C.J.B., Casari, S.A. & Constantino, R. (Eds.) (2012). Insetos do Brasil: Diversidade e Taxonomia. Ribeirão Preto: Holos Editora, 810 p.

Richards, O.W. (1978). The social wasps of the Americas, excluding the Vespinae. London: British Museum (Natural History), 580 p.

Rodrigues, F.H.G. (1996). Influência do fogo e da seca na disponibilidade de alimentos para herbívoros do Cerrado. In H.S. Miranda, C.H. Saito & B.F.S. Dias (Eds.), Impactos de queimadas em áreas de cerrado e restinga (pp. 76-83). Brasília: Universidade de Brasília.

Santos, G.M.M. & Gobbi, N. (1998). Nesting habits and colonial productivity of *Polistes canadensis canadensis* (L.) (Hymenoptera-Vespidae) in a caatinga area, Bahia State - Brazil. Journal of Advanced Zoology, 19: 63-69.

Santos, G.M.M., Bichara Filho, C.C., Resende, J.J., Cruz, J.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. doi: 10.1590/S1519-566X2007000200002.

Santos, G. M. M., Cruz, J.D & Marques, O.M. (2009). Diversidade de Vespas Sociais (Hymenoptera: Vespidae) em áreas de Cerrado na Bahia. Neotropical Entomology, 38(3):317-320. doi: 10.1590/S1519-566X2009000300003

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. doi: 10.1590/S1519-566X2006000200003.

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

Tanaka-Junior, G.M. & Noll, F.B. (2011) Diversity of Social Wasps on Semideciduous Seasonal Forest Fragments with Different Surrounding Matrix in Brazil. Psyche, 2011: 8 p. doi: 10.1155/2011/861747. Retrieved from: https://www.hindawi.com/journals/psyche/2011/861747/.

Urbini, A., Sparvoli, E. & Turillazzi, S. (2006). Social paper wasps as bioindicators: a preliminary research with *Polistes dominulus* (Hymenoptera, Vespidae) as a trace metal accumulator. Chemosphere, 64: 697-703. doi: 10.1016/j.chemosphere.2005.11.009.

Vasconcelos, H.L., Leite, M.F., Vilhena, J.M.S., Lima, A.P. & Magnusson, W.E. (2008). Ant diversity in Amazonian savanna: Relationship with vegetation structure, disturbance by fire, and dominant ants. Austral Ecology, 33: 221-231. doi: 10.1111/j.1442-9993.2007.01811.x.

Vieira, E.M., Andrade, I. & Price, P.W. (1996). Fire effects on a *Palicourea rigida* (Rubiaceae) gall midge: A test of the plant vigor hypothesis. Biotropica, 28: 210-217. doi: 10.2307/2389075.

Zucchi, R., Sakagami, S.F., Noll, F.B., Mechi, M.R., Mateus, S., Baio, M.V. & Shima, S.N. (1995). *Agelaia vicina*, a swarm-founding Polistinae with the largest colony size among wasps and bees (Hymenoptera: Vespidae). Journal of the New York Entomological Society, 103: 129-137.