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High Number of Species of Social Wasps (Hymenoptera, Vespidae, Polistinae) Corroborates the Great Biodiversity of Western Amazon: a Survey from Rondônia, Brazil

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Abstract

A survey of social wasps (Vespidae, Polistinae), common insects of Neotropical fauna, which perform a great variety of ecosystemic services, was conducted for the first time in areas of the Amazon forest in Rondônia state. The state is part of the Western Amazon, a region harboring high biodiversity, which is under threat due to constant deforestation. Three areas were sampled, and the wasps were actively collected, and an attractive liquid was sprayed onto the vegetation to bait the wasps. Two thousand nine hundred and sixty-one wasps were sampled in all three areas, distributed in 72 species of 15 genera. Thirty-nine species were recorded for the first time in the state and three others (*Agelaia melanopyga* Cooper*, Brachygastra cooperi* Andena and Carpenter and *Polybia diguetana* du Buysson) represents the first record for Brazil. *Agelaia* Lepeletier was the most abundant genus in all areas and the greatest species richness was found for *Polybia* Lepeletier. The highest number of species was recorded in Floresta Nacional do Jamari (51), followed by Estação Ecológica de Cuniã (46) and forest fragment of Universidade Federal de Rondônia (39). The latter also presented the highest number of different genera. The great diversity, mainly for Epiponini, which represented 64 of the 72 species, can be attributed to location of the areas and methodology.

Introduction

The Neotropical region has a rich fauna of social insects, as well as a great diversity of social wasps (Vespidae, Polistinae) (Richards, 1978; Carpenter & Marques, 2001; Noll, 2013). Polistinae wasps are represented by around 940 species (Noll, 2013; Somavilla et al., 2014a) and the Brazilian social wasps fauna (Polistinae) is the richest in the world, with more than 300 species, 104 of them endemic from Brazil (Somavilla et al., 2014b). This subfamily is divided into four tribes: Mischocyttarini (with one genus, *Mischocyttarus*), Polistini (with one genus, *Polistes*), Epiponini (19 genera) and Ropalidiini, with no representatives in Brazil (Noll, 2013).

Social wasps perform important and priceless ecosystemic services. As predators of other insects, they are important in the maintenance of food chains and in biological control, since they feed on larvae that are crop pests such as tomato, coffee, corn, eucalyptus, citrus fruits and vegetables (Carpenter & Marques, 2001; Souza et al., 2008, 2010a; Brügger et al., 2019; Prezoto et al., 2019). These wasps also act as pollinators (Hunt et al., 1991; Hermes & Köler, 2006; Santos et al., 2006; Nadia et al., 2007) and are well known for symbiosis with ants (Espelie & Herman, 1988), honey insects (Letourneau & Choe, 1987) and birds (Joyce, 1993). Some species are still useful as indicators of environmental quality (Souza et al., 2010b; Urbini et al., 2010).

The Brazilian Amazon harbor the great diversity of Polistinae wasps (Silveira, 2002; Silva & Silveira, 2009), where 20 genera and about 200 species were recorded, representing 70% of the Brazilian social wasps fauna (Silveira, 2002). Although this number seems very expressive, they are probably underestimated, given the extent of the Amazon and the low number of surveys for social wasps in this biome: Ilha de Maracá – Roraima (Raw, 1998), Caxiuanã – Pará (Silveira, 2002; Silveira & Silva, 2009), Serra do Divisor – Acre (Morato et al., 2008), Porto Acre, Senador Guiomard and Rio Branco – Acre (Gomes et al., 2018), dos Lagos Region – Amapá (Silveira et al., 2008), Mamirauá and Alvarães – Amazonas (Silveira et al., 2008), Reserva Ducke and Jaú National Park - Amazonas (Somavilla et al., 2014b; 2015) and Gurupi Biological Reserve – Maranhão (Somavilla et al., 2014a). There is also a bias in sampling, with most of the inventories (and consequently, the highest number of recorded species) concentrated in the Amazonas state (Barbosa et al., 2016). Thus, further investigations should lead to an increase in recorded species.

Located in the Northwestern of Brazil, the state of Rondônia is part of the Western Brazilian Amazon (Martins et al., 2014), which includes Bolivia, Colombia, Ecuador, Peru, and Western Brazil (Finer et al., 2015). This region is one of the world's last high-biodiversity wilderness areas (Finer et al., 2015), characterized by large tracts of relatively intact humid tropical forest, which harbor an extraordinary species richness (Bass et al., 2010; Pointekowski et al., 2019). However, the Western Amazon has been suffering from constant deforestation (Rosa et al., 2012; Mayes et al., 2019). Rondônia presents the third highest rate of deforestation and forest degradation of this biome, totaling 21% of the deforested areas of Amazon from August 2014 to January 2016 (Fonseca et al., 2016; Pointekowski et al., 2019). The high index of deforestation in the state is a reflection of the expansion of the agriculture frontier towards northern Brazil during the recent decades (Souza Jr. et al., 2013). The destruction of natural areas in the Amazon, especially habitat fragmentation is the direct cause of the reduction of diversity due to severe abiotic and biotic changes (Magnago et al., 2014; Rocha et al., 2018).

The only previous information regarding the social wasps of Rondônia are the works of Richards (1978), which is still the largest source of information on the distribution of Epiponini and other Neotropical Polistinae, and Raw (1988). In a current context of global climate change and accelerated species loss, the knowledge of biodiversity and the consequences of its destruction has become a major concern and challenge for the 21st century, since, as species disappear, we lose both known and unknown benefits they provide (Gascon et al., 2015; Troudet et al., 2017). Despite the high abundance and richness in Amazonian areas, knowledge about the diversity and biology of social wasps in the region is still underestimated. Here, we presented the first survey of social wasps (Polistinae) of Rondônia state.

Material and Methods

Three areas of Amazon rainforest located in the northern state of Rondônia, Brazil were studied (Fig 1): I – Estação Ecológica de Cuniã (ESEC) with approximately 186.743,26 ha (ICMBio, 2019a) is located between the cities of Porto Velho - RO and Humaita - AM (8º 05' 24'' S 63º 26' 07'' W); II – Floresta Nacional do Jamari (FLONA) with 222.114,24 ha (ICMBio, 2019b) the region covers the districts of Candeias do Jamari, Itapuã do Oeste and Cujubim - RO (09º 00' 00'' S 62º 44' 05'' W); III – Forest Fragment of Universidade Federal de Rondônia (UNIR) in the capital Porto Velho (08º 49' 53'' S 63º 56' 26'' W), with approximately 50 ha (Miranda, 2005). In the three areas, the vegetation is composed of dense ombrophilous forest and open ombrophilous forest. The climate is tropical humid, with an average temperature of 25 ºC, very rainy summer and winter a little drier. The relief is a little rough, and the average altitude is 240 meters (Schlindwein et al., 2012; SEDAM, 2012).

Samples were performed from April 2010 to November 2011 in ESEC and, from December 2011 to December 2012 in FLONA and UNIR. Wasps were collected actively (with the aid of an entomological net), follow the protocol developed by Noll and Gomes (2009), on trails or roads previously available in the forest. The protocol is based on the use of an attractive solution (50g of salt and 200g of sugar per liter of water), which was sprayed on the vegetation in five points equidistant 20 m. The points were observed individually for ten minutes and the liquid was reapplied every three hours of collection. Fourteen collections of 12 hours (6:00 am to 06:00 pm) were made in each area, totaling 168 hours of work and 504 hours considering all areas.

The collected specimens were stored in micro-tubes containing ethanol absolute. After identified, part of the collected material was deposited in the zoological collection of the Museu Paraense Emílio Goeldi, in Belém, Pará state, Brazil (*Mischocyttarus*) and in the Hymenoptera collection of Universidade Estadual Paulista "Júlio de Mesquita Filho", in São José do Rio Preto, São Paulo state, Brazil.

Sampling adequacy was evaluated by the construction of a rarefaction curve for each area using the Mao Tau method (Colwell et al., 2004). The non-parametric estimator Jackknife 1 was used to compare the sample with the estimated richness since the species richness observed is often an additive estimator in relation to the real species richness (Campos et al., 2013). Both analyses were performed using PAST 3.24 (Hammer et al., 2001).

Results

A total of 72 species of 15 genera of social wasps were collected (Table 1), most of them (17) sampled in the three areas, totalizing 2961 specimens. FLONA was the area with the highest number of species, 51, followed by ESEC, with 46 species and UNIR with 39 species. Considering the number of

Fig 1. Satellite image of the areas sampled. A. Floresta Nacional do Jamari (FLONA); B. Estação Ecológica de Cuniã (ESEC); C. forest fragment of Universidade Federal de Rondônia (UNIR). Scale bar: 10Km. Source: GoogleEarth.

genera, 14 different genera were sampled in UNIR, followed by ESEC and FLONA, both with ten genera. Four of the 15 genera sampled – *Apoica* Lepeletier, *Chartergellus* Bequaert, *Chartergus* Lepeletier, and *Pseudopolybia* von Dalla Torre – were only found in UNIR. FLONA was also the area with the largest number of exclusive species (12), followed by UNIR (11) and ESEC (6). Four of the six species of *Mischocyttarus* de Saussure were found only in ESEC. Seventeen species were collected in all areas.

Polybia Lepeletier and *Agelaia* Lepeletier were the most diverse genera, with 23 (one-third of species) and 13 species collected respectively. The greatest species richness for each area was also found for *Polybia,* with 19 species in FLONA, 16 in UNIR and 14 in ESEC. Despite the highest number of species of *Polybia*, for all three areas, the most abundant genus was *Agelaia* Lepeletier, representing almost half (47.8%) of the total wasps sampled. The same occurred when each area was analyzed individually, with *Agelaia* representing 46.8% of specimens sampled in FLONA, 58,7% in ESEC and 36% in UNIR.

From the 72 species, 39 of them are new records for the state. Other three species – *Agelaia melanopyga* Cooper 2000*, Brachygastra cooperi* (Richards, 1978), and *Polybia diguetana* du Buysson 1905 – were sampled for the first time in Brazil. Despite the high number of species sampled, Jackknife values indicate that there were still species to be collected. However, the rarefaction curve (Fig 2) tended to stabilize, indicating that the sampling effort was sufficient for a significant species registration.

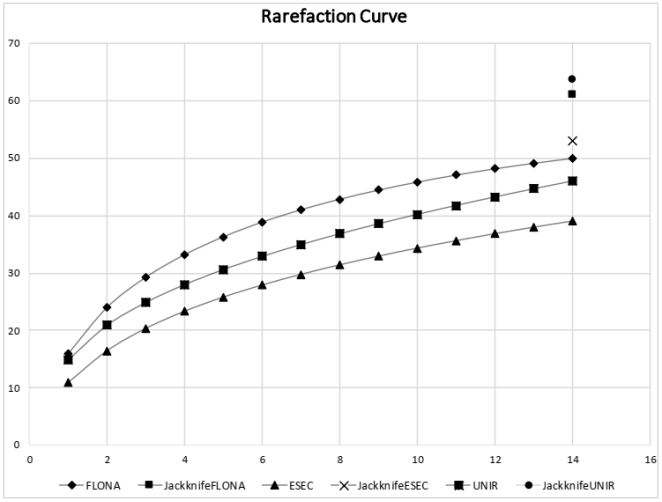

Fig 2. Rarefaction curve for species of social wasps (Polistinae) collected in Floresta Nacional do Jamari (FLONA), Estação Ecológica de Cuniã (ESEC) and in the forest fragment of Universidade Federal de Rondônia (UNIR). The x-axis represents the number of collections (1 to 14) and the y-axis represents the number of species sampled. The isolated symbols represent the richness estimated by the Jackknife1 index, indicating that there were still species to be sampled for all areas.

Discussion

From the surveys of social wasps carried out for the Amazon biome, this survey sampled the highest number of Epiponini species (64) and was the second in the number of Polistinae species, 72 in total (the first was Silveira, 2002 with 79 species sampled). Three species were recorded for the first time in Brazil. Prior to this survey, the only distributional record for *B. cooperi* was the data of the holotype, in Colombia (Andena & Carpenter, 2012). *P. diguetana* has already been recorded in Bolivia, a country bordering Rondônia. This species presents a broad distribution in other eastern Amazon countries (Peru, Ecuador, and Colômbia), Venezuela, Central America, México and Southwestern of U.S.A. The presence of *A. melanopyga* in Rondônia extends its distribution southernmost since the previous records are from Central America, Colombia and Ecuador (Richards, 1978; Natural History Laboratory IUNH).

Table 1. List of species and number of specimens of social wasps (Vespidae, Polistinae) collected in three areas of Rondônia state, Brazil. Floresta Nacional do Jamari (FLONA); Estação Ecológica de Cuniã (ESEC); forest fragment of Universidade Federal de Rondônia (UNIR).

Species	FLONA	ESEC	UNIR	Total
Epiponini				
Agelaia angulata (Fabricius, 1804)	25	49	-	74
Agelaia cajennensis (Fabricius, 1798)[1]	13	21	21	55
Agelaia centralis (Cameron, 1907)[1]	15	53	-	68
Agelaia fulvofasciata (Degeer, 1773)	278	165	142	585
Agelaia hamiltoni (Richards, 1978)	117	223	7	347
Agelaia lobipleura (Richards, 1978)[1]	1	-	-	1
Agelaia melanopyga Cooper, 2000[2]	1	-	-	1
Agelaia myrmecophila (Ducke, 1905)[1]	11	33	37	81
Agelaia ornata (Ducke, 1905)[1]	16	18	-	34
Agelaia pallipes (Olivier, 1791)	20	-	3	23
Agelaia pallidiventris (Richards, 1978)[1]	1	-	-	1
Agelaia testacea (Fabricius, 1804)	61	1	84	146
Agelaia timida Cooper, 2000[1]	1	-	-	1
Angiopolybia paraensis (Spinola, 1851)	54	35	31	120
Angiopolybia zischkai Richards, 1978[1]	85	190	198	473
Apoica gelida Van der Vecht, 1973	-	-	1	1
Brachygastra albula Richards, 1978	3	-	-	3
Brachygastra augusti (de Saussure, 1854)[1]	2	1	-	3
Brachygastra bilineolata Spinola, 1841	8	2	-	10
Brachygastra cooperi (Richards, 1978)[2]	1	-	-	1
Brachygastra lecheguana (Latreille, 1824)	5	-	-	5
Brachygastra scutellaris (Fabricius, 1804)	5	1	1	7
Chartergellus amazonicus (Fabricius, 1804)[1]	-	-	30	30
Chartergellus communis Richards, 1978[1]	-	-	1	1
Chartergellus zonatus (Spinola, 1851)[1]	-	-	1	1
Charterginus fulvus Fox, 1898[1]	-	1	1	2
Chartergus globiventris de Saussure, 1854[1]	-	-	2	2
Leipomeles dorsata Fabricius,1804 [1]	5	8	7	20
Parachartergus flavofasciatus (Cameron, 1906)[1]	4	4	15	23
Parachartergus fraternus (Gribodo, 1892)[1]	3	-	1	4
Parachartergus lenkoi Richards, 1978[1]	-	1	2	3
Parachartergus pseudoapicalis Willink, 1959[1]	1	-	1	2
Parachartergus smithii (de Saussure, 1854)[1]	-	1	1	2
Polybia bifasciata de Saussure, 1854[1]	5	-	-	5
Polybia bistriata (Fabricius, 1804)	2	-	6	8
Polybia catillifex Moebius, 1856[1]	4	-	9	13
Polybia depressa (Ducke, 1905)[1]	-	4	-	4
Polybia diguetana Buysson, 1905[2]	1	-	-	1
Polybia dimidiata (Olivier, 1791)	3	5	2	10
Polybia eberhardae Cooper, 1993[1]	4	-	20	24
Polybia emaciata Lucas,1879	-	19	23	42
Polybia gorytoides gorytoides Fox, 1899[1]	13	3	17	33
Polybia jurinei de Saussure, 1854	39	1	5	45
Polybia liliacea (Fabricius, 1804)	42	4	2	48
Polybia micans Ducke, 1904[1]	24	10	48	82

Table 1. List of species and number of specimens of social wasps (Vespidae, Polistinae) collected in three areas of Rondônia state, Brazil. Floresta Nacional do Jamari (FLONA); Estação Ecológica de Cuniã (ESEC); forest fragment of Universidade Federal de Rondônia (UNIR). (Continuation)

Species	FLONA	ESEC	UNIR	Total
Epiponini				
Polybia parvulina Richards, 1970[1]	3	-	3	6
Polybia platycephala Richards, 1951	7	2	8	17
Polybia procellosa dubitata Ducke, 1910[1]	-	1	-	1
Polybia quadricincta Saussure, 1854	3	-	-	3
Polybia rejecta (Fabricius, 1798)	79	58	59	196
Polybia rufitarsis Ducke, 1904[1]	4	2	-	6
Polybia scrobalis Richards, 1970	1	-	5	6
Polybia sericea (Olivier, 1791)	-	-	1	1
Polybia singularis Ducke, 1909	7	1	-	8
Polybia striata (Fabricius, 1787)	59	4	1	64
Polybia tinctipennis tinctipennis Fox, 1898[1]	24	1	1	26
Protopolybia acutiscutis Cameron, 1907	1	-	-	1
Protopolybia chartergoides Gribodo, 1891	-	-	1	1
Protopolybiarotundata Ducke, 1910[1]	-	-	1	1
Pseudopolybia compressa de Saussure, 1864[1]	-	-	1	1
Pseudopolybia vespiceps de Saussure, 1864	-	-	1	1
Synoeca chalibea de Saussure, 1852[1]	14	-	1	15
Synoeca surinama (Linnaeus,1767)	8	3	-	11
Synoeca virginea (Fabricius, 1804)	96	18	1	115
Mischocyttarini				
Mischocyttarus flavicans flavicans (Fabricius, 1804)[1]	-	-	1	1
Mischocyttarus gomesi Silveira, 2013	-	1	-	1
Mischocyttarus interruptus Richards, 1978[1]	-	2	-	2
Mischocyttarus labiatus (Fabricius, 1804)[1]	13	2	3	18
Mischocyttarus lecointei (Ducke, 1904)[1]	2	-	1	3
Mischocyttarus tomentosus Zikan, 1935	-	6	-	6
Polistini				
Polistes canadensis Linnaeus, 1758[1]	-	4	-	4
Polistes occipitalis Ducke, 1904[1]	1	-	-	1
Species richness	51	46	39	
Species abundance	1195	958	808	2961

[1] New records for Rondonia; [2] New records for Brazil.

Although many of the species found are common in other areas of the Amazon, we also found species, such as *Agelaia pallidiventris* (Richards, 1978), with a single previous record for Brazil in Amazonas state. This species seems to be endemic to the Western Amazon, occurring also in Colombia, Ecuador and Peru (Richards, 1978; Natural History Laboratory IUNH). For other species, the presence in Rondonia helps to fill a gap in geographical distribution, as observed for *Chartergellus zonatus* (Spinola, 1851) and *Protopolybia rotundata* Ducke, 1910. Geographic records for the former were from Peru and Pará state, in the north of Brazil. The later, also represents the first record in northern Brazil, since previous occurrence data were from French Guiana and Mato Grosso state, in middle-west of Brazil (Richards, 1978; Natural History Laboratory IUNH). The first occurrence in northern Brazil was also found for *Parachartergus pseudoapicalis* Willink, 1959, previously recorded for the Northeast, Middle-west, South and Southeastern regions of the country (Richards, 1978; Natural History Laboratory IUNH).

Agelaia was more abundant not only in this work but also in other regions of Amazon Forest (Raw, 1988; Silveira, 2002; Silveira et al., 2008; Morato et al., 2008; Silva & Silveira, 2009), probably by the habits of this genus that presents generalist and opportunistic species in relation to

the food and resources choice (Oliveira et al., 2010). *Polybia* was the richest genus in number of species, and also had been collected more frequently in other studies conducted in Amazonia (Silveira, 2002; Silveira et al., 2008; Morato et al., 2008; Somavilla et al., 2014a; 2014b; 2015; Gomes et al., 2018). Once it is the genus of Epiponini that presents the greatest number of species, with 58 already described (Carpenter & Kojima, 2002), this could be considered a predictable result.

A sampling of a large diversity of Polistinae can be attributed to more than one factor. One of them is the location of the collection areas in the Western Amazon, known for harboring great biodiversity (Brown, 1991; Hoorn et al., 2010; Gomes et al., 2018). Another factor is the methodology used. Although the employment of only one type of capture method seems not to be able to conduct a comprehensive species inventory, due to the great diversity of ecological niches occupied by wasps (Santos et al., 2007), the use of an attractive demonstrated to be a successful methodology, allowing the collection of more wasps than in previous surveys (Raw, 1988; Silveira, 2002; Silveiraet al., 2008; Moratoet al., 2008; Silva & Silveira, 2009).

Raw (1988) studying the activity of social wasps visiting various crops in two indigenous tribes in eastern Rondonia, collected 13 species of which only five *Agelaia fulvofasciata* (Degeer, 1773), *Polybia bistriata* (Fabricius, 1804), *P. jurinei* de Saussure, 1854, *P. striata* (Fabricius, 1787) and *Synoeca surinama* (Linnaeus, 1767) were also sampled in this study. The author also collected *Epipona tatua*, a species belonging to a genus not sampled in this survey, even with a much longer period of sampling and almost six times more species collected than Raw. This fact is in line with data on the rarefaction curve and the richness index, suggesting that all the diversity of social wasps of the state was not accessed, reinforcing the need for further studies not only for Rondônia but for Amazonia and the entire Neotropical region.

An interesting result was the greater diversity in terms of the genera found in UNIR, with the presence of *Apoica, Chartergellus, Chartergus,* and *Pseudopolybia* registered only in this area. UNIR is the smallest area (around three and four times smaller than ESEC and FLONA, respectively) and the one with the greatest anthropogenic interference, with nearby buildings and constant flow of people and vehicles. Studies conducted in areas with different levels of environmental preservation in the semideciduous Atlantic forest, showed a great diversity of social wasps also in small fragments and degraded areas (Noll & Gomes, 2009; Tanaka Jr. & Noll, 2011).

The generalist characteristic of many species of social wasps in the choice of food and resources on foraging activities (Raveret-Richter, 2000; Oliveira et al., 2010), and the flexibility in building nests according to the variety of ecological and climatic conditions (Rodrigues, 1968; Santos et al., 2007) allows some species to be well adapted to areas with anthropic interference (Gomes & Noll, 2009). Nevertheless, consideration should also be given to the fact that anthropogenic environments provide resources, such as water, which may make it advantageous for wasps to nest near them. Moreover, a smaller area is easier to be sampled more significantly than the larger ones.

Conclusion

This is the first survey of social wasps carried out for the state of Rondônia. Among the 72 species collected, there were three new records for Brazil. Three areas were sampled and even in UNIR, the smallest one and under the anthropic influence, diversity was high, with some genera found only there, showing the importance of conservation of small forest fragments. Moreover, most of the species were recorded for the first time in the state helping to fill in gaps in geographic distribution. Nevertheless, large holes still remain in the geographic distribution for many species of social wasps in Brazil, mainly in the Amazon Region, but also throughout the Neotropical region. The absence of taxonomic and biogeographic data generates insufficient information to attribute any condition (such as “rare” or “threatened”) to the wasp species of the sampled areas. In a region of great diversity but also high indexes of deforestation, as Western Amazon, further studies become necessary and urgent.

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