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ORIGINAL ARTICLE

Biology of *Phyllostomus hastatus* (Pallas, 1767) (Chiroptera, Mammalia) From Two Urban Parks at Rio de Janeiro, Brazil

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RESUMO

Biologia de *Phyllostomus hastatus* (Pallas, 1767) (Chiroptera, Mammalia) em dois parques urbanos no Estado do Rio de Janeiro, Brasil. Estudos sobre a biologia de morcegos, englobando hábitos alimentares, reprodução e parasitologia são importantes para conhecer o papel desses pequenos mamíferos no ecossistema, porém poucas pesquisas apresentam essas informações. O presente artigo foi feito no intuito de reunir informações sobre a biologia de *Phyllostomus hastatus*, e comparar os resultados entre dois parques urbanos da cidade Rio de Janeiro (Rio de Janeiro, Brasil): Parque Natural Municipal da Freguesia (PNMF), e Parque Estadual da Pedra Branca (PEPB), sendo este último consideravelmente maior que o anterior. Trabalhos de campo de longa duração foram conduzidos nas duas áreas, e dados sobre a biometria, reprodução, parasitos e dieta foram obtidos. Os animais foram capturados com redes de neblina e colocados em sacos de algodão, de onde foi retirado o material fecal para posterior análise. Eles foram medidos vivos e foi observada a condição reprodutiva; ectoparasitos foram coletados e, quando possível, esfregaços sanguíneos foram feitos. Os animais foram soltos ao final do trabalho de campo. Em laboratório as fezes e os esfregaços foram analisados. Como resultado, foram capturados 53 espécimes de *Phyllostomus hastatus*, 13 do PNMF e 40 do PEPB. Encontramos indivíduos com medidas menores no parque mais antropizado - PNMF; a reprodução ocorreu entre setembro e dezembro nos dois parques; a dieta incluiu Curcubitaceae, Urticaceae, Bombacaceae, Lythraceae, Coleoptera, Lepidoptera, Hemiptera e Diptera. Sobre ectoparasitos, Diptera e Acari foram encontrados; não havia hemoparasitos nas amostras de sangue. Apesar de no menor parque haver mais animais afetados por influência antrópica, nossos resultados reforçam a ideia de que a criação de áreas preservadas pequenas é importante para a manutenção de espécies, pois elas podem servir como corredores ecológicos e fornecem alimentos para os animais.

Palavras-chave: Biometria, Dieta, Morcegos, Parasitos, Reprodução.

ABSTRACT

Studies about bats biology encompassing diet, reproduction and parasitology are important to understand the role of these small animals in the ecosystem. However, few studies present such information. Therefore, the present paper was made to congregate information about biology of *Phyllostomus hastatus*, and compare the results between two urban parks at Rio de Janeiro City (Rio de Janeiro, Brazil): Parque Natural Municipal da Freguesia (PNMF) and Parque Estadual da Pedra Branca (PEPB), the latter being considerably larger than the other one. Long-term fieldworks were conducted in both areas and data on biometry, reproduction, parasites and diet were assembled. Animals were captured in mists nets and put in cotton sacs, from where fecal material was collected for further analysis. They were measured alive and inspected for reproductive stage; ectoparasites were collected and blood smears were made whenever possible. Bats were released at the end of the fieldwork. The feces and blood material were analyzed at the lab. Thus, 53 specimens of *Phyllostomus* were captured, 13 from PNMF and 40 from PEPB. We found individuals with smaller measurements at the most anthropized park – the Freguesia Park; reproduction occurred between September and December at both parks; diet included Curcubitaceae, Urticaceae,

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Bombacaceae, Lythraceae, Coleoptera, Lepidoptera, Hemiptera and Diptera. Concerning ectoparasites, Diptera and Acari were recorded; no haemoparasites were found in the blood smears. Although specimens from the smaller park seem to be most affected by anthropization, our results reinforce the idea that the creation of small parks is important for species maintenance, since it may serve as ecological corridor and as a food source for the animals.
Keywords: Bats, Biometry, Diet, Parasites, Reproduction.

INTRODUCTION

The Greater Spear-nosed Bat, *Phyllostomus hastatus* (Pallas, 1767), is one of the largest bat species in the Americas, distributed in several phytophysiognomies from Belize to southeastern Brazil, including parts of Bolivia and Peru (Santos et al., 2003). This mammal occurs in both forested and urban areas, presenting an omnivorous diet that may include fruits, flowers, insects, and small vertebrates, even other bats (Carvalho, 1961; Silva & Peracchi, 1995; McNab, 2003; Santos et al., 2003). The reproduction varies geographically, being monoestrous or polyestrous (Santos et al., 2003).

Little is known about interactions of *P. hastatus* and parasites – studies report dipterans (Hexapoda) and mites (Acarii) as ectoparasites and the presence of hemoparasite *Trypanosoma* (Euglenozoa) (Marshall, 1982; Giorgi et al., 2001; Raharimanga et al., 2003; Dias et al., 2008; Cottontail et al., 2009; Portella, 2010). Among endoparasites, studies conducted at Central America, South America and Mexico found Nematoda (Ubelaker et al., 1979), Acanthocephala (Gibson & McCarthy, 1987), Cestoda (Travassos, 1965) and Trematoda (Marshall & Miller, 1979; Castiblanco & Veléz, 1982) associated to this bat species.

It is largely known that urban factors affect bats biology, such as artificial lightening (Boldogh et al., 2007), road traffic (Zurcher et al., 2010), indiscriminate pollution (Kunz et al., 1977) and deforestation (Fenton et al., 1992). Some factors may affect bats positively, such as artificial lightening attracting insects (Tomassini et al*.,* 2014), however there are studies correlating a better life condition and major number of bats in less impacted areas (Fenton et al., 1992; Russo & Ancillotto, 2015). Also, small remnants house lower density of mammals than big areas (Chiarello, 2008). Our study was conducted in two parks, one smaller and most anthropized and other bigger and more far away from the urban areas, so we could see differences between areas with variances of anthropogenic interference.

Despite the ecological associations described above, data on the interactions of these animals are still scarce, especially in urban areas. And bats, beside its abundance in anthropogenic areas, may have a degraded life condition due to human interference, which can contribute with changes in their biology. Although distributed in great part of the Neotropical region, few studies were published about the *Phyllostomus* species biology. Bats have an important ecological and economic role, and knowledge about then may help understand and valorize these animals, contributing for future research and environment conservation plans. All things considered, the present paper aims to report information about *P. hastatus* - including its biometry, diet, reproduction and parasitology - from two urban parks at Rio de Janeiro City (Rio de Janeiro, Brazil).

MATERIALS AND METHODS

The study was conducted in two areas from the Rio de Janeiro City (Rio de Janeiro State, Brazil): Parque Natural Municipal da Freguesia (PNMF) and Parque Estadual da Pedra Branca (PEPB), both located at the western zone of the city, with 5,444 m distanced one from another (Figure 1). The PNMF (-22.933 3S, -43.333 3N) is an area of 31 ha in the district of Jacarepaguá. Placed in a region between the PEPB and Parque Nacional da Tijuca, it is composed essentially by secondary forest – in the past it used to be a farm and since 1989 it is recognized as a municipal conservation unit – presenting vegetation at medium or initial stage of regeneration, however still displaying exotic species; this area was originally a Pioneer Formation and Dense Lowland Ombrophilous Forest (Silva et al., 2010). The PEPB (-22.9405 S, -43.4805 W) is one of the biggest urban forests in the world (INEA, 2015), with an area of 12,393.84 hectares, housing more than 50% of remaining Atlantic Forest of the city, also harboring endangered, endemics, and rare species besides exotics ones, such as *Artocarpus heterophyllus* (jack fruit) and *Mangifera indica* (mango trees) (INEA, 2015).

At PNMF the collects were conducted from September 2011 to March 2018. Two mist nets (9 x 2.5 m; 20 mm) were installed along three park trails, approximately from 5 PM to 10 PM. Collects were performed once a month at PEPB (9 x 2.5 m; 20 mm), with three to four mist nets from June 1994 to October 2010, approximately from 6 PM to 12 PM. Nets were extended at the floor level in both places.

After being captured in mist-nets, bats were kept in individualized cotton bags in order to obtain fecal samples. These cotton bags were always washed after the fieldwork to avoid contamination. Each specimen was measured and weighed in the field, being inspected for reproductive stage and presence of ectoparasites, which were collected with forceps and placed in distinct vials containing 70% ethanol. All animals were ringed and released after each capture night. The body mass and sizes of the bats in between the parks were compared using statistical tests (t test and Wilcoxon), in order to understand if there is any difference in these factors and if they are related to the level of anthropogenic influence – assumed to be higher in the PNMF.

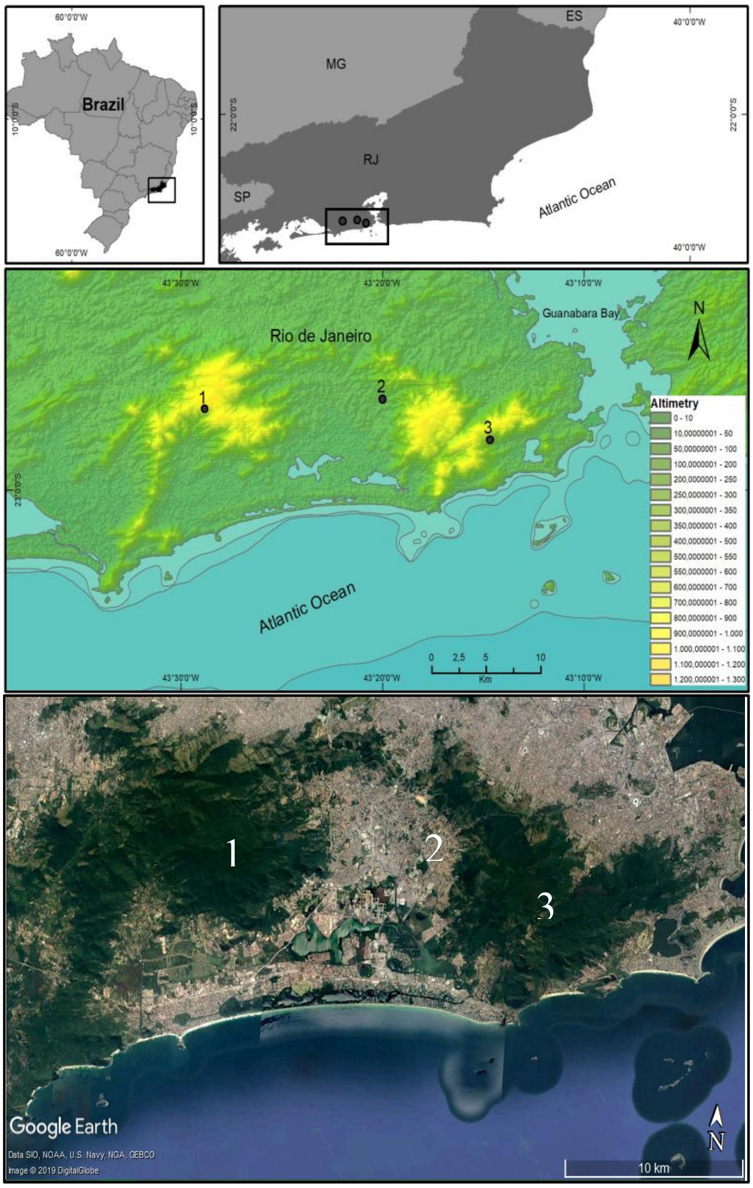

Figure 1. Map showing the two study sites, Parque Estadual da Pedra Branca (1) and Parque Natural Municipal da Freguesia (2), and the Parque Nacional da Tijuca (3), a conservation unit placed close to these parks; all three are located at the Rio de Janeiro City (Rio de Janeiro State, Brazil). Google Earth image highlights the differences in size and the proximity to urban districts.

After mounted in permanent slides, the ectoparasites identification was made with the aid of a stereomicroscope, using the taxonomical keys available in the literature. The ectoparasites are deposited in the Entomological and Acarological collection of the Laboratory of Entomological Biodiversity of the Oswaldo Cruz Institute (FIOCRUZ). Fecal samples were also placed in distinct vials, being dismantled under stereomicroscope (40 x) at the laboratory for the identification of consumed food items, which were placed in permanent slides and identified with the aim of available literature (Shiel et al., 1997; Kruger et al., 2018). Blood smears were obtained from the peripheral blood (propatagial vein) of some specimens of PNMF through usual procedures for observation under light microscope. The material was then prepared with quick panotic stainning and analyzed under light microscope (oil lens; 1,000 x) at the laboratory. The bats incorporated as vouchers are deposited in the Adriano Lúcio Peracchi collection (ALP) at the Universidade Federal Rural do Rio de Janeiro (UFRRJ). The ectoparasites are deposited in the Entomological and Acarological collection of the Laboratory of Entomological Biodiversity of the Oswaldo Cruz Institute (FIOCRUZ). Authorization for activities with scientific purposes follows: ICMBio 22393-4 (PNMF), and IBAMA: 1598-1, 11598-2, 11666-1; ICMBio: 18852-1 / 22393-1; INEA: 023 / 2011 (PEPB).

RESULTS

Fieldwork at PNMF was shorter in comparison to that at PEPB: the capture effort was 14,310 m^2 / h and 34,020 m^2 / h, respectively (following Straube & Bianconi, 2002). As a result, 53 specimens of *P. hastatus* (Figure 3A) were collected – 13 from a total of 603 bats registered at PNMF (2.2%) and 40 from a total of 1163 bats registered at PEPB (3.4%). From the total number of bats captured in the PEPB, five specimens were incorporated as vouchers (ALP 5678; 5775; 5776; 5785; 5786), all animals captured in the PNMF were ringed and released; no recapture was recorded. Pregnant females were observed during the spring at both PNMF and PEPB. This corresponds with descended scrotal testes in males, suggesting that reproduction occurs from September to December in both fragments.

Unfortunately, there was a lack of measures of some individuals at PEPB due to technical equipment problems. However, data obtained show that the specimens' body mass varied from 64.0 to 118.5 g, being the specimens lighter at PNMF: one male and one female. There is not enough data available from PEPB to make a proper comparison. Total length was similar in animals from both places ($p = 0.01$), but again the smaller individuals were found at PNMF. Forearm measure indicates a female sexually inactive at PNMF with smaller size (65.3 mm); from the same place, a male in reproductive period had presented very small ear size (7.4 mm) in comparison to the mean around 15 to 33 mm. A higher variance was found in foot sizes – from 14 mm (PEPB) to 36.5 mm (PNMF), although statistic test does not confirm this ($p = 1$). At PNMF one female sexually inactive presented a 7.4 mm tibia, smaller than the other specimens. Calcaneus size had no discrepancy in size, and the tail varied from 10 mm (PEPB) to 28.9 mm (PNMF). As seen, in most measures the specimens from PNMF obtained the smallest numbers, and statistics test (t test and Wilcoxon) confirmed the differences between total length, tibia ($p = 0.04$) and tail ($p = 9.034e^{-07}$). The intervals of measurements for the specimens, organized by reproductive condition, are presented in the Table 1. Also, mean and standard deviation for the values, presented in Table 2, shows major differences in the total length, forearm and tibia measurements (all bigger at PEPB). Only tail presented a bigger score at PNMF.

Table 1. Biometric data from *Phyllostomus hastatus* individuals collected in PNMF and PEPB (Rio de Janeiro, Brazil). Legend – MSI: male sexually inactive; MRP: male in reproductive period; FSI: female sexually inactive; PF: pregnant female; LacF: lactating female.

	nº	Body mass (g)	Total length (mm)	Forearm (mm)	Ear (mm)	Foot (mm)	Tibia (mm)	Calcaneus (mm)	Tail (mm)
PNMF									
MSI	2	90.0 - 113.0	95.8 - 100.0	85.9 - 88.6	19.7 - 22.5	34.0 - 35.9	21.2 - 27.1	20.5 - 24.3	20.6 - 26.4
MRP	1	64.0	101.0	88.6	7.4	18.8	-	20.5	12.0
FSI	6	64.0 - 104.0	84.5 - 104.5	65.3 - 89.3	20.0 - 21.6	26.8 - 36.5	7.4 - 24.1	18.5 - 27.4	15.7 - 20.0
PF	4	92.0 - 107.0	88.4 - 102.4	80.8 - 89.7	18.4 - 23.0	29.9 - 32.4	20.1 - 27.8	20.2 - 29.8	19.9 - 28.9
LacF	-	-	-	-	-	-	-	-	-
PEPB									
MSI	20	102.8 - 118.5	90.0 - 118.7	83.7 - 92.6	15.0 - 33.0	16.1 - 33.0	27.0 - 38.6	18.4 - 35.0	11.1-24.3
MRP	1	-	116.9	87.2	23.8	18.1	33.5	25.0	20.0
FSI	14	95.2	90.2 - 115.7	84.3 - 89.9	18.3 - 33.4	14.0 - 25.0	28.5 - 56.6	20.6 - 27.0	10.0 - 21.0
PF	2	-	-	84.5 - 87.5	-	-	-	-	-
LacF	3	-	95.9 - 100.2	85.7 - 90.2	21.5 - 29.0	17.2 - 21.9	29.8 - 36.0	21.6 - 24.6	16.2 - 21.0

Considering the diet, bats at PNMF consumed Curcubitaceae (Figure 2B) and Urticaceae plants; among insects, it was possible to identify consumed specimens from the following insect (Hexapoda) groups: Coleoptera (including some Curculionidae), Lepidoptera, Hemiptera and Diptera. At PEPB the items consumed included insects, pollen, and pulp; plants were identified as Bombacaceae (Figure 2C), Lythraceae and Urticaceae (Cecropiaceae).

Table 2. Mean and standard deviation (SD) for measurements (in mm) from *P. hastatus* specimens at PNMF and PEPB (Rio de Janeiro, Brazil).

	Total lenght	Forearm	Foot	Tibia	Calcaneus	Ear	Tail
Mean PNMF	97.1	84.2	19.3	30.8	21.3	24.0	30.8
SD PNMF	5.5	6.3	4.2	4.5	5.2	3.8	4.5
Mean PEPB	103.2	87.0	20.6	34.6	23.4	23.1	17.8
SD PEPB	8.0	2.1	3.7	4.5	3.1	4.6	4.5

At the PNMF, 53.8% of bats had ectoparasites, and 27.5% at the PEPB. Seven from the 13 bats collected at PNMF were parasitized by dipterans (Streblidae), being two females at reproductive period. At PEPB, 11 from the 40 bats had Diptera (Streblidae) and/or Acari ectoparasites: Streblidae – *Trichobius longipes* (Rudow, 1871), *Paratrichobius longicrus* (Miranda-Ribeiro, 1907), *Trichobius joblingi* (Wenzel, 1966) and *Trichobius dugesioides* (Guerrero, 1998); Acari – *Periglischrus torrealbai* (Machado-Allison, 1965) (Spinturnicidae) (Figure 2D) and *Eudubasbekia* sp. (Myobiidae). The analysis of blood smears didn't reveal the presence of haemoparasites. One specimen from each park displayed alopecia at the abdomen and chest in the PNMF (Figure 3), and in the PEPB individual it was at the dorsal base of the tail.

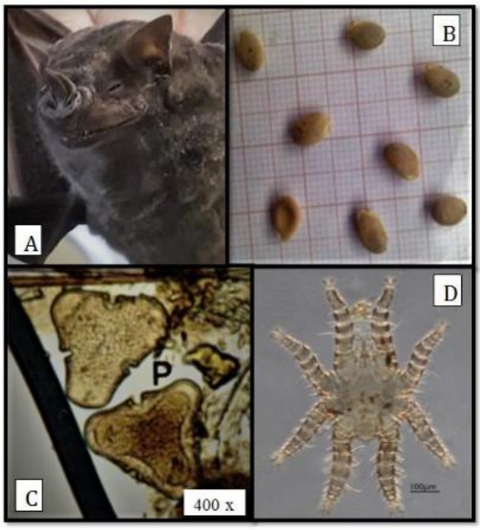

Figure 2. *Phyllostomus hastatus* collected at PNMF (A); Seeds of Curcubitaceae (B); Pollen of Bombacaceae (C); Ectoparasite: *P. torrealbai* male (D). Photos: Isabela S. Bellizzi (A); Isabel C. Resende (B); Shirley S. P. Silva (C); Juliana C. Almeida (D).

Figure 3. *P. hastatus* specimen from PNMF with alopecia at abdomen and chest (Photo: Isabel C. Resende).

DISCUSSION

Considering the body measurements presented in Reis et al. (2013) for *P. hastatus* – total length between 94 and 124 mm, forearm length from 77 to 93 mm and body mass from 64 to 112 g – the specimens collected in our study are in accordance with exception of five animals with total length smaller, and one female with a smaller forearm. Besides that, most measures indicated smaller individuals at PNMF with statistical difference in total length, forearm, tibia and tail. Another difference between both places is the proportion of bats infected by ectoparasites, most frequent at PNMF. We suppose that differences in body size and the incidence of parasites may be caused by the same factor: the anthropogenic impact. PEPB have a bigger area and suffers less anthropic influence, meanwhile PNMF suffers more the border effect as consequence of its smaller area. It is known that food abundance and prey size influence body size; then a bigger area may host a bigger variety of food resources, a more complex community and proportionate a better life condition (Chiarello, 1999; Ashton et al., 2000; Freckleton et al., 2003). Human alterations affect bats hibernation pattern (Thomas, 1995), immunity (Quarles, 2013), and food availability (Bourne & Hamilton-Smith, 2007). Also, urban illumination may retard the exit to foraging, reducing the time of alimentation, thus generating smaller and lighters individuals (Boldogh et al., 2007).

Two females were caught in the reproductive period, and no relationship was found between reproductive stage and the incidence of parasites. Also, female and males were infected with the similar intensity.

Although the presence of hemoparasites in bats is described elsewhere, we did not notice any data reporting these on bats from PEPB and PNMF. Infestation by helminthes is reported to about one third of South American bats (Santos & Gibson, 2015), and by *Trypasoma* sp., including *T. cruzi* and *T. cruzi marinkelle* (Corrêa et.al., 2013). According to Scott (1988), infestation may occurs by reasons such as nutritional issues and stress.

Reproduction of *P. hastatus* varies geographically, being monoestrous in some areas and polyestrous in another ones (Santos et al., 2003). In our study, we concluded that their reproduction occurs from September to December in both researched areas. A study made in the Brazilian Cerrado relates pregnancy from April to October, and lactation in September to April (Willig, 1985), differently of the pattern found. Fleming et al. (1972) reported lactating female at April and May in Panamá. Our data is in accordance with data from Peracchi & Albuquerque (1986) in Rio de Janeiro, where authors relate pregnant females on September. However, the presence of a male in reproductive period at May diverges from the data presently reported by these authors.

Concerning diet, there was no record of *P. hastatus* eating parts of flowers, as described by other authors (Carvalho, 1961; Silva & Peracchi, 1995). They were described feeding on *Parkia gigantocarpa* Ducke, *Parkia pendula* (Willd.) Walp., *Ceiba pentandra* (L.) Gärtner. A, *Pseudobombax grandiflorum* (Cav.) A. Robyns, *Cecropia* spp., *Gurania lobata* (L.) Pruski, *Lecythis* spp., and specimens from Lythraceae, Urticaceae (including Cecropiaceae) and Curcubitaceae (Carvalho, 1961; Silva & Peracchi, 1995, Fábian et.al., 2008; Reis et al., 2013). The lasts three families were identified in the present study – Lythraceae at PEPB, Curcubitaceae at PNMF and Urticaceae at both areas. Among insects, Reis et al. (2013) described the inclusion of Coleoptera, Hemiptera, Lepidoptera, Hymenoptera, Orthoptera and Isoptera; all these insect groups were identified among the items consumed, with exception to Isoptera.

The influences of ectoparasites in hosts are reported by some studies as affecting bats causing irritation and physical damage to the skin or hair, due the contact to toxins and/or transmission of pathogenic organisms (Marshall, 1982). Opposingly, Fenton et al. (1992) affirms that bats seem to suffer no particular ill effects from parasites that live in association with them. About 687 described species are known to parasite bats, with six insects (Hexapoda) families involved, such as Arixeniidae, Cimicidae, Polyctenidae, Nycteribiidae, Streblidae and Ischnopsyllidae, all exclusively associated, with exception of Cimicidae (Hemiptera), that also infects birds; phyllostomids are infected by a large number of Nycteribiidae and Streblidae species (Diptera) (Marshall, 1982). In fact, a study made by Portella (2010) related *P. hastatus* as the bat most infected by Streblidae, in agreement with Dias et al. (2008). These information matches with the results here reported – all identified ectoparasites from PNMF were Diptera; at PEPB more than half of ectoparasites was Diptera, Streblidae.

Concerning mites ectoparasites, Bruyndonckx et al. (2009) studied cospeciation between bats and Spinturnicidae; this mite family was recorded at PEPB. The same association is related by Gettinger & Gribel (1989) in Central Brazil Spinturnicidae infesting *Phyllostomus discolor* (Wagner, 1843). A study conducted by Almeida et al. (2011) report that one of the lesser frequent mite family at PEPB is Myobiidae, found in *P. hastatus*. Therefore, mite parasites do not differ from previously researches.

From the 53 individuals, only two had alopecy, with may be related to factors such as biologic dysfunction (vitamin and minerals imbalances, endocrine disorders, immunologic diseases, and genetic mutations); or naturally occurring processes (for example, seasonality, aging). It may also be caused by bacterial, fungal, or parasites infections, or even psychogenic factors, such as stress (Racey, 2004; Novak & Meyer, 2009).

In conclusion, biometry and ectoparasites varied between both studied places; apparently small parks help animal conservation, but larger places are essential to species preservation. Regarding diet, we found major number of fruit and insects consumed, besides it's known they can eat another part of plants and small animals. Reproduction apparently occurs in southern hemisphere spring, specimens being monoestrous in these areas. *P. hastatus* at these Rio de Janeiro parks were infected by Diptera and Acari and no haemoparasite was found. All this information contributes for the development of future research and species conservation, especially for those occupying urban areas.

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