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Trap-nesting Bees from Protected Areas of Atlantic Forest, Southeastern Brazil

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Abstract

The solitary bees that use preexisting cavities can be captured in trap-nests allowing to collect data on nesting biology and associated organisms. This man-made trap-nest facilitates the understanding of environmental components and landscape composition in the fauna of solitary bees. Here, we aimed to increase the knowledge about trap-nesting bee species from four protected areas Atlantic Forest in southeastern Brazil and to test how abiotic local environmental components (temperature and rainfall) and forest cover affects the trap-nesting bee fauna. We recorded occupants from 847 nests founded by 17 bee species and seven cleptoparasite bees, associated to their host, summing 24 bee species sampled. The family with highest species richness was Megachilidae, and the species with the largest number of founded nests was *Tetrapedia diversipes* Klug (Apidae). Diptera, coleoptera, and hymenoptera parasitized 15.2% of the founded nests. The period of highest nest occupation occurred between November and February, which correspond to the warmest and most humid months in the region. We found significant positive correlation between the number of nests and monthly accumulated rainfall. We verified that Boraceia and Ilhabela have the best status conservation based on native forest cover and we sampled the highest diversity of species in these areas. We improved the knowledge on trap-nesting bees communities from Atlantic Forest on new species sampled in this biome with their nesting biology and highlighted that rainfall influences positively the nest founding throughout the year and native forest cover influences diversity of species.

Introduction

Areas with exceptional concentrations of endemic species and high habitat loss (or high level of threats) are often referred as hotspots (Myers et al., 2000). In Brazil, the Atlantic Forest is one of these areas (Mittermeier et al., 1999). Among the various typologies of the Atlantic Forest, the Ombrophylous Dense is the most vigorous, heterogeneous and complex formation, characterized by the presence of upper strata with trees above 25 and 30m height, perennial and densely arranged (Oliveira-Filho & Fontes, 2000). Such heterogeneous environment has a high diversity of bee species (Gonçalves & Brandão, 2008).

Worldwide there are around 20,250 bee species described and solitary bees comprise about 85% of the known species (Ascher & Pickering, 2018). Solitary bees collect food, build and defend nest, and lay eggs without help from other nestmates. After accomplishing all those tasks, the female dies and therefore, there is no generation overlap (Michener, 2007). Most solitary bees nest in the ground, however many species use preexisting cavities to nest, such as bamboo canes (Krombein, 1967; Garófalo, 2000).

The use of trap-nests to survey bees of an area results in more than a list of species only. Such surveys can also provide information about the biology, nest materials, associated organisms, and even the influence of the abiotic

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local environmental components such as temperature and rainfall on nest colonization (Camillo et al., 1995; Tscharntke et al., 1998; Jesus & Garófalo, 2000; Aguiar & Garófalo, 2004; Thiele, 2005; Buschini, 2006; Menezes et al., 2012). Trap-nests have been broadly used for sampling solitary bees since the extensive study by Krombein (1967) in North America. After that, this technique has gained an application to agriculture as a means of increasing the solitary bee as crop pollinators (Bosch & Kemp, 2001; Pitts-Singer & Cane, 2011; Sedivy & Dorn, 2014). This methodology also allowed to investigate the influence of landscape composition on trap-nesting bee fauna (Tscharntke et al., 1998; Morato & Campos 2000; Steckel et al., 2014; Stangler et al., 2016). However, nothing is known about the effects of landscape composition on this bee fauna in Atlantic Forest.

In tropical countries trap-nesting bee species have been recorded in agroecosystems and forest fragments (Camillo et al., 1995; Morato & Campos, 2000; Viana et al., 2001; Klein et al., 2002; Alves-dos-Santos, 2003; Thiele, 2005; Buschini, 2006; Tylianakis et al., 2005; Klein et al., 2006; Pereira-Peixoto et al., 2014; Stangler et al., 2016). In Atlantic Forest, studies on the diversity of trap-nesting bee species and nesting biology were carried out mainly in Semideciduous vegetation (Garófalo, 2000; 2008; Gazola & Garófalo, 2009; Rocha-Filho & Garófalo, 2015; Oliveira & Gonçalves, 2017) or forest urban remnants (Alves-dos-Santos, 2003; Loyola & Martins, 2006). Therefore, the knowledge about trap-nesting bees from the Ombrophilous Dense vegetation in the Atlantic Forest still is scarce (Menezes et al., 2012).

Correlating abiotic local environmental components and landscape conditions with trap-nest colonization and diversity can improve our understanding of how land use and planning decisions impact bees and pollination services (Steffan-Dewenter & Schiele, 2008; Pereira-Peixoto et al., 2014).

Therefore, we aimed to increase the knowledge about trap-nesting bee species from Atlantic Forest and to test how abiotic local environmental components such as temperature and rainfall and forest cover affects the trap-nesting bee fauna. For that, we dispose trap-nests in four protected areas of different conservation status along two years.

Material and Methods

Study areas

The study was carried out during two years from March 2007 to February 2009, in four protected areas of Atlantic Forest biome of Ombrophilous Dense vegetation in the state of São Paulo, southeastern Brazil (Fig 1). (1) Boraceia Biological Station (23º38'S - 45º52'W; 750 to 900 m a.s.l.), with 16,450 ha, is located within the municipality of Salesópolis. (2) Neblinas Park (23°45'S - 46°09'W; 700 to 1,100 m a.s.l.), with 2,800 ha, is located within the municipalities of Mogi das Cruzes and Bertioga. (3) Ilhabela State Park (23º47'S - 45º21'W; 0 to 1,378 m a.s.l.), with 27,025 ha, is an island located in the municipality of Ilhabela, which has elements of the Ombrophilous Dense vegetation, Sandbanks, and Mangrove. (4) Serra da Cantareira State Park (23°22'S - 46°36'W; 950 to 1,074 m a.s.l.), with 8,000 ha, is located within the municipalities of São Paulo, Guarulhos, Mairiporã, and Franco da Rocha. The Cantareira State Park is a remnant fragment of Atlantic Rainforest located within the metropolitan region, just 12 km from the center of the São Paulo city, with an intense interference of the metropolis.

According to an updated Köppen-Geiger climate classification, the regional climate of the study areas is type Cfa, characterized as humid subtropical, without a dry season, with a hot summer and average annual rainfall over 1400 mm (Peel et al., 2007).

Fig 1. Main reference cities and study sites in the four protected areas of Atlantic Forest domain, in the state of São Paulo, Brazil. BBS: Boraceia Biological Station; NP: Neblinas Park; ISP: Ilhabela State Park; SCP: Serra da Cantareira State Park.

Collection of trap-nests

We sampled solitary bees in five trap-nests shelters (Fig 2) containing a total of 1,000 trap-nests per study area. Our trap-nests consisted of paper tubes (cardboard) housed in wood blocks and bamboo canes housed in plastic bottles. We used three sizes of paper tubes: TP1: 0.6 cm in diameter and 5.8 cm in length, TP2: 0.6 cm in diameter and 8.5 cm in length, and TG: 0.8 cm in diameter and 8.5 cm in length. The bamboo canes varied from 0.5 to 3.0 cm in diameter and from 8 to 25 cm in length. Each shelter received a total of 200 trap-nests: 50 paper tubes of each size (TP1, TP2, and TG) and 50 bamboo canes. The use of different types of materials and cavity diameters are recommended because females choose cavities to build their nests based on preferred size and material (Krombein, 1967; Jesus & Garófalo, 2000).

We checked the trap-nests monthly, removed those used and filled, and took them to the laboratory, where they remained in room temperature into closed test-tube until the emergence of bees. Each removed nest was replaced with an equivalent trap nest. As the individuals emerged, we fixed them with ethyl acetate vapor, and then pinned, labeled, and deposited them in the Paulo Nogueira Neto Entomological Collection (CEPANN).

Landscape structure

We measured the landscape spatial structure to assess the status conservation of the study areas. The identification of the land use types and the spatial arrangements of the landscape elements were carried out following Metzger (2006).

Fig 2. Nesting shelter providing trap nests with bamboo canes housed in plastic bottle and paper tubes housed in wood blocks.

The following land uses were considered: native vegetation, reforestation (*Eucalyptus* plantation), pastures, exposed soil, buildings, roads, and water surface. We measured the landscape structures from each sample unit delimited by the circumference of a circle with 1 km radius around the trap-nest shelter as the medium point of the circumference using Google Earth Pro® (version 7.3.1). This mapping is consistent with the dispersion and flight capacity of the most bee species (Zurbuchen et al., 2010; Benjamin et al., 2014). Figures of landscape structure mapping around each sample unit are available in the Supplementary material (Figs 1-4).

Data analyses

We calculated correlations between climatic data, monthly average temperature and monthly accumulated rainfall separately with number of nests per month with the Spearman coefficient (a = 0.05). We obtained climatic data from each municipality of the study areas at the website of Instituto Agronômico (http://www.ciiagro.sp.gov.br). To estimate the diversity of the trap-nests bees in the study areas we used the Shannon (H') and Simpson (D) (Magurran, 2004) indexes. We calculated evenness (ED) based on the Simpson and Shannon indexes, and Pielou evenness (J'). The analyses were made in the program PAST 1.85 (Hammer et al., 2001).

Results

Trap-nesting bees and associated organisms

Bees founded 1,201 nests in the four study areas. A total of 1,693 individual bees emerged from 814 nests emerged, which includes the offspring of hosts and cleptoparasitic bees together. From the remaining nests yielded non-bee parasites or lack of emergence due to complete mortality. The nests were founded by 17 bee species of three families: Apidae (6 spp.), Colletidae (1 sp.), and Megachilidae (10 spp.). In addition to founders, seven species of cleptoparasitic bees of the families Apidae (2 spp.) and Megachilidae (5 spp.) occupied the nests. *Tetrapedia diversipes* was the most abundant species and it was the only species found at all study areas, summing 88% of the founded nests. Ilhabela had the highest richness of species (12 spp.), while Cantareira had the lowest (3 spp.). Neblinas had the highest values of diversity indexes Shannon (H'=1.38) and Simpson (D=0.62) diversity, but its species richness (8 spp.) was lower than in Boraceia (11 spp.) and Ilhabela (12 spp.) (Table 1).

More than 90% of the nests were founded in paper tubes, otherwise bamboo canes were used by a larger number of species (14 spp.). The bamboo canes with diameters between 0.8 and 1.3 cm were most frequently occupied, but preference varied among species. Nest architectures of nesting species are available in Supplementary material (Supplementary material Fig 5).

Table 1. Number of nests and individuals of the bee species that used trap nests in four study areas sampled from March 2007 to February 2009. Three sizes of paper tubes were used: TP1: 0.6 cm in diameter and 5.8 cm in length, TP2: 0.6 cm in diameter and 8.5 cm in length, and TG: 0.8 cm in diameter and 8.5 cm in length, bamboo canes varied from 0.5 to 3.0 cm in diameter and from 8 to 25 cm in length.

Occupant species	Boraceia	Neblinas	Ilhabela	Cantareira	N. nests	N. indiv.	♂	♀	TP1	TP2	TG	Bamboo canes
Apidae												
Centris (H.) tarsata Smith	4	1	44		49	119	95	24	1	1	16	31
Coelioxoides waltheriae Ducke[a]	1*		41*	8*		55	35	20				
Eufriesea violaceae Blanchard			1		1	3	3					1
Euglossa anodorhynchi Nemésio[b]	2				2	5	5					2
Euglossa truncata Rebêlo & Moure	1				1	3	1	2				1
Mesocheira bicolor Fabricius[a]			13*			17	7	10				
Tetrapedia diversipes Klug	185	35	425	78	723	1346	819	527	324	371	22	6
Tetrapedia sp.				9	9	22	14	8	9			
Colletidae												
Hylaeus aff. *brachyceratomerus* Moure[b]			1		1	2	2					1
Megachilidae												
Anthodioctes santosi Urban[b]			1		1	1	1		1			
Austrostelis iheringi Schrottky[a]	1*					1	1					
Coelioxys (Acrocoelioxys) sp.1[a]		1*				2	2					
Coelioxys (Acrocoelioxys) sp.2[a]	1*					1	1					
Coelioxys (Acrocoelioxys) sp.3[a]			1*			4	4					
Coelioxys (Cyrtocoelioxys) sp.[a]			5*			5	5					
Megachile (A.) sussurans Haliday	2	4			6	26	18	8				6
Megachile (C.) pseudanthidioides Moure[b]			1		1	6		6				1
Megachile (Chrysosarus) sp.			5		5	17	16	1		1		4
Megachile (M.) benigna Mitchell[b]		1			1	1	1					1
Megachile (M.) maculata Smith[b]	3	1			4	26	14	12				4
Megachile (P.) nudiventris Smith[b]	1				1	2	1	1				1
Megachile (P.) bertonii Schrottky[b]		2			2	10	4	6				2
Mielkeanthidium dissimile Parizoto & Urban[b]			4		4	12	6	6		4		
Saranthidium musciforme Schrottky[b]	1	2			3	7	6	1		2		1
TOTAL of nests	199	46	482	87	814	1693	1061	632	335	379	38	62
TOTAL of species	11	8	12	3								
Shannon index (H')	0.55	1.38	0.89	0.58								
Simpson index (D)	0.20	0.62	0.38	0.31								
Simpson evenness (ED)	0.16	0.49	0.20	0.59								
Shannon evenness (J')	0.23	0.66	0.36	0.52								

[a]cleptoparasitic bees (see Table 2 for respective hosts); [b]first time sampled in trap-nests; *Number of attacked nests.

The months with the largest number of founded nests were November and December (Table 2), which correspond to the warmest and most humid season in southeastern Brazil. We did not find a significant correlation between the number of nests and monthly average temperature, (Parque das Neblinas: r = 0.33, p = 0.10; Cantareira: r = 0.35, p = 0.27; Ilhabela: r = 0.38, p = 0.14; Boraceia: r = 0.35, p = 0.08). Otherwise, there were significant positive correlations between the number of nests and monthly accumulated rainfall in Boraceia (r = 0.45, p = 0.02), Ilhabela (r = 0.49, p = 0.05), and Neblinas (r = 0.39, p = 0.05) except Cantareira (r = -0.06, p = 0.86) (Fig 3).

There was complete mortality in 351 nests and in 151 nests the mortality was partial. In nests with partial mortality, we recorded 199 individuals. Among the causes of death there were mainly fungal infestation at different development stages and natural enemies at the larval phase. In some nests, we observed dead pre-emergent adults, but we could not determine their cause of death.

Table 2. Number of nests founded by bees each month sampled from March 2007 to February 2009. (-) Before starting the study.

Year	**2007/2008/2009**			**2007/2008**								
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Centris (H.) tarsata Smith	-/1/1										28/17	1/1
Eufriesea violaceae Blanchard		-/0/1										
Euglossa anodorhynchi Nemésio										1/0	1/0	
Euglossa truncata Rebêlo & Moure												1/0
Tetrapedia diversipes Klug	-/37/6	-/69/69	12/29/0	10/49	8/36	1/42	0/6	1/0	2/0	24/0	132/16	151/23
Tetrapedia sp.			9/0/0									
Hylaeus aff. *brachyceratomerus* Moure												1/0
Anthodioctes santosi Urban		-/1/0										
Megachile (A.) sussurans Haliday			0/1/0			0/1		1/0		0/2		1/0
Megachile (C.) pseudanthidioides Moure			0/0/1									
Megachile (Chrysosarus) sp.		-/1			0/1						2/0	1/0
Megachile (M.) benigna Mitchell				0/1								
Megachile (M.) maculate Smith		-/0/1								2/0	1/0	
Megachile (P.) nudiventris Smith										0/1		
Megachile (P.) bertonii Schrottky	-/0/1									1/0		
Mielkeanthidium dissimile Parizoto & Urban		-/0/4										
Saranthidium musciforme Schrottky		-/0/3										
TOTAL of nests	46	149	52	60	45	44	6	2	2	31	197	180
TOTAL of species	3	7	4	2	2	2	1	2	1	6	5	6

Diptera, Coleoptera, and Hymenoptera (wasps and other bees) parasited 183 (15.2%) nests. Among cleptoparasitic bees, *Coelioxoides waltheriae* Ducke was the most frequent species and parasitized only nests of *T. diversipes*. The most frequent non-bee cleptoparasites were two species of *Anthrax*: *Anthrax hylaios* Marston and *Anthrax oedipus* Fabricius, most emerged from nests of *T. diversipes* (Table 3). We recorded mites *Roubikia* sp. (Chaetodactylidae) in 118 nests of *T. diversipes* but no deaths were observed.

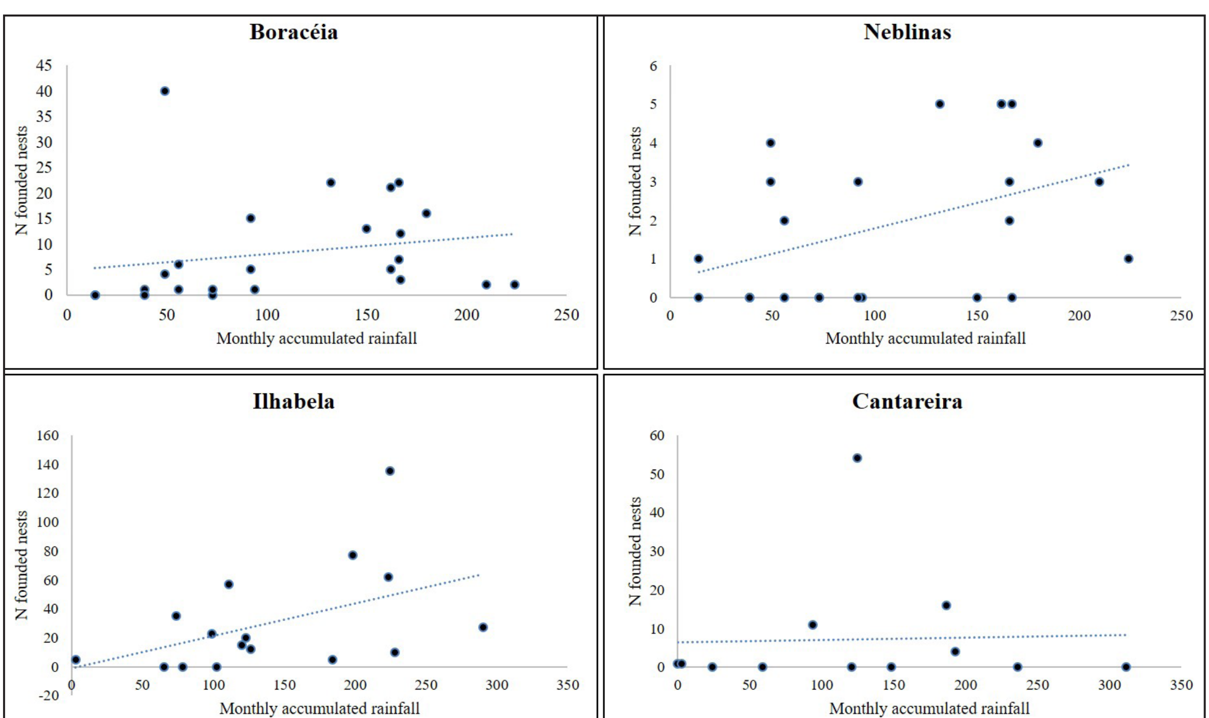

Fig 3. Relationship between number of founded nests and monthly accumulated rainfall in four study areas.

Table 3. Parasitic species and their respective host species in trap nests in four study areas from March 2007 to February 2009.

Order Family	Parasite species	Emerging individuals	Hosts species
Diptera			
Bombilidae	*Anthrax hylaios* Marston	29	*Tetrapedia diversipes*
		4	*Centris tarsata*
		25	UH
	Anthrax oedipus Fabricius	13	*Tetrapedia diversipes*
		1	*Megachile (Chrysosarus)* sp.
		7	UH
Coleoptera			
Meloidae	*Tetraonyx sexguttatus* Olivier	2	*Centris tarsata*
Hymenoptera			
Eulophidae	*Melittobia* sp.	+	*Megachile sussurans*
Leucospidae	*Leucospis egaia* Walker	7	*Megachile maculata*
	Leucospis manaica Roman	3	UH
Apidae	*Coelioxoides waltheriae* Ducke	28	*Tetrapedia diversipes*
		24	UH
	Mesocheira bicolor Fabricius	4	*Centris tarsata*
		13	UH
Megachilidae	*Austrostelis iheringi* Schrottky	1	UH
	Coelioxys (*Cyrtocoelioxys*) sp.	2	*Centris tarsata*
		3	UH
	Coelioxys (*Acrocoelioxys*) sp.1	2	*Megachile bertonii*
	Coelioxys (*Acrocoelioxys*) sp.2	1	*Megachile maculata*
	Coelioxys (*Acrocoelioxys*) sp.3	4	UH

UH: Unknown host; +: Many individuals in one nest.

Landscape structure

In total 30.9 km² were measured in the four study areas. Boraceia and Ilhabela have the best status conservation considering the native forest cover around trap-nest shelters (Table 4). Boraceia has vegetation cover composed of 92% native forest without fragmentation; Ilhabela has vegetation cover composed of 75% native forest and the remaining is urban areas; Neblinas has a heterogeneous vegetation cover, composed of 57% native forest in different stages of succession and 40% *Eucalyptus* plantations between 2 and 50 years old; Cantareira has 65% native forest and the remaining is urban areas.

Table 4. Measures (Km^2 and percentage) of the land-uses on the four study areas.

	Boraceia	Neblinas	Ilhabela	Cantareira
Native forest	12.0	5.0	3.1	3.3
Eucalyptus plantation		3.6		
Roads	0.2	0.2		
Buildings	0.01	0.01	1.0	1.8
Water surface	0.8	0.1		
TOTAL (Km²)	**13.0**	**8.9**	**4.1**	**5.1**
% *Eucalyptus* plantation		40.5		
% Roads	1.3	2.0		
% Buildings	0.1	0.1	25.4	35.0
% Water surface	6.1	1.4		
% TOTAL native forest	**92.5**	**55.9**	**74.6**	**65.0**

Discussion

In the two years of sampling we caught 17 trap-nesting bee species, as well as seven cleptoparasite bees, associated to their host, summing a community of 24 bee species in the trap-nests. The number of species captured in the four areas studied ranged from three in Cantareira to 12 in Ilhabela. The diversity indexes of Ilhabela and Boraceia, with larger number of species (12 and 11 species, respectively), were not higher because of the lower evenness among these species. In both areas, as well as the other two areas, the dominance of *T. diversipes* was remarkable.

Ilhabela, Boraceia, and Neblinas had species richness higher or similar than other trap-nests studies in Atlantic Forest fragments of Semideciduous vegetation which reached a maximum of 12 species (Garófalo, 2000; 2008; Gazola & Garófalo, 2009; Oliveira & Gonçalves, 2017), forest urban remnants seven species (Alves-dos-Santos, 2003; Loyola & Martins, 2006), and seven species in Araucaria Forest (Buschini, 2006). However, it was lower when compared to studies performed in other biomes, such as 25 species in Cerrado (Camillo et al., 1995) and 14 species in Amazon (Morato & Campos, 2000). Cantareira had lower number of species than aforementioned studies. However, as argued by Oliveira and Gonçalves (2017) comparisons between species richness obtained with trap-nests from different studies may be problematic because of the differences in sampling methodology, periods, the types, and arrangement of traps in the study areas.

We are confident about the degree of representativeness of the trap-nesting bees community in the study areas, because of the temporarily and spatially scale we performed. To obtain the data on this bee guild, we offered the traps for two years in the studied areas, while most studies using trap-nests method are performed in general for one year. This timescale showed some dynamic of the occupancy, as for example the low rate of nesting or activity during the winter, but not a complete stop. The activity of the trap-nesting bee species followed the typical flowering seasonality of tree species in Atlantic Forest, which occurs in the warmest and most humid months (Morellato et al., 2000). Consequently, in this period there are more resources to found nests. Indeed, we found significant positive correlation between the number of nests and monthly accumulated rainfall in Boraceia, Ilhabela, and Neblinas. The positive relationship between nesting frequency and rainfall was also reported in various studies (Camillo et al., 1995; Aguiar et al., 2005; Thiele, 2005; Buschini, 2006; Gazola & Garófalo, 2009). Therefore, we highlighted that abiotic environmental components (rainfall) can influence number of nests of trap-nesting bees also in Atlantic Forest of Ombrophylous Dense vegetation.

Neblinas and Cantareira are the least preserved fragments among the areas investigated here these localities have more than 30% of non-native forest areas. This factor probably influenced the lower species richness than well-preserved areas, such as Ilhabela and Boraceia, because the values between 35-50% of non-native forest is considered the threshold that affects the richness of bee species and bee-plant interaction networks (Winfree et al., 2009; Moreira et al., 2015; Ferreira et al., 2015; Saturni et al., 2016). Moreover, Cantareira is an isolated fragment surrounded by a metropolis, and this is pointed out that with increasing isolation of fragmented habitats the bee species richness declines significantly mainly due to the decrease in food sources and nesting sites (Tscharntke et al., 1998; Morato & Campos, 2000; Steckel et al., 2014; Stangler et al., 2016). Our results reinforce that ongoing fragmentation and deforestation affect diversity of trap-nesting bee communities even in dense vegetation as Atlantic Forest.

Associated organisms were abundant in the founded nests. While about 15% of founded nests were parasitized, the main mortality was caused by fungal infestation. Parasites, especially parasitoids like *Melittobia* and *Anthrax*, attacked different species. However, parasites are common when cavities are offered in unnatural large numbers (Sedivy & Dorn, 2014). The natural enemies founded here belonged to the same families and genera as those found in the most studies throughout Brazil (Jesus & Garófalo, 2000; Alves-dos-Santos, 2003; Gazola & Garófalo, 2009; Aguiar & Garófalo, 2004; Aguiar et al., 2005; Rocha-Filho & Garófalo, 2015). However, a lack of taxonomic knowledge on these insects has made it difficult to do a comprehensive comparison. The fungal infestation as one of the main causes of immature mortality of trap-nesting bees (Antonini et al., 2003; Camarotti-de-Lima & Martins, 2005; Stangler et al., 2016), and the present study support this. This is probably due to the period of highest activity of bees coincides with high rainfall in the region. In the study areas, the annual rainfall is over 1,400 mm, one of the highest precipitation rates in South America (Peel et al., 2007), consequently the air humidity is high which favors fungal infestation. Otherwise, mites *Roubikia* sp. (Acari: Chaetodactylidae) which emerged from *T. diversipes* exert a positive effect to control the fungi infestation (Cordeiro et al., 2011).

Within solitary bees species using pre-existing cavities we found the patterns that are expected in general for insect communities: many rare species and few common or abundant species (Magurran, 2004). Indeed, there were one species dominant in all study sites: *T. diversipes*, which built more than 80% of the nests in the traps. Probably the high occupation rate of this species in trap-nests results from its gregarious behavior and high rate of reuse by individuals emerged in the same site (Alves-dos-Santos et al., 2002; Alves-dos-Santos, 2003). *Tetrapedia diversipes* is commonly caught in trap-nests in Atlantic Forest fragments (Camilo et al., 1995; Garófalo, 2000; 2008; Garófalo et al., 2004). By contrast, in other open biomes, *Centris* species are usually those whom nest at highest frequency in trap-nests (Camillo et al., 1995; Morato & Campos, 2000; Buschini 2006).

To conclude, we improved the knowledge on trap-nesting bees and their associated organisms from Atlantic Forest. In addition, we showed that accumulated rainfall and forest cover play a role in trap-nesting bee community. Rainfall influences positively the nest founding throughout the year and native forest cover influences diversity of species.

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Supplementary Material

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