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Tree cavities used as diurnal roosts by Neotropical bats

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Abstract. Bats occupy a variety of natural and artificial diurnal roosts. These environments offer several advantages for bats, among which we highlight the relative climatic stability, darkness, and protection from predators. The aim of this study was to identify and describe the use of tree hollows as natural diurnal roosts by *Molossops temminckii*, *Molossus rufus*, *Artibeus planirostris* and *Sturnira lilium* in southeastern Brazil. In the first one, we sought to describe the physical characteristics of shelters. In the second objective, we determined the number of individuals in the colonies and, we described and classified the posture adopted by bats within cavities. In the third objective, we seek to relate the physical characteristics of refuges with the foraging behavior and diet of bat species. Moreover, we also discussed the advantages and disadvantages that tree cavities may confer for bats, in the context of approximation of opportunistic predators. We found four colonies, one of each species, which roosted within tree trunk cavities. In general, the colonies were small, with less than 10 individuals of both sexes. Usually the molossids left the roost at dusk, while phyllostomids left later, around three hours after dusk. Individuals of the first three species were recaptured while foraging near the roosts. We believe (through observations) that the location in the landscape and the physical characteristics (dimensions of access to the cavities and height from the ground) of shelters used by bats, depend exclusively on the morphology, foraging behaviour and diet of each species of bat. Furthermore, this study contributes to an increase of knowledge about the natural history of Neotropical bats, which can provide relevant information for conservation.

Key words: *Molossops temminckii*, *Molossus rufus*, *Sturnira lilium*, *Artibeus planirostris*, roosting ecology, Southeastern Brazil

Introduction

Bats can use different micro-habitats for roosting, both those considered natural and artificial (Kunz 1982). Approximately 1100 species roost in plants, using foliage and/or trunk cavities as their refuge both in temperate and tropical regions (Kunz & Lumsden 2003). Bats remain for approximately half of their life inside diurnal roosts, so the conditions and events related to these refuges play an important role in their ecology and evolution (Kunz 1982). In addition to providing sites for mating, raising young, social interaction, digestion, urination and defecation, roosts protect bats from bad weather and predators (Kunz 1982, Kunz & McCracken 1996).

Knowledge of how forest-dwelling bats select roosts has increased, especially in North America (Miller et al. 2003, Veilleux et al. 2004), Australia (Lumsden et al. 2002), New Zealand (Sedgeley & O'Donnell 2004) and Europe (Russo et al. 2004). However, little is known about the factors that influence the distribution and abundance of bats roosting in vegetation, although the availability and characteristics of different roosts seem to be important (Morrison 1980). In general, most authors have focused on external characteristics of trees (Kunz & Lumsden 2003, Lacki & Baker 2003), and few have examined internal features of cavities occupied by bats (see Ruczynski & Bogdanowicz 2005), or the influence of position of individual bats inside shelters.

Although there are studies describing roosting ecology for microchiropterans (Trajano 1984, Taddei 1988, Bredt et al. 1996, Bernard & Fenton 2003, Kunz & Lumsden 2003), there are few records describing the use of roosts in plants by *Molossops temminckii* (Burmeister, 1854), *Molossus rufus* Geoffroy, 1805, *Sturnira lilium* (Geoffroy, 1810) and *Artibeus planirostris* (Spix, 1823).

This study aims to identify cavities in tree trunks used as a refuge by Neotropical bats. For this purpose, we search for bat's shelter by examining evidences of the presence of these animals, such as accumulation of feces inside or/and nearby the tree cavities. After identifying bat species, we seek to achieve three objectives. In the first one, we sought to describe the physical characteristics of shelters (e.g. identification of the trees species and their location in the landscape, height of the cavity relative to the ground, the number of access used by bats as well as its dimensions). In the second objective, we determined the number of individuals in the colonies and, we described and classified the posture adopted by bats within cavities. In the third objective, we seek to relate the physical characteristics of refuges (c.f. above) with the foraging behavior and diet of each bat species. Moreover, we also discussed the advantages and disadvantages that tree cavities may confer for bats, in the context of approximation of opportunistic predators. Furthermore, this study contributes to an increase of knowledge about the natural history of Neotropical bats, which can provide relevant information for conservation.

Material and Methods

Study area

Data were collected from June 2005 to May 2006 and during four other field campaigns that took place during the months of October and November 2010. The surveys were carried out in the Central North Regional Center for Technological Development of Agribusiness ("Pólo Regional de Desenvolvimento Tecnológicos dos Agronegócios do Centro Norte" approx. 21°13′ S 48°56′ W – Pindorama Farm), located in the municipality of Pindorama in the northwest of São Paulo State. The center contains three fragments (totaling 128 ha) of native semideciduous forest ("Floresta Estacional Semidecidual" according to the Brazilian forest classification system), surrounded by a matrix formed by different monocultures, including: banana, soybean, corn, mango and coffee. Currently, this type of forest is restricted to just 4 % of its original area (SMA/IF 2005, MMA/SBF 2007), mainly due to the expansion of livestocking, plantations and urban areas (São Paulo/Probio 1998) and is found in small remnants scattered among various types of monocultures and Cerrado patches (Ab'Saber 2003). The predominant monoculture around Pindorama Farm is sugar cane (MMA/SBF 2007).

The regional climate is classified as tropical hot and humid (Köppen "Aw") and is characterized by two well defined seasons: the rainy season between October and March, and a pronounced dry season, between April and September (Barcha & Arid 1971). During the study period (June 2005 to May 2006), the average monthly rainfall was 239 mm, with an average of 45 mm during the dry season (Austral winter) and 173 mm during the wet. The average rainfall during the months of October and November 2010 was 17 mm (CIIAGRO 2013).

Community of bats in the study area

In the study area we recorded 24 species composing the community of bats, which are; *Sturnira lilium* (Geoffroy, 1810), *S. tildae* De la Torre, 1966, *Carollia perspicillata* (Linnaeus, 1758), *Platyrrhinus lineatus* (Geoffroy, 1810), *Anoura caudifer* (Geoffroy, 1810), *Glossophaga soricina* (Pallas, 1766), *Desmodus rotundus* (Geoffroy, 1810), *Chrotopterus auritus* (Peters, 1856), *Artibeus lituratus* (Olfers, 1818), *A. planirostris* (Spix, 1823), *A. fimbriatus* Gray, 1823, *A. obscurus* (Schinz, 1821), *Phyllostomus discolor* (Wagner, 1843), *P. hastatus* (Pallas, 1767), *Eumops perotis* (Schinz, 1821), *M. molossus* (Pallas, 1766), *M. rufus* Geoffroy, 1805, *Molossops temminckii* (Burmeister, 1854), *Cynomops planirostris* (Peters, 1866), *Noctilio leporinus* (Linnaeus, 1758), *N. albiventris* Desmarest, 1818, *Lasiurus blossevillii* ([Lesson, 1826]), *Myotis albescens* (Geoffroy, 1806), *M. nigricans* (Schinz, 1821).

Methodology

Throughout the study period, various trees of the center were examined for openings in the trunk and branches, and the presence of feces inside. The trees examined were located within and along the edges of forest remnants, and along roadsides. During the observations, hollows/cavities were considered as potential roosts when they contained accumulated feces, wings and/or exoskeletons of insects and seeds, either within the cavity or stuck to the outer edges of the roost entrance.

Where possible after checking for the presence of bats within a given cavity, the orientation of these animals was observed relative to the substrate and characterized according to the description given by Taddei (1988). In the colonies, individuals can take two types of posture based on the contact with the substrate. The first was "Contact Posture", in which the bats were found hanging, clinging to the roughness of the vertical wall with the aid of their feet and leaning against the same roost wall with their thumbs, wings folded laterally around the body, with or without the belly in contact with the substrate. In the second type, the bats adopted a "Free Posture", in which they hung from the ceiling of the roost with the aid of the feet, wings folded laterally around the body with no contact between the substrate and the belly, back or thumbs. In all cases studied here, the groups were considered as colonies as they contained individuals of both sexes and different stages of development.

After this procedure, three mist nets (each 6 m long × 2 m high) were set around each tree. Nets were positioned at the level of the cavity entrances, remained open from dusk (17:00 h) to 04:00, and captured individuals were removed immediately after capture. After capture, we recorded the following data for each bat: approximate exit time from the roost, age, sex and reproductive condition. Age was determined by the degree of ossification of long bone epiphysis (Anthony 1988, Brunet-Rossinni & Wilkinson 2009). The reproductive activity of males was determined by the position of the testicles, where active males had descended testicles and inactive males abdominal testicles (Racey 1988). Females were considered inactive or pregnant after probing and confirmation of the presence of fetuses or when lactating nipples showed secretion (Racey 1988). Bats were banded (numbered aluminum ring placed on the forearm) and subsequently released at the same location and night. After capture we could identify whether the colonies were simple (consisting of only one species) or mixed groups (see Taddei 1988).

Statistical analyses

To estimate the abundance of individuals cohabiting the sampled cavities, we used the mark-recapture method. The absolute abundance of these bats was assessed through the index of Lincoln-Petersen, with appropriate modifications for small samples proposed by Bailey (Begon 1979). For this, we standardized our sampling as follows. After detecting the presence of bats in the cavity, we performed the capture of bats using three mist nets (see above) during two consecutive nights. On the first night, we marked all captured bats. In the second night, the number of captured animals was quantified, as well as the recaptures. The captures were realized in consecutive nights and the mist nets were mounted/arranged at the side of the roosts to avoid interference with the index, that considers closed populations (disconsidering births, deaths and migration). For the same reason, the captured bats were promptly removed shortly after their capture, in order to avoid attraction of bats from other colonies or other animals/predators foraging nearby.

Results

Hollow trees as diurnal roosts

At the Pindorama Farm we identified four hollow trees that housed only one colony of bats, three pink trumpet trees *Handroanthus heptaphylla* (Vell.), Bignoniaceae, and one avocado *Persea americana*, Lauraceae (Table 1).

The three *H. heptaphylla* trees were 10-12 m in height and located along the side of the main road traversing the farm. On the eastern side of the road there were plantations of bananas (*Musa* sp. Musaceae) and peach palm (*Bactris gasipaes* Kunth, Arecaceae) and the area to the west was open fallow without crops. The avocado tree was approximately 15 m high and was located on the edge of a forest fragment. All openings to the tree hollows where the bat colonies roosted were located in the tree trunk. The *P. americana* and one *H. heptaphylla* had only a single entrance to the cavity whereas the cavity in the other two *H. heptaphylla* had two openings (Table 1), but only the uppermost opening was used by bats.

Roosts in *H. heptaphylla* trees (21°13′2350″ S 48°54′3078″ W, 563 m, 21°13′2635″ S 48°54′3056″

Table 1. Bat species that used tree hollows as day roosts at the Pindorama Farm. The table shows the number (N) of males and females in each colony, Index (Lincoln-Petersen) with modification proposed by Bailey (±SE), the tree species used as a roost, dbh, the number of openings of the trunk cavities (N), the above ground height (m) of the access used by the bats to get in and out of roosts, and the horizontal and vertical size (cm) of these openings.

Bat species	Male (N)	Female (N)	Index (SE)	Tree species	DBH (cm)	Openings (N)	Height (m)	Horizontal (cm)	Vertical (cm)
Molossus rufus	8	2	10.8 (1.8)	*H. heptaphylla* (Vell.) Mattos*	46	2	6.38	2.3	2
Molossops temminckii	2	4	6 (1.25)	*H. heptaphylla*(Vell.) Mattos*	50	2	3.98	2	10
Artibeus planirostris	2	3	5 (1.23)	*H. heptaphylla* (Vell.) Mattos*	40	1	0.70	20	91
Sturnira lilium	1	4	5 (0.84)	*P. americana* Mill.*	101	1	2.45	6	15

* The identification of plant species follows APG II (2003) and Grose & Olmstead (2007).

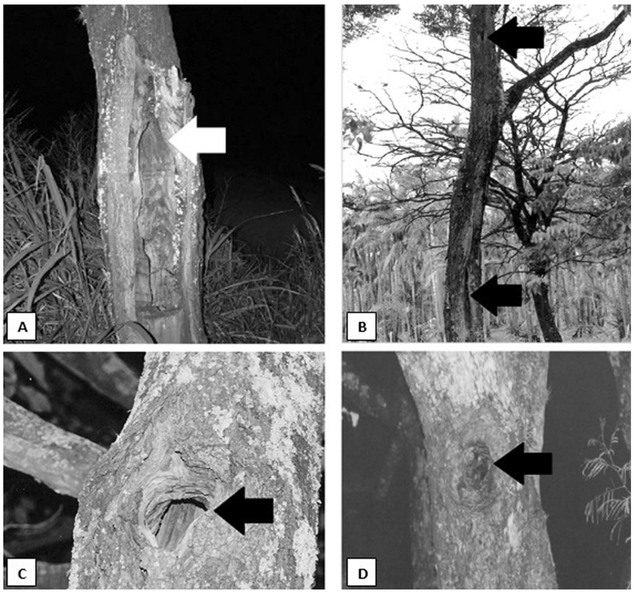

Fig. 1. A) Long opening of the diurnal roost of *Artibeus planirostris* in a trunk of *H. heptaphylla* (arrow). Highlighted with an arrow (white) the upper portion of the cavity. B) Two openings (arrows) of the diurnal roost of *M. rufus* in a trunk of *H. heptaphylla*. C) Opening of the diurnal roost of *M. temminckii* in the trunk of *H. heptaphylla*. D) Entrance to the diurnal roost of *S. lilium* located in the trunk of *P. americana*.

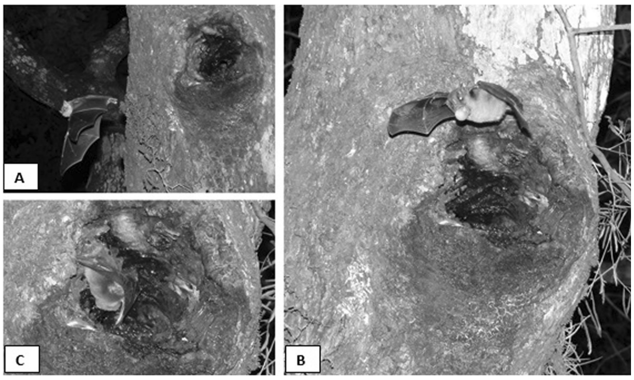

Fig. 2. A) *Sturnira lilium* flying from a trunk cavity of *P. americana*. B) *Sturnira lilium*, with a fruit of *S. paniculatum* in its mouth, flying around the opening of its diurnal roost, located in the trunk of an avocado tree. C) *Sturnira lilium* perched at the tree (*P. americana*) hollow entrance and moving into the roost.

Fig. 3. A) *Philodryas patagoniensis* leaving the diurnal roost of *M. temminckii* in a trunk of *H. heptaphylla*. B) *Didelphis albiventris* sitting in the trunk of a *P. americana* tree, just above the opening of the hollow that housed a colony of *S. lilium*.

W, 563 m and 21°13′3107″ S 48°54′2985″ W, 565 m) were inhabited by colonies of *Artibeus planirostris* (Fig. 1A), *Molossus rufus* (Fig. 1B) and *Molossops temmnickii* (Fig. 1C), respectively and a small colony of *Sturnira lilium* was found in the avocado tree (21°13′2350″ S 48°54′3078″ W, 563 m) (Fig. 1D).

Colony size and behavior

In general, the colonies of bats from Pindorama Farm were small with individuals of both sexes caught in nets set against the entrance of the tree hollows (Table 1). The *H. heptaphylla* tree situated near a banana plantation was home to a small colony of *A. planirostris*, consisting of five individuals that were resting on the inner wall of the tree-hollow, approximately 1.5 meters from the opening. Individuals were perched side by side in a contact posture. In November 2005, only one male had testicles in the scrotum, while one adult female was lactating and the other two had no signs of pregnancy. A young male was captured manually in February 2006, while resting near the entrance of the roost. All four adults were captured around 20:00 h, as they left the roost and flew east from the opening toward to the banana and peach palm plantations.

The second *H. heptaphylla* contained a colony of *Molossus rufus*. This group was roosted far from the tree-hollow entrance and it was therefore not possible to observe them inside. However, we believe that there were approximately ten adults roosting in this refuge. This estimate is based on the number of captures, the amount of feces deposited and the number of bats flying around the tree. The exit of *M. rufus* started with the setting of the sun and the emerging decreased two to three hours later. Nine individuals were captured during the first three hours after sunset, all leaving toward the west of the roost. Only one individual was caught leaving the roost after 22 h. Males were found with testicles in the scrotum during the months of February, May, June, July, August and November. Females with palpable fetuses were captured only in October and November.

The third *H. heptaphylla* tree housed a colony with six individuals of *Molossops temminckii* that roosted approximately 20 cm above the cavity opening. These individuals roosted side by side and adopted a contact posture on the vertical wall of the roost. At dusk, the bats began to leave the roost singly or in pairs and flew west from the roost, in the direction of the fallow area. The return occurred approximately 20-30 minutes after the last individual had left. Additional exits occurred throughout the night, but the nocturnal activity decreased two to three hours after sunset.

A male was captured in February with descended testicles and when it was recaptured in June, its testicles were abdominal. The bat captured in May also had abdominal testicles.

The hollow of the avocado tree was inhabited by a *Sturnira lilium* colony. It was not possible to observe the bats inside the hollow. In February 2006 and October 2010, five individuals were captured, one of which was collected at 20:00 h, and four around 23:00 h. No further activity was observed after capture in any individual. In November 2010, we observed a male with testicles in the scrotum and two pregnant and two non-pregnant females.

Around 20:00 h on October 12, 2010, an individual of *S. lilium* was found hanging on the wall of entrance of the avocado tree hollow. The bat quickly launched into flight around the tree and then flew away towards the edge of the forest remnant (Fig. 2A). A few minutes later, an individual was observed flying in a circle around the avocado tree, carrying a fruit of *Solanum paniculatum* L. in its mouth (Fig. 2B). The bat then landed and rested upside down in the entrance of the shelter, holding the *S. paniculatum* fruit in its mouth, and quickly moved to the inside, supporting itself using its toes (Fig. 2C). The fruit was then apparently consumed inside the roost. Using a flashlight several *S. lilium* individuals were observed defecating in flight around the tree. On some occasions, it was possible to hear the sound of bat feces falling onto the dry leaves, accumulating on the ground around the avocado. Several plants of *S. paniculatum*, with ripe fruits were observed near the avocado tree and along the edges of the forest fragments.

Presence of possible predators at the diurnal roosts

The presence of potential bat predators near the roosts was observed only after the present study period, when the roosts were still used by the colonies, with the exception of *A. planirostris* that was not observed after April 2010. At that time, the surrounding landscape was modified by the removal of the banana plantation.

At around 15:00 h on March 12, 2011, we observed a green snake *Philodryas patagoniensis* (Girard, 1858) (Colubridae) (Fig. 3A) leaving the interior of the *M. temminckii* roost. However, when illuminated, the snake returned to the roost and was not observed further. After this event, the molossids continued to be frequently observed within this tree hollow.

Around 20:00 h on October 12, 2010 a white-eared opossum *Didelphis albiventris* Lund, 1840 (Didelphidae) was observed on the avocado tree that housed the *S. lilium* colony. This individual sat on the fork between the trunk and a branch (Fig. 3B), located one meter above the opening of the tree-hollow. At the time, different *S. lilium* individuals were flying around the tree, entering and leaving the roost. Around 23:30 h on the same night, the opossum was seen in the same location and at 01:00 h, it was sitting on another branch ten meters away from the opening of the roost. At no time was the opossum observed preying on bats in this avocado tree.

Discussion

Bat colonies

Artibeus planirostris usually uses external roosts, adopting a free posture while perched in foliage (Hollis 2005) or on roof tops (Dobson 1878). In Brazil, this species has also been found sheltering inside caves (Bredt et al. 1996). In Panama, the congener *A. jamaicensis* often roosts in tree hollows (Morrison 1980). In Pindorana Farm, the apparently temporary use of a tree hollow as a diurnal roost by *A. planirostris* shows the versatility of this species in using different roost structures and its direct relationship with a food source, suggesting this species could move from one area to another depending on the availability of food. This behaviour has been observed in other species, such as the congener *A. jamaicensis* in Panama (Morrison & Handley 1991) and the hematophagous species *Desmodus rotundus* in Costa Rica (Turner 1975). Turner (1975) observed that colonies of *D. rotundus* moved from one roost to another, following the rotation of cattle through different pastures. Therefore we suspect that the *A. planirostris* colony in Pindorama Farm abandoned *H. heptaphylla* and moved to another roost close to a different food source. In Brazil, there are few reports describing the roost type used by *A. planirostris* or the composition of the colonies (Pacheco et al. 2010). Small colonies have been reported roosting in coconut fronds (Husson 1962), caves, tree hollows and buildings (Hollis 2005), though these studies do not describe the characteristics of the position of the colonies or the sex ratio. We believe that the characteristics of the *A. planirostris* colonies and types of roosts used should be similar in as more common larger bodied congeners, for example, *A. lituratus* and *A. jamaicensis*. These species also shelter in foliage and tree hollows (Gardner 2007).

Molossus rufus and *Molossops temminckii* are aerial insectivores (Fabián & Gregorin 2007) that forage in open areas (Vaughan 1966, Farney & Fleharty 1969). These species were recaptured while foraging on fallow land located opposite the trees used as day roosts. According to Reis et al. (2007), *M. temminckii* can use tree hollows, cracks in posts and fencing as roosts. On the other hand, *M. rufus* is commonly observed using roofs of buildings and various other anthropogenic structures in urban areas (Bredt et al. 1996, Esbérard et al. 1999, Pacheco et al. 2010), but they also roost in tree hollows, as observed in Teodoro Sampaio (SP) by the first author and Poconé (MT), by the second author (unpublished data). We believe that the frequent occurrence of these species in buildings is related to food availability. Artificial lights that are commonly found close to residences in both rural and urban areas attract many insects and consequently their predators, such as insectivorous bats (Goldsmith 1970, Furlonger et al. 1987, Schnitzler et al. 1987, Kronwitter 1988, Barak & Yom-Tov 1989, Bredt et al. 1996, Clements 1999). Therefore, the increased availability of food and shelter influences the occupancy of attics and ceilings by bats in both rural and urban environments (Bredt et al. 1996), especially considering that the density of trees (mostly dead and hollow) is much lower in anthropogenic areas.

The daytime roost of *Sturnira lilium* was inside the trunk of an avocado tree, located on the edge of a forest fragment. This species mainly consumes fruits belonging to the family Solanaceae (Gannon et al. 1989, Handley & Morrison 1991, Iudica & Bonaccorso 1997, Wendeln et al. 2000), whose species are in general considered to be pioneers (Bohs 1994, Silva et al. 1996). The Solanaceae are commonly found along the edges of forest fragments and in disturbed environments (Tabarelli et al. 1990, Nepstad et al. 1998). It is therefore to be expected that *S. lilium* use day roosts on the edges of the remnants and/or near altered areas due to the high density of these food resources. The use of forest edges by *S. lilium* during foraging has been reported by several authors (Simmons & Voss 1998, Fenton et al. 2000, Mello et al. 2008). In the present study, we also observed this species feeding on fruits of *Solanum paniculatum* around the roost. These data suggest that *S. lilium* uses day roosts and food sources that are near to each other just like *A. planisrostris*, *M. rufus* and *M. temminckii*. According to Kunz (1982), the associations of bats with roosts depends mainly on their availability in the immediate environment. Nevertheless, the proximity of food sources or foraging environments may influence the choice of the roost by optimizing the foraging time, resulting in energy savings and decreased predation risk. Fenton et al. (2000) followed nine colonies of *S. lilium* in Belize, five of which roosted inside hollow logs, two in tangles of lianas ("vine tangles") and one on a palm leaf. The colonies ranged from one to four individuals inside the trunks, one to three on vine tangles and from one to ten individuals on the palm leaf. Our findings from Pindorama Farm regarding roost types and colony sizes were similar to those of Fenton et al. (2000) in Belize and suggest that in general *S. lilium* colonies tend to have few individuals, especially when roosting in tree hollows. According to Dalquest & Walton (1970), colonies of *S. lilium* generally contain few individuals and other authors have shown that this species uses tree hollows, attics, tunnels, foliage, tangled vines and the lower palm leaves as roosts (Walker 1964, Villa-R 1966, Gannon et al. 1989, Fenton et al. 2000).

Selection of species as a consequence of roost characteristics

There are several advantages for species that use cavities in tree as shelter, among which we highlight the relatively stable microclimate (Genoud 1993), the dark inside, and protection from predators (Taddei 1988, Kunz & Lumsden 2003). However, both the height of the access above the ground as well as its dimensions are important factors influencing roost occupation by bats.

According to Taddei (1988), the occupation of these shelters is related to the flight capacity, echolocation and morphology of each bat species; as such the animals must be adapted to the physical characteristics of the shelters in order to colonize them. The height of the shelter used by *S. lilium* in Pindorama Farm was similar to the height of the shelters in Belize studied by Fenton et al. (2000). This similarity suggests that the strategy of choice for shelter in *S. lilium* is the same regardless of the region.

When released, none of the *M. rufus* individuals captured in study area took to flight directly from the ground or from heights of less than two meters. On the other hand, in same situation, all individuals of *M. temminckii* managed to fly from launch heights above one meter. This feature seems to be related to the height of day roosts. Taddei & Vizotto (1976) found that the height of *M. temminckii* roosts ranged from one to three meters. We believe that the larger (i.e. with greater biomass) molossids use higher roosts compared to smaller species due to their apparent inability to take off from lower heights, as proposed by Walker (1964). On the other hand, the phyllostomids studied have no restrictions as to the height of the roost access because all individuals captured in this study took to flight directly from the ground.

The dimensions of the roost cavity access also influences its occupation by bats. According to Taddei & Vizotto (1976), the dimensions of the access used by *M. temminckii* did not exceed 2 cm wide. In Pindorama Farm, *M. rufus* used a narrow opening (approximately 2 cm wide), unlike *A. planirostris* and *S. lilium* that used relatively wide access (ranging from 6 to 20 cm).

According to Vaughan (1966), the morphological traits of molossids enable greater mobility in narrow shelters during their quadruped displacement. Another feature that favors its displacement in narrow gaps is its coat, which is thick and dense like velvet, and closely resembles that of the fossorial mammals. Being dense and short the coat can be easily brushed in any direction and this reduces friction with the substrate during movements in natural or artificial cracks (Dalquest &Walton 1970).

Nocturnal activity

In Pindorama Farm, we found a clear difference between the times of emergence and return to the daytime roosts by the two bat families. The molossids left roosts mainly at dusk while the phyllostomids left after 20 h. This behavior is probably related to the feeding habits of each species. According to Provost (1959), the density of insects increases at dust and dawn, therefore insectivorous bats are most active during these periods. According to Chase et al. (1991) and Esbérard (2002), *M. rufus* has a crepuscular habit and returns to the roost approximately three to four hours after leaving. *Molossops temminckii* adopts the same crepuscular activity pattern, yet returns more times to rest during the period of activity (Taddei & Vizotto 1976).

The differences in bat species foraging patterns offers the possibility of coexistence when exploiting the same food resources (Pedro & Taddei 1997). Diet and space are the resources most commonly used to measure niche overlap (Krebs 1989), but temporal activity also has an important role in the foraging behavior of these animals. Phyllostomids started their evening activities two to three hours after sunset. This behavior has also been reported by Pedro & Taddei (1997) for both the species studied here. Heithaus et al. (1975) first suggested that temporal variation in activity reduces competition between some frugivorous bat species. However, several factors such as lunar phobia (Morrison 1980, Uieda 1992, Breviglieri 2011), temperature, seasonality, weather (Uieda 1992, O'Donnell 2002) among others, may interfere with bat activity.

Reproduction

Reproductive activity of *M. rufus* occurred throughout the year in Pindorama Farm, indicating polyestry. This behavior was similar to that reported for the same species by Marques (1986) in Manaus and, Esberárd (2002) in Rio de Janeiro. According to Marques (1986) and Reis et al. (2007), *M. rufus* is polyestrous, with pregnant females found in almost every month of the year.

Despite the limited data on the reproduction of *M. temminckii* in Pindorama Farm, we believe that this species is polyestrous like *M. rufus*. Studies by Taddei & Vizotto (1976) and Gargaglioni et al. (1998) in the northwest and northeast of the State of São Paulo showed the presence of gravid *M. temminckii* females in June, September and October. Gonçalves & Gregorin (2004) reported reproductive characteristics (pregnant females and males with descended testicles) during October in the state of Tocantins, northern Brazil. Contrary to the findings of the authors cited above, we observed abdominal testicles in males of this species in June, indicating no sexual activity in this month.

The family Molossidae presents both monoestrous and polyestrous strategies, but most species are polyestrous, however the strategy may change within the same species depending on the location (Krutzch 2000). Thus, we can infer that the reproductive strategy of this species is probably related to their regional location and the particular environmental conditions such as seasonality, rainfall and temperature. This conclusion can also be inferred for the phyllostomid species described herein.

In Pindorama Farm, both *S. lilium* and *A. planirostris* reproduced during the rainy season. According to Taddei & Vizotto (1976), *A. planirostris* is polyestrous and *S. lilium* shows bimodal polyestry. Zortéa (2002) commented that *S. lilium* may present variations in reproductive patterns depending on locality. In the region of Pindorama, there is a distinct difference in rainfall between the wet (October to March) and dry seasons (April to September), which can dramatically influence the supply of food resources. Therefore, we suggest that the reproductive activity of the phyllostomid and molossid species studied here show reproductive cycles determined by resource availability, which reflects the fluctuations in rainfall. The reproductive cycles of these species are therefore synchronized with the seasonal cycles of the biome in which the species occurs and this behavior is not necessarily standard for the species. However, future studies can confirm these patterns by comparing the reproductive cycles of these species in different biomes.

Possible predators
Some authors suggest that sheltering in hollow trees inhibits the action of natural predators (Taddei 1988, Kunz & Lumsden 2003), especially those that cannot enter these cavities. Smaller predators, such as snake *Philodryas patagoniensis* can forage in the cavity, as we observed in the roost of *M. temminckii* in Pindorama Farm. This diurnal species is a medium sized snake and may forage both on the ground and in the trees (Thomas 1976). It is commonly found in various locations in South America (Thomas 1976) and is considered a predator of frogs and lizards, but also consumes other snakes, birds and small mammals (Hartmann & Marques 2005). The congener *Philodryas viridissimus* (Linnaeus, 1758) has been recorded preying on bats (Otto & Miller 2004).

In Pindorama Farm, the presence of the opossum *Didelphis albiventris* was recorded at the avocado roost entrance of *S. lilium*. According to Fonseca et al. (1996), this species presents a frugivorous-omnivorous habit and can eat small rodents and birds, frogs, lizards, snakes, insects, crabs and fruit (Lange & Jablonski 1998, Eisenberg & Redford 1999, Nowak 1999), and also bats (Gardner et al. 1992, Gazarini et al. 2008, Breviglieri & Pedro 2010). According to Gardner et al. (1992), *D. albiventris* can easily consume a whole bat, but they do not usually have access to this type of prey, so bats are consumed opportunistically. We believe that the opossum we saw in Pindorama Farm was attracted by the movement of the bats around the entrance to the roost and that it was attempting to prey on them as they entered the roost.

This study provided the description of the characteristics of the internal refuges and the composition of the colony, focusing on the behavior of four species of Neotropical bats. These results are of paramount importance for a better understanding of the ecology of these animals, considering the lack of this kind of information for several bat species in Brazil.

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