COMPOSITION OF A BAT ASSEMBLAGE (MAMMALIA: CHIROPTERA) IN THE NATURAL RESERVE SALTO MORATO, EAST COAST OF PARANÁ, SOUTH BRAZIL

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ABSTRACT. Brazilian fauna is characterized by megadiverse groups. Within those, there are bats that are directly responsible for important ecosystem services, such as pollination, dispersion and pest control. Despite of their importance, there are several geographical gaps in the Brazilian bat fauna knowledge. Thus, the present study aimed to analyze the composition of bat assemblage in a Conservation Unit in the Atlantic Forest biome, East Coast of Paraná state, southern Brazil. Samplings were carried out during six nights, in average, per month between 2013 and 2014. Captures were performed by 18 mist nets installed at different heights in the forest. Reaching sampling sufficiency, we found high species richness (n = 25 spp.), which imply the important role of Conservation Units to maintain bat diversity. The high number of captures (n = 1201) can be explained by sampling in different forest height, which may indicate the occurrence of spatial variation in habitat use. Moreover, the current results can assist the management and administration of protected areas, as well as the species conservation in situ.

RESUMO. Composição da assembleia de morcegos (Mammalia: Chiroptera) na Reserva Natural Salto Morato, costa oeste do Paraná, sul do Brasil. A fauna brasileira é caracterizada por grupos megadiversos. Dentro desses grupos estão os morcegos, os quais são responsáveis por importantes serviços ecosistêmicos, como polinização, dispersão e controle de pragas. Apesar de sua importância, existem várias lacunas geográficas no conhecimento da fauna de morcegos do Brasil. Assim, o presente estudo teve como objetivo analisar a composição da assembleia de morcegos em uma Unidade de Conservação no bioma Mata Atlântica, no litoral leste do Paraná, Região Sul do Brasil. As amostragens foram realizadas entre 2013 e 2014, durante em media por seis noites mensais. As capturas foram realizadas por 18 redes de neblina instaladas em diferentes alturas na floresta. Atingindo a suficiência amostral, encontramos alta riqueza de espécies (n = 25 spp.), o que implica o importante papel das Unidades de Conservação na manutenção da diversidade de morcegos. O grande número de capturas (n = 1201) pode ser explicado pela amostragem em diferentes alturas na floresta, o que pode indicar ocorrência de variação espacial no uso do habitat. Além disso, os resultados atuais podem auxiliar no gerenciamento e administração de áreas protegidas, bem como na conservação de espécies in situ.
Key words: abundance patterns, Atlantic Forest, conservation, diversity, inventory, southern Brazil.

Palavras-chaves: biodiversidade, conservação, inventário, Bosque Atlantico, padrões de abundância, sul do Brasil.

INTRODUCTION

Brazil is a megadiverse country in terms of its faunal groups, among which are the bats. Currently, there are 182 bat species occurring within Brazilian boundaries (Nogueira et al. 2018), which represents about 13.15% of the global bat fauna (Taylor & Tuttle 2019). Beyond the high richness, several species were described in Brazil lately (Miranda et al. 2007; Nogueira et al. 2018; Dias et al. 2013; Feijó et al. 2015; Moratelli & Dias 2015), expanding the knowledge on Brazilian bat fauna.

Among the Brazilian biomes, Amazon owns the highest specific richness – 146 spp., followed by Atlantic Forest – 118 spp., Cerrado – 101 spp., Caatinga – 77 spp., Pantanal – 60 spp., and Pampa – 24 spp. (Paglia et al. 2012; Varzinczak et al. 2015; Carvalho et al. 2017). The Atlantic Forest is the one that represents greater diversity of bats (Marinho-Filho 1996), with greater knowledge about its richness and species distribution (Bergallo et al. 2003; Bernard et al. 2011; Muylaelrt et al. 2017). Despite scientific knowledge increases in the Atlantic Forest, great rates of habitat loss and high levels of fragmentation reduced the biome to only 13% of its original coverage (Scarano & Ceotto 2015).

The maintenance of the remaining fraction of the Atlantic Forest is partly due to the implantation of Conservation Units (CU). In South America, Atlantic Forest’s protected areas increased in the last decades (Galindo & Câmara 2003; Tabarelli et al. 2005). On the other hand, the range of effectively protected territory within CUs is still small, about 2% of the total range of this biome and, among the forest remnants 24% are protected within conservation areas (Tabarelli et al. 2005).

In Brazil, among the CUs that cover Atlantic Forest fragments, the Reserva Particular do Patrimônio Natural Salto Morato (RSM) – freely translated to “Private Reserve of the Natural Patrimony Salto Morato”, with other annex CUs in Paraná and São Paulo –, constitute the largest continuous remnant of this biome. Specifically for bats, the East Coast of Paraná was considered as with low priority for inventories, region where the RSM is located (Miretzki 2003). Meanwhile, recent studies in this region described the occurrence of new species for the State (Scultori et al. 2009a;bc; Carvalho et al. 2014; 2019), showing that despite the historical research, bat fauna on this portion of Atlantic Forest is still poorly known (Varzinczak et al. 2015).

To fill these knowledge gaps inventories may be carried out, which are considered base studies for conservation actions and ecological macro approaches (Bergallo et al. 2003). Although the inventories provide static perception of biodiversity patterns (Silveira et al. 2010) and for bat communities tend to vary seasonally (e.g. Moya et al. 2008; Mello 2009), the resulting information of these studies are important to manage and conserve protected areas. In this context, the present study had the goal to analyze the composition of bat assemblage in a Conservation Unity in the Atlantic Forest, East Coast of Paraná state, southern Brazil.

MATERIAL AND METHODS

Study area

Private Reserve of the Natural Patrimony Salto Morato is located in the Guaraqueçaba municipality, North Coast of Paraná state (25°09'98"N e 48°17'90"W – Fig. 1). According to the Koeppen classification, the region presents Cfa climate, which is characterized by hot summers, without a well-defined dry season (Alvares et al. 2013).

The RSM has an area of 2,340 ha that is inserted in the Environmental Protection Area of Guaraqueçaba (Straube & Urban-Filho 2005) that covers 282,444 ha (SISBIO 2015) of Atlantic Forest (IBGE 2012). Due to its colonization history, the RSM has different vegetation succession stages. We carried out samplings in a secondary vegetation, with canopy of 12 to 25 meters high of Dense Submontane Forest.

Sampling protocol

Samplings were carried out between September 2013 and August 2014, during 61 capture nights (an average of six nights monthly). Capture nights were not consecutive in cases of heavy rain, so not all months had six capture nights. The capture of bats was performed with mist nets installed at different heights, which aimed to sample the different strata (understory, sub-canopy and canopy) used by bats. Thus, for each night, 18 nets were opened – three nets of 12 x 2.5m; nine nets of 9 x 2.5 m and six nets of 6 x 2.5 m – all Avinet brand with mesh of 36 mm. Nets were installed inside and in forests edges, on trails and over a water body, opened for six hours after the twilight and checked every 20 minutes. The total sampling effort was 139,995 m².h (Straube & Bianconi 2002).

The bats captured were allocated in individual cotton bags and taken to the field base, where they were identified.
There, we did biometrics and tagged each specimen with numbered metal rings. After that, the specimens were released where they were caught. For all captured species, up to 10 individuals were collected as testimonial material, fixed in humid via and forwarded to the scientific collection of Laboratório de Zoologia e Ecologia de Vertebrados (LABZEV) of the Universidade do Extremo Sul Catarinense (Appendix 1). All procedures followed the American Society of Mammalogists protocols for the use of mammals in research (Sikes et al. 2016). The taxonomic identification followed Barquez et al. (1999), Gardner (2007) and Díaz et al. (2016).

The sample sufficiency was calculated by the species accumulation curve using the rarefaction method, considering each night as a sampling unit. In addition, Chao1 and Bootstrap estimators were the inventory complementary analysis. We used Chao1 since this estimator allows us to assess the richness expected in the sampling area taking into consideration the number of species represented in one or two sample units (giving more weight to rare species). On the other hand, we used Bootstrap because it weights all species equally, not considering their frequency or abundance (all species are given equal weight). Since our species abundance are almost equally divided between rare and abundant species, we believe it is efficient to estimate richness in these two different ways, so similar results from both estimators may reach more confident results.

The analysis were performed in the software EstimateS 9.1 (Colwell 2013) considering 999 randomizations. Recapture were not considered in sample sufficiency, although rates were calculated for each species.

RESULTS

We obtained 1 201 captures of 1 008 individuals, with a recapture rate of 16.06% from 25 species from two families and 18 genera (Table 1). Phyllostomidae was the dominant family in terms of capture number (98% of the sample) and richness (20 species) when compared to Vespertilionidae – 2% of the sample and five species. *Artibeus lituratus (n =249), Artibeus fimbriatus (n =200) and Carollia perspicillata (n =167) were the most frequent species (Table 1), which together correspond to 51.29% of the sample. A total of 193 recapture events were recorded involving 10 species (Table 1), of which Carollia perspicillata (33,53%), *Sturnira tildae (29,91%) and *Artibeus fimbriatus (16%) have the highest recapture rates (Table 1).

The accumulation species curve shows an asymptote trend (Fig. 2). The estimators Chao1 and Bootstrap indicate the occurrence of 26.1 and 26.6 species respectively, what suggests that 95.7% and 93.9% of the total expected species for RSM area were sampled.
Fig. 2. Cumulative bat species sampled and the species richness estimated by rarefaction method, based on the standardized samples sampled at Reserva Particular do Patrimônio Natural Salto Morato (RNSM), located in Guaraqueçaba, northern coast of Paraná state.

Table 1

Bat species captured in the Reserva Particular do Patrimônio Natural Salto Morato (RNSM), located in Guaraqueçaba, northern coast of Paraná state. Recaptures are expressed in absolute numbers and in percentages (%).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Captures</th>
<th>Recaptures</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYLLOSTOMIDAE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Carollia perspicillata</em> (Linnaeus, 1758)</td>
<td>167</td>
<td>56</td>
<td>33.53</td>
</tr>
<tr>
<td><em>Desmodus rotundus</em> (É. Geoffroy, 1810)</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Anoura caudifer</em> (É. Geoffroy, 1818)</td>
<td>44</td>
<td>2</td>
<td>4.54</td>
</tr>
<tr>
<td><em>Anoura geoffroyi</em> Gray, 1838</td>
<td>18</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Glyphonycteris sylvestris</em> Thomas, 1896</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Lampronycteris brachyotis</em> (Dobson, 1879)</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Chrotopterus auritus</em> Peters, 1856</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Mimon bennettii</em> (Gray, 1838)</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Trachops cirrhosus</em> (Spix, 1823)</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Artibeus fimbriatus</em> Gray, 1838</td>
<td>125</td>
<td>20</td>
<td>16.00</td>
</tr>
<tr>
<td><em>Artibeus lituratus</em> (Olfers, 1818)</td>
<td>249</td>
<td>29</td>
<td>11.65</td>
</tr>
<tr>
<td><em>Artibeus obscurus</em> (Schinz, 1821)</td>
<td>200</td>
<td>28</td>
<td>14.00</td>
</tr>
<tr>
<td><em>Chiroderma doriae</em> Thomas, 1891</td>
<td>11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Dermanura cinerea</em> Gervais 1856</td>
<td>57</td>
<td>7</td>
<td>12.28</td>
</tr>
<tr>
<td><em>Pygoderma bilabiatum</em> (Wagner, 1843)</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Platyrhinus recifinus</em> (Thomas, 1901)</td>
<td>40</td>
<td>1</td>
<td>2.50</td>
</tr>
<tr>
<td><em>Sturnira lilium</em> (É. Geoffroy, 1810)</td>
<td>99</td>
<td>14</td>
<td>14.40</td>
</tr>
<tr>
<td><em>Sturnira tildae</em> de la Torre, 1959</td>
<td>117</td>
<td>35</td>
<td>29.91</td>
</tr>
<tr>
<td><em>Vampyressa pusilla</em> (Wagner, 1843)</td>
<td>19</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Vampyrodes caraccioli</em> (Thomas,1889)</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>VESPERTILIONIDAE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Myotis nigricans</em> (Schinz, 1821)</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Myotis riparius</em> Handley, 1960</td>
<td>11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Myotis ruber</em> (É. Geoffroy, 1806)</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Eptesicus brasiliensis</em> (Desmarest, 1819)</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Eptesicus diminutus</em> Osgood, 1915</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1201</td>
<td>193</td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION**

We recorded a high species richness at RSM ($n = 25$ spp.), reinforcing that the Coastal region of Paraná is an important area for bat conservation in the Atlantic Forest (Varzinczak et al. 2015). Considering that there are 70 species in the entire State and 71 in Brazil’s South Region, RSM shelters 35.7% and 35.2% of the bat fauna for these regions, respectively (Passos et al. 2010; Carvalho et al. 2014; 2017;
Portella et al. 2017; Carvalho et al. 2019). Also, for Vampyrodes caraccioli and Lasiusurus egregius this is the unique location with a confirmed record in the State (Carvalho et al. 2014; 2019). For Glyphonycteris sylvestris, the records at RSM represent its second confirmed record in Paraná state, also captured at the Parque Nacional do Iguaçu (Sekiama et al. 2001). Furthermore, Chiroderma doriae, Chrotoperus auritus and Mimon bennetti are included as priority species for conservation actions in Paraná (Miranda et al. 2009). These characteristics show the important role that RSM plays to conserve bats in the Atlantic Forest, mainly in its southern portion.

Our data about the species accumulation curves, with the richness estimators, suggest that the composition of the bat assemblage in RSM was enough sampled (95.7% and 93.9%). This scenario is probably given to two attributes: (1) sampling at different heights, that provides detailing of the bat fauna composition (Bernard 2001; Carvalho et al. 2013; Gregorin et al. 2017); and (2) the high number of captures \((n = 1,008\) captures, more 193 recaptures). It is estimated that, at least for phyllostomids in Atlantic Forest of southeast Brazil, 1,000 captures are required to consider an area as successfully sampled (Bergallo et al. 2003). This number was overcome in the RSM (Number of Phyllostomidae captures: 1,174 individuals, see Table 1). However, even with sampling sufficiency for that family, species as Artibeus planirostris (Spix, 1823), Tonatia bidens (Spix, 1823), Myotis levis (I. Geoffroy, 1824), Molossus molossus (Pallas, 1766), Molossus rufus (E. Geoffroy, 1805), Thyroptera tricolor Spix, 1823 and Lasiusurus egregius (Peters, 1970) were not recorded on the present study. This number was overcame in the RSM (Number of Phyllostomidae captures: 1,174 individuals, see Table 1). However, even with sampling sufficiency for that family, species as Artibeus planirostris (Spix, 1823), Tonatia bidens (Spix, 1823), Myotis levis (I. Geoffroy, 1824), Molossus molossus (Pallas, 1766), Molossus rufus (E. Geoffroy, 1805), Thyroptera tricolor Spix, 1823 and Lasiusurus egregius (Peters, 1970) were not recorded on the present study even been recorded in the RSM yet (Kaku-Oliveira 2010; Passos et al. 2010; Carvalho et al. 2019). Even enough sufficiently sampled inventories, as ours, tend to not record all the occurring species in a given area.

The abundance pattern of bat species at RSM is similar to what was observed in other Atlantic Forest assemblages (Esberard 2003), and in most of the Neotropical environments (Estrada & Coates-Estrada 2002; Bernard& Fenton 2002; Bordignon & Franço 2009): Few species are abundant, and the vast majority is rare. Among the species with greater number of captures, Artibeus lituratus, Carollia perspicillata, Artibeus fimbriatus and Sturnira lilium are among the most abundant in Southern Brazil (Sekiama et al. 2001; Bianconi et al. 2004; Reis et al. 2006; Carvalho et al. 2013), including the Paraná state (Kaku-Oliveira 2010; Rubio et al. 2014). This characteristic is associated to the ecological tolerance of these species, which can adapt to modified environments (Reis et al. 2006).

The recapture rate was high when compared to other studies developed in the Atlantic Forest (Esberard et al. 2014) recaptured an average of 9 and Bôlla et al. (2017) an average of 6 bats per year. For two species (Carollia perspicillata and Sturnira tildae) recapture rates were over 29%, which could indicate changes in the habitat use patterns caused by anthropic impacts as lack of food, increasing in individuals displacement and diminishing foraging sites fidelity (Pedro et al. 2001) or even a natural fluctuation, as suggested by Aguirre et al. (2003). Nevertheless, this hypothesis seems not been justified since RSM is a Conservation Unit inserted in a large continuous of Atlantic Forest. Other possibility is that this attribute is related to biological and ecological characteristics of species, as space use. Carollia perspicillata potentially presents large foraging territory (Heithaus et al. 1975), but the effectively used area can be very small (Fleming et al. 1972; Cloutier & Thomas 1992), justifying its high recapture rate. We could not find data on this attribute for Sturnira tildae.

Comprehending how bats explore the environment is fundamental to evaluate the dynamics of the assemblages in natural and fragmented areas. The temporal availability of food resources may also influence the recapture rate. Species such as Carollia perspicillata, Sturnira tildae and Sturnira lilium, that base their diets in resources with small temporal variation in their availability (e.g. Marinho-Filho 1991; Mello et al. 2004; 2008; Barbosa-Marquez & Aguirre 1999), tend to show greater fidelity to the foraging areas. Species that use resources that vary less temporally tend to show smaller foraging areas, what would elevate the recapture rates. Those species that use ephemeral resources, which require moving through a larger area to reach energy demand (Passos et al. 2010; Bianconi et al. 2006; Mello 2009) tend to be less loyal to foraging sites (Egert-Berg et al. 2018). The habitat use is a complex characteristic, that is related to several factors (biotics, abiotics and ecological).

In the opposite, species as Artibeus fimbriatus, Artibeus lituratus and Artibeus obscurus, that use the resources with high temporal variation (Passos et al. 2010; Passos & Graciolli 2004), tend to show lower fidelity to foraging locations, mainly the males (Lewis 1995). In addition, A. lituratus is known by its long-distance displacements (see Bianconi et al. 2006; for displacements recorded with banding method):
19.4 km (Carvalho et al. 2017) and 113 km (Arnone et al. 2016), both in the Atlantic Forest.

Due to the high anthropogenic influence on Atlantic Forest environments, studies developed in conserved areas, such as RSM, are of great importance. The data collected at these areas enable conservationists and stakeholders to evaluate the impact of anthropic actions over the biodiversity of bats and other species related. Moreover, because it is a Conservation Unit, the data resulting from the studies about assemblages’ composition can assist the management and administration of other protected areas too, as well as species conservation actions in situ.

ACKNOWLEDGMENTS

The legal licenses to capture, mark and collect bats were granted by SISBIO under the number 36103-3. We thank Fundação Botânica de Proteção à Natureza for the financial and logistical support for the for the research (Partnership term RNSM_089_2018); FAPESC for financial support to LABZEV (Edital Jovens Pesquisadores, Termo de Outorga N°: 2017TR1706); CAPES for the doctoral scholarships granted to BFLL, VM and Master Scholarship granted to LSB and CNPq to the Master Scholarship granted to DASB.

LITERATURE CITED


Carvalho, F., V. Mottin, J. M. B. Miranda, & F. C. Passos. 2014. First record of Vampyronydes caraccioli (Thomas, 1899) (Chiroptera: Phyllostomidae) for the state of Paraná, and range extension to southern region of Brazil. Check List 10: 1189-1194. https://doi.org/10.15560/10.5.1.1189


APPENDIX 1

List of bats collected as testimonial material, at Reserva Particular do Patrimônio Natural Salto Morato (RSM), located in Guaraqueçaba, northern coast of Paraná state. These voucher specimens are available at Labotarório de Zoologia e Ecologia de Vertebrados of the Universidade do Extremo Sul Catarinense.