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Activity schedule and foraging in *Protopolybia sedula* (Hymenoptera, Vespidae)

Horario de actividad y forrajeo en *Protopolybia sedula* (Hymenoptera, Vespidae)

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Abstract: *Protopolybia sedula* is a social swarming wasp, widely spread throughout many countries in the Americas, including most of Brazil. Despite its distribution, studies of its behavioral ecology are scarce. This study aimed to describe its foraging activity and relation to climatic variables in the city of Juiz de Fora in southeastern Brazil. Three colonies were under observation between 07:00 and 18:00 during April 2012, January 2013, and March 2013. Every 30 minutes, the number of foragers leaving and returning to the colony was registered along with air temperature and relative humidity. Activity began around 07:30, increased between 10:30 and 14:30, and ended around 18:30. A mean of 52.7 exits and 54 returns were measured every 30 minutes. The daily mean values were 1,107 ± 510.6 exits and 1,135 ± 854.8 returns. Only one colony showed a significant correlation between forager exits and temperature ($r_s = 0.8055$; $P < 0.0001$) and between exits and relative humidity ($r_s = -0.7441$; $P = 0.0001$). This paper shows that climatic variables are likely to have little control on the foraging rhythm of *P. sedula* when compared to other species, suggesting the interaction of other external and internal factors as stimuli of species foraging behavior.

Key words: Social wasps. Foraging behavior. Climatic variables.

Resumen: *Protopolybia sedula* es una avispa social enjambradora, ampliamente distribuida por varios países de las Américas, inclusive gran parte de Brasil. No obstante su distribución, son escasos los estudios sobre su ecología comportamental. Este estudio tuvo el fin de describir el horario de forrajeo y su relación con factores climáticos en Juiz de Fora, de Brasil. Tres colonias estuvieron bajo observación, entre las 00: 07 a las 18:00 horas, durante abril de 2012, enero de 2013 y marzo de 2013. Cada 30 minutos se registró el número de avispas forrajeadoras que salían o retornaban, así como temperatura y humedad del aire. La actividad forrajeadora se iniciaba cerca de las 07:30 con intensificación entre las 10:30 y 14:30 terminando cerca de las 18:00. Se registró una media de 52,7 salidas y 54 retornos cada 30 minutos. La media diaria fue de 1.107 ± 510,6 salidas y 1.135 ± 854,8 retornos. Sólo una colonia mostró relación significativa entre las salidas y la temperatura ($r_s = 0{,}8055$; $P < 0{,}0001$) y entre salidas y humedad ($r_s = -0{,}7441$; $P = 0{,}0001$). Este trabajo demuestra que las variables climáticas ejercen poco control sobre el ritmo de forrajeo de *P. sedula* en comparación con otras especies, sugiriendo la interacción de otros factores extrínsecos e intrínsecos estimulando esta actividad.

Palabras clave: Avispa social. Comportamiento de forrajeo. Variables climáticas.

Introduction

The swarm-founding social wasp *Protopolybia sedula* (de Sausurre, 1854) is a widely spread species, distributed throughout various countries in the Americas such as Colombia, Venezuela, Guyana, Suriname, Ecuador, Peru, Paraguay, Argentina and most of Brazil (from Maranhão to Santa Catarina state). The nests are small (about 14 cm tall and 11 cm wide), sessile, covered by an envelope and usually found in shady areas under leaves of trees and bushes (Wenzel 1998).

Protopolybia Ducke, 1905 species are recorded in studies that measure diversity in anthropic areas (Lima *et al.* 2000; Alvarenga *et al.* 2010). However, studies about its foraging behavior are scarce (Ribeiro Junior *et al.* 2006). Foraging activity in social wasps results in the collection of different materials: water for cooling the colony, carbohydrates for feeding adults and larvae, vegetal fiber as construction material and protein for nourishing the larvae (Hunt 2007; Prezoto *et al.* 2008; Elisei *et al*. 2010; Clemente *et al.* 2012; Barbosa *et al.* 2014). Lepidoptera caterpillars represent up 90% of the main prey captured by social wasps (Gobbi and Machado 1985, 1986; Prezoto *et al.* 1994; Prezoto *et al.* 2005, 2006). Caterpillars are common agricultural pests, making wasps valuable allies by providing ecological services of predating them (Prezoto 1999; Prezoto *et al.* 2008; Elisei *et al.* 2010).

Environmental factors such as intensity of light, wind speed, relative humidity of air and temperature, significantly affects wasps' foraging behavior, whether stimulating or inhibiting it (Bonabeau 1998; Richter 2000). Studies on various social wasps species' foraging behavior have shown that this activity is strongly related to temperature and relative humidity of air, and usually varies among the seasons of the year and different phases of the colonial cycle (Lima and Prezoto 2003; Elisei *et al.* 2005; Ribeiro-Junior *et al.* 2006; Castro *et al.* 2011).

This paper describes the foraging activity for *P. sedula* and its relation with climatic variables.

Material and methods

The study was carried out in the municipality of Juiz de Fora (21°48'21"S 43°22'09"W, 781 m altitude), Minas Gerais state, southeast region of Brazil. Observations were made in three *P. sedula* colonies (C1, C2 and C3), from 07:00 h to

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18:00 h during a single day each, totaling 33 hours of data during the months of April of 2012 and January and March of 2013, according to the methodology suggested by Prezoto *et al.* (1994).

We registered the number of wasps that left and returned to the colony for foraging every 30 minutes; air temperature (ºC) and relative humidity (%) was also measured in these intervals by means of a digital thermohygrometer set near the colony. In order to relate the climatic variables and the foraging activity, data on the air temperature and relative humidity was correlated with the number of foragers leaving the colony by using Spearman's coefficient of correlation. Calculations were done with the freeware software BioEstat 5.3.

Results and discussion

Activity begun around 07:30 and ended around 18:00; forager exits intensified between 10:30 and 14:30, the hottest hours of day (Fig. 1). These agree with the results of Ribeiro Junior *et al*. (2006) and Rocha and Giannotti (2007), who recorded the activity of *Protopolybia exigua* (Saussurre, 1854) ranging from around 07:00 to around 18:00. This rhythm is typical for neotropical social wasps during hot and humid seasons (spring and summer), a time of the year in which the foraging activity is intense (Elisei *et al.* 2013).

A mean of 52.7 exits and 54 returns for every 30 minutes was registered (Table 1). For the daily mean, 1107 ± 510.6 exits and 1135 ± 854.8 forager returns were measured. This was higher than the number recorded by López *et al.* (2013) for *Polybia emaciata* Lucas, 1854, in Colombia, with 262 exits and 270 returns. The study made by Rocha and Giannotti (2007) on *P. exigua* in Bahia state, Brazil, found a mean of 44.4 exits and 37.6 returns per hour. This difference can be explained as follows: colonies and individuals of *P. sedula* are smaller in comparison to other swarming species such as *Apoica* Lepeletier, 1836, *Polybia* Lepeletier, 1836 and *Synoeca* de Saussurre, 1852; compared to *P. exigua*, even though individuals are similar in size, the colonies of *P. sedula* are bigger, explaining an intense foraging flux (Fig. 2A-B).

Activity intensification during the hottest hours of the day (from 10:30 to 15:00, Fig. 1) was observed in other swarming social wasps studied at the same locality; *Polybia platycephala* Richards, 1951 (Lima and Prezoto 2003), *Synoeca cyanea* (Fabricius, 1775) (Elisei *et al.* 2005), *P. exigua* (Saussurre, 1854) (Ribeiro Junior *et al.* 2006) and also for *P. emaciata* (López *et al.* 2013) in Colombia.

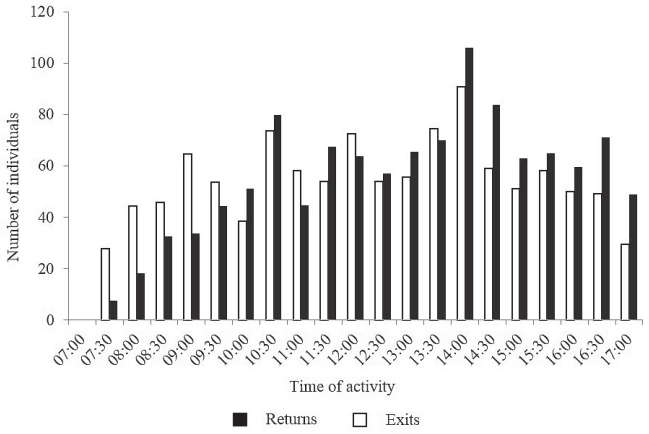

Figure 1. Mean of the total *Protoplybia sedula* worker exits (white bars) and returns (filled bars) for the three colonies (C1, C2 e C3) along a whole day (April of 2012, January and March of 2013) in the municipality of Juiz de Fora, Minas Gerais state, Brazil.

Comparison between forager exits, air temperature and relative humidity showed various results. Colony C1 was the only one to show significant values for the correlation between forager exits, air temperature ($rs = 0.8055$; $P < 0.0001$) and relative humidity of air ($rs = -0.7441$; $P = 0.0001$). Correlation results for both temperature and exits, and humidity and exits were not significant for colonies C2 and C3 (Fig. 3).

Studies relating forage and environmental variables have been conducted with many species. López *et al.* (2013) and Lima and Prezoto (2003) studied *P. emaciata* e *P. platycephala* and both studies verified that the increase in the foraging activity is related to temperature increases and humidity decreases, mainly during the hot and humid season (spring and summer). Similar results were found by Ribeiro Junior *et al*. (2006) regarding temperature for another species of *Protopolybia*. In the same locality, Elisei *et al.* (2005) verified that the intensification of forager exits in *S. cyanea* occurs in the hottest hours of the day.

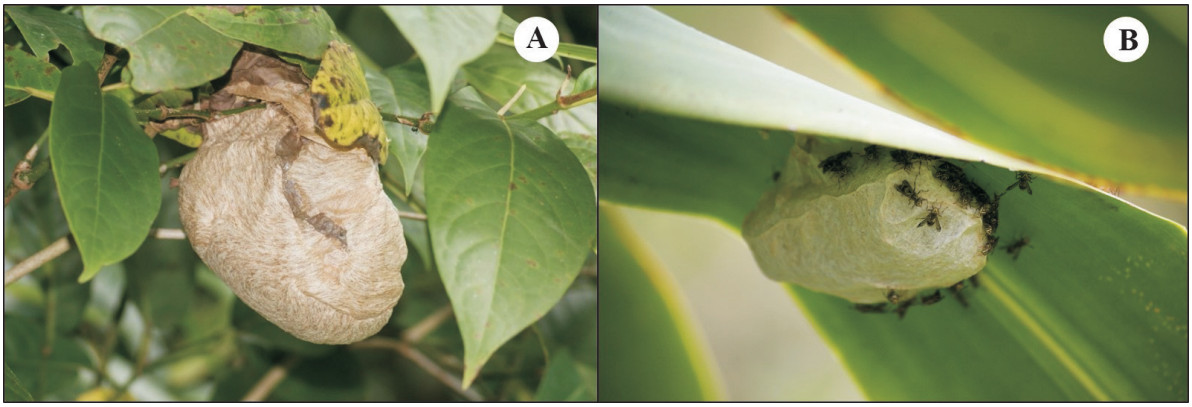

Figure 2. Size difference of nests: **A**. *Protoplybia sedula*. Nest lenght: 19 cm. **B**. *Protoplybia exigua.* Nest lenght: 11 cm.

Table 1. Data on the climatic variables (air temperature and relative humidity), forager exits and returns [X ± S (amp)] for the three *Protopolybia sedula* colonies (C1, C2 e C3) for every 30 minutes between 07:00 and 18:00 (April of 2012, January and March of 2013) in the municipality of Juiz de Fora, Minas Gerais state, Brazil.

	Temperature (ºC)	Relative humidity of air (%)	Exits of foragers	Returns of foragers
C1	23.5 ± 2.95	64.14 ± 10.52	42.14 ± 19.05	36.24 ± 21.86
	(17.8-27.9)	(48-77)	(0-74)	(0-69)
C2	27.53 ± 3.11	65 ± 3.6	35.48 ± 18.85	32.1 ± 20.24
	(22.4-33)	(60-71)	(0-73)	(0-80)
C3	23.87 ± 2.41	68.38 ± 5.9	80.52 ± 39.75	93.8 ± 48.43
	(18.2-26.6)	(60-79)	(0-169)	(0-215)
Total	24.9 ± 3.34	65.8 ± 7.38	52.7 ± 33.79	54 ± 43
	(17.8-33)	(48-79)	(0-169)	(0-215)

Absence of correlation between forager exits and climatic variables observed for colonies C2 and C3 is evidence that, during certain phases of the biological cycle, the foraging demand does not depend on climatic variables, but on the colony's biological needs. Castro *et al.* (2011) suggested that the lack of correlation between humidity and forager exits in certain colony phases for the wasp *Mischocyttarus cassununga* (von Ihering, 1903) might be due to the colony's nutritional needs.

The presence of an envelope protecting *P. sedula* nests might generate a certain level of homogenization of the internal environment in terms of temperature and humidity, increasing the importance of the colony`s internal stimuli when regarding forager exits.

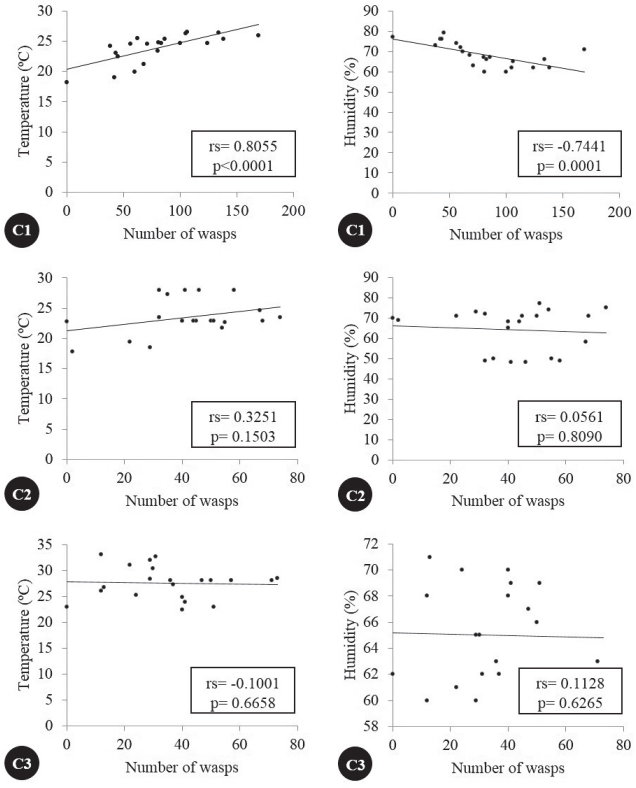

Figure 3. Correlation between temperature and forager exits, and relative humidity of air and forager exits, for the three *Protopolybia sedula* colonies (C1, C2 e C3) (April of 2012, January and March of 2013) in the municipality of Juiz de Fora, Minas Gerais state, Brazil.

Conclusions

This work presents the first foraging rhythm study for *P. sedula*, showing that climatic variables possibly have low control on the foraging rhythm when compared to other social wasps species and suggesting the existence of an interaction between external and internal factors as stimuli for this activity in the species.

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