

Research Article

Foraging of *Scaptotrigona* aff. *depilis* (Hymenoptera, Apidae) in an Urbanized Area: Seasonality in Resource Availability and Visited Plants

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Received 1 August 2012; Accepted 17 September 2012

Academic Editor: Kleber Del-Claro

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The floral sources used by bees can be identified by analyzing pollen grains obtained from their bodies, feces, brood cells, or storage pots in the nests. In addition to data on resource availability, this information enables the investigation on the selection of food resource by bees. We assessed the foraging patterns of *Scaptotrigona* aff. *depilis* in an urbanized area with seasonal availability of food resources. The species visited a percentage of 36.60% of the available flora, suggesting that these bees are selective at spatiotemporal scale. When many types of resources were available, the workers concentrated their collection activities on a limited group of sources. In contrast, more plant species were exploited during periods of lower number of flowering plants. A monthly analysis of the foraging patterns of the studied colonies revealed that *Syzygium cumini* (88.86%), *Mimosa* sp.1 (80.23%), *Schinus terebinthifolius* (63.36%), and *Eucalyptus citriodora* (61.75%) were the most frequently used species and are therefore important for maintaining *S.* aff. *depilis* at the study area. These plants are close to the colonies and exhibit mass flowering. This study is one of few works to quantify natural resource availability and to analyze the effects of flowering seasonality on the selection of food sources by bees.

1. Introduction

The Meliponini, popularly known as stingless bees, are highly social organisms that occur in tropical and subtropical areas throughout the world [1]. One of the many important activities performed by workers is the collection of nectar (an important source of carbohydrates) and pollen (a source of protein and vitamins) [2, 3]. These resources are collected and stored in the colonies to feed adult and immature bees. The collection of these resources is primarily regulated by abiotic factors such as environmental temperature, relative humidity, and wind speed [4, 5]. Among the biotic factors that can influence foraging are the morphological and physiological characteristics of the bee species, resource availability, and the reproductive status of the colony [6, 7].

While collecting pollen and/or nectar from flowers, bees usually stay with pollen grains adhered to various parts of the body besides those pollen stored into the corbicula. As a result, on subsequent visits, the bees may unwittingly perform pollination [8]. Bees, along with other animals, pollinate up to 94% of angiosperms in tropical areas [9]. Several species of stingless bees have been considered good candidates as commercial pollinators because they can easily be kept in hives, have numerous workers per colony, and are nonaggressive [10, 11]. In addition to nine crops pollinated by stingless bees and related by Heard [11], studies made after that publication showed that stingless bees are also effective pollinators of other nine crops [12]. Conservation of forest fragments around such crops can provide resources

for the bees, maintaining pollinator populations and thereby improving crop pollination rates [13, 14].

Stingless bees, which maintain perennial colonies, visit multiple types of flowers to obtain resources and are thus considered to be generalists [1]. However, they can intensify collection at certain sources, indicating some degree of selectivity [15–19], as also observed in specialized solitary bees [20, 21]. Their focus on a few selected sources can be explained by optimal foraging theory [22], which proposes that bees concentrate their visits on the most profitable sources, that is, those that offer more energy than what spent to acquire the resource.

The food sources exploited by bees can be identified by direct observation of the visiting bee at the flower [23, 24] or by pollen analysis [14, 25, 26]. Pollen analysis enables quantification of the diversity and frequency of pollen grains found on the bodies of the bees [14, 27], the nest [28, 29], and/or feces of adult and immature bees [13].

Studies aiming to identify the food sources used by bees are considered more complete if there is an estimation of resource availability performed throughout the study period [27, 30–32]. However, due to the difficulty of evaluating resource availability under natural conditions, only a few studies were made with this focus [33].

Data on the plant species that bees use as food sources improve our understanding of their food resources and niche overlap between species [27]. Furthermore, this information provides a base for studies on the interactions between the bees and their preferred plants as well as support for the elaboration of management plans and the conservation of both bees and plant species that depend on them for pollination (and, consequently, for reproduction) [14].

This study aimed (i) to identify the floral sources used by *Scaptotrigona* aff. *depilis* by analyzing the pollen loads from returning workers and (ii) to assess the foraging pattern of this species in relation to the availability of floral resources.

2. Material and Methods

2.1. Study Area and Bee Species. The study was performed in the experimental meliponary of the Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto (FFCLRP), Universidade de São Paulo (USP) (21°10'30 S and 47°48'38 W). The University campus is urbanized but retains areas with plants that are native to seasonal semi-deciduous forests as well as exotic plants used in urban landscape projects. There is also a 75 ha forest area planted with species that are typical of the original vegetation [34]. The local climate is characterized by two well-defined seasons: a cool/dry season extending from May to September and a hot/wet season extending from October to April.

In Brazil, *Scaptotrigona* aff. *depilis* is found at Rio Grande do Sul, Paraná, Mato Grosso do Sul, São Paulo, and Minas Gerais states [35]. The term “affinis” is used when the identity of a distinct biological species is unknown but it has a strong similarity with a known species, in this case *Scaptotrigona depilis* (Moure, 1942). Nests of *S.* aff. *depilis* are found in tree cavities, its colonies are populous, and the workers are very aggressive defending the nest by flying

around and biting invaders. For this study, four strong colonies with similar population sizes and distant from each other by up to 15 m were selected.

2.2. Spatiotemporal Distribution of Floral Resources. The spatiotemporal distribution of floral sources was evaluated from an area of 500 m radius from the place where the nests of *S.* aff. *depilis* were maintained. Monthly surveys were conducted within this area from March 2010 to February 2011, and species of flowering plants were identified across the vertical strata (trees, shrubs, herbaceous plants, and vines) [14]. The surveys were made during five days per month, totaling 480 hours along the year. The number of individual plants in flower was used to assess the availability of resources. Samples were collected from flowering plants and deposited in the Herbário SPFR (Herbarium of the Departamento de Biologia-FFCLRP-USP). Flower buds of the same species were also collected, the pollen grains were removed and, after acetolysis, mounted on reference slides, which were subsequently deposited in the palynotheca of the Laboratory of Pollen Ecology of FFCLRP-USP.

2.3. Pollen Samples. To assess pollen loads content, 40 returning foraging workers were collected monthly from each colony ($n = 4$) for a total of 160 samples per month. Collections were performed between 7:30 am and 1:30 pm, depending on climatic conditions and pollen foraging activity. This activity was evaluated by counting the number of workers who returned to the colony with pollen load, through observation during the morning (5-minute scans at 30-minute intervals) and afternoon (5-minute scans at 60-minute intervals) one day per month. This method was adopted because pollen collection by workers is known to diminish considerably in the afternoon [36, 37].

Corbicula pollen loads were removed using pincers, placed in Falcon tubes containing 2 ml of 70% ethanol and fixed for at least 24 h [14]. The tubes were then centrifuged for 15 min, and the ethanol was discarded. Glacial acetic acid (4 mL) was added to the remaining pollen material, which was then acetolysed [38] and placed on slides prepared with Kisser gelatin and deposited in the palynotheca at FFCLRP-USP. The pollen grains were identified by comparison with other materials deposited in the palynotheca.

2.4. Data Analysis. Pearson's correlation coefficient (r) [39] was calculated to examine the relationship between the mean number of returning pollen workers from the four colonies and the temperature, relative air humidity, and wind speed. This coefficient was also used to examine the relationship between the number of different pollen types collected and the numbers of species and individuals in flower. These analyses were conducted using R (version 2.13.1, R Development Core Team 2009).

The climatic data used in the analysis were obtained from a weather station located next to the meliponary (available at: <http://www.b-lab.at/B-Lab-Research/B-Lab-Research.html>).

The spatiotemporal distribution of floral resources was evaluated by a circular analysis implemented with Oriana 4.0 [40]. This analysis was performed for both the number of

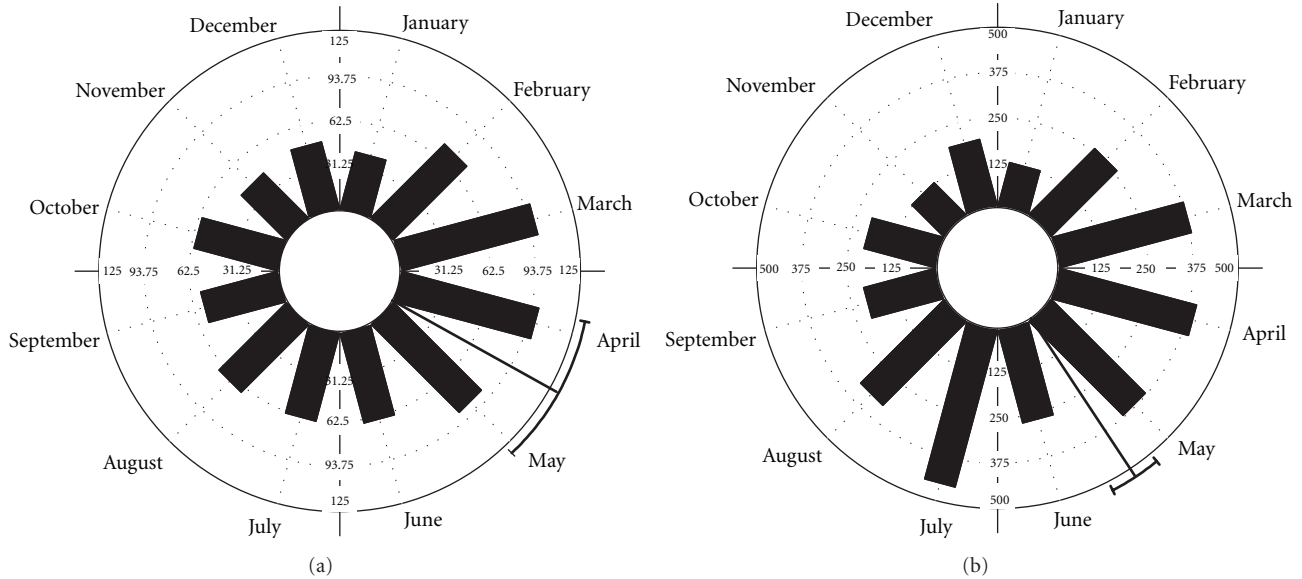


FIGURE 1: Circular analysis of resource availability during one year (March 2010 to February 2011) in the University campus. (a) Number of species in bloom. (b) Number of individuals in bloom. Each month represents 30° of the circle, and each bar represents the number of flowering species and individuals, respectively. The line at the top of the vector indicates the standard deviation.

species and number of individuals in flower in the study area. Circular analysis was also used to evaluate the number of *S. aff. depilis* workers performing pollen collection activities.

Analysis of the pollen collected by the bees was performed using a binocular microscope with up to 2560x magnification. Digital images of the pollen grains were taken using a camera attached to the microscope. Qualitative analysis was used to assess the richness of the visited species and was supplemented by a quantitative analysis of the first 400 pollen grains from each sample [41]. The monthly percentages and the following occurrence classes were then determined: dominant pollen (>45% of the total number of grains on the slide), supplementary pollen (15 to 44%), important isolated pollen (3 to 14%), and occasionally isolated pollen (<3%) [42–44].

An analysis of the Sørensen similarity coefficients using UPGMA clustering was made to examine the overlap in resource use between the four colonies. These analyses were conducted using R (version 2.13.1, R Development Core Team 2009).

3. Results and Discussion

A total of 3285 individuals were distributed in 235 species and flowered in the studied area. The mean date of flowering species was significant ($z = 20.60$; $P < 0.001$), with a concentration of species occurring around April ($r = 0.16$) (Figure 1(a)). The highest numbers of flowering species were observed during March and April 2010, with 97 and 98 species, respectively. The mean date was also significant for the flowering individuals ($z = 167.50$; $P < 0.001$) with a concentration of them in May ($r = 0.23$). The majority of the plant individuals flowered in July ($n = 450$) (Figure 1(b)).

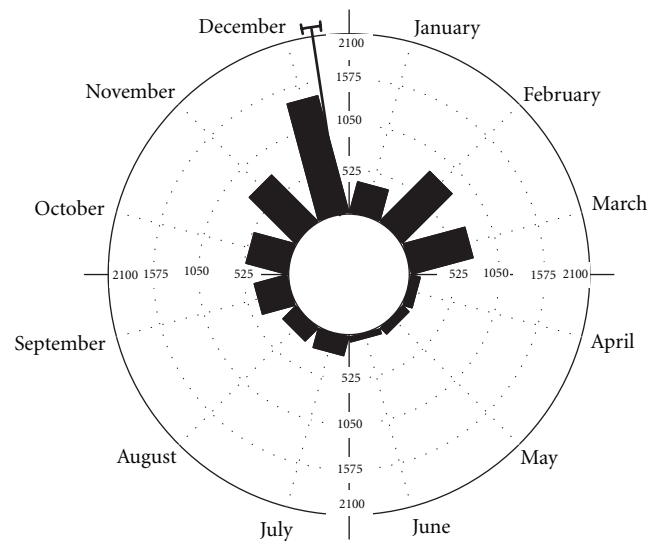


FIGURE 2: Circular analysis of the mean number of pollen foraging workers of *Scaptotrigona aff. depilis*. Each month represents 30° of the circle, and each bar represents the number of returning pollen workers. The line at the top of the vector indicates the standard deviation.

The number of returning pollen workers differed across the study period, with a significant peak in December ($z = 1171.24$; $P < 0.001$), revealing an accentuated seasonal pattern ($r = 0.45$) (Figure 2). Out of all the climatic variables evaluated on the collection days, only temperature was positively correlated with the number of workers returning with pollen loads (Table 1). This result could explain the lower mean number of workers returning with pollen loads observed in June, as this collection day had the

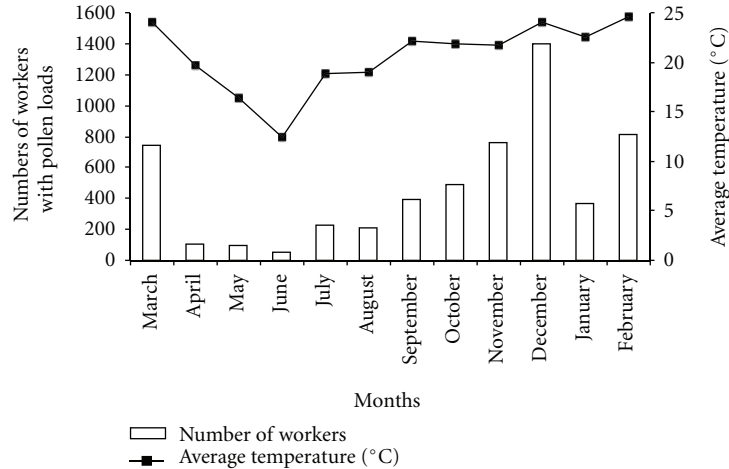


FIGURE 3: Mean number of pollen foraging workers of *Scaptotrigona* aff. *depilis* related to the average temperature.

TABLE 1: Pearson coefficients (r) between the mean number of returning foraging workers and climatic factors and between pollen collected and resource availability.

	r	P
Mean number of returning pollen workers \times mean temperature	0,754	0,00464
Mean number of returning pollen workers \times relative air humidity	0,174	0,5888 (ns)
Mean number of returning pollen workers \times wind speed	-0,012	0,9713 (ns)
Pollen types \times number of flowering species	-0,479	0,1154 (ns)
Pollen types \times number of flowering individuals	-0,346	0,2698 (ns)

*ns: not significant.

lowest mean temperature (16.6°C) recorded over the year (Figure 3). The reduced number of workers observed in June was apparent when the colonies were analyzed separately (Figure 4). Temperature is an important determining factor for the normal activity of bees, being perhaps the most important factor for regulating the onset of flight [45–48]. Low temperatures reduce metabolic rates, thereby impeding flight activity and other movements in bees [49].

Eighty-six pollen types belonging to 66 genera in 36 botanical families were identified in the samples. From this total, 83.72% were identified to the species level, while the others were identified to the family or genus level or remained unidentified (Table 2).

The families with the highest number of visited species were Fabaceae, Malvaceae, and Myrtaceae, accounting for 36.04% of the total species visited (Figure 5). Species of Fabaceae and Myrtaceae were considered as important sources of pollen due to frequency of occurrence of different pollen types (dominant, supplementary, or important isolated pollen). Malvaceae, on the other hand, considering the frequency of occurrence was important source of nectar (occasionally isolated pollen), including *Basiloxylon*

brasiliensis (Allemão) K. Schum. which was also important as a source of pollen (Table 2). Eusocial bees, such as those of the Meliponini tribe and *Apis mellifera* L. (Apini), were previously reported to most commonly visit Fabaceae and Myrtaceae species [28, 50, 51].

Ferreira et al. [52], who examined pollen loads of workers of *Scaptotrigona depilis* over one year in an urban area in Dourados (Mato Grosso do Sul, Brazil), reported that a total of 42 species were visited and that the Myrtaceae and Fabaceae-Mimosoideae families were the most highly represented. Similarly, Marques-Souza et al. [53], who studied the pollen loads of *Scaptotrigona fulvicutis* (Moure 1964) in an old regrowth forest in Manaus (Amazonas, Brazil), showed that these bees collected pollen from the flowers of 97 plant species distributed across 73 genera and 36 families, with the most frequently visited species belonging to the Fabaceae-Mimosoideae, Myrtaceae and Sapindaceae families.

Ramalho et al. [51] proposed that it is not unexpected that social bees should most frequently visit plant families containing many Neotropical species, such as the Fabaceae, Malvaceae and Myrtaceae, for both pollen and nectar, with possible regional differences. Additionally, species of Myrtaceae commonly hold open flowers with many stamens and anthers opening lengthwise, exposing the pollen grains, and facilitating visits by bees [52].

Notably, of all the plant species visited, *S.* aff. *depilis* concentrated its collection on only a few sources along the year. Based on the monthly percentage, the most frequently visited species were *Syzygium cumini* (L.) Skeels (Myrtaceae) (in October), *Mimosa* sp. 1 (Fabaceae) (in January), *Schinus terebinthifolius* Raddi (Anacardiaceae) (in February), and *Eucalyptus citriodora* Hook. (Myrtaceae) (in May) (Figure 6) once their pollen grains were classified as dominant in the samples (Table 2). *Eucalyptus* species are often cited as commonly used by Meliponini. Ramalho [54] attributes this loyalty to the high concentration of pollen in the crowns of these trees, which serve as a visual display for the bees. This pattern was also observed by Cortopassi-Laurino and Ramalho [28], who studied *Trigona spinipes* (Fabricius, 1793) and *Apis mellifera*.

TABLE 2: Plant species used by *Scaptotrigona* aff. *depilis*, based on analyses of the pollen load from workers of 4 colonies, between March 2010 and February 2011 in the University campus.

Family	Species	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dec	Jan	Feb
Acanthaceae	<i>Hypoestes sanguinolenta</i> (Van Houtte) Hook. f.					11.67							
Amaranthaceae	<i>Chamissoa altissima</i> (Jacq.) Kunth sp.1			1.25	5.28 18.25	3.50 3.52	0.02	0.02	0.02		0.02		
Anacardiaceae	<i>Anacardium occidentale</i> L. <i>Myracrodruon urundeuva</i> Allemão <i>Schinus terebinthifolius</i> Raddi sp.1			12.83	8.41	20.92 0.54 3.75	32.52 10.92	8.34 1.80	1.80	20.37 37.82	12.55	7.92	0.17 63.36
Areaceae	<i>Archontophoenix alexandrae</i> (F. Muell.) H. Wendl. and Drude sp.1						2.27			0.02			0.16
Asteraceae	<i>Syagrus romanzoffiana</i> (Cham.) Glassman <i>Bidens sulphurea</i> (Cav.) Sch. Bip. <i>Tithonia diversifolia</i> (Hemsl.) A. Gray <i>Sphagneticola trilobata</i> (L.) Pruski			0.28	0.02	0.02					0.05	0.10	
Bignoniaceae	<i>Handroanthus roseo-albus</i> (Ridl.) Mattos				0.09			24.05	0.05		0.05		
Boraginaceae	<i>Cordia trichotoma</i> (Vell.) Arráb. ex Steud.									0.10	0.03	0.02	
Cannabaceae	<i>Celtis iguanaea</i> (Jacq.) Sarg.							1.84		0.07			1.80
Caricaceae	<i>Carica papaya</i> L.					0.04							
Chrysobalanaceae	<i>Licania tomentosa</i> (Benth.) Fritsch												
Calophyllaceae	<i>Calophyllum brasiliense</i> Cambess.							4.81					
Commelinaceae	<i>Tradescantia pallida</i> (Rose) D. R. Hunt <i>Tradescantia zebrina</i> Heynh.					1.35	1.19	0.03 0.05		0.42			
Dilleniaceae	<i>Dolioscarpus dentatus</i> (Aubl.) Standl. <i>Groton urucurana</i> Baill.			2.00 1.81							1.30	0.10	0.73
Euphorbiaceae	<i>Joannesia princeps</i> Vell. <i>Ricinus communis</i> L. sp.1			0.06	4.95 8.91 0.28		4.06	0.05		10.72	0.03 10.70		0.25
	<i>Anadenanthera macrocarpa</i> (Benth.) Brenan <i>Cassia grandis</i> L. f. <i>Centrosema</i> sp.								2.56 1.84	2.77 0.33	0.05	1.13	2.86
	<i>Delonix regia</i> (Bojer ex Hook.) Raf. <i>Erythrina cristae-galli</i> Krukoff <i>Gliricidia sepium</i> (Jacq.) Kunth ex Walp. <i>Inga vera</i> Willd		0.17							0.10	13.34	0.20	0.03
Fabaceae	<i>Leucaena leucocephala</i> (Lam.) de Wit <i>Machaerium aculeatum</i> Raddi <i>Mimosa</i> sp.1 <i>Mimosa</i> sp.2 <i>Poincianella pluviosa</i> (DC.) L. P. Queiroz. <i>Senna spectabilis</i> (DC.) H. S. Irwin and Barneby sp.1	0.61	2.03 1.39 5.67 19.14	13.61	5.17	0.77		0.02 2.17	0.91	0.47 3.92 0.02	14.52 1.45 0.03	0.33 80.23	0.02 0.02 27.22
	<i>Tipuana tipu</i> (Benth.) Kuntze				5.11			1.19	0.03	0.10			1.98

TABLE 2: Continued.

Family	Species	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dec	Jan	Feb
Heliconiaceae	<i>Heliconia psittacorum</i> L. f.				0.11								
Lamiaceae	<i>Ocimum gratissimum</i> L.	0.03											0.03
	<i>Tectona grandis</i> L. f.							0.38					
Lythraceae	<i>Lagerstroemia indica</i> L.							0.63					
	<i>Lagerstroemia speciosa</i> (L.) Pers.												
Malvaceae	<i>Basiloxylon brasiliensis</i> (Allemão) K. Schum.					18.05							
	<i>Bombacopsis glabra</i> (Pasc.) Robyns					0.02							
	<i>Ceiba speciosa</i> (A. St.-Hil.) Ravenna	0.08								0.03			
	<i>Guazuma ulmifolia</i> Lam.	1.30						0.02					
	<i>Heliocarpus americanus</i> L.					1.97							
	<i>Luehea divaricata</i> Mart.				0.02								
	<i>Pseudobombax grandiflorum</i> (Cav.) A. Robyns									0.03			
	<i>Triumfetta rhomboidea</i> Jacq.				19.42	0.52							
Melastomataceae	sp.1		0.09										
	<i>Tibouchina granulosa</i> (Desr.) Cogn.								0.50				
Meliaceae	<i>Cedrela odorata</i> L.								0.19	0.03			0.06
Muntingiaceae	<i>Muntingia calabura</i> L.	0.31	0.22		1.61	0.06		4.52	0.75	0.48	0.41	0.65	
	<i>Eucalyptus citriodora</i> Hook.	40.64	35.47	61.75	2.72	17.23	3.41	8.00					3.09
	<i>Eucalyptus grandis</i> W. Mill ex Maiden					7.48	15.97						
	<i>Eucalyptus moluccana</i> Roxb.	14.36	0.23		14.55	1.12			0.70	5.13	0.06	7.07	0.20
Myrtaceae	<i>Eugenia brasiliensis</i> Lam.									3.77			
	<i>Eugenia involucrata</i> DC.								0.13				
	<i>Eugenia pyriformis</i> Cambess.								0.02				
	<i>Eugenia uniflora</i> L.	2.20	11.05		4.50	4.56	0.03	4.33	0.03				
	<i>Syzygium cumini</i> (L.) Skeels				16.14	2.37		13.92	88.86	0.27			
Oleaceae	<i>Ligustrum lucidum</i> W. T. Aiton			5.81	0.27						42.97	0.03	
Phytolaccaceae	<i>Galliesia integrifolia</i> (Spreng.) Harms	5.27	21.33							8.23			
Poaceae	<i>Paspalum notatum</i> Alain ex Flüggé	0.02	0.02	0.11	0.03			0.02					
Polygalaceae	<i>Antigonon leptopus</i> Hook. and Arn.		0.02										
Rubiaceae	<i>Ixora chinensis</i> Lam.				3.72						1.42		
	sp.1										0.02		
Rutaceae	<i>Citrus latifolia</i> (Tanaka ex Yu. Tanaka) Tanaka							0.41				0.07	
	<i>Citrus limonia</i> Osbeck						0.02			0.05			
Salicaceae	<i>Casearia sylvestris</i> Sw.						0.73						
Sapindaceae	<i>Paullinia elegans</i> Cambess.												
	<i>Serjania lethalis</i> A. St.-Hil.	0.11	0.03			0.67	19.44	4.25					
Solanaceae	<i>Acnistatus arborescens</i> (L.) Schlttdl.												0.03
	<i>Bruinfelsia uniflora</i> (Pohl) D. Don							4.27					

TABLE 2: Continued.

Family	Species	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dec	Jan	Feb
Strelitziaceae	<i>Ravenala madagascariensis</i> Sonn.			0.50									
Urticaceae	<i>Cecropia pachystachya</i> Trécul	0.09				0.90		0.02					
Verbenaceae	<i>Durania erecta</i> L.									0.10			
Zingiberaceae	sp.1									0.22			
Unidentified	Unidentified 1					0.06							
	Unidentified 2								1.55				
	Unidentified 3							0.08		0.33			
										1.17	0.02		

* Data are presented as monthly percentages (%). Dominant pollen (>45%), supplementary pollen (15 to 44.99%), important isolated pollen (3 to 14.99%), and occasionally isolated pollen (<3). Mar: March, Apr: April, May: May, ...Feb: February.

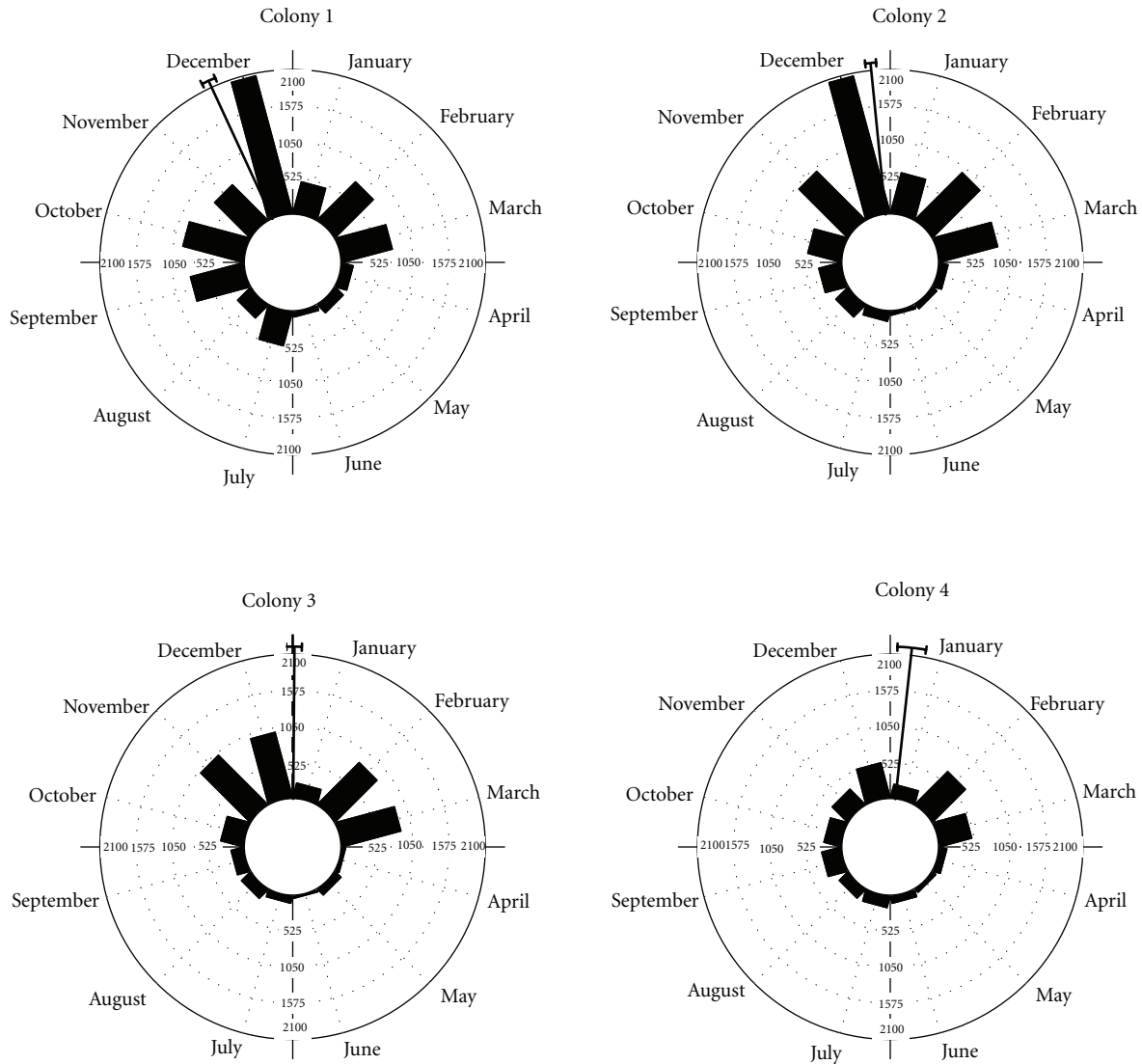


FIGURE 4: Circular analysis of the number of pollen foraging workers of *Scaptotrigona* aff. *depilis* for each colony. Each month represents 30° of the circle, and each bar represents the number of returning pollen workers. The line at the top of the vector indicates the standard deviation.

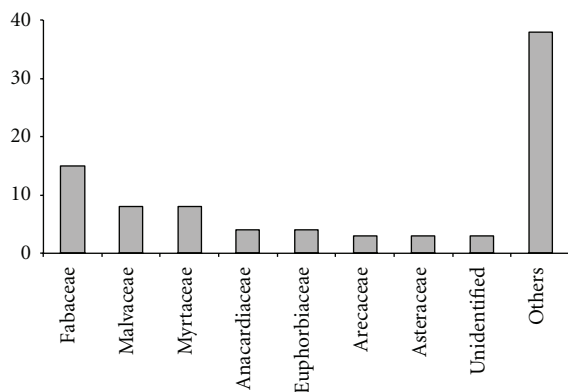


FIGURE 5: Number of species visited by *Scaptotrigona* aff. *depilis* per plant family during one year (March 2010 to February 2011) in the University campus.

Ricinus communis L., *Leucaena leucocephala* (Lam.) de Wit, *Eucalyptus moluccana* Roxb., *Eugenia uniflora* L., and *Muntingia calabura* L. were also important in the study area because they provided food to the colonies for a period of at least six months (Table 2).

Species of the genus *Scaptotrigona* forage in groups [55] and exhibit recruitment mechanisms, for example, scent trails and source marking [56, 57], that result in the concentration of workers on few sources of pollen. *Scaptotrigona* aff. *depilis* also behaves aggressively and can therefore dominate certain resources [58]. Factors such as proximity to the colony, high protein content, and mass flowering may also explain the high frequency with which certain plants are used by bees [6].

Of the 235 species of flowering plants sampled in the meliponary and its surrounding area, *S. aff. depilis*

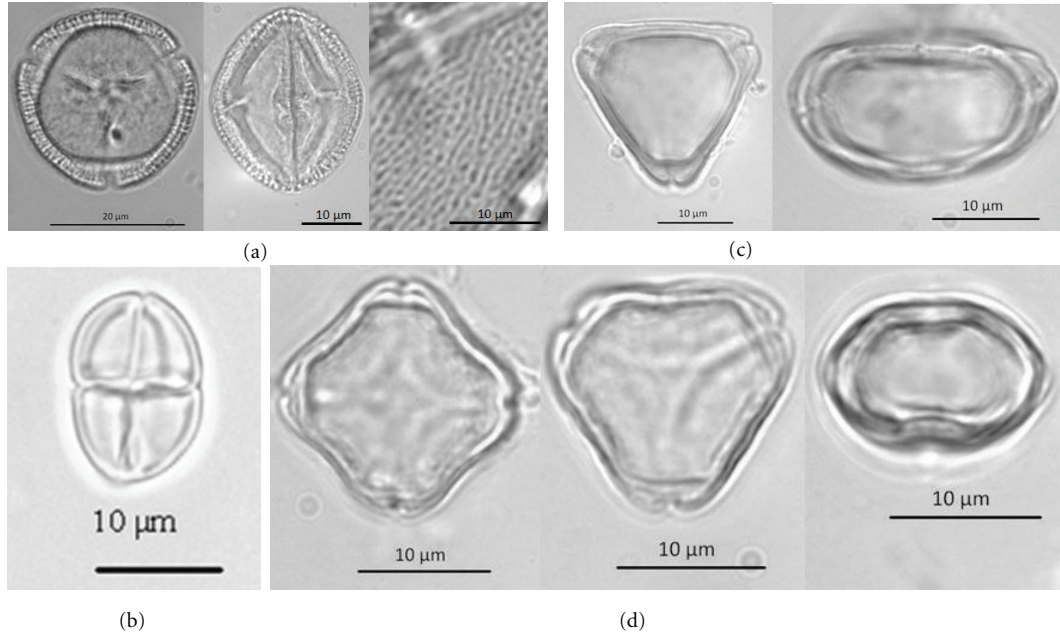


FIGURE 6: Photomicrographs of pollen grains of the most used species by *Scaptotrigona* aff. *depilis*. (a) *Schinus terebinthifolius* Raddi (Anacardiaceae) in polar and equatorial view and detail of the exine. (b) *Mimosa* sp1 (Fabaceae), a polyad. (c) *Eucalyptus citriodora* Hook. (Myrtaceae) in polar and equatorial view. (d) *Syzygium cumini* (L.) Skeels (Myrtaceae) in polar and equatorial view and detail of the exine.

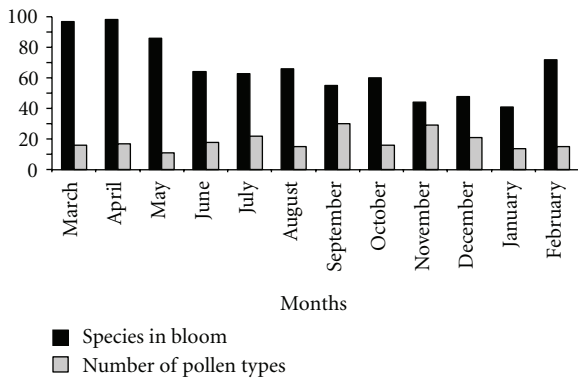


FIGURE 7: Number of flowering species and species used by *Scaptotrigona* aff. *depilis* during one year (March 2010 to February 2011) in the University campus.

used 36.60% of the available resources. Other stingless bees species also obtain most of their food from a small number of sources [16, 18, 50]. Antonini et al. [59] found that *Melipona quadrifasciata* Lepeletier, 1836, visited only 19.30% of the flowering plants in its habitat. This preference may be related to the fact that social bees, even when classified as generalists, focus their collection activities on the sources that are most profitable and nearest to the colony, as predicted by optimal foraging theory [22, 27].

The number of pollen types collected by bees and the number of species and individuals in flower were not correlated (Table 1). However, an analysis of the ratio between the number of flowering species and species used each month

revealed that in November, *S. aff. depilis* used 65.91% of the available sources in the study area (Figure 7). Besides those species, two others unidentified species were also used by the bees (Table 2). Certainly, these species were growing out of the study area. Thus, in November, the resource collection radius had been expanded. According to Eltz et al. [27], when there are few resources available in the environment, workers are forced to forage at more distant sources, and the larger the radius of the foraged area, the higher the probability that workers from different colonies will visit different food sources. The reverse was also true, as during the months of March, April, and May, which were periods of greater resource availability, workers harvested proportionately fewer pollen types as compared with other months. In periods with a greater amount of resource availability, the bees could switch from less profitable to more profitable resources, which could lead the colonies to concentrate on particular sources [27].

Cluster analysis showed a high overlap among the colonies, with the distance (Sørensen similarity coefficients) between them being small. The largest distance (0.294) occurred between colonies 1 and 4 (Figure 8). This high overlap of resource use among the colonies was expected, as they belong to the same species and share morphophysiological constraints and possibly the pheromone trails marking the sources. Additionally, as the four colonies were located relatively close together within the meliponary, they share the same foraging area. More detailed studies may show whether intraspecific resource sharing occurs at the same or different times of day, which would allow them to avoid competition.

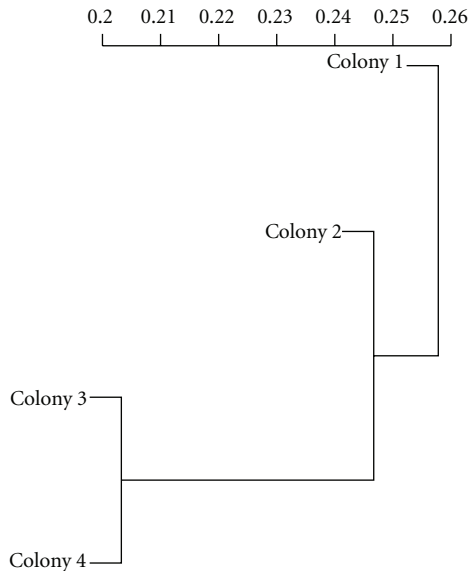


FIGURE 8: Dendrogram based on qualitative similarity of the pollen collected by 4 colonies in the study period. Distances are Sørensen Index; clustering was done with UPGMA.

Acknowledgments

The authors greatly thank the Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto and the Universidade de São Paulo for the infrastructure. They also thank Milton Groppo Jr., curator of the Herbário SPFR; Maurício M. N. Castro and Hipólito Ferreira Paulino Neto for the help in collecting the plants; João Paulo Castro for the collection and identification of flowering plants; Cristiano Menezes for lending us the bee colonies. The authors also thank Programa Nacional de Pós Doutorado (PNPD) of Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) (Process no. 02958/09-0) and Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) (Processes no. 2010/02659-1 and 2010/10285-4) for financial support.

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