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Phyllostomidae assemblage (Chiroptera: Mammalia) in altitudinal forests at the Parque Estadual do Ibitipoca, Southeast of Minas Gerais, Brazil

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ABSTRACT. Many studies have demonstrated the ecological relevance and great biodiversity of bats in Brazil. However, mountainous areas have been disproportionately less sampled, mainly in the Southeast. The aim of this study was to identify and compare the richness and diversity of Phyllostomidae, the most diverse bat family, in different forest types in Parque Estadual do Ibitipoca, trying to understand the causes of possible differences. The Parque Estadual do Ibitipoca is inserted in the Serra da Mantiqueira's domain, in an Atlantic Forest region known as "Zona da Mata", state of Minas Gerais, with an altitudinal range between 1200-1784 meters. The study was conducted in two forest types, classified as "Nanofloresta Nebular" and "Floresta Nebular", whose respective data on richness and diversity were compared. The bats were captured with 8-10 mist nets for 14 months (April 2011 to May 2012) and four nights per month totaling 62,171.25 m^2h of capture effort. A total of 392 captures (12 species) belonging to the Phyllostomidae family were obtained. The most abundant species were *Sturnira lilium* (59.9%), *Platyrrhinus lineatus* (11.3%), *Artibeus lituratus* (8.7%) and *Carollia perspicillata* (7.6%). The two sampled areas presented differences in bat richness, diversity and species composition, and this difference was predominantly influenced by *S. lilium*. It is likely that the observed difference in the assembly of bats between the two study sites depends on the variation in floristic composition. The records of *A. lituratus* and *P. lineatus* in a few months of the year and close to *Ficus mexiae* bearing ripe fruits suggests that at least these species move to the park for a few periods of the year in search of food resources, possibly moving through the altitudinal landscapes.

KEYWORDS: Atlantic Forest, bats, Serra da Mantiqueira.

RESUMO. Assembleia de Phyllostomidae (Chiroptera: Mammalia) em florestas altitudinais no Parque Estadual do Ibitipoca, sudeste de Minas Gerais, Brasil. Muitos trabalhos têm demonstrado a relevância ecológica e a grande diversidade de morcegos no Brasil. Contudo, áreas montanhosas têm sido desproporcionalmente menos amostradas, principalmente na Região Sudeste. O objetivo principal deste estudo foi inventariar e comparar a riqueza e diversidade de morcegos Phyllostomidae, a mais diversa família de morcegos, em diferentes formações florestais no Parque Estadual do Ibitipoca, buscando compreender as causas das possíveis diferenças encontradas. O Parque Estadual do Ibitipoca está inserido nos domínios da Serra da Mantiqueira, em área de Mata Atlântica, na Zona da Mata do estado de Minas Gerais, cujas altitudes variam de 1.200 a 1.784 metros. O estudo foi conduzido em dois tipos de florestas, classificadas como "Nanofloresta Nebular" e "Floresta Nebular", cujos respectivos dados sobre riqueza e diversidade foram comparados. Os morcegos foram capturados com 8-10 redes de neblina por 14 meses (entre abril de 2011 a maio de 2012) e 4 noites por mês, totalizando 62.171,25 m^2h de esforço de captura. Foram obtidas um total de 392 capturas (12 espécies) pertencentes à família Phyllostomidae. As espécies mais abundantes foram *Sturnira lilium* (59,9%), *Platyrrhinus lineatus* (11,3%), *Artibeus lituratus* (8,7%) e *Carollia perspicillata* (7,6%). As duas áreas amostradas apresentaram diferenças relacionadas à riqueza, diversidade e composição de espécies de morcegos, sendo esta diferença influenciada predominantemente por *S. lilium*. É provável que as diferenças observadas na assembleia de morcegos entre as duas áreas amostradas apresentem alguma relação com a variação na composição florística. O registro de *A. lituratus* e *P. lineatus* em poucos meses do ano e próximo a *Ficus mexiae* em frutificação sugere que pelo menos estas espécies se deslocam para o parque durante alguns períodos do ano em busca de recursos alimentares, possivelmente movendo-se através das variações altitudinais da paisagem.

PALAVRAS-CHAVE: Mata Atlântica, morcegos, Serra da Mantiqueira.

The Chiroptera Order is represented by 1,120 species (Reis *et al*., 2007), the greatest diversity found along the Neotropical region, with about 83 genera and 288 species (Mickleburgh *et al*., 2002). In Brazil, 178 species are recorded (Nogueira *et al*., 2014), of which 1 is considered vulnerable, 4 near-threatened and 24 are data deficient, according to IUCN (IUCN, 2015). Among the Chiroptera, Phyllostomidae family is the most diverse in the Neotropics (Fenton *et al*., 1992), and represent 52.9% of the recorded species in Brazil (Peracchi *et al*., 2011).

There are 77 species of bats recorded in the state of Minas Gerais, representing 55% of the species listed for

Brazil. Such species are distributed in seven out of the nine families registered in the Neotropics. Among these, the Phyllostomidae family represents about 53% of the species (Tavares *et al*., 2010). Despite having the greatest richness of bats in the southeast region of Brazil, the state of Minas Gerais has many areas that remain unknown regarding the composition of Chiroptera fauna (Tavares *et al*., 2010). In this state, the Atlantic Forest, a biome that is considered a global hotspot with priority for conservation (Myers *et al*., 2000), occupies 46% of the territory and is currently restricted to forest fragments of various sizes and levels of degradation. Of these, only about 10% of the original Atlantic Forest range has forest remnants (Fundação SOS Mata Atlântica & Inpe, 2011), and an important part of this vegetation cover is in mountainous areas.

In southeastern Brazil, few studies have focused on the diversity of bats at high altitude sites (e.g., Falcão *et al*., 2003; Dias & Peracchi, 2008; Mello *et al*., 2008; Moras *et al*., 2013; Nobre *et al*., 2013). In these environments, the availability of food, as well as the environmental variables, may differ from the lower areas, creating different environmental conditions that in particular reflect fauna along the altitudinal gradients (Giannini, 1999; Mello *et al*., 2008). Thus, in order to contribute to the knowledge of the ecology of phyllostomid bats at high altitude sites, this study aimed to determine the richness and diversity of this group in two areas of montane forests of Parque Estadual do Ibitipoca, in the Atlantic Forest domains, trying to understand the causes of possible differences.

MATERIALS AND METHODS

Study areas. The Parque Estadual do Ibitipoca (PEIB) is inserted in the Atlantic Forest domains, Serra da Mantiqueira region, state of Minas Gerais (21°42'S and 43°54'W). The park has an area of 1488 ha with altitudes ranging between 1,200 and 1,784 m.a.s.l. The climate is mesothermal highland tropical, with dry cold winters and rainy summers. Areas with grassland occupy about 50% of the Park and the forest physiognomies correspond to about 32% (Herrmann, 2006). The forests of the Park belong to the Atlantic Forest biome and are classified as Floresta Nebular, Nanofloresta Nebular and Arbustal Nebular according to Oliveira-Filho *et al*. (2013).

Two forest areas were selected for sampling (Fig. 1): one of Floresta Nebular and the other of Nanofloresta Nebular. The two areas are interspersed with savannahs and grasslands located about 600 meters apart. The Nanofloresta Nebular is known locally as Mata de Grota, and is 1300 m.a.s.l., with an area of approximately 15 ha. These forest types have developed failures in rocks, which accumulates products of decomposition from the higher places inside the Park, resulting in taller vegetation development (Dias *et al*., 2002). This forest formation is closer to several caves, and has a connection with semi-deciduous forests located outside the limits of the Park.

The second selected area, a patch of Floresta Nebular, known locally as Mata Grande, has an area of about 94 ha and altitudes around 1400 m.a.s.l.; it is the main forest fragment in the Park. In this sampling site, the canopy has many gaps and an average height of 17 meters, with emergent trees reaching 25 meters (Rodela, 1998; Oliveira-Filho *et al.*, 2013).

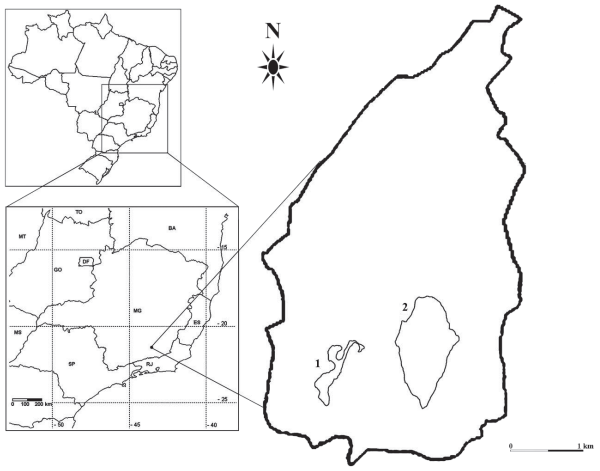

Fig. 1. Sampling sites in Parque Estadual do Ibitipoca, MG, Brazil: 1, Mata de Grota (Nanofloresta Nebular) and 2, Mata Grande (Floresta Nebular).

During the samplings, the monthly average temperature was 19.9°C. The minimum temperature was 5.3°C, recorded in July, and the maximum was 36.8°C, in September. The months with the highest precipitation indices were October 2011 to May 2012. December 2011 was the month with the highest rainfall (726.9 mm). The lowest rainfall (7.5 mm) was recorded in September 2011 (Mello *et al*., 2014).

Samplings. Captures were carried out for 14 months from April 2011 to May 2012. Each area was sampled for two nights each month, except in April 2011 (three nights in each area) and January 2012 (two nights in Mata de Grota and one in Mata Grande), due to intense rainfall and logistical problems. Thus, 57 nights of sampling were conducted, of which 26 occurred in the Mata Grande and 31 in Mata de Grota, prioritizing night with the moon in the dark phase. Intervals between sampling periods were approximately 15 days. For captures, 8 to 10 mist nets (2.5 x 9 meters) per night were used, which were installed 30 cm from the ground, reaching 337 hours of mist net exposure and 2785 mist net/hour. The total capture effort was 62171.25 m^2h, calculated according to the methodology proposed by Straube & Bianconi (2002).

The mist nets were opened at dusk, after approximately 18 hours, and stayed open for six hours, with monitoring every 15 minutes. Captured bats were held in cloth bags for later identification and marked with color-coded collars for as proposed by Esbérard & Daemon (1999). After this procedure, bats were released near the same place of capture. Identifications followed the criteria of Vizotto & Taddei (1973), Reis *et al*. (2007) and Miranda *et al*. (2011).

In order to maintain a collection of reference for the study area, two individuals of each bat species were

sacrificed and fixed in 10% formalin and then preserved in 70% alcohol. The voucher material was incorporated in the Mammal Collection of Mammals of the Department of Natural Sciences, Universidade Federal de Juiz de Fora.

Data analysis. The methodology with mist nets installed at ground level favors the capture of species of the Phyllostomidae family (Fenton *et al.*, 1992; Passos *et al.*, 2003). Thus, only species belonging to this family were analyzed, disregarding the recaptures.

The diversity of bats was calculated by the inverse of Simpson's index (1-D). These values were recorded for the total area of the study, as well as for each area individually, and the difference between two areas was tested by the bootstrap method. Simpson's index (1-D) was chosen because it is less sensitive to sample size and provides a good estimate for small population sizes (Magurran, 2004).

The difference in richness observed between the areas was analyzed by means of rarefaction curves, the result of which was also compared to bootstrap analysis. Analysis of Similarity (ANOSIM) was used to verify differences in species composition, based on Bray-Curtis distance. The contribution of each taxon for the difference observed between the areas was performed by the Similarity Percentages analysis (SIMPER).

Species accumulation curves, along with their respective confidence intervals, were generated by the Mao Tau method to verify the occurrence of stabilization of the species richness. The richness estimates were calculated based on the first-order Jackknife index. Here, 1000 randomizations were adopted to perform bootstrap analysis, similarity (ANOSIM) and richness estimators.

Analysis were performed using the PAST software version 2.15 (Hammer *et al.*, 2001) and EstimateS version 9.1 (Colwell, 2009).

RESULTS

A total of 392 captures of 12 species were obtained, of which 48 correspond to recaptures (Tab. I). The most common species were *Sturnira lilium* (E. Geoffroy, 1810) with 59.9% (N = 206), followed by *Platyrrhinus lineatus* (E. Geoffroy, 1810) with 11.3% (N = 39), *Artibeus lituratus* (Olfers, 1818) with 8.7% (N = 30) and *Carollia perspicillata* (Linnaeus, 1758) with 7.6% (N = 26); the remaining species totaled 43 captures, representing 12.5% of the total. The occurrence of phyllostomid varied between the two areas. In Mata de Grota, 305 captures were obtained, of which 44 correspond to recaptures. At this site, 11 species of phyllostomid bats were recorded, and the most common were *S. lilium* (53.6%) and *P. lineatus* (14.6%). In the Mata Grande, 87 captures of five species, four of which correspond to recaptures. The most abundant species in the Mata Grande were *S. lilium* (79.5%), followed by *A. lituratus* (8.4%) (Fig. 2).

The species accumulation curve did not reach an asymptote, however, from the twenty-eighth sampled night, about 83% of the species in this study had been captured. In the remaining nights only two species were added (Fig. 3). Rarefaction curves for phyllostomid species showed differences in richness between the two areas, with the largest number of species in the Mata de Grota (Fig. 4). Such difference was confirmed by the Bootstrap analysis (p = 0.003). According to the first-order Jackknife index,

Tab. I. Total captures of phyllostomid bat species in Parque Estadual do Ibitipoca, MG, Brazil (including recaptures). *, Number of recaptures: *Anoura caudifer*: 1 (Mata de Grota); *Carollia perspicillata*: 9 (8 [Mata de Grota]/1[Mata Grande]); *Platyrrhinus lineatus*: 2 (Mata de Grota); *Sturnira lilium*: 36, (33[Mata de Grota]/3 [Mata Grande]).

	Mata de Grota N(%)	Mata Grande N(%)	Total N(%)
PHYLLOSTOMIDAE			
Phyllostominae			
Chrotopterus auritus (Peters, 1856)	-	3 (3.3)	3 (0.8)
Glossophaginae			
Anoura caudifer (E. Geoffroy, 1818)	12 (3.9)	-	12* (3)
Carolliinae			
Carollia perspicillata (Linnaeus, 1758)	28 (9.1)	7 (7.7)	35* (8.8)
Stenodermatinae			
Artibeus fimbriatus Gray, 1838	2 (0.6)	-	2 (0.5)
Artibeus lituratus (Olfers, 1818)	23 (7,4)	7 (7.7)	30 (7.5)
Chiroderma doriae Thomas 1891	3 (1)	-	3 (0.8)
Pygoderma bilabiatum (Wagner, 1843)	1 (0.3)	-	1 (0.3)
Platyrrhinus lineatus (E. Geoffroy 1810)	40 (12.9)	1 (1.1)	41* (10.3)
Platyrrhinus recifinus (Thomas, 1901)	8 (2.6)	-	8 (2)
Sturnira lilium (E. Geoffroy, 1810)	173 (56)	69 (75.8)	242* (60.5)
Vampyressa pusilla (Wagner, 1843)	11 (3.6)	-	11 (2.8)
Desmodontinae			
Desmodus rotundus (E. Geoffroy, 1810)	4 (1.3)	-	4 (1)
Total	305	87	392

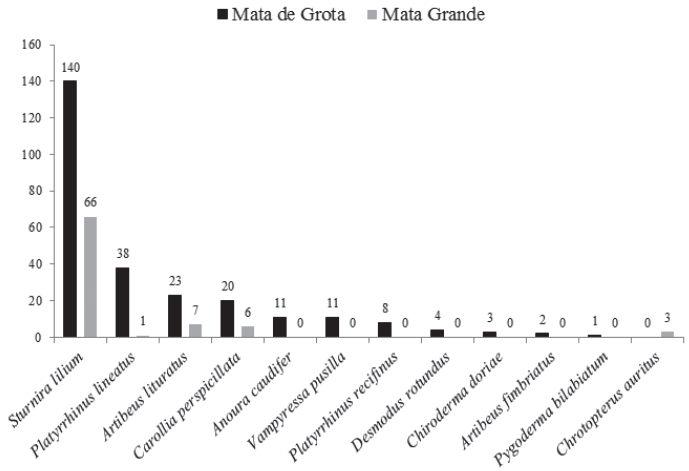

Fig. 2. Abundances of phyllostomid bat species recorded in Mata de Grota and Mata Grande in Parque Estadual do Ibitipoca, MG, Brazil.

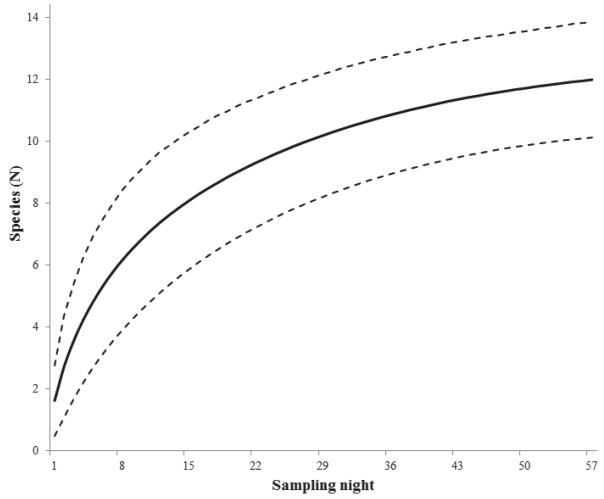

Fig. 3. Species accumulation curve of phyllostomid bats captures based on sampling nights in the Parque Estadual do Ibitipoca, MG, Brazil. Dotted lines correspond to the 95% confidence interval obtained by the Mao Tau method.

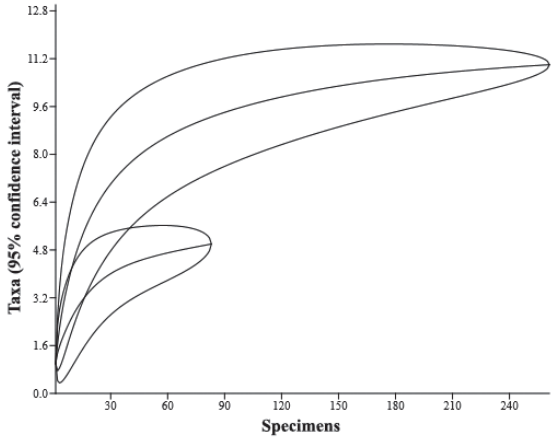

Fig. 4. Rarefaction curves with confidence intervals representing two areas of forest types in Parque Estadual do Ibitipoca, MG, Brazil. The largest curve refers to Mata de Grota, and the smaller curve to the Mata Grande.

85.9% of the phyllostomid species present in studied forest sites of PEIB were captured. Estimates of species point out that, for Mata de Grota, 85.1% were recorded species, while for Mata Grande, 83.9% of the species were present in this environment.

The diversity of phyllostomid in Ibitipoca was 1-D = 0.6126, while analyzing each area separately, Mata de Grota showed greater diversity than Mata Grande (0.6725 and 0.3539, respectively; p = 0.001). The areas were also different with regard to species composition (R = 0.2673, p = 0.0012), mainly due to the contribution of *S. lilium*, *C. perspicillata* and *Anoura caudifer* (E. Geoffroy, 1818) to dissimilarity (Tab.II).

DISCUSSION

Altitudinal changes are an important factor that influences the structure of mammalian communities (Owen, 1990). Montane environments can present bat communities that are structurally different from low areas, and some studies have revealed reduction of phyllostomid bats richness with increasing altitude (Navarro & Leon-Paniagua, 1995; M. A. Martins, unpubl. data). This reduction may be related to the distribution of resources, because highland forests have a higher proportion of plant species dispersed by birds (S. Campassi, unpubl. data). In fact, the phyllostomid species richness observed in PEIB was lower than that recorded in lowland areas, as in places of Atlantic Forest from Rio de Janeiro, where Esbérard (2003) recorded 24 species of phyllostomid, and to the Ilha Grande, municipality of Angra dos Reis, where Esbérard *et al.* (2006) found 26 species.

Some bat species can present an increased abundance with increasing altitude (Giannini, 1999). Studying a bat assemblage in Caraça at altitudes between 850-2070 m, Falcão *et al*. (2003) observed that *S. lilium* accounted for about 64% of the captures. According to these authors, this

Tab. II. Similarity Percentages (SIMPER) of the species composition of phyllostomid bats between two forest areas (Mata de Grota and Mata Grande) in Parque Estadual do Ibitipoca, MG, Brazil based on the distance of Bray-Curtis (Aver. Diss., Average Dissimilarity).

Species	Aver. Diss.	Contribution %
Sturnira lilium (E. Geoffroy, 1810)	44.87	53.58
Carollia perspicillata (Linnaeus, 1758)	11.59	13.84
Anoura caudifer (E. Geoffroy, 1818)	9.19	10.89
Platyrrhinus lineatus (E. Geoffroy 1810)	5.27	6.29
Artibeus lituratus (Olfers, 1818)	4.50	5.37
Vampyressa pusilla (Wagner, 1843)	3.94	4.71
Chrotopterus auritus (Peters, 1856)	1.55	1.85
Platyrrhinus recifinus (Thomas, 1901)	1.54	1.84
Desmodus rotundus (E. Geoffroy, 1810	0.69	0.82
Pygoderma bilabiatum (Wagner, 1843)	0.29	0.34
Chiroderma doriae Thomas 1891	0.26	0.31
Artibeus lituratus (Olfers, 1818)	0.12	0.14

abundance may be related to the increase of food resources close to the capture sites. However, Mello *et al.* (2008), studying in a mountainous area, 850 meters high in the state of São Paulo, found that the abundance of *S. lilium* was more related to the variation in temperature than the supply of Solanaceae fruits. Other studies in highland regions, such as Nobre *et al*. (2009), and Nobre *et al*. (2013) in Minas Gerais and M. A. Martins (unpubl. data) have demonstrated the high abundance of *S. lilium* in altitudes around 1000m.

Sturnira lilium also prevailed in Ibitipoca (60.5%) with smaller representativeness in the Mata de Grota (56%) and highest in the Mata Grande (75.8%). In addition, *S. lilium* was the species with the highest contribution to the differences in species composition between the sampled areas. This difference, which shows the representativeness of this species in the bat fauna of their area, may be related to vegetation structure, since in the Mata de Grota there are edges and clearings, which provide a proper environment for the development of pioneer plants, such as the *Solanum*, widely consumed by *S. lilium*, attracting the species in this area.

The occurrence of frugivores in a given place may be associated with spatial and temporal distribution of feeding resources (Fleming *et al*., 1977). Thus, captures of *P. lineatus* and *A. lituratus* in Ibitipoca suggested a strong association with the occurrence of *Ficus mexiae* Standl. (Moraceae) in Mata de Grota. Both species have feeding habits usually related with plants of the genus *Ficus* (Muller & Reis, 1992; Sartore & Reis, 2012; Passos & Graciolli, 2004). In Ibitipoca, most of the captures of these bat species occurred in the months where *F. mexiae* was observed bearing fruits in the Mata de Grota.

In PEIB, *C. perspicillata* was the second most important species to the dissimilarity in species composition between Mata de Grota and the Mata Grande (13.8%). By studying the movement of bats in the Atlantic forest in Paraná, Bianconi *et al*. (2006) suggest that *C. perspicillata* has small feeding area as possibly due to the availability of fruits of *Piper*. However, in the absence of plants of this genus, this species can consume predominantly other genres such as *Solanum* (Mello *et al*., 2004). Thus, the presence of pioneer plant families can contribute to the occurrence of *C. perspicillata* in Ibitipoca, especially in Mata de Grota, where these plants occur more frequently.

In studies performed in Serra Negra, near to Ibitipoca, Nobre *et al.* (2013) compared two mountain slopes, and found that the abundance of *C. perspicillata* represented 13.6% in the south and 38.1% in the north. The authors considered the spatial and temporal distribution of food resources as a possible factor to explain this pattern, since *Piper* was regularly found at the capture sites on the north slope. Thus, it is plausible that the low occurrence of *C. perspicillata* in PEIB compared to the Serra Negra, can also be associated with the availability of food resources, as this species has preference for fruits of the genus *Piper* (Fleming *et al*., 1977; Heithaus & Fleming, 1978) which, despite being found in PEIB, is more common below 1,000 m.a.s.l. (Bornstein, 1989).

Rarefaction curves revealed differences in species richness of phyllostomid bats between the Mata de Grota and the Mata Grande. As well as the difference in diversity, this can be related to phytophysionomic characteristics peculiar to each area. In Mata de Grota, the Solanaceae, Piperaceae, Moraceae and Urticaceae families are over-represented in relation to the Mata Grande. These families provide food resources to the bats and probably favor the greater diversity of phyllostomids. However, the absence of more consistent information regarding the floristic composition of Mata de Grota hinders comparisons with other areas. Another factor that may contribute to the increased occurrence of bats in Mata de Grota is its proximity to semi-deciduous forests located around the park, offering a connection with several forest fragments, including fragments located in lower altitudinal areas. This connection can generate conditions that allow the movement of bats through the landscape, favoring phyllostomid fauna in Mata de Grota. On the other hand, the Mata Grande, besides not being connected by forest remnants to Mata de Grota, is regarded as a mature forest, dominated by Lauraceae, Melastomataceae and Rubiaceae families (Carvalho *et al*., 2000). Such families have few species whose fruits are used by the bat community as a feeding resource (Lobova *et al*., 2009), possibly causing

the low richness and diversity of frugivorous bats observed in this site.

The only species of the Phyllostominae subfamily captured in this study was *Chrotopterus auritus* (Peters, 1856), also observed in the Serra Negra region, near the PEIB (Nobre *et al*., 2013). The records of this species occurred only near to the stream within the Mata Grande. *Chrotopterus auritus* has carnivorous habits, feeding mainly on small mammals (Bonato *et al*., 2004). The presence of species belonging to the subfamily Phyllostominae has been considered an indicator of the degree of preservation for some areas (Fenton *et al*., 1992). The presence of *C. auritus* suggests that Mata Grande has the trophic structure necessary for the maintenance of its population, which may be associated with a good state of preservation of this area.

According to Mello *et al*. (2008), the preservation of altitudinal gradients is of extreme importance for migratory species. In PEIB, the occurrence of some bats in only a few months of the year suggests that some species are moving in the landscape partly because of the demand for feeding resources. Thus, the connection between the forests of PEIB and forests preserved in the lower areas becomes highly important for the continuing existence of bat populations through the landscape.

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