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# Foraging Behavior of *Scaptotrigona depilis* (Hymenoptera, Apidae, Meliponini) and its Relationship with Temporal and Abiotic Factors

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**Abstract**

Stingless bees play an important role in Tropical and Subtropical ecosystems as pollinators of many plants. The aim of this study was to characterize the pattern of flight activity and foraging for pollen by *Scaptotrigona depilis* workers and their relation with climatic and temporal factors. We observed flight activity from July 2001 to June 2002 and pollen collection by scoring the flow of workers entering and exiting the colonies. We tested whether environmental (temperature, relative humidity, pluviosity and luminosity) and temporal predictors (month and time of day) affected bees' activities. The study was conducted during one year and the records of observations showed that during the dry season when the length of light is longer, the external activity was more intensive, while during cold months with shorter light period, foraging activity was reduced. Pollen collection showed a peak in February, but in general this activity was regulated by temperature, humidity and daily luminosity.

## Introduction

It is known the importance of bees as pollinators and visiting of flowers in the most world's ecosystems and the special role that stingless bees play in the tropical areas (Roubik, 1989; Biesmeijer & Slaa, 2006). Bees are also known to be efficient pollinators of many crops as about 30% of human food is derived frombee-pollinated crops (reviewed in Slaa et al., 2006).

Unpredictable environmental changes affect foraging activities in terms of timing and location of food. There are two main features regulating departure of foraging bees: individual memory and threshold response to react to the foraging stimuli (internal factors), and environmental and colony conditions which determine the level of exposure to stimuli associated with decision to forage (external factors) (Biesmeijer & de Vries, 2001). Colonies of honey bees and stingless bees can allocate more foragers to collect nectar and pollen in response to the amount of food in storage and availability of resources in the field (Seeley, 1995; Biemeijeret al., 1999, Fewell &Winston, 1992).

The stingless bee *Scaptotrigona depilis* has an efficient communication by pheromones trails and presents a highly eusocial pattern in which the oldest workers perform basically foraging activities while younger workers are engaged in intra nest activities such as maintenance, brood care and defense (Nogueira-Neto, 1970; Roubik, 1989; Engels et al., 1997; Michener, 2000). The colonies of this species are estimated around 2.000 to 50.000 individuals (referred as *S. postica* in Lindauer & Kerr, 1960). The nests, built with wax, resin and cerumen, occur in tree cavities and present an elaborated architecture that include an entrance tube that communicates with the brood cells, pollen and honey pots as a food storage in the sides of the nest and horizontal brood combs with vertical cells and involucrum to provide protection (Nogueira-Neto, 1970; Michener, 1974; Kerr, 1996).

Although the forager bees collect different products such as resins, rotting wood, seeds, leaves, trichomes, fra-

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grances, spores, waxes, feces and animal hairs, the principal materials collected are pollen and nectar used for feeding bees (Roubik, 1989).

According to Michener (1974) colony development depends to the success of the foraging flight and the ability to bring resources to the nest from carefully chosen flowers. The interaction between the bees' activity and the environmental factors has been described by several authors. The mode that the bees perceive and react to these factors reflected in the flight activity pattern as described by Nelson and Jay (1967), Szabo (1972) for *Apis mellifera*, Szabo and Smith (1972) for *Megachile rotundata*, and Shiag and Abrol (1986) for *Apis florae.* Especially in Meliponini the pioneering works on foraging activities were in the following species: *Plebeia saiqui* and *P. droryana* (Oliveira, 1973), *Tetragonisca angustula* (Iwama, 1977), *P. emerina* (Kleinert-Giovanini, 1982), *P. remota* (Imperatriz-Fonseca et al., 1985) and in two subspecies of *Melipona marginata* (Kleinert-Giovanini & Imperatriz-Fonseca, 1986). The aim of this study was to test whether the pattern of flight activity and foraging for pollen in *S. depilis* is affected by environmental and temporal effects. We predicted that in high-sized populated stingless bee colonies such as *S. depilis* environmental factors have not significant effects compared to temporal or seasonal variables. As seasonality is a limiting trait for plants, nectar and pollen availability may represent a key constraint for tropical stingless bees.

## Materials and Methods

*Scaptotrigona depilis* occurs from the Southeast of Mato Grosso State to the West of São Paulo State (Camargo & Pedro, 2012). The estudy site was the meliponary at the University of São Paulo, Campus of Ribeirão Preto in São Paulo, Brazil. We used four colonies of *Scaptotrigona depilis* housed inside the wooden boxes. The observations were made from July 2001 to June 2002, and were carried out twice a month with intervals of approximately fifteen days. Each observation was made with intervals of 1 hour and 15 minutes from 7:00 am to 18:15 pm. For each colony the pattern of flight activity and pollen collected was scored by counting the number of workers entering and exiting the colonies during three minutes. Later, we recorded the number of workers that entered the colonies with pollen during two minutes. These data were obtained using manual counters and a chronometer. The environmental predictors (temperature, relative humidity, pluviosity and luminosity) were recorded at each interval of time using digital thermo-hygrometer and a luximeter.

The data were analysed with a general linear model (GLM) where colonies, season and time of day were entered into the analysis as the independent variables and number of bees entering or exiting as the dependent variables (Neter et al., 1996). A regression test was also used to estimate the relationship between abiotic, colony and the frequency of departures. All analyses were made using Statistica 7.0 (Statsoft inc.).

## Results

### *General activities*

Our data showed that foraging activities were ruled out by the typical seasonal pattern found in the Southern of Brazil: the external activity increased during the wet season in warm months (August /March) and decreased during the cold and driest months (April/July). The general results showed that in lower temperature periods bees began the flight activity later and the traffic was less intense, while in high temperature values the bees began the flight activity earlier and more intensively. The onset of the external movement occurred only at temperatures above 15°C. The end of the activity was determined by the decreasing of light intensity more than under the temperature effect. However, in warmer months, when the days are longer, the bees flew even in low luminous intensity in both the beginning and ending of the activity.

The foraging activity occurred during all year but it presented peaks at different months. Although the pollen collection occurred throughout the year, there was a conspicuous decline in July/2001 and from March to June/2002. In February/2002 there was a large increment in all activities, but mainly for the pollen collection (Fig. 1).

General linear models showed that foraging activities were significantly affected by almost all parameters tested (Table 1). Variance between colonies was significant, meaning that thenumber of foraging departures and returns between the four colonies was different. Concerning the temporal variables, the general linear models showed that month (season), time of day and state of colony presented a significant influence on the flight departure (Table 1).

Abiotic variables had a smaller influence on the bees' departures compared to the temporal variables. Only luminosity and pluviosity were significantly important to regulate foraging departure. Multiple regression analysis revealed a low, but significant interaction between all abiotic variables taken altogether and exiting of foragers ($R^2 = 0.04$; $F = 9.73$; $p < 0.0001$).

### *Pollen collection*

Foraging for pollen was regular during almost all period of study, presenting a conspicuous peak during February, rainy season (Fig. 2A). Multiple regression analysis revealed a low but still significant influence of climatic factors on the pollen collection ($R^2=0.17$; F = 40.83; $p<0.001$; (Fig. 2B). The most important parameters explaining the influence of abiotic factors on pollen collection were temperature (R = 0.17; $p < 0.05$), luminosity (R = 0.19; $p < 0.05$) and humidity (R = -0.21; $p < 0.05$).

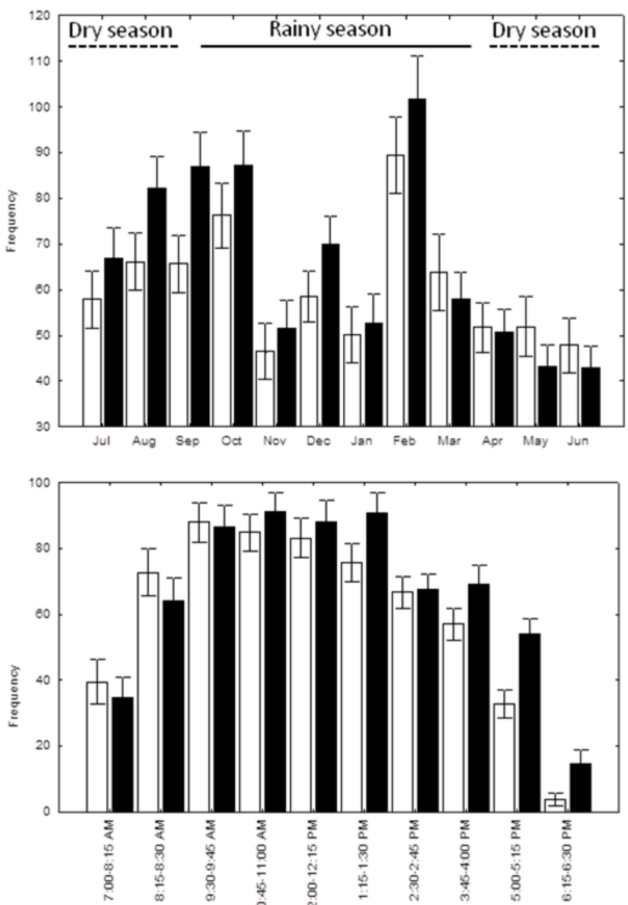


Fig 1. Mean±S.E. of *Scaptotrigona depilis* entries (black bars) and exits (white bars) related to temporal variables and season from July 2001 to June 2002.

Table 1. General linear models results of the departure frequency of *Scaptotrigona depilis* foragers related to temporal and abiotic variables.

| | D.F. | MeanSquared | *F* | *p* |
|---|---|---|---|---|
| **Temporal effects** | | | | |
| Intercept | 1 | 345765.6 | 684.70 | <0.0001 |
| month | 11 | 5273.0 | 10.44 | <0.0001 |
| timeofday | 9 | 6238.7 | 12.35 | <0.0001 |
| month*time | 99 | 1071.7 | 2.12 | <0.0001 |
| Error | 478 | 505.0 | | |
| **Abioticeffects** | | | | |
| Intercept | 1 | 11242.29 | 3.13 | 0.077 |
| luminosity (lux) | 1 | 51158.03 | 14.25 | <0.0001 |
| pluviosity (pluv) | 1 | 20888.02 | 5.82 | 0.016 |
| temperature (temp) | 1 | 276.40 | 0.07 | 0.781 |
| humidity (humid) | 1 | 6863.24 | 1.91 | 0.167 |
| lux*temp*humid*pluv | 1 | 12455.51 | 3.47 | 0.063 |
| Error | 752 | 3588.96 | | |

## Discussion

This study showed that in this species flight activity starts with a few number of bees and the external movement increases gradually according to the raising of the luminosity and temperature. However, the peak of entrance and exit do not occur at times of the day at higher temperatures, as also verified by Heard and Hendrikz (1993), in *Trigona carbonaria* and Hilário et al. (2001) in *P. pugnax.* In cold days, the flight activity was less intense and the beginning of the flights occurs later as reported by Hilário et al. (2012) for *P. remota* as a "more compact flight activity". On the other hand, in warmer days the traffic of bees was more intense and began earlier, therefore the period of the external activity was longer as observed by Hilário et al. (2000). In late afternoon the luminosity seems to determine the end of the activity as also observed for *Tetragonisca angustula* (Iwama, 1977). However, in days with higher temperatures, both the first flights that occurs approximately 21°C and the last between 27° to 30°C were maintained even in significantly lower luminosity conditions. Therefore, there was a significant interaction between temperature and luminosity determining the activity of flight.

During heavy rain or stronger wind, the entrance of workers became more intense and the departures almost stopped, decreasing practically all the traffic, just returning to regular flow right after the rain, as also reported for *P. pugnax* (Hilário et al., 2001). Hilário et al. (2007b) observed that *P. remota* foragers guided most of their flights to certain wind directions that matched with the local where the floral resources were. On cloudy drizzled days, the external movement was finished at 5:00 p.m. despite the high temperatures. However on cloudy days preceded by rainy night, even with high levels of light and temperature, the external activity became greatly reduced. In days of weather instability, with a few moments of rain and variations of temperature and luminosity, the external activity occurred irregularly. It demonstrated clearly the influence of climatic factors on flight activity of bees.

Bees began the foraging for pollen soon after the start of flight activity and arrived with pollen during all period of observation. The peaks of collection occurred at different times on each day, so it was not possible to establish a pattern of activity for pollen. In February, there was a significant increase in the external activity, especially for pollen collecting. It may be related to the climatic factors, although the interactions between these factors and the some changes in the availability of flower resources. In fact, Faria et al. (2012) verified that the foraging for pollen was concentrated on a few sources, despite of all the plants species visited

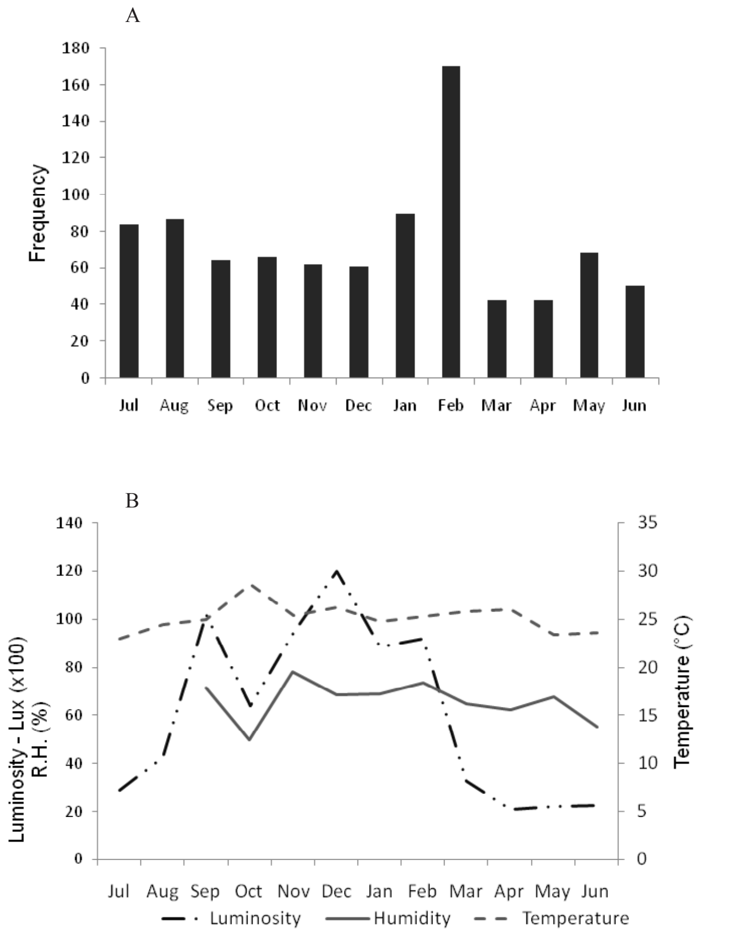


Fig. 2.A - Average number of *Scaptotrigona depilis* workers that arrived with pollen, and B. average luminosity, relative humidity and temperature from July/2001 to June/2002. Humidity in July and August were not registered.

for *S. depilis*. According to this study, both the availability and localization of floral resources affect the choice of the pollen sources in this species. In *M. bicolor*, pollen forager ratios varied significantly between seasons and this variation was related to both the production of reproductives and the number of individuals in the colonies (Hilário & Imperatriz-Fonseca, 2009). Quezada-Euán et al (2011) also reported that the worker's body size of *Nannotrigona perilampoides* may change according to the protein and sugar concentration in larval food. As pollen is the main protein source of larval food, so flower phenology and the seasonal availability of different pollen types may influence brood development in this species.

On the days of intense rain, bees reduced the external activity, so restarting quickly after the rain ceased probably to maintain the food storage, also described by Hilário (2007a) for *P. remota*. Veiga et al. (2013) observed in *Melipona flavolineata* foraging decline on rainy season followed by a decrease of food stores and the subsequent change in the size of the worker, which suggested that the climate is a key determinant of foraging activity. So, the foraging "explosion" occurred on February could be explained by the highest rates of rainfall recorded from October to March, especially on February, when there were consecutive rainy days before the observation. This increase in pollen foraging may be influenced by the resource availability, probably acting together with climatic factors, as observed by other authors. According to Pereboom and Biesmeijer (2003) stingless bees has a differentiated capability to gain and losing heat due the size and coloration of the body, and it can be explained by biophysical principles that correspond to differential thermo regulatory capabilities. So, for these authors the thermal characteristic scan influence the pattern of foraging according to the morphology and anatomy of the bees. Bellusci and Marques (2001) observed that even if exiting to outside is restricted, activity of the foragers follow a circadian rhythm, synchronized by the light/dark cycle and probably influenced by other environmental cycles as temperature and the availability of food sources.Thus, all these factors should be considered interactively in determining the external activity of bees.

Based on the present and previous studies we can state that *S. depilis* due to its large colonies and number of individuals tolerate climate changes such as higher temperatures, high and low relative humidity values and variations of light intensity. There was recorded no flights activity on temperatures below 15°C so the only factor that can limit the flight activity was the low luminosity. On the other hand, the pollen collectionis probably influenced by climatic factors associated with availability of the food resources.

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