

Conservation Units as a protection tool for social wasps in Minas Gerais state, Brazil

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Abstract. Conservation Units are an important tool for the Brazilian biota protection. However, various taxa, including the social wasps, are undersampled or are unknown in these areas. Therefore, our study aimed to assess the social wasp richness and distribution in the Conservation Units in Minas Gerais state, southeastern Brazil. The social wasps were sampled between 2015 and 2019 in the Ritópolis National Forest (FLONA Ritópolis), in the Alto-Montana Private Natural Heritage Reserve (RPPN Alto-Montana), in the Rio Machado Basin State Environmental Protection Area (APA Rio Machado) and in the Serra de São José Environmental Protection Area (APA Serra de São José), using two different sampling methodologies. Fourteen species were sampled for FLONA Ritópolis, 10 for RPPN Alto-Montana, 35 for APA Rio Machado and 19 for APA Serra de São José. Ninety-six social wasp species of the known richness in Minas Gerais were sampled in 14 Conservation Units, representing 90% of the fauna of the state. Thirty-four species are exclusive to these areas, with emphasis on the Rio Doce State Park, the Serra do Papagaio State Park, the Pandeiros River Wildlife Refuge and the APA Rio Machado. Most of the Conservation Units sampled are in the Atlantic Forest areas, but further efforts are needed in this biome, because of its accelerated destruction. There is still an urgent need for more studies in the Cerrado and Caatinga areas in the state, especially in Conservation Units.

Keywords. Atlantic Forest; Caatinga; Cerrado; Insect conservation; Wasp distribution.

INTRODUCTION

Brazil harbors one of the greatest biodiversity in the entire world and, unfortunately, habitat destruction is threatening its environmental richness in a dangerously fast way. More than ever, it is essential that efforts are made for species preservation and the role of the Conservation Units becomes more important (Siqueira *et al.*, 2017; Steinke *et al.*, 2018). There are about 2,446 Brazilian Conservation Units covering around 1.6 million km² on continental areas, and their main purpose is nature protection, including species, landscapes and any resources and ecosystem services (MMA, 2019). Conservation Units are distributed into five categories of fully protected areas (Ecological Station, Biological Reserve, Park, Natural Monument and Wildlife Refuge), and seven of sustainable use protected areas (Environmental Protection Area, Area of Relevant Ecological Interest, Forest, Extractive Reserve,

Fauna Reserve, Private Natural Heritage Reserve and Sustainable Development Reserve). They cover about 18% of the national territory, but only 6% of these are fully protected areas (Schiavetti *et al.*, 2013; MMA, 2019).

Minas Gerais state is extremely biodiverse and exhibits two main biomes, the Cerrado and the Atlantic Forest, in addition to a smaller portion of the Caatinga biome, and there are about 120 public Conservation Units for both fully protected and sustainable use areas in the state (IEF, 2019; ISA, 2020). The Cerrado and the Atlantic Forest biomes are recognized for their great fauna and flora richness, several endemic and endangered species, in addition to being both worldwide biodiversity hotspots (Brooks *et al.*, 2002; Siqueira *et al.*, 2017; Steinke *et al.*, 2018), harboring a great insect variety and, among them, the social wasps.

In Brazil, 365 species of social wasp (Prezoto *et al.*, 2020; Souza *et al.*, 2020a) belonging to three tribes on the subfamily Polistinae (Hymenoptera:

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Vespidae): Mischocyttarini, Polistini and Epiponini (Carpenter, 2004) are reported. The country is home of the higher richness of Polistinae in the world, representing more than 40% of the total richness. Social wasps are of great ecological importance since they act as bioindicators and performed various ecosystem services, behaving as predators, floral resource robbers and even as pollinators (Somavilla *et al.*, 2017; Souza *et al.*, 2017 and references therein). This is a very abundant insect group and at least 30% of the known native species richness was sampled in Minas Gerais state (Souza *et al.*, 2017).

Species distribution is important for defining conservation priorities based on species that need greater protection (endemic, threatened and rare species), in addition to contribute to the biodiversity knowledge of the ecosystem (Elpino-Campos *et al.*, 2007). Knowledge of richness, abundance and occurrence of communities is also essential to support future research, since they provide basic important data. Although species surveys are encouraged and social wasps are a relatively well-sampled group in Minas Gerais state (Barbosa *et al.*, 2016; Souza *et al.*, 2017), there is a need for further investigation in Conservation Units, especially considering that only about 10% of them were studied so far for this insect group.

Therefore, the aim of our study was to provide a macroecological approach on the knowledge of social wasp species in Conservation Units in the state of Minas Gerais, assessing the species richness and distribution through the review and grouping of data from articles, and inclusion of unpublished data in order to highlight the importance of Conservation Units for social wasp species.

MATERIAL AND METHODS

Study area and data sampling

Our study presents unpublished data from social wasp surveys in three Conservation Units in Minas Gerais state, Brazil (Fig. 1): the first fauna inventory for the Ritópolis National Forest, the first insect inventory for the Alto-Montana Private Natural Heritage Reserve, and the first wasp inventory for the Rio Machado Basin State Environmental Protection Area. In addition, we present an update of the species list of the Serra de São José Environmental Protection Area to the previously published by Souza *et al.* (2010).

Ritópolis National Forest (FLONA Ritópolis, 21°03'30"S, 44°16'25"W) is the smallest Conservation Unit in Minas Gerais state, with 89,5 ha in the municipality of Ritópolis, and exhibits phytophysionomies of the Cerrado and Atlantic Forest. The climate is marked by mild summers and winter droughts (Köppen classification: Cwb), the average annual rainfall is about 1.400 mm and the average temperature ranges 19°C (Ferreira *et al.*, 2016). Wasp sampling was conducted actively using insect nets (Souza & Prezoto, 2006), totaling 40 effective hours in six non-consecutive days in February, March and June 2016.

Alto-Montana Private Natural Heritage Reserve (RPPN Alto-Montana, 22°21'55"S, 44°48'32"W) spans 672 ha in

the municipality of Itamonte and exhibits phytophysionomies of the Atlantic and Araucaria Forests. The climate is marked by mild rainy summers and winter droughts (Köppen classification: Cwb), the average annual rainfall is about 1.749 mm and the temperature ranges 12-17°C (Cruz *et al.*, 2014). Wasp sampling was conducted actively (Souza & Prezoto, 2006) within 27 net-hours over a week in October 2015, and through attractive traps with sardine bait (Souza *et al.*, 2015c) along nine altitudinal ranges between 1,335 m and 2,135 m, with one bottle trap at every 100 m of altitude. The traps remained in the field for 72 hours, within 648 trap-hours, totaling 675 effective sampling hours.

Rio Machado Basin State Environmental Protection Area (APA Rio Machado, 21°44'40"S, 45°58'31"W) spans 125,4 ha and exhibits phytophysionomies of the Atlantic Forest. The climate is marked by dry winters and wet summers (Köppen classification: Cwa), the average annual rainfall is about 1.556 mm and the temperature ranges 9-29°C (Latuf *et al.*, 2019). Wasps were sampled in the municipalities of Machado (21°40'30"S, 45°55'12"W), Poço Fundo (21°46'51"S, 45°57'54"W) and Fama (21°24'21"S, 45°49'44"W) in 16 non-consecutive days from September 2018 to April 2019. Wasp sampling was conducted actively (Souza & Prezoto, 2006) seeking individuals and colonies, totaling 211 net-hours.

Serra de São José Environmental Protection Area (APA Serra de São José, 21°07'08.87"S, 44°07'22.84"W) spans 4.758 ha and exhibits phytophysionomies of the Cerrado and Atlantic Forest. The climate is marked by mild summers and winter droughts (Köppen classification: Cwb), the average annual rainfall is about 1.500 mm and the average temperature ranges 19-20°C (Henriques & Cornelissen, 2019). Wasp sampling was conducted actively using insect nets (Souza & Prezoto, 2006), totaling 46 effective hours on nine non-consecutive days in March, April, July and November 2016, February 2017 and January 2018, along seven altitudinal ranges between 800 m and 1,400 m in the campos rupestres areas, with sampling at every 100 m of altitude.

The social wasps were sacrificed in the field, placed in containers with information of date and area of sampling. They were later identified with the aid of specialists and deposited at the Biological Collection of Social Wasps of the Zoology Laboratory of the Federal Institute of Southern Minas (IFSULDEMINAS), Inconfidentes campus. Data from other studies carried out in different Conservation Units in the Minas Gerais state were also considered for the macroecological approach (Table 1).

RESULTS AND DISCUSSION

Richness and distribution of social wasps in the four Conservation Units sampled in this study

Thirty-five species of social wasps were registered for the APA Rio Machado, 19 for the APA Serra de São José, 14 for the FLONA Ritópolis and 10 for the RPPN Alto-Montana (Table 2). In the APA Serra de São José, four other spe-

cies were registered for the first time in this Conservation Unit at intermediate and high altitudes of the campos rupestres: *Agelaia vicina* (Saussure 1854) (1,000, 1,300 and 1,400 m), *Brachygastra lecheguana* (Letreille 1824) (1,400 m) and *Polistes pacificus* Ducke 1918 (1,100 m); in addition, *Mischocyttarus giffordi* Raw, 1987 was reported in a semideciduous seasonal forest on this same mountain in 2018. The APA Serra de São José has potential to

harbor a greater number of species, also because of the vegetation heterogeneity in other areas of the mountain. However, several negative anthropic influences such as fires, disordered tourism and pollution caused by it, the presence of cattle and the invasion of exotic species (eg. Poaceae, used as pasture) put this biodiversity at risk.

The variation in the social wasp richness for the four areas can be explained by several factors, such as

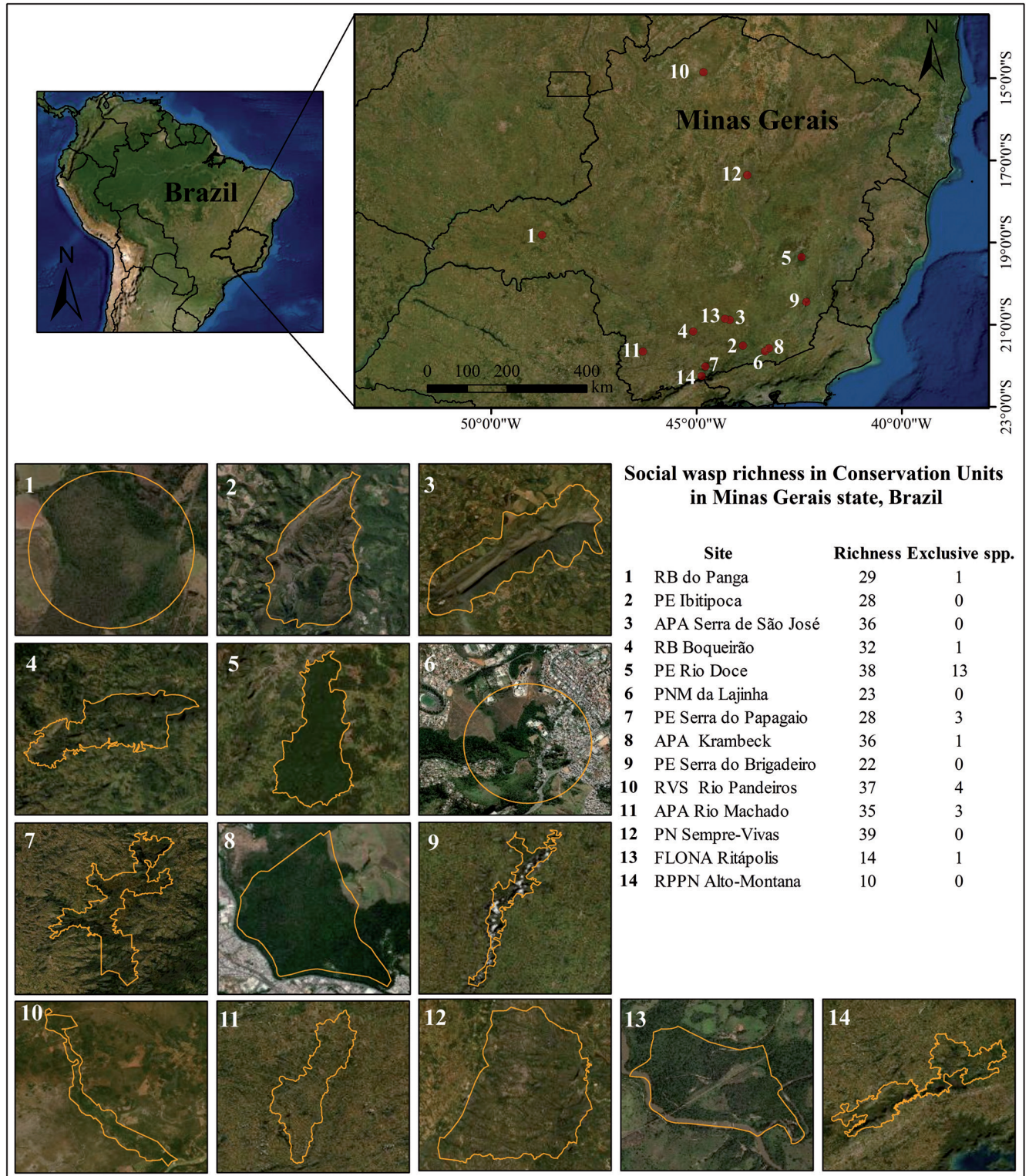


Figure 1. Geographic location of the sampled Conservation Units in the Minas Gerais state, southeastern Brazil, where social wasp inventories were carried out so far (maps at the top, Conservation Units are represented by the red points numbered from 1 to 14). The table on the right shows data of species richness and exclusive occurrence in each Conservation Unit. Aerial view of the Conservation Unit areas (satellite images 1-14). The numbers of map, table, and satellite images are corresponding.

Table 1. Social wasp studies carried out in Conservation Units in Minas Gerais state, southeastern Brazil. UC = Conservation Units, FLONA Ritópolis = Ritópolis National Forest, RPPN Alto-Montana = Alto-Montana Private Natural Heritage Reserve, APA Rio Machado = Rio Machado Basin State Environmental Protection Area, APA Serra de São José = Serra de São José Environmental Protection Area, RB do Panga = Panga Biological Reserve, PE Ibitipoca = Ibitipoca State Park, RB Boqueirão = Boqueirão Biological Reserve, PE Rio Doce = Rio Doce State Park; PNM da Lajinha = Lajinha Municipal Natural Park, PE Serra do Papagaio = Serra do Papagaio State Park, APA Krambeck = Krambeck Environmental Protection Area, PE Serra do Brigadeiro = Serra do Brigadeiro State Park, RVS Rio Pandeiros = Pandeiros River Wildlife Refuge, PN Sempre-Vivas = Sempre-Vivas National Park, SSF = Seasonal Semideciduous Forest, DOF = Dense Ombrophilous Forest, CR = Campos Rupestres, CE = Cerrado, RF = Riparian Forest, MF = Mixed Forest, AF = Altitude Fields, SDF (DF) = Seasonal Deciduous Forest – Dry Forest.

Studies	UC	Biome	Vegetation type	Richness
Our study	FLONA Ritópolis	Atlantic forest	SSF	10
Our study	RPPN Alto-Montana	Atlantic forest	DOF, SSF	14
Our study	APA Rio Machado	Atlantic forest	SSF	35
Our study, Souza <i>et al.</i> , 2010	APA Serra de São José	Cerrado/Atlantic forest	CR	36
Elpino-Campos <i>et al.</i> , 2007	RB do Panga	Cerrado	CE	29
Prezoto & Clemente, 2010, Souza <i>et al.</i> , 2018	PE Ibitipoca	Atlantic forest/Cerrado	CR, SSF, RF	28
Simões <i>et al.</i> , 2012	RB Boqueirão	Cerrado	CE	32
Souza <i>et al.</i> , 2012	PE Rio Doce	Atlantic forest	DOF, SSF	38
Brugger, 2014	PNM da Lajinha	Atlantic forest	SSF	23
Souza <i>et al.</i> , 2015b, 2018	PE Serra do Papagaio	Atlantic forest	MF, AF	28
Barbosa, 2015	APA Krambeck	Atlantic forest	SSF	36
Souza <i>et al.</i> , 2015a	PE Serra do Brigadeiro	Atlantic forest	SSF	22
Brunismann <i>et al.</i> , 2016	RVS Rio Pandeiros	Cerrado/Atlantic forest	SDF (DF)	37
Souza <i>et al.</i> , 2020b	PN Sempre-Vivas	Cerrado	CE	39

the sampling effort and methodology, elevation, phytophysognomy, ecosystem conservation degree and regeneration stage, in addition of the forest fragmentation and degradation effect. The sampling effort between the areas exhibits a marked difference, as observed in the APA Rio Machado, where were 211 net-hours, and in the FLONA Ritópolis where 40 hours were carried out. However, the effort-hour was also proportional to the size difference of the sampled areas. In the APA Serra de São José, there was a total sampling effort of 168 net-hours, considering the sum of the hours of the previously published paper (Souza *et al.*, 2010) and our study, and in the RPPN Alto-Montana, there were 27 net-hours and 648 trap-hours. However, even with the expressive number of hours invested in the passive method it was a little ineffective, because it registered the same four species already captured by active sampling. The sampling effort invested in each area may have impacted the number of registered species, as also observed in other studies (Souza & Prezoto, 2006; Jacques *et al.*, 2018; Somavilla *et al.*, 2019), demonstrating how much the sampling effort can influence the richness recording.

A second factor that can influence the difference in richness between areas is the elevation, theme of some work with social wasps carried out in Brazil (Albuquerque *et al.*, 2015; Souza *et al.*, 2015a; Ribeiro *et al.*, 2019). In the RPPN Alto-Montana, the sampling was carried out in nine altitudinal ranges ranging from 1,335 to 2,135 m, while in the APA Serra de São José the altitudes vary from 800 to 1,400 m, which can affect the distribution of social wasp communities. It is also important to consider that each community probably have different adaptive characteristics to each elevational gradient. The highest elevation in the APA Serra de São José is the lowest in the RPPN Alto-Montana, for example, where social wasp

species adapted to higher altitudes on one mountain may not be the same as those on the other mountain, generating differences in the species composition and distribution across different gradients. Several species have restrictions to high altitudes, generated by the increase in climatic severity (eg. decrease in temperature, greater exposure to ultraviolet rays, greater wind speed), decrease in area, resources and primary productivity, absence or reduction of adaptative morphophysiological traits and even due to geographical isolation (Janzen, 1973, Lawton *et al.*, 1987, Fernandes, 2016).

In addition to the factors mentioned, the area conservation and regeneration situation must also be considered (Souza *et al.*, 2010; Clemente *et al.*, 2019), as well as the habitat fragmentation degree (Bueno *et al.*, 2019; Graça & Somavilla, 2019) and the available substrates for nesting by social wasp species (Corbara *et al.*, 2009; Souza *et al.*, 2014; Francisco *et al.*, 2018). Lawton (1983) and Santos *et al.* (2007) reported that environments with more complex structure enable the establishment and survival of more social wasp species. The vegetation exerts considerable influence on the social wasp communities, because 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 (Santos *et al.*, 2007; Milani *et al.*, 2020). The social wasp species that nest only on certain conditions, select the locations of their nests by the vegetation density and types, whether it is open or closed, as well as the shape and arrangement of leaves and other plant structures (Machado, 1982; Santos & Gobbi, 1998). It should also be considered, in a context of accelerated climate changes, generated by environmental degradation, that the small body size of wasps makes them a sensitive group to these variations (Deutsch *et al.*, 2008).

Relevance of Conservation Units for species of social wasps

There are 96 species of social wasps distributed in 14 Conservation Units in Minas Gerais state, which represents just about 10% of these areas in the state. This species number makes up about 90% of the 111 occurrences for the state (Souza et al., 2020a; Souza et al., 2020b), including *Mischocyttarus garbei* Zikán, 1935 sampled in the FLONA Ritápolis, recorded for the first time in the state. This species is restricted to the Atlantic Forest (Souza et al., 2020a), with occurrence records, until then, only for the states of Rio de Janeiro and Espírito Santo (Richards, 1978; Souza et al., 2015d). Three species, *Mischocyttarus buysoni* (Ducke, 1906), *Polybia brunnea* (Curtis, 1844) and *Polybia emaciata* (Saussure, 1854) are reported for the state (Richards, 1978), however there is no precise information regarding their distribution and occurrence (Souza et al., 2017; Souza et al., 2020a; Souza et al., 2020b). Thirty-four species occurring in Minas Gerais were sampled only in Conservation Units, which may be due to less sampling effort outside UCs in the state. Twenty-seven of the 34 species are exclusive to a single location and seven others are common to more than one (Table 3).

All these data evidences the relevance of the Conservation Units for the preservation of the social wasp populations in Minas Gerais state, especially four of them: the Serra do Papagaio State Park, the Rio Doce State Park, the Pandeiros River Wildlife Refuge and the APA Rio Machado. The Serra do Papagaio State Park, besides harboring an expressive richness of social wasps, it stands out for the first record of *Mischocyttarus anthracinus* Richards, 1945 unprecedented for Brazil, occurring until then only in Paraguay (Richards, 1978). This Conservation Unit also harbors a great butterfly (Oliveira et al., 2018) and harvestmen diversity (Ferreira et al., 2019), showing itself as an important refuge for several arthropod groups.

In the Rio Doce State Park, as already pointed out by Souza et al. (2017), the great richness and the large number of exclusive species could be a reflection of the climate, the great territorial extension, once this is the largest Conservation Unit of Minas Gerais state, and also of the large extension of conserved vegetation, that covers the largest portion of preserved Atlantic Forest of the state. Souza et al. (2012) showed that the social wasp richness in the area can reach 70 species, reinforcing how much this Conservation Unit is extremely biodiverse and important for the maintenance of these populations. The difference between the number of sampled and estimated species, pointed out by Souza et al. (2012), may be the result of the sampling difficulty in a high-canopy forest environment and by the camouflage of the nests in these environments (Jeanne & Morgan, 1992), which justifies new studies that emphasize the canopy communities.

The Rio Pandeiros Wildlife Refuge shows itself as an important area because it harbors the second greatest richness among the Conservation Units listed. Additionally, we report the need for further studies in de-

Table 2. Species of social wasps sampled in Rio Machado Basin State Environmental Protection Area (APA Rio Machado), Serra de São José Environmental Protection Area (APA São José), Ritápolis National Forest (FLONA Ritápolis), and Alto-Montana Private Natural Heritage Reserve (RPPN Alto-Montana). 0 = absence; 1 = presence; * = new record updating the inventory by Souza et al., 2010).

Species	Conservation Units			
	APA Rio Machado	APA São José	FLONA Ritápolis	RPPN Alto-Montana
<i>Agelaja multipicta</i> (Haliday, 1836)	1	0	1	1
<i>Agelaja vicina</i> (Saussure, 1854)	1	1*	1	1
<i>Apoica gelida</i> Van der Vecht, 1973	0	0	1	1
<i>Apoica pallens</i> (Fabricius, 1804)	1	0	0	0
<i>Brachygastra augusti</i> (Saussure, 1854)	1	0	0	0
<i>Brachygastra lecheguana</i> (Latreille, 1824)	1	1*	0	0
<i>Parachartergus fraternus</i> (Griboldo, 1892)	1	0	0	0
<i>Parachartergus wagneri</i> Buysson, 1904	1	0	0	0
<i>Polybia chrysothorax</i> (Lichtenstein, 1796)	0	0	0	0
<i>Polybia fastidiosuscula</i> de Saussure, 1854	1	0	1	1
<i>Polybia ignobilis</i> (Haliday, 1836)	1	1	1	0
<i>Polybia jurinei</i> de Saussure, 1854	1	0	0	0
<i>Polybia minarum</i> Ducke, 1906	1	0	0	0
<i>Polybia occidentalis</i> (Olivier, 1791)	0	1	1	0
<i>Polybia paulista</i> H. von Ihering 1896	1	1	1	0
<i>Polybia platycephala</i> Richards, 1978	1	0	1	0
<i>Polybia punctata</i> du Buysson, 1907	1	0	0	1
<i>Polybia scutellaris</i> (White, 1841)	1	1	1	0
<i>Polybia sericea</i> (Olivier, 1791)	1	1	0	0
<i>Pratonectarina sylveirae</i> (Saussure, 1854)	1	1	0	0
<i>Protopolybia sedula</i> (Saussure, 1854)	1	0	0	1
<i>Pseudopolybia vespiceps</i> (Saussure, 1854)	1	0	0	0
<i>Synoeca cyanea</i> (Fabricius, 1775)	1	1	0	1
<i>Polistes actaeon</i> (Haliday, 1836)	1	0	0	0
<i>Polistes bicolor</i> Fox, 1898	1	0	0	0
<i>Polistes billardi</i> Saussure, 1853	0	1	0	0
<i>Polistes cinerascens</i> Saussure, 1854	1	1	0	1
<i>Polistes davillae</i> Richards, 1978	0	1	1	0
<i>Polistes ferreri</i> Saussure, 1853	1	1	0	0
<i>Polistes pacificus</i> Ducke, 1918	0	1*	0	0
<i>Polistes similis</i> Zikán, 1951	1	1	0	0
<i>Polistes subsericus</i> Saussure, 1854	1	1	0	0
<i>Polistes versicolor</i> (Olivier, 1791)	1	0	1	0
<i>Mischocyttarus cassununga</i> (R. von Ihering, 1903)	1	0	0	0
<i>Mischocyttarus confusus</i> Zikán, 1935	0	0	0	0
<i>Mischocyttarus drewseni</i> Saussure, 1857	1	1	1	1
<i>Mischocyttarus garbei</i> Zikán, 1935	0	0	1	0
<i>Mischocyttarus giffordi</i> Raw, 1987	1	1*	0	0
<i>Mischocyttarus ignotus</i> Zikán, 1949	1	0	0	0
<i>Mischocyttarus interjectus</i> Zikán, 1935	1	0	0	0
<i>Mischocyttarus latior</i> (Fox, 1898)	0	0	0	0
<i>Mischocyttarus marginatus</i> (Fox, 1898)	0	0	0	0
<i>Mischocyttarus mirificus</i> Zikán, 1935	1	0	0	0
<i>Mischocyttarus paraguayensis</i> Zikán, 1935	0	0	1	0
<i>Mischocyttarus parallelogramus</i> Zikán, 1935	1	0	0	0
<i>Mischocyttarus rotundicollis</i> Cameron, 1912	0	1	0	0
<i>Mischocyttarus socialis</i> (Saussure, 1854)	1	0	1	1
<i>Mischocyttarus wagneri</i> (Buysson, 1908)	0	0	0	0
<i>Mischocyttarus ypiraguensis</i> da Fonseca, 1926	0	0	0	0
Total	35	19	14	10

Table 3. Rare social wasp species (1 = presence; 0 = absence) of the Conservation Units in the Minas Gerais state, southeastern Brazil. PERD = Rio Doce State Park; PESP = Serra do Papagaio State Park; PEIB = Ibitipoca State Park; PESB = Serra do Brigadeiro State Park; RVRP = Pandeiros River Wildlife Refuge; APASJ = Serra de São José Environmental Protection Area; APARM = Rio Machado Basin State Environmental Protection Area; PNSV = Sempre-Vivas National Park; APAK = Krambeck Environmental Protection Area; FLONAR = Ritópolis National Forest; PML = Lajinha Municipal Natural Park; RPPNAM = Alto-Montana Private Natural Heritage Reserve; RBB = Boqueirão Biological Reserve; RBP = Panga Biological Reserve.

Species	Conservation Units													
	PERD	PESP	PEIB	PESB	RVRP	APASJ	APARM	RNSV	APAK	FLONAR	PML	RPPNAM	RBB	RBP
<i>Agelaia angulata</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Apoica thoraxica</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Brachygastra moebiana</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Chartergellus communis</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	1
<i>Chartergus globiventris</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	1
<i>Epipona tatua</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Metapolybia cingulata</i>	1	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Parachartergus pseudopalpis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Parachartergus wagneri</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Parachartergus smithii</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Polybia dimidiata</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polybia flaviformis hecuba</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polybia lugrui</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Polybia rejecta</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polybia signata</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Synoeca surinama</i>	0	0	0	0	1	0	0	1	0	0	0	0	0	0
<i>Polistes bicolor</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Polistes canadensis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polistes cavapytiformes</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polistes davillae</i>	0	0	0	0	0	1	0	0	0	1	0	0	0	0
<i>Polistes geminatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Polistes melanossoma</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polistes occipitalis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus anthracinus</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus annulatus</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus bahiaensis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus bahiae</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus frontalis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus garbei</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Mischocyttarus giffordi</i>	0	1	0	0	0	1	1	0	0	0	0	0	0	0
<i>Mischocyttarus interjectus</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Mischocyttarus marginatus</i>	0	0	0	0	0	1	0	1	0	0	0	0	0	1
<i>Mischocyttarus montei</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Mischocyttarus proximus</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Exclusive species	13	3	0	0	4	0	3	0	1	1	0	0	1	1
Total richness	38	28	28	22	37	35	35	39	36	14	23	10	32	29

ciduous forests, also known as dry forests (Brunismann et al., 2016), as this is the only work that assesses the social wasp richness in this area, as well as in the entire northern region of the state. Dry forest constitutes a transition ecosystem for the Caatinga biome, where there were no studies on these insects up to now in Minas Gerais (Souza et al., 2017). There are few studies in Caatinga also for other states (Andena & Carpenter, 2014; Somavilla et al., 2017), and this lack of information justifies other studies in Conservation Units that shelter this semi-arid ecosystem. The APA Rio Machado has 35 species of social wasps and, until now, three of which were sampled only in Conservation Units. These species were sampled in the region of the Poço Fundo municipality, where there is greater continuous vegetation cover, but which suffers from many anthropic disturbances, such

as livestock, burning, deforestation, reduction of riparian forests and coffee monoculture. Another problem of this area is the reduced staff team of the Minas Gerais Forestry State Institute (IEF-MG) to inspect the entire area of 211.8 km², comprising eleven municipalities in the region (Porto et al., 2019), which indicates a difficulty in performing more efficient protection.

One of the most worrying disturbance events that negatively affect terrestrial ecosystems is the fire, which is very common in Brazil both natural and (mostly) anthropogenic. According to Herawati & Santoso (2011), forest fires cause various environmental problems that compromise biodiversity and its interactions, as well as increase CO² emissions. In a study by Clemente et al. (2019) the influence of fire in a social wasp community in a Cerrado vegetation was assessed and a 33% reduction

in richness and 49% in abundance after the fire disturbance was discovered, evidencing the great biodiversity loss caused by fires. Fires are one of the main and continuous threats to the Conservation Units purposes (Koproski et al., 2011). In Brazil, the causes of fires in Conservation Units have been mainly due to the incorrect use to renew pastures and clean up crop residues in neighboring properties and surrounding areas, which should act as a buffer zone to prevent impacts on biodiversity within the Conservation Unit area (Pereira et al., 2004). These factors demonstrate the need for greater investment in policies that aimed to reduce the impacts caused by fire and also its prevention, as well as the maintenance of brigade groups in the most favorable periods for fires. These methods are vital to protect all Conservation Units, but especially those listed in this study, as they all have a major negative impact on biodiversity due to fires.

Another relevant aspect is the concentration of studies in areas dominated by the Atlantic Forest biome over the Cerrado and Caatinga biomes (Fig. 1, Table 1). Souza et al. (2017) argued that this may be a reflection of logistics and cost issues, because the two main research centers dedicated to social wasp inventories in Minas Gerais state are in the Federal University of Juiz de Fora (UFJF) and the Federal Institute of the South of Minas (IFSULDEMINAS), which invest greater sampling efforts in the Atlantic Forest due to its geographical location.

Moreover, there are 11 social wasp species that occur in the state, but have not been registered in Conservation Units, where they would be more protected. Among these, we can mention *Mischocyttarus paraguaensis* Zikán 1949, *Mischocyttarus artifex* (Ducke, 1914), *Mischocyttarus funerulus* Zikán 1949 and *Polistes pacificus flavopictus* Ducke, 1918 occurring in Mata do Baú, the largest fragment of semideciduous seasonal forest in the Barroso municipality, southern center of Minas Gerais state, which harbors the greatest known social wasp richness of the state: 45 species (Souza & Prezoto, 2006; Souza et al., 2010, Souza et al., 2017). In this fragment there is also an expressive Odonata richness, with newly discovered species (Souza et al., 2013; Machado & Souza, 2014; Machado, 2015), and solitary wasps with unprecedented records for Brazil (Tanque et al., 2010), in addition to a great Orchidaceae richness (Menini-Neto et al., 2004). However, this area suffers from several anthropogenic disturbances, such as livestock, eucalyptus cultivation and fires (Souza, 2006), which represent a great threat to the environment integrity and the species preservation in the region.

In addition to the species occurring in the Barroso municipality, others are registered only outside the UCs. Among them, *Mischocyttarus nomurae* Richards, 1978 which also occurs in this biome areas in the Montes Claros municipality, in the north of Minas Gerais, as well as *Metapolybia docilis* Richards, 1978 (Souza et al., 2015c). *Mischocyttarus mourei* Zikán 1949 occurs in the region of Monte Verde district, an area of marked tourist flow, in the Camanducaia municipality (Abulquerque et al., 2015). *Polybia bistrriata* (Fabricius, 1804) occurs on the campus of the Federal University of Lavras (UFLA), and

in Cerrado enclaves associated with semideciduous forest in the Atlantic Forest domain in the south of the state (Jacques et al., 2018). *Polybia liliacea* (Fabricius, 1804) occurs in eucalyptus monoculture regions in the east of the state, bordering the Rio Doce State Park (Silva-Filho et al., 2020). *Mischocyttarus wygodzinskyi* Zikán 1978, occurs in forest fragments of semideciduous seasonal forest, in the Inconfidentes municipality region (Buono et al., 2019), where *Polybia quadricinta* Saussure, 1858 is also registered. All of these species registered outside Conservation Units are more vulnerable and their populations are at risk of reduction. This is because these Conservation Units are one of the most efficient tools for protecting the biota, as discussed by Drummond et al. (2005), who also recommends the creation of this conservation mechanism for the Barroso municipality.

Despite the social wasp studies are concentrated in the Atlantic Forest areas, it is still necessary to continue efforts in this extremely threatened and highly diverse biome due to a large number of exclusive species and also to the fact that it harbors more than half of the species of social wasps of the country (Souza et al., 2020a). In the Cerrado biome, only two Conservation Units had been sampled until 2017. More recently, other areas that are fully inserted in this biome were studied, such as the Sempre Vivas National Park (Souza et al., 2020b) and the Serra da Canastra National Park (Marcos Magalhães de Souza, personal communication, unpublished data). Considering the great extent of these two biomes in the Minas Gerais state and the number of Conservation Units not yet sampled in both, there is still a lack of studies in the protected areas of these global biodiversity hotspots (Siqueira et al., 2017; Steinke et al., 2018). For the Caatinga biome, it is urgent to carry out more studies, because although it harbors great biodiversity of different taxa (Gusmão et al., 2016), this biome has been suffering a continuous reduction of its area by different impacting agents. For this reason, Caatinga experiences increasing desertification, with consequent loss of habitats, species, and its interactions, so important for the ecosystem functioning (Araújo & Sousa, 2011).

CONCLUSIONS

Conservation Units fulfill their purpose of protecting the social wasp diversity in Minas Gerais, as they harbor more than 90% of the species sampled in the state. However, there are still many of these protected areas in which the biodiversity of social wasps is unknown, as well as biomes that need further investigation on surveying species richness, such as the Cerrado and especially the Caatinga. There are new records in Conservation Units, such as *Mischocyttarus garbei* Zikán, 1935 sampled in the FLONA Ritópolis, recorded for the first time in the state, reinforcing the importance of new studies in these areas for the biodiversity knowledge. Four Conservation Units stand out for their richness and the number of exclusive species: the Rio Doce State Park, which needs a greater sampling effort; the Serra do Papagaio State

Park, which suffers from frequent fires; the Rio Pandeiros Wildlife Refuge, which harbors dry forest vegetation and it is also in need of studies; and the APA Rio Machado, which suffers various anthropic disturbances. Finally, it is recommended the creation of a Conservation Unit in the Barroso municipality, which harbors some social wasp species that do not occur in protected areas and harbors a great richness of other insect groups.

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AUTHORS' CONTRIBUTIONS STATEMENT

Master G.C.S.O.: Lead author and responsible for all phases of this study. Master N.R.H.: Lead author and responsible for all phases of this study. PhD M.A.C.: Lead author and responsible for all phases of this study. PhD M.M.S.: Responsible advisor, author and responsible for all phases of this study.

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