



## RESEARCH ARTICLE - WASPS

## Social wasp guild (Hymenoptera: Vespidae) visiting flowers in two of the phytophysiognomic formations: Riparian Forest and campos rupestres

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### Abstract

Social wasps are part of the floral visitor guild. In this study, we investigated the distribution of flower-visiting wasp species in two phytophysiognomies in the State Park of Ibitipoca, Minas Gerais, Brazil. We inspected flowering plants with visiting wasps along a 1 km transect in riparian forest and another 1 km transect in campos rupestres over the course of one year, for a total sampling effort of 240 hours. We found a total of 103 individuals with 15 species distributed among 7 genera, the most common belonging to the Erythroxyloaceae ( $n = 10$ ) and Asteraceae ( $n = 10$ ) families. Asteraceae had the highest abundance ( $n = 55$ ). The diversity and evenness of these insects was higher in riparian forest ( $H' = 0.78$  and  $J' = 0.75$ ) than in campos rupestres ( $H' = 0.30$ ,  $J' = 0.39$ ). All species visited flowers of 19 plant species in riparian forest, and eight wasp species visited 11 plant species in campos rupestres. These Polistinae acted as regular floral visitors, thus, conservation programs in these areas may be relevant for the maintenance of social wasp diversity.

### Introduction

Social wasps belong to the order Hymenoptera and the family Vespidae, which is divided into six subfamilies. Polistinae contains 26 genera (Carpenter, 2004) and is the only eusocial subfamily, with occurrence throughout Brazil (Carpenter, 1993).

Social wasp surveys have been carried out in riparian forest (Souza et al., 2010; Pereira & Antonialli-Junior, 2011; Locher et al., 2014) and campos rupestres (Silva-Pereira & Santos, 2006). However, studies that focus on the use of floral resources by wasps in the Neotropical region are scarce, particularly in these habitats. Social wasps constitute part of the floral visitor guild, and overlap with the bees in the exploitation of floral resources; they are thus a representative of the foragers (Heithaus, 1977 a, b; Santos et al., 2010; Melo

et al., 2011). Male wasps, principally social wasps, are regular floral visitors that consume nectar and pollen, in addition to storing nectar for colonies (Gadagkar, 1991).

Riparian forest and campos rupestres are vegetation formations of extreme importance for conservation. The riparian forest study site is considered a Permanent Preservation Area (Conselho Nacional do Meio Ambiente – CONAMA, 2002) for protecting water resources and maintaining their quality in equilibrium with local flora and fauna (Lima & Leopold, 1999). The campos rupestres site is protected due to high species richness (with many in the process of extinction) and endemism (Giulietti et al., 1997; Menezes & Giulietti, 2000).

An accurate assessment of social wasp species acting as floral visitors and possible pollinators is fundamental for our knowledge of plant reproductive cycles in the study areas, and has implications for conservation of both plants and wasps.



In this study we estimated the richness, diversity, abundance, niche amplitude, and evenness of social wasp floral visitors in riparian forest and campos rupestres in Ibitipoca State Park, Minas Gerais, Brazil.

### Material and methods

The State Park of Ibitipoca has an area of 1,923 hectares and is located in the Serra de Ibitipoca in southeastern Minas Gerais, Brazil. The climate is characterized as Cwb according to the Köppen classification (humid mesothermic with dry winters and mild summers). The mean annual precipitation is approximately 1,532 mm and the mean annual temperature is 18.9 °C (CETEC, 1983).

Social wasp collections were carried out in two of the phytophysiognomic formations present in Ibitipoca State Park: riparian forest and campos rupestres (sand land).

**Riparian Forest-** The phytophysiognomic profile of this area is transition between Cerrado de Altitude and Ombrophilic forest, which consists of a vegetational gradient that shifts from arbustive-arboreal physiognomy to predominantly arboreal (Rodela, 1998). The main plant families of the Ibitipoca State Park are Orchidaceae, Myrsinaceae, Melastomataceae, Bromeliaceae, Rubiaceae, Labiatae, Piperaceae, Araceae, Passifloraceae, Gesneriaceae, Polypodiaceae, Compositae and Erythroxylaceae (Rodela, 1998).

**Campos Rupestres-** These areas present a xeromorphic physiognomy composed of a great diversity of herbaceous species, primarily represented by the families Orchidaceae, Poaceae, Asteraceae and Bromeliaceae, and shrub species, represented mainly by the Velloziaceae, Asteraceae, Melastomataceae and Asclepiadaceae, distributed across quartzitic outcrops (Rodela, 1998).

The study was carried out from November 2007 to October 2008, with one collection day per month per site taking place from 07:00 am to 05:00 pm. Total sampling effort was 240 hours. One transect of approximately one kilometer was established in each area, along which two observers surveyed plants on collection days. When wasps were observed foraging in the flowers, observers collected them using an entomological net and remained near the plant for ten minutes in case of arrival of new individuals (Aguilar, 2003; Lorenzon et al., 2003). Collected specimens were fixed in 70% alcohol and transported to the Laboratório de Ecologia Comportamental (LABEC) at the Universidade Federal de Juiz de Fora in Minas Gerais, Brazil. Specimens were identified using taxonomic keys for genus and species (Carpenter, 2004; Cooper, 1997; Carpenter & Marques, 2001; Pickett & Wenzel, 2007).

The plants visited by the wasps were described in the field according to floral characteristics, such as type of flower, color, and size. Date and collection location were recorded. Exsiccates from plant species visited by wasps were identified using keys for family and genus, and reviewed by

Professor Fátima Regina Gonçalves Salimena. We prepared a species list in alphabetical order of families and genera based on the Angiosperm Phylogeny Group III system (APG, 2009). Species nomenclature confirmed using the Brazilian Plant Species List (Jardim Botânico do Rio de Janeiro, 2012), the International Plant Names Index sites (INPI, 2016), and electronic databases of the Missouri Botanical Garden (MOBOT, 2016), the latter being also used to confirm nomenclature of exotic species.

The diversity and evenness of visiting social wasps in the hot-humid and cold-dry periods were calculated using the Shannon-Wiener Index ( $H'$ ), (Shannon, 1948) in the PAST program (Hammer et al., 2001). Shannon-Wiener index ( $H'$ ) and evenness values were compared using a Mann-Whitney in BioEstat 4.0 (Freeware). Niche amplitude was calculated using the Shannon-Wiener Index ( $H'$ ) with the following formula:

$$H' = -\sum pK \times \ln$$

where  $pK$  is the proportion of individuals collected in plant  $K$ , and  $\ln$  is the logarithm of the  $pK$  value. Plant species visitation evenness for each wasp species was calculated using the following formula:

$$J' = H' / H'_{\max}$$

where  $H'_{\max}$  is the natural logarithm of the total number of plant species visited by wasp species. The values found for the Shannon-Wiener index ( $H'$ ) and evenness were compared using a Mann-Whitney test in BioEstat 4.0 (Freeware).

### Results and discussion

A total of 103 individuals were collected, including 15 species distributed among seven genera. Wasps visited 27 plant species distributed among 14 families. The most important plant families for wasps were Erythroxylaceae ( $n = 10$ ), Asteraceae ( $n = 10$ ) and Rubiaceae ( $n = 4$ ), Malastomataceae ( $n = 3$ ), and Myrtaceae ( $n = 3$ ). The highest abundance of visiting social wasps was observed in Asteraceae with 55 individuals out 103 visiting this family, followed by Erythroxylaceae ( $n = 14$ ), Rubiaceae ( $n = 10$ ), Melastomataceae ( $n = 5$ ), Cunoniaceae, Myrtaceae ( $n = 4$ ), Apocynaceae ( $n = 3$ ) and Velloziaceae ( $n = 2$ ). The families with only one visitor were Orquidaceae, Lythraceae, Fabaceae, Theaceae, Poaceae, and Ochnaceae, accounting for 55% of the foraging species during the entire collection period (Tables 1 and 2).

The diversity and evenness values for social wasp visits to flowers were higher in riparian forest ( $H' = 0.78$ ,  $J' = 0.75$ ) than in campos rupestres ( $H' = 0.30$ ,  $J' = 0.39$ ), however the Shannon-Wiener indices for the two sites did not significantly differ ( $Z(U) = 1.84$  ( $p = 0.064$ )). There were 19 plant species visited by wasps in riparian forest, and all wasp visitor species were observed visiting all 19 plant species. The most abundant wasp species were *Mischocyttarus confusus* Zikán 1935 ( $n = 16$ ), *Polybia occidentalis* (Oliver) ( $n = 14$ )

**Table 1:** Numbers of social wasps collected while visiting plant species at the Ibitipoca State Park in riparian forest phytophysiognomy at the Ibitipoca State Park, Minas Gerais, Brazil. Collections took place from November 2007 to October 2008.

Plant Family/Species	Social Wasp Species															Total
	Amu	Apa	Ble	Mco	Mdr	Pbi	Pci	Pfe	Pac	Pfa	Pig	Ppa	Pse	Poc	Psy	
<b>Apocynaceae</b>																
<i>Mandevilla sellowii</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
<i>Minaria acerosa</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
<b>Asteraceae</b>																
<i>Inulopsis scaposa</i>	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
<i>Mikania acuminata</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
<i>L. linearifolius*</i>	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	3
<i>Baccharis crispa</i>	0	0	0	1	4	0	0	0	1	0	0	1	0	3	5	15
<i>Senecio brasiliensis</i>	0	0	0	6	2	0	0	0	0	0	0	6	0	6	0	20
<i>Baccharis rufidula</i>	1	0	0	1	1	0	0	0	0	0	0	3	0	1	0	7
<b>Cunoniaceae</b>																
<i>W. paulliniifolia*</i>	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
<b>Erythroxylaceae</b>																
<i>E. gonucladum*</i>	0	0	0	1	1	1	0	2	1	1	2	1	1	3	0	14
<b>Fabaceae</b>																
<i>P. mediterranea*</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
<b>Melastomataceae</b>																
<i>Trembleya, parviflora</i>	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	4
<b>Myrtaceae</b>																
<i>Eugenia acutata</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
<b>Orquidaceae</b>																
<i>P. pachysepala*</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Poaceae</b>																
<i>Tristachya chrysothrix</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
<b>Rubiaceae</b>																
<i>Posoqueria latifolia</i>	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	4
<b>Theaceae</b>																
<i>Laplacea fructicosa</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
<b>Velloziaceae</b>																
<i>Barbacenia flava</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
<i>Vellozia albiflora</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Abundance	1	2	1	16	11	4	1	2	2	1	3	16	2	14	7	83

Abbreviations used for social wasp species. **Amu**= *Agelaia multipicta*, **Apa**= *Apoica pallens*, **Ble**= *Brachgastra lecheguana* **Mco**=*Mischocyttarus confusus*, **Mdr**= *Mischocyttarus drewseni*, **Pbi**= *Polistes billardieri* **Pci**= *Polistes cinerascens*, **Pfe**= *Polistes ferreri*, **Pac**= *Polistes ac-taeon*, **Pfa**= *Polybia fastidiosuscula*, **Pig**= *Polybia ignobilis*, **Ppa**= *Polybia paulista*, **Pse**= *Polybia sericea*, **Poc**= *Polybia occidenta-lis*, **Psy**= *Protonectarina sylveirae*; \**Lessingianthus linearifolius*; \**Weinmannia paulliniifolia*; \**Erythroxylum gonucladum*; \**Periantra mediterranea*; \**Prosthechea pachysepala*.

and *Mischocyttarus drewseni* Saussure 1857 (n = 11), which were found foraging in eight, five, and seven plant species, respectively (Table 1). In the campos rupestres site eight social wasp species visited 11 plant species, with *P. occidentalis* (n = 7) and *M. drewseni* (n = 6) having highest abundance and greatest diversity in resource use (visiting three and five plant species, respectively) (Table 2).

The diversity and evenness were higher in the hot-humid period (October-March) in riparian forest ( $H' = 0.83$ ,  $J' = 0.73$ )

and campos rupestres ( $H' = 0.73$ ,  $J' = 0.62$ ) than in the cold-dry period (April-September) ( $H' = 0.31$  and  $H' = 0.21$ , respectively), however Shannon-Weiner index values for hot-humid versus cold-dry seasons did not differ in riparian forest ( $Z(U) = 0.2402$  (p) = 0.8102) or campos rupestres ( $Z(U) = 0.080$  (p) = 0.936).

The amplitude of the trophic niche ( $H'$ ) varied from 0.63 to 2.34 (Table 3), with *M. drewseni* and *M. confusus* having highest values ( $H' = 2.34$  and  $H' = 1$ , respectively).

**Table 2:** Numbers of social wasps collected while visiting plant species in campos rupestres phytophysiognomy at the Ibitipoca State Park, Minas Gerais, Brazil. Collections took place from November 2007 to October 2008.

Plant Family/Species	Social Wasp Species								Total
	Apa	Mco	Mdr	Pbi	Pfe	Ppa	Poc	Psy	
<b>Asteraceae</b>									
<i>Chromolaena decumbens</i>	0	0	0	1	0	0	0	0	1
<i>Lessingianthus linearifolius</i>	0	0	1	0	0	0	0	0	1
<i>Mikania microdonta</i>	0	0	0	0	0	0	0	1	1
<i>Baccharis crispa</i>	0	0	0	0	0	0	1	0	1
<i>Eremanthus glomerulatus</i>	0	0	0	0	1	0	2	0	3
<b>Lythraceae</b>									
<i>Cuphea carthagenensis</i>	0	0	1	0	0	0	0	0	1
<b>Melastomataceae</b>									
<i>Tibouchina hieracioides</i>	0	0	1	0	0	0	0	0	1
<b>Myrtaceae</b>									
<i>Myrcia eriocalyx</i>	0	1	2	0	0	0	0	0	3
<b>Ochnaceae</b>									
<i>Ouratea semiserrata</i>	1	0	0	0	0	0	0	0	1
<b>Orchidaceae</b>									
<i>Prosthechea pachysepala</i>	0	0	1	0	0	0	0	0	1
<b>Rubiaceae</b>									
<i>Borreria capitata</i>	0	0	0	0	0	2	4	0	6
Abundance	1	1	6	1	1	2	7	1	20

Abbreviations used for social wasp species. **Amu**= *Agelaita multipicta*, **Apa**= *Apoica pallens*, **Ble**= *Brachygastra lecheguana*, **Mco**= *Mischocyttarus confusus*, **Mdr**= *Mischocyttarus drewseni*, **Pbi**= *Polistes billardieri*, **Pci**= *Polistes cinerascens*, **Pfe**= *Polistes ferreri*, **Pac**= *Polistes actaeon*, **Pfa**= *Polybia fastidiosuscula*, **Pig**= *Polybia ignobilis*, **Ppa**= *Polybia paulista*, **Pse**= *Polybia sericea*, **Poc**= *Polybia occidentalis*, **Psy**= *Protonectarina sylveirae*.

*Polistes ferreri*, *Apoica pallens* (Fabricius, 1804), and *Polybia ignobilis* had the lowest value ( $H' = 0.63$ ). *M. drewseni* visited the greatest number of plant species ( $n = 12$ ), but did not concentrate foraging on any particular species. *Polybia occidentalis* ( $H' = 1.78$ ) also visited a significant number of plant species ( $n = 7$ ) and had the highest abundance ( $n = 21$ ) during the collection period. We note that half of all plant species sampled in this study ( $n = 13$ ) received a low number of individual visitors (from one to three). Nine wasp species (60%) had low abundance in flowers, with only one to three individuals found in each study site.

The evenness of wasp visits ranged from 0.77 to 0.96, with the lowest value found for *Protonectarina sylveirae* Saussure, 1854; 62.5% of all floral visits by this species were to *Baccharia crispa* (Asteraceae).

The higher species richness of social wasps visiting Asteraceae and Erythroxylaceae is partially explained by the fact that these botanical families are, according to Rodela (1998), widely distributed in riparian forests and campos rupestres at the Ibitipoca State Park. Wasps display opportunistic behavior, foraging in the most abundant resources to meet population resource demand (Raveret-Richter, 2000). Further, Asteraceae have a large number of small compressed flowers, called “brush-

like” flowers, which provides easy access to floral resources (Proctor & Lack, 1996; Cerana, 2004). These flowers produce a high abundance of nectar which is located only a few millimeters deep, and present shiny, yellow and white flowers that tend to attract insects (Faegri & Pijl, 1979). Granja and Barros (1998) in a study in open Cerrado at the Reserva Ecológica da Fazenda Experimental of the University of Brasilia, found 14 species of wasps using Erythroxylaceae floral resources. The authors, as well as Amaral Jr. (1980), suggest that some *Polybia* and *Polistes* are effective pollinators of Erythroxylaceae due to their efficiency in contacting the stigmas. In the present study, *Polistes billardieri* Fabricius, 1804, *Polybia ignobilis* (Haliday, 1836), and *Polybia sericea* (Oliver, 1791) were found in *Erythroxylum gonucladum*, the only representative of the family Erythroxylaceae in either study area.

Niche amplitude values for *P. ferreri*, *A. pallens* (Fabricius) and *P. ignobilis* were low, indicating a narrow niche. This is reflected in the small number of floral resources used by these species and the small number of individuals. Variation in niche amplitude values among social wasps may be associated with factors that influence foraging activity (e.g., large differences in biomass), where greater values may indicate higher foraging capacity (Santos et al., 1998).

Populations with higher biomass also use a greater amount of food resources (Santos et al., 2006). For example, in the current study *Polybia occidentalis* had the highest abundance of visiting individuals ( $n = 21$ ) and displayed a broad foraging spectrum, visiting nine plant species. Swarming wasps build large colonies that host many individuals, and the size of the colony can be the determining factor for resource consumption. This may affect foraging amplitude of these species through the influence of colony productivity on foraging activity (Spradbery, 1973).

The amplitude of a species trophic niche is an index subject to temporal and spatial changes, and may influence the degree of specialization (Camillo & Garófalo, 1989). In Costa Rica, Heitatus (1977b) observed such variation in wasp species both among habitats and in the same habitat in different seasons. This author emphasizes the influence of plant flowering phenology on the abundance of floral resources and the strategy of resource exploration by visitors, which involves substitution of resources based on the quantity of food available. Flexibility in foraging behavior makes the amplitude of the trophic niche a dynamic variable in ecosystems. Wasp species with the highest evenness values with respect to plant visits frequently explored only one or two plant species, but also occurred in other species (Table 3). This generally agrees with the results of Heitatus (1977a) and Santos et al. (2006), who found that social wasp species are infrequent floral visitors, and that many plant species were visited by a small number of individuals.

Social wasp diversity was higher in the hot-humid period in both phytophysiognomies due to the increased biomass of plants and other insects (e.g., lepidopteran larvae), which provides more abundant supply of food (Souza & Prezoto, 2006; Auad et al., 2010). The greater number of social

wasp species visiting flowers in the riparian forest can be explained by vegetational heterogeneity in this environment, which generates higher niche complexity.

This forest formation in Ibitipoca is characterized by a sequence of shrub-tree species (predominantly trees) located near waterways (Rodela, 1998), an ideal location for wasp colony founding. In a study by Clemente et al. (2013) in the same site, riparian forest fostered a greater number of interactions between social wasp and plant species, providing support for the idea that vegetation complexity is positively correlated with social wasp diversity. The campos rupestres site showed lower species richness of social wasp floral visitors, likely due to having a less complex vegetation structure composed predominantly by herbaceous plants, grasses, and shrubs that are distributed among quartzite outcrops (Rodela, 1998). This area also has strong winds and a higher light incidence, which can lead to strong variation in microclimate (Elpino-Campos et al., 2007). Wasp-flower interactions in campos rupestres tend to be more specialized (Clemente et al., 2013), a situation that increases risk of species co-extinctions (Hernandes et al., 2004). *Protonectarina sylveirae* Saussure, 1854, *P. sericea*, *P. paulista*, *A. pallens*, *B. lecheguana*, were among the social wasp species found in this environment. The occurrence of these species is unsurprising, as they are known to have high ecological tolerance (Clemente et al., 2013) and to be generally dominant in open ecosystems, thriving under severe environmental conditions. These and other highly tolerant species may thus be important for plant and insect community structure in harsh ecosystems such as campos rupestres. Santos et al. (2007) evaluated social wasp communities in mangrove, Atlantic forest and restinga, and found that wasp diversity was significantly (positively) correlated with plant diversity in each environment. The tropical Atlantic forest had the highest

**Table 3:** Amplitude and evenness of the trophic niche in social wasps collected in the Ibitipoca State Park, Lima Duarte, Minas Gerais, Brazil.

Species	Individuals	Plant Species Visited	Niche Amplitude (H')	Evenness (J')
<i>Mischocyttarus drewseni</i> Saussure, 1857	17	12	2.34	0.94
<i>Mischocyttarus confusus</i> Zikán, 1935	17	9	1.92	0.87
<i>Polybia occidentalis</i> (Oliver, 1791)	21	9	1.78	0.91
<i>Polybia paulista</i> (Von. Ihering, 1896)	18	7	1.72	0.88
<i>Polistes billardieri</i> Fabricius, 1804	5	4	1.33	0.96
<i>Protonectarina sylveirae</i> Saussure, 1854	8	4	1.07	0.77
<i>Polistes actaeon</i> Haliday, 1836	2	2	0.69	1
<i>Polybia sericea</i> (Oliver, 1791)	2	2	0.69	1
<i>Apoica pallens</i> (Fabricius, 1804)	3	2	0.63	0.91
<i>Polistes ferreri</i> Saussure, 1853	3	2	0.63	0.91
<i>Polybia ignobilis</i> (Haliday, 1836)	3	2	0.63	0.91
<i>Agelaia multipicta</i> Haliday, 1836	1	1	-	-
<i>Brachgastra lecheguana</i> (Latreille, 1824)	1	1	-	-
<i>Polistes cinerascens</i> (Saussure, 1854)	1	1	-	-
<i>Polybia fastidiosuscula</i> Saussure, 1854	1	1	-	-

wasp richness (18 species), followed by restinga (16 species), and mangrove (eight species). Mangrove forest presents some ecological restrictions (i.e., salinity, temperature, and aridity) that can influence the diversity of wasps. Floristic composition, and vegetation structure and complexity are determinants of social wasp community composition and structure, directly influencing their fundamental and realized niches (Santos et al., 2007). Further, vegetation provides nesting substrate (Santos et al., 2006), carbohydrate resources (Santos et al., 1998), and materials for nest construction such as plant fibers (Rodrigues & Machado, 1982; Marques & Carvalho, 1993), and prey foraging area (Santos et al., 1998). Some wasp species only nest under certain structural conditions (e.g., open or closed physiognomies), and depend on specific plant morphological parameters (e.g., leaf shape and size, trunk diameter, presence of spines) (Henriques et al., 1992, Santos & Gobbi, 1998; Cruz et al., 2006).

## Conclusion

The Ibitipoca State Park contains various discrete vegetational profiles, and is composed by semi-deciduous forest and Cerrado species as well as endemic campos rupestres vegetation, typical of the rare and unique Brazilian montane savanna ecoregion. The flora of Ibitipoca provide diverse resources, favoring a rich fauna of social wasps. Although considered to be less effective compared to other pollinators in natural ecosystems, wasps did regularly visit flowers in the study areas. Thus, conservation of these areas may be relevant for the maintenance of social wasp diversity.

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