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Species composition and seasonal variation in abundance of Phyllostomidae bats (Chiroptera) in an Atlantic Forest remnant, southeastern Brazil

Abstract: Normally, the Phyllostomidae bat community varies in number of individuals depending on food availability, which in turn varies with changes in annual rainfall. The aims of this study were to list species of Phyllostomidae bats in Curió Municipal Natural Park located in the municipality of Paracambi, state of Rio de Janeiro, southeastern Brazil, and determine possible differences in species richness, abundance and composition between rainy and dry seasons. Sampling was carried out between September 2011 and August 2012 with the use of mist nets. The total sampling effort was 51,840 m^2 h, and 745 individuals of 18 bat species were caught. *Myotis riparius* (Vespertilionidae) was the only non-Phyllostomidae species caught. *Artibeus lituratus* and *Carollia perspicillata* were the most abundant species. The collector curve did not become stabilized, with 21±2 phyllostomid species being estimated for the park. No significant difference in species richness or change in the community composition was found between seasons; however a higher number of individuals was captured in the rainy season. The occurrence of specie indicator of good-quality habitats (*Chrotopterus auritus*, *Micronycteris microtis* and *Trachops cirrhosus*) and species threatened with extinction (*Chiroderma doriae* and *Dermanura cinerea*) indicate that the park is an important forest remnant for the conservation of bats and needs to be monitored.

Keywords: conservation unit; Curió Park; seasonality; species richness.

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Introduction

In Brazil, most publications on mammals involve the Atlantic Forest biome and the state of Rio de Janeiro (Brito et al. 2009). Considering bat communities in the southeastern region of the country, the state of Rio de Janeiro is also well inventoried (Bergallo et al. 2003). However, gaps in the knowledge on these animals remain in a number of areas of the state (Peracchi and Nogueira 2010), such as the Médio Paraíba and Central South regions (Dias et al. 2010), and even areas in the metropolitan region of the city of Rio de Janeiro. Inventories allow biogeographical comparisons and inferences on the ecology of a given taxon and offer data for decision making with regard to the conservation of endangered species (Bergallo et al. 2000a).

The bat community may vary on an annual or seasonal basis depending on the availability of resources (Mello 2009). For instance, the abundance of frugivores in a given location depends on the availability of fruits (Coates-Estrada and Estrada 1986, Mello 2009, Pereira et al. 2010). Moreover, seasonality is a strong factor affecting the distribution of bats, with a higher number of individuals normally found in the rainy season due to the higher availability of food resources, especially for frugivores (Marinho-Filho 1991). Understanding the community structure of Phyllostomidae bats allows analyzing possible differences in the services performed by these bats over time (Mello 2009).

The aims of the present study were to carry out an inventory of species of Phyllostomidae in the Curió Municipal Natural Park and determine possible seasonal differences

in their occurrence. The following null hypotheses were tested: (1) Higher richness and abundance of Phyllostomidae are found in the rainy season, and (2) species composition differs between rainy and dry seasons.

Materials and methods

Study area

The Curió Municipal Natural Park (Curió Park) (22°33′ to 22°36′S, 43°40′ to 43°43′W) is located in the municipality of Paracambi, which is part of the metropolitan region of the state of Rio de Janeiro, Brazil.

Curió Park is a conservation unit created in the year 2002. The park has approximately 914 ha divided among forest remnants, areas in initial, intermediate and late stages of regeneration and important springs that provide water for the municipalities of Paracambi, Engenheiro Paulo de Frontin and Mendes [Secretaria Municipal do Meio Ambiente de Paracambi (SEMA) and Instituto Terra de Preservação Ambiental (ITPA) 2010]. This forest remnant is included to Atlantic Forest, being classified as dense rainforest, with altitudes ranging from 53 to 632 m above sea level.

The park has approximately 240 species of trees, bushes, herbs, creeping plants and vines. The richest families in number of plant species are Myrtaceae, Fabaceae, Lauraceae, Euphorbiaceae, Rubiaceae, Sapotaceae, Moraceae, Sapindaceae, Meliaceae and Bignoniaceae (Amorim 2012, Fraga et al. 2012). Despite the large number of plant species, areas of the park have suffered a high degree of human influence (Fraga et al. 2012). Curió Park is located between the Serra da Bocaina National Park and Tinguá Biological Reserve, which are conservation units in which previous bat surveys have been performed (10 and 28 species, respectively) (Dias and Peracchi 2008, Delciellos et al. 2012). This position between conservation units allows Curió Park to serve as an ecologic corridor (SEMA and ITPA 2010), favoring gene flow among animals and plants.

The climate of the region is classified as Aw by the Köppen-Geiger classification, characterized by a minimum temperature of 18°C in the coldest month and minimum precipitation of <60 mm in the driest month (Kottek et al. 2006). Between June 2010 and October 2012, mean monthly temperatures in the study area ranged from 19°C to 28°C, precipitation ranged from 5 to 261 mm and relative humidity ranged from 64% to 85% (data obtained from the Meteorological Station of the Environmental Monitoring Laboratory of the Paracambi Technological Institute). The rainy season occurred between October and April and the dry season was from May to September (Figure 1). With the exception of February, dry months had mean precipitation of <80 mm.

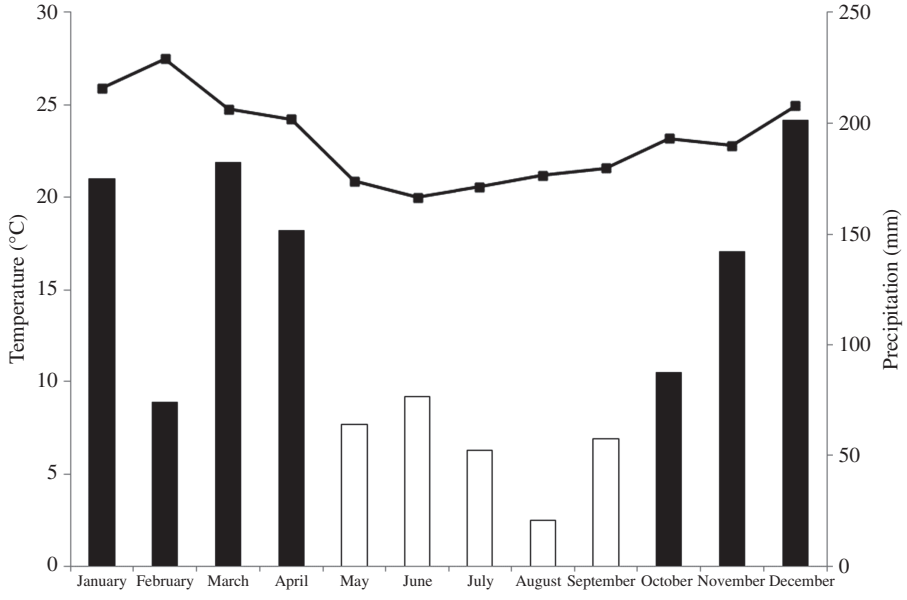

Figure 1 Monthly means of temperature (line) and precipitation (bars) from June 2010 to October 2012 in Curió Municipal Natural Park, municipality of Paracambi, state of Rio de Janeiro, Brazil. Source: Meteorological Station, Environmental Monitoring Laboratory, Paracambi Technological Institute.

Bat sampling

Sampling was performed monthly between September 2011 and August 2012 along two preexisting trails: Escravos Trail (22°35′49″S, 43°42′21″W), approximately 1200 m long, and Jequitibá Trail (22°35′53″S, 43°42′23″W), measuring approximately 800 m. The maximum and minimum distance between the two trails was 930 and 67 m, respectively. For logistical reasons, each of the trails was divided into three portions, which were sampled in the following sequence: first portion in the first month, second portion in the second month and third portion in the third month. The process was then repeated in subsequent months following the same order. The aim of this sampling method was to avoid the reduction in the efficiency of the bat capturing process due to continuous sampling at the same site (Esbérard 2006, Marques et al. 2013).

Bats were caught using six mist nets (12 m×2.5 m; mesh, 40 mm), which were deployed at ground level from dusk to dawn. Sampling nights were preferentially chosen to be near the period of the new moon to maximize the number of frugivorous bats, because species of Phyllostomidae forage less on nights with greater moonlight (Morrison 1978, Esbérard 2007). Captured bats were placed in cloth sacks, preliminarily identified in the field, submitted to forearm and weight measurements, tagged with an individualized collar (Esbérard and Daemon 1999) and released.

Specimens were identified based on Gardner (2007), Dias and Peracchi (2008), Araújo and Langguth (2010) and Miranda et al. (2011). The zoological nomenclature of the species followed Gardner (2007), except for *Dermanura*, which has been elevated to generic status (Redondo et al. 2008, Solari et al. 2009). A maximum of two specimens of each sex and each species were removed to serve as voucher specimens, which are preserved in fluid in the Adriano Lúcio Peracchi Mammal Collection deposited at the Biology Institute of the Universidade Federal Rural do Rio de Janeiro, located in the municipality of Seropédica, state of Rio de Janeiro, Brazil.

Data analysis

The sampling effort was calculated based on the method proposed by Straube and Bianconi (2002). A species accumulation curve was created to estimate species richness based on the accumulated number of species observed as a function of the accumulated number of catches per month (12 samples) (Magurran 2004). The number of expected species was calculated by the nonparametric first-order jackknife estimator (Jackknife-1) using the EstimateS program version 8.0 (Colwell 2005). This estimator is indicated for inventories with few samples and tends to be less likely to overestimate or underestimate richness in a given area (Smith and van Belle 1984, Colwell and Coddington 1994, Hellmann and Fowler 1999).

The t-test was used to analyze seasonal variations in species richness and abundance. One-way analysis of similarity (ANOSIM) with a Jaccard distance matrix was used to determine possible differences in species composition between the rainy and the dry seasons. ANOSIM tests similarity between ranked distances that compose submatrices (groups) of a given matrix (Valentin 2012). This analysis is based on the significance of the R value, which ranges from -1 to 1, for which values close to zero indicate a lack of similarity within or between groups, and values approaching -1 or 1 indicate greater similarity (Clarke 1993). The t-test and ANOSIM were performed using the PAST program version 2.02 (Hammer et al. 2001). For the determination of the structuring of the bat community, bats were classified in feeding guilds according to Kalko et al. (1996), Kalko and Handley (2001) and Mello (2009). Only the first capture of each individual was considered in the analyses.

Results

Over the 12-month period with a total sampling effort of 51,840 m^2 h, 745 individuals distributed among 18 species were captured. With the exception of *Myotis riparius* from the family Vespertilionidae, all species belonged to the family Phyllostomidae, 44% of which were canopy frugivores. *Artibeus lituratus*, *Carollia perspicillata* and *Glossophaga soricina* were the most abundant species, accounting for more than 82% of the catches (Table 1).

The accumulation curve for the species of Phyllostomidae reached the asymptote in the beginning of the sixth month of sampling and the Jackknife-1 estimator was in accordance with the accumulation curve from the third to the sixth month of sampling. However, although the curve continued to be stable in the last month of sampling, the richness estimator calculated 21±2 species for the area, indicating that observed richness probably represented 81% of the richness of Phyllostomidae estimated for the park (Figure 2).

Throughout the year, the monthly number of recorded species ranged from 4 to 12 (mean, 8; standard deviation, 3) (Figure 3). The number of captures ranged from 14 to 44 (median, 25) in the dry season and 41 to

Table 1 Species, voucher number, trophic/foraging guild and number of catches of bats in Curió Municipal Natural Park, municipality of Paracambi, state of Rio de Janeiro, Brazil.

Taxa	Voucher number (ALP)	Guilds	Individuals
Phyllostomidae			
Desmodontinae			
Desmodus rotundus (Ė. Geoffroy, 1810)	♀10289, ♀10291, ♂10263 and ♂10275	A	25
Diphylla ecaudata (Spix, 1823)	♀10301	A	1
Glossophaginae			
Anoura caudifer (Ė. Geoffroy, 1818)	♀10277, ♀10312 and ♂10259	B	6
Glossophaga soricina (Pallas, 1766)	♀10247, ♀10287, ♂10254 and ♂10314	B	46
Phyllostominae			
Chrotopterus auritus (Peters, 1856)	♀10261	C	1
Micronycteris microtis (Miller, 1898)	♀10272, ♀10273 and ♂10278	D	5
Phyllostomus hastatus (Pallas, 1767)	♀10299, ♀10310 and ♂10262	E	11
Trachops cirrhosus (Spix, 1823)	♂10276 and ♂10320	D	2
Carollinae			
Carollia perspicillata (Linnaeus, 1758)	♀10284, ♀10292, ♂10281 and ♂10294	F	211
Stenodermatinae			
Artibeus fimbriatus (Gray, 1838)	♀10307, ♀10323, ♂10282 and ♂10290	G	37
Artibeus lituratus (Olfers, 1818)	♀10293, ♀10317, ♂10280 and ♂10288	G	349
Chiroderma doriae (Thomas, 1891)	♀10260 and ♂10265	G	3
Dermanura cinerea (Gervais, 1856)	♀10285	G	1
Platyrrhinus recifinus (Thomas, 1901)	♀10266, ♀10274, ♂10315 and ♂10318	G	21
Pygoderma bilabiatum (Wagner, 1843)	♂10271 and ♂10304	H	2
Sturnira lilium (Ė. Geoffroy, 1810)	♂10309	H	1
Vampyressa pusilla (Wagner, 1843)	♀10252, ♀10283, ♂10267 and ♂10306	G	10
Vespertilionidae			
Myotinae			
Myotis riparius (Handley, 1960)	♀10268, ♀10269, ♂10270 and ♂10295	I	13
Total	–	–	745

ALP, Adriano Lucio Peracchi Mammal Collection; A, sanguivore; B, nectarivore; C, carnivore; D, gleaning insectivore, E, omnivore; F, understory frugivore; G, canopy frugivore; H, opportunistic frugivore; I, cluttered aerial insectivore.

165 (median, 73) in the rainy season, with a significantly greater number in the latter (t=2.857; df=1; p=0.017; Figure 4A). However, no significant differences between seasons were found regarding species richness (t=1.483; df=1; p=0.168; Figure 4B) or composition (ANOSIM: R=0.072, p=0.279).

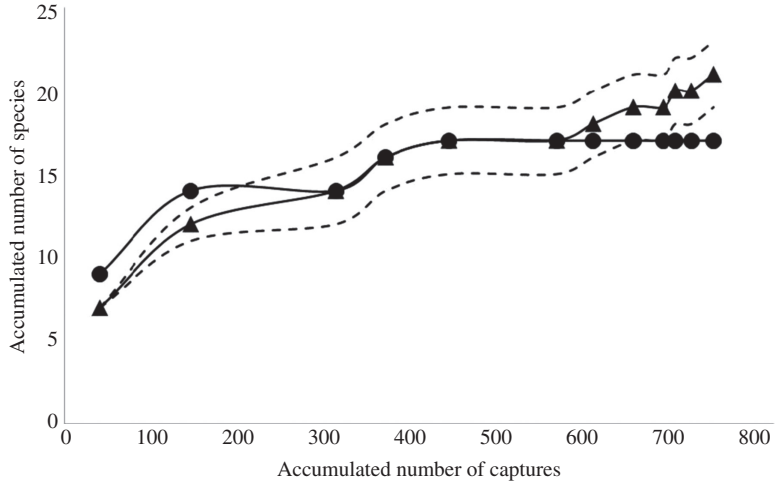

Figure 2 Accumulation curve and richness estimator (Jackknife-1) of species of Phyllostomidae in Curió Municipal Natural Park, municipality of Paracambi, state of Rio de Janeiro, Brazil. Line with circles, observed species; line with triangles, Jackknife-1 richness estimator; dashed line, standard deviation of Jackknife-1 richness estimator.

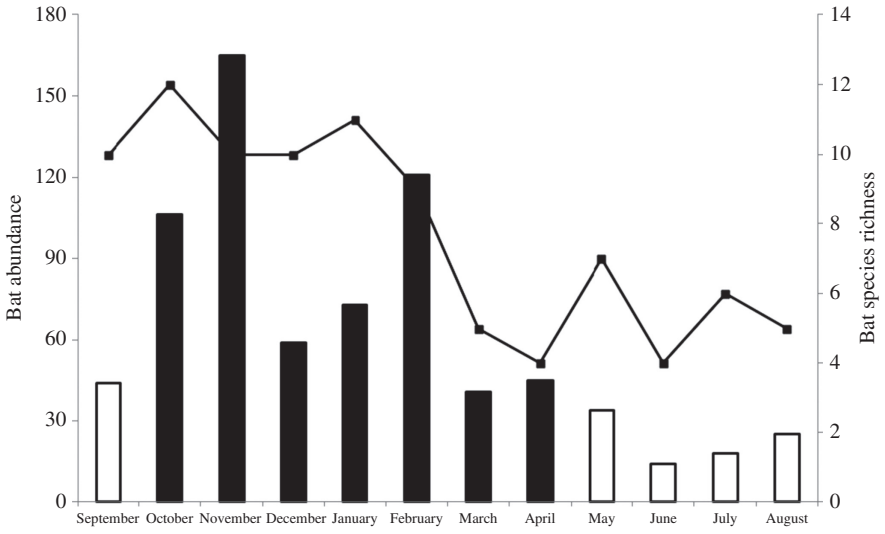

Figure 3 Monthly richness (line) and number of catches (bars) between September 2011 and August 2012 in Curió Municipal Natural Park, municipality of Paracambi, state of Rio de Janeiro, Brazil. Black bars represent rainy months and white bars represent dry months.

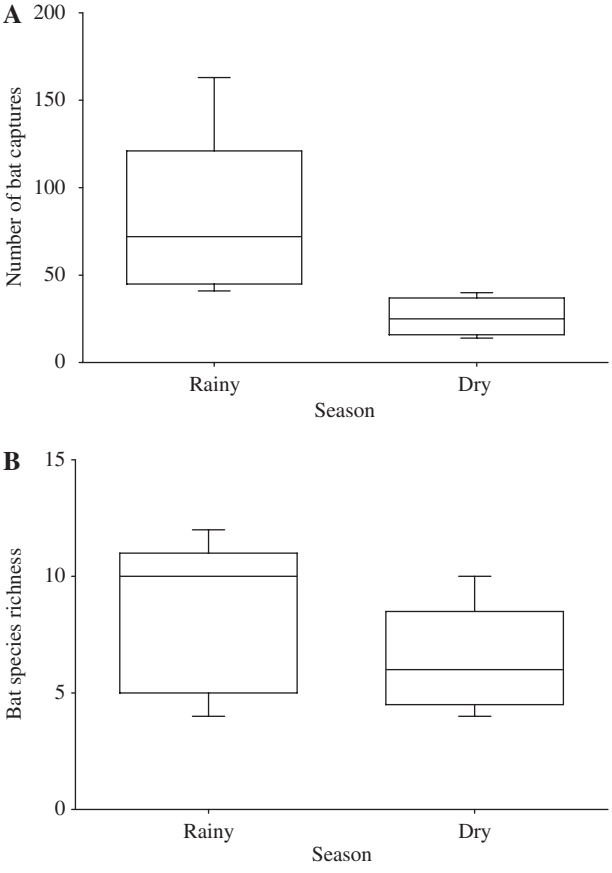

Figure 4 Variation in abundance (A) and richness (B) of bat species between rainy and dry seasons in Curió Municipal Natural Park, municipality of Paracambi, state of Rio de Janeiro, Brazil. In box plots, horizontal line in center of boxes indicates median of data; rectangles adjacent to median indicate quartiles; vertical lines of boxes indicate outliers.

Discussion

As expected, a greater number of bats of the family Phyllostomidae were found in the present study. The methodology employed tends to favor the capture of this family over other families, such as Molossidae, Vespertilionidae and Emballonuridae, which are predominantly aerial insectivores and therefore greatly undersampled when mist nets are deployed on the ground (Kalko et al. 1996, Kalko 1998). The vespertilionid *Myotis riparius* was the only predominantly insectivorous species captured using this method. According to Kalko et al. (1996), aerial insectivorous bats fly high and constantly use echolocation to orient themselves in space, thereby easily detecting and avoiding mist nets. Indeed, it is often difficult to capture bats at their foraging sites due to their keen sensory perception (Kunz and Kurta 1988).

Artibeus lituratus and *Carollia perspicillata* were the most abundant species and they have been normally captured in abundance in other bat studies in the Atlantic Forest (Esbérard 2003, Dias and Peracchi 2008, Mello 2009, Delciellos et al. 2012). These frugivores feed primarily on pioneer plants, such as *Cecropia* spp. (Urticaceae) and *Ficus* spp. (Moraceae) for *A. lituratus*, and plants of the genus *Piper* (Piperaceae) for *C. perspicillata*, that are more common around clearings (Válio and Scarpa 2001). Thus, the fact that trails are cleared environments with a greater incidence of light and consequently greater abundance of pioneer plants in the vicinity also contributed to the greater catch rates of *A. lituratus* and *C. perspicillata* in these places. Sampling in areas beyond trails may

confirm whether the abundance pattern of these species is maintained.

Despite the greater number of individuals caught in the rainy season, no seasonal difference in species richness was found. Herein, frugivores made up the majority of captures. Considering that in the Atlantic Forest fruit availability is higher in the rainy season (Marinho-Filho 1991), the larger number of bat catches in rainy season in the studied area may have been due to an increase in local food availability. The low number of specimens caught in the dry season may also be explained by the fact that bats disperse in search of other food sources (Marinho-Filho 1991). According to Mello (2009), bats adjust their foraging activities based on the availability of food, which leads to seasonal differences in abundance. Regarding species richness, the lack of a seasonal difference among frugivores suggests the shared consumption of fruits. The sharing of resources enables interspecies coexistence due to differentiated food consumption (Marinho-Filho 1991) and foraging times (Muller and Reis 1992). The different guilds encountered may also have favored this coexistence, with the avoidance of competition among species stemming from the use differentiated of the resource. The same explanation can be used for the lack of a significant difference in composition between the rainy and the dry seasons. These findings demonstrate that the community did not undergo any significant change between sampling months.

The accumulation curve of species of Phyllostomidae demonstrated stabilization after the sampling period, but the Jackknife-1 estimator suggests that species richness was underestimated, with one to five species still to be added to the list for Curió Park. According to Bergallo et al. (2003), it is necessary to capture at least 1000 individuals to obtain complete representativeness of the species of Phyllostomidae in a given Atlantic Forest area with the use of mist nets. On the basis of this criterion and considering the mean of 45 individuals caught per month, at least six additional sampling months would be needed to reach the total number of species of Phyllostomidae predicted for the park (21±2 species). Thus, future surveys should consider environments other than trails, such as potential roosts and bodies of water, in order to add species of Phyllostomidae and other families to the list of bats from the study area (Lourenço et al. 2010).

The present investigation is the first study on mammals carried out in Curió Park, which was created 11 years ago to preserve the largest fragment of the Atlantic Forest in the municipality of Paracambi. Regarding bats, 17 species were recorded for the municipality (Bolzan et al. 2010), three of which were not recorded in the present study: *Anoura caudifer* (Ė. Geoffroy, 1818), *Artibeus obscurus* (Schinz, 1821) and *Platyrrhinus lineatus* (É. Geoffroy, 1810). Adding the species recorded herein to those listed by Bolzan et al. (2010) a total of 21 species of bats occur in Paracambi, which represents 27% of the species listed for the entire state of Rio de Janeiro (78 species) (Peracchi and Nogueira 2010, Moratelli et al. 2011). This finding indicates that the municipality has been undersampled and further sampling sites should be investigated within Curió Park as well as the entire territory of Paracambi. Indeed, the occurrence of other species of Phyllostomidae is likely, because among the 10 species recorded for the Serra da Bocaina National Park (Delciellos et al. 2012) and the 19 recorded for the Tinguá Biological Reserve (Dias and Peracchi 2008), five and six, respectively, were not caught in the present study. Such captures in the study area may be possible and explained by the fact that the two conservation units form an ecological corridor with Curió Park (SEMA and ITPA 2010).

Four species of the subfamily Phyllostominae were recorded in Curió Park. This subfamily is considered an important indicator of habitat quality and is sensitive to altered environments (Fenton et al. 1992, Medellín et al. 2000). Despite belonging to the subfamily, *Phyllostomus hastatus* is not considered an indicator of good habitat quality, as this species is found in urban and periurban environments due to its omnivorous habits (e.g., Pacheco et al. 2010).

Two Stenodermatinae, *Chiroderma doriae* and *Dermanura cinerea*, are classified as vulnerable on the list of endangered mammals of the state of Rio de Janeiro (Bergallo et al. 2000b). Moreover, *D. cinerea* is rarely captured and has been sighted only in the best-preserved areas of the state (cited as *Artibeus cinereus* in Esbérard 2003, 2007, Esbérard et al. 2006, Dias and Peracchi 2008). This indicates that Curió Park is an important forest remnant for the conservation of bats that should be protected and carefully monitored by the authorities.

The number of captures of *Desmodus rotundus* demonstrates that Curió Park is under considerable anthropogenic pressure despite having areas in a good state of conservation. Approximately 32% of the area of the park is composed of pastures and 6% constitutes urban and agricultural areas (SEMA and ITPA 2010). The presence of cattle and other domesticated animals, such as dogs and poultry, on the edges of the park may explain the catches of the hematophagous bat. This situation is worrisome because *D. rotundus* is an important reservoir and transmitter of rabies to other vertebrates, including humans (e.g., Sodré et al. 2010).

In summary, the occurrence of bat species indicator of good-quality habitats and of locally endangered species indicate that the Curió Municipal Natural Park is an important Atlantic Forest remnant that needs to be preserved by the local community and governmental agencies. Moreover, the present data suggest that phenological sampling of food resources is necessary to a better understanding of the foraging activity of Phyllostomidae species.

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