



Species composition of small non-volant mammals in the Parque Estadual das Fontes do Ipiranga, São Paulo, Brasil

Cauê Monticelli¹, *^{ID}, Thatiane Cristina Antunes¹, †^{ID}, Kauê Souza de Moraes¹, †, Luan Henrique Morais¹ & Amanda Alves de Moraes¹, †

Fundação Parque Zoológico de São Paulo, Divisão de Ciências Biológicas, Setor de Mamíferos, Avenida Miguel Estéfano, Água Funda, CEP 04301-002, São Paulo, SP, Brasil.

*Corresponding author: caue.monticelli@gmail.com

†These authors contributed equally to this work.

MONTICELLI, C., ANTUNES, T.C., MORAES, K.S., MORAIS, L.H., MORAES, A.A. . **Species composition of small non-volant mammals in the Parque Estadual das Fontes do Ipiranga, São Paulo, Brasil.** Biota Neotropica 21(2): e20201128. <https://doi.org/10.1590/1676-0611-BN-2020-1128>

Abstract: This study provides the first inventory of small non-volant mammals in the Parque Estadual das Fontes do Ipiranga (PEFI), a protected area in the city of São Paulo, Brazil. The data was collected from 2015 to 2017 in 16 research campaigns with a duration of five days each. Four areas with different phytophysiognomies were sampled throughout the dry and rainy seasons. We sampled small mammals using live-capture and pitfall traps. Eleven species were captured, composed of six rodents and five marsupials. The sampling effort involved 5,600 traps/night, there were 527 capture events, and we captured 302 distinct individuals: 174 marsupials and 128 rodents. Recaptures accounted for 42.7% of the total captures. No significant differences were observed in the richness and abundance of small non-volant mammals between the different phytophysiognomies. We also found no significant differences in the richness and abundance of small non-volant mammals between the dry and rainy seasons. The relative abundance (Ar) and constancy index (C) of the species showed that the three most abundant and common species in the PEFI are: *Didelphis aurita*, *Akodon montensis* and *Oligoryzomys nigripes*, which represented 93.7% of the captures. Tomahawk traps accounted for 69% of the total captures, and pitfall traps were responsible for detecting the greatest richness, capturing 81.8% of the species. Comparing the efficiency of the different sampling methods in capturing small mammals in the PEFI, we observed significant differences between both pitfall *versus* Tomahawk and pitfall *versus* Sherman in the understory. The results obtained in this study are consistent with the past and current situations of the forest fragment which are in recovery after significant altered by anthropic activity. In light of this scenario of degradation and isolation, a defaunation process affecting the mastofauna is very likely in the PEFI, which favors the establishment and dominance of generalist species. This study could be the basis for further monitoring programs of small non-volant mammals. The data obtained here will also increase knowledge about the diversity of small mammals in urban fragments of the Atlantic Forest and demonstrate the importance of the PEFI for the maintenance of ecologically important species within the largest metropolitan region in Brazil. These species play important biological roles for the maintenance of ecological interactions and for the provision of rare ecosystem services for the anthropic landscape, which is of great value to the city of São Paulo.
Keywords: *Rodentia; Didelphimorphia; inventory; mastofauna.*

Composição de espécies de pequenos mamíferos não voadores do Parque Estadual das Fontes do Ipiranga, São Paulo, Brasil

Resumo: Este é o primeiro inventário para pequenos mamíferos não voadores no Parque Estadual das Fontes do Ipiranga (PEFI), uma Unidade de Conservação da cidade de São Paulo. A coleta de dados ocorreu entre 2015 e 2017, em 16 campanhas de cinco dias cada. Quatro diferentes fitofisionomias foram amostradas entre os períodos seco e chuvoso. Amostramos os pequenos mamíferos não voadores utilizando armadilhas de captura viva. Foram capturadas 11 espécies, sendo seis de roedores e cinco de marsupiais. O esforço amostral foi de 5.600 armadilhas/noite, com 527 eventos de captura, sendo 174 marsupiais e 128 roedores. As recapturas representaram 42.7% do total de eventos. Não foi observada diferença significativa entre riqueza e abundância de pequenos mamíferos

não voadores entre as diferentes fitofisionomias. Nós também não encontramos diferença significativa na riqueza e abundância de pequenos mamíferos entre o período seco e chuvoso. A abundância relativa (Ar) e o índice de constância (C) das espécies foram calculados, demonstrando que as três espécies mais abundantes e comuns no PEFI são: *Didelphis aurita*, *Akodon montensis* e *Oligoryzomys nigripes*, as quais representaram 93.7% das capturas. As armadilhas Tomahawk foram responsáveis por 69% do total de capturas, e as armadilhas de queda foram responsáveis por detectar a maior riqueza, capturando 81.8% das espécies. Comparando a eficiência dos diferentes métodos de amostragem para capturar os pequenos mamíferos do PEFI, nós observamos diferença significativa entre pitfall *versus* Tomahawk do sub-bosque e pitfall *versus* Sherman também do sub-bosque. Os resultados obtidos neste estudo condizem com o histórico e situação atual do fragmento florestal, considerado em recuperação após ser severamente alterado por ações antrópicas. Diante do cenário de degradação e isolamento, é muito provável que no PEFI tenha existido um processo de defaunação que acometeu a mastofauna, favorecendo o estabelecimento e predominância de espécies generalistas. Este primeiro estudo poderá servir como base para futuros programas de monitoramento dos pequenos mamíferos não voadores. Os dados aqui obtidos também agregam conhecimento sobre a diversidade de pequenos mamíferos em fragmentos urbanos de Mata Atlântica e demonstram a importância do PEFI para a manutenção de espécies ecologicamente importantes dentro da maior cidade do Brasil. Essas espécies cumprem papel biológico importante para a manutenção das interações ecológicas e provimento de serviços ecossistêmicos raros para a paisagem antrópica, com grande valor para a cidade de São Paulo.

Palavras-chave: *Rodentia*; *Didelphimorphia*; inventário; mastofauna.

Introduction

The Atlantic Forest is one of the most threatened biomes in the world and one of the 25 global biodiversity hotspots (Mittermeier et al. 2004, Ribeiro 2009, Jenkins et al. 2013). It originally covered a total area of 1,315,460 km², spread over 17 Brazilian states (Peres 2010). The Atlantic Forest is also one of the regions with the highest biological richness on the planet (Mittermeier et al. 2006). Its remnants currently comprise only 12.4% of its original coverage and are mostly found in small fragments of less than 250 ha, of which only 9.3% are within protected areas (Hirota 2018). Although extremely degraded, the Atlantic Forest remains remarkably heterogeneous and its wide variety of ecosystems allows the occurrence of diverse plant and animal species (Galindo-Leal & Câmara 2005).

Considered to be the Brazilian biome with the second largest number of species and endemic mammals (MMA 2002, Paglia et al. 2012), the Atlantic Forest is one of the most diverse regions of small mammals in South America (Galindo-Leal & Câmara 2003), comprising 105 species of rodents (Patton et al. 2015) and 30 species of marsupials (Bovendorp et al. 2017). However, the absence of published species inventories of some areas has created a significant knowledge gap concerning the presence and distribution of its taxa (Costa et al. 2005, Brito et al. 2009, Galetti et al. 2009, De Vivo et al. 2011). Bovendorp et al. (2017) compiled information from 136 studies conducted on small non-volant mammals from seven different types of vegetation in the biome and these results enabled the identification of priority areas for future sampling efforts. Despite some advances in research, further studies on the diversity of the Atlantic Forest species are necessary in order to increase both the understanding and direct conservation efforts for biodiversity (Galetti et al. 2009, Ribeiro 2009).

The Parque Estadual das Fontes do Ipiranga - PEFI is among the few, but important, remaining areas of Atlantic Forest effectively protected as *Conservation Units* in the city of São Paulo (Whately et al. 2008). Its boundaries have been set since 1893, when the PEFI area had approximately 697 ha (Barbosa et al. 2002). Since then, this fragment has been affected by the construction of highways and avenues, the urbanization of neighboring districts and by fires, leading to a decline

in its vegetation cover (Peccinini & Pivello 2002). The PEFI vegetation is typical of dense tropical rainforest of the Atlantic hillside (São Paulo 2008), where altitude ranges from 770 to 825 m (Barbosa et al. 2002). The area is typically used for recreation, teaching and research. A number of studies were carried out in the PEFI, and its hydrography, topography, plant physiognomy and climate are well known (Fernandes et al. 2002, Santos 2008, Villagra & Romaniuc-Neto 2010). However, there have been very few studies on the local fauna (Bicudo et al. 2002, Malagoli et al. 2008) until 2013, when some studies on vertebrates began to be carried out (Perrella & Guida 2013, Benedicto 2015, Monticelli & Morais 2015, Lisboa et al. in press, Moraes 2017, Rossi 2017, Monticelli & Antunes 2018, Perrella et al. 2018, Monticelli 2019, Rossi et al. 2020). The aim of these studies has been to increase the knowledge about local fauna and create opportunities for new research.

Studies concerning mammals in the PEFI were mainly conducted on larger species. Thus, despite the advances in research on mammalian fauna, knowledge remains deficient regarding the composition of the small non-volant mammal community. Even though the PEFI is situated along the Atlantic Forest phytophysiology best studied regarding to composition of small non-volant mammals (Bovendorp et al. 2017, Figueiredo et al. 2017), it is precisely located in the Paulista plateau, a regional sampling gap for the group (Figueiredo et al. 2017). Therefore, this study has three objectives: 1) to inventory the small non-volant mammals occurring in the PEFI in order to create a database for future monitoring programs; 2) to compare the success of distinct sampling methods; and 3) to compare richness and abundance of small non-volant mammals throughout seasons and phytophysionomies.

Materials and Methods

1. Study area

The Parque Estadual das Fontes do Ipiranga (PEFI) is located in the municipality of São Paulo (Figure 1) and borders the municipality of Diadema (23°38'08" S and 23°40'18" S and 46°36'48" W and 46°38'00" W) (Fernandes et al. 2002). The PEFI is one of the country's largest

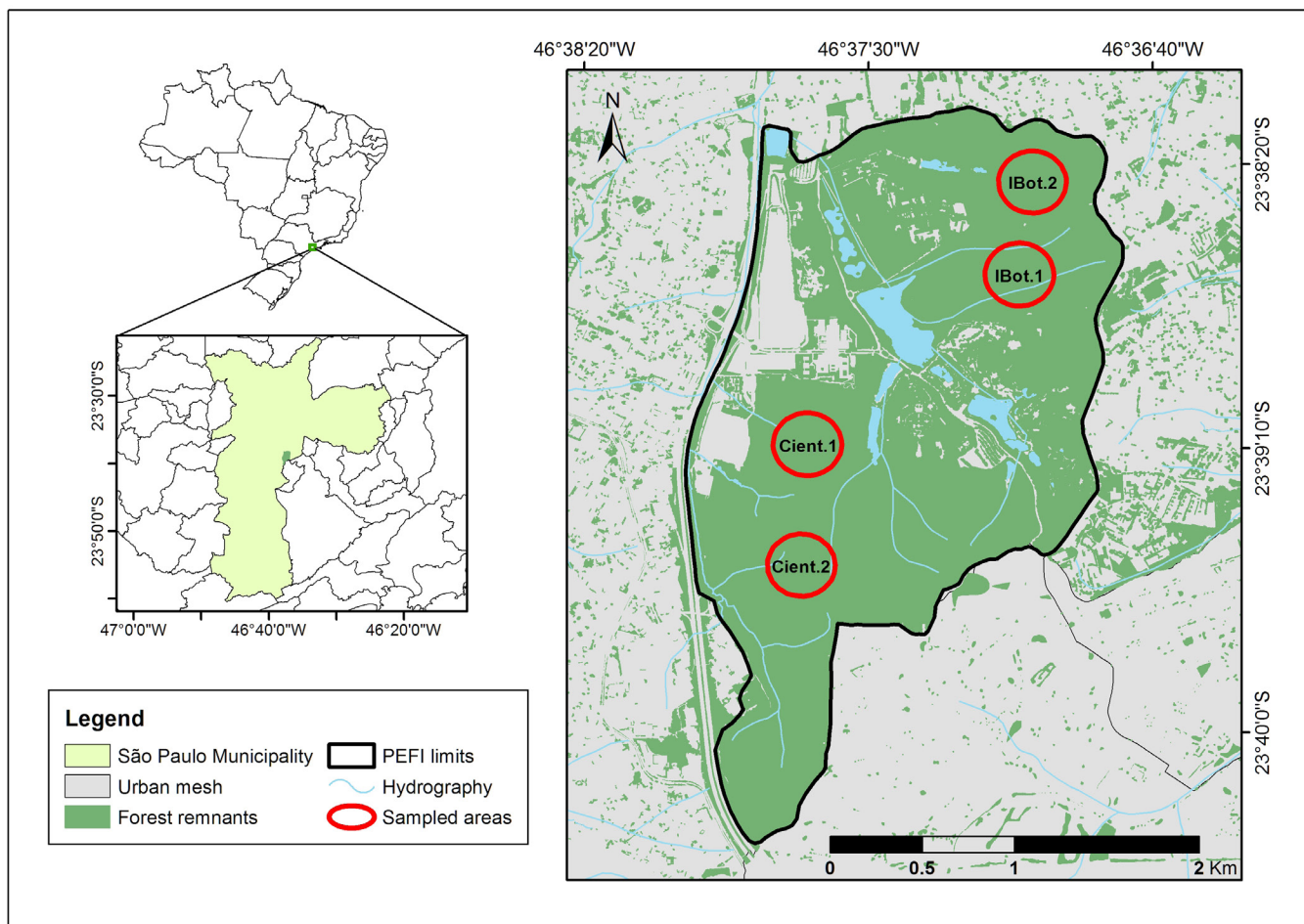


Figure 1. Location of the Parque Estadual das Fontes do Ipiranga (PEFI) in the city of São Paulo, Brasil, and indication of the sampled areas

and most important remnants of Atlantic Forest inside an urban area (Bicudo et al. 2002) and the third largest fragment of the biome in the city of São Paulo (Rancura & Cerati 2020). It currently comprises a total area of 526.4 ha with 340 ha of biological reserve (Bicudo et al. 2002).

The original area of the PEFI was composed of lands owned by farmers and which underwent a vegetation recovery process after their expropriation by the São Paulo State government, making it an area of secondary forest with little more than 100 years of recovery (Barbosa et al. 2002, Barros et al. 2002). The PEFI phanerogamic flora is composed of 1,159 species from 129 families (Barros et al. 2002, Villagra 2008).

The climate in the city of São Paulo is categorized as Cwa (according to Köppen classification), also called humid subtropical, and is marked by a dry winter and a rainy summer. The average temperature and rainfall establishes that the driest and coldest periods are between the months of April and September, whereas the warmest and rainiest periods of the year correspond to the months of October to March (IAG 2017).

The Atlantic Forest fragment closest to the PEFI is the Parque Estadual da Cantareira which is located approximately 20 km away. Such a scenario of isolation associated with the urban pressure generated by the growth of the surrounding cities led to negative impacts on PEFI biodiversity (Gomes et al. 2003, Monticelli & Morais, 2015).

Based on the Unit Management Plan directions, this study sampled four different points of the PEFI, namely: Instituto de Botânica 1 (Ibot.1) - an area of dense forest with homogeneous canopy; Instituto de Botânica

2 (Ibot.2) - forest with high-sized heterogeneous canopy; Parque de Ciência e Tecnologia 1 (Cient.1) - forest with sparse homogeneous canopy; Parque de Ciência e Tecnologia 2 (Cient.2) - forest with discontinuous canopy/degraded forest.

2. Data collection, capture and tagging

Data collection took place from 2015 to 2017, for a total of 16 monthly research campaigns with a duration of five days each. In all campaigns, the four aforementioned areas (Ibot.1, Ibot.2, Cient.1 and Cient.2) were sampled. Every area was sampled four times, for two campaigns in the rainy season and two in the dry season.

In order to capture the small non-volant mammals, we employed two types of live capture traps: a box-trap (Sherman, size 30 x 7.5 x 9 cm) and a cage-trap (Tomahawk, size 45 x 20 x 20 cm). Traps were baited with a mixture of sardines, cornmeal, bananas, peanut butter and pineapple essence. The mixture was replenished daily.

Two parallel 100-meter lines were established in each area, 30 m apart from each other. Each line had 10 capture stations equidistant at every 10 m. In every station, three live traps were placed spread along the ground (named “forest layer 1”) and at about two meters high (named “forest layer 2”), attached to understory branches, totaling 60 live traps per sample site.

Pitfall traps were also arranged in the sampled points, but at 100 m apart and parallel to the live trap lines. On each site, 10 buckets

were installed, 10 m apart from each other, buried up to the soil level (named “forest layer 0”), connected by a guide fence made with black 80-centimeter high plastic canvas and supported by wooden poles and metal staples. Inside each bucket, a piece of expanded polystyrene foam was set down to avoid animal drowning in case of flooding.

Upon the animal capture, the following procedures were executed: taxonomic identification, individual tagging with a numbered metallic earring (Ear tags, National Band and Tag Company, USA), collecting of feces and ectoparasites, weighing, body measuring, sex and reproductive condition recording and subsequent release at the capture site.

The species identity was determined following Gardner (2007) and Patton et al. (2015). Taxonomic identifications of representatives of genera with cryptic species-diversity were performed based on cytogenetic analyses carried out in the Special Laboratory of Ecology and Evolution of the Instituto Butantan.

As there are no previous studies concerning small non-volant mammals from the PEFI, testimony specimens of all the species captured were collected. The specimens were deposited in the mammal collection of the Museu de Zoologia da Universidade de São Paulo and prepared according to the guidelines established by the institution.

The capture success was determined by the total number of captures multiplied by 100 and divided by the capture effort (traps per night). All procedures were authorized by the pertaining environmental agencies under license SISBIO no. 45520 and SISGEN no. AE48610.

3. Richness, abundance and seasonality

The species richness was assessed through the non-parametric estimator Jackknife 1 (Burnham & Overton 1979), using the software EstimateS 9.0 (Colwell 2013). The analysis was performed with 100 randomizations and the days as the sample unit.

In order to compare the richness and abundance among the different phytophysionomies sampled, we employed a Kruskal-Wallis test. The capture data was also used to evaluate putative differences in richness and abundance of small mammals between the dry and rainy seasons. Finally, we applied a paired t-test for parametric data and the Mann-Whitney test for non-parametric data. In all cases, the significance level adopted was 5% ($p < 0.05$).

The relative abundance (Ar) of species was determined by the number of individuals of each species captured multiplied by 100 and divided by the total number of individuals captured. The constancy index (C), which allows species to be grouped into categories based on its capture frequency, was established as: common species - present in more than 50% of the samples; relatively common species - present in 25 to 50% of the samples; and rare species - present in less than 25% of the samples (Dajoz 1983).

4. Capture method assessment

The different methods implemented for the capture of small mammals in the PEFI were compared to assess their efficacy at the study site, using the Kruskal-Wallis test and the Dunn post-test.

Results

1. Data collection, capture and tagging

During this study, 11 species of small non-volant mammals were captured, six of which were rodents belonging to the Cricetidae and

Caviidae families and five were marsupials belonging to the Didelphidae family (Figure 2). From a 5,600 traps/night sampling effort, 527 capture events occurred, represented by 302 individuals (174 marsupials and 128 rodents; Table 1). Recaptures accounted for 42.7% of the total capture events. The success rate of small mammal capture was 9.41%, being 5.55% in the dry season and 3.85% in the rainy season. The vegetation formation with the highest number of captures was Cient.1, followed by Cient.2, Ibot.2 and Ibot.1 (Table 1).

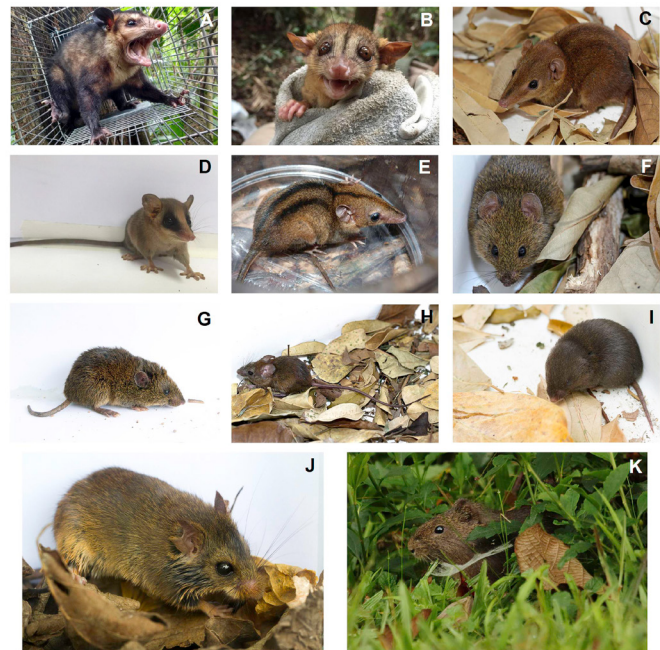


Figure 2. Species of small mammals captured in the Parque Estadual das Fontes do Ipiranga (PEFI). A) *Didelphis aurita*, B) *Caluromys phylander*, C) *Monodelphis americana*, D) *Gracilinanus microtarsus*, E) *Monodelphis iheringi*, F) *Akodon montensis*, G) *Thaptomys nigrita*, H) *Oligoryzomys nigripes*, I) *Blarinomys breviceps*, J) *Juliomys pictipes*, K) *Cavia aperea*

2. Richness, abundance and seasonality

The estimated richness of small mammals calculated was close to the empirical results, indicating 12.04 species occurring in the PEFI (Figure 3). There was no significant difference in the small mammal richness among the different sampled areas ($H = 3.779$; $p = 0.286$), nor in the abundance among the different sampled physiognomies ($H = 0.602$; $p = 0.895$).

The relative abundance analysis showed the following values for each species: *Didelphis aurita* (52.7%), *Akodon montensis* (32.4%), *Oligoryzomys nigripes* (8.44%), *Monodelphis iheringi* (2.03%), *M. americana* and *Thaptomys nigrita* (1.01%), *Gracilinanus microtarsus* and *Juliomys pictipes* (0.67%), *Blarinomys breviceps*, *Cavia aperea* and *Caluromys phylander* (0.34%). The constancy index determined three common species: *D. aurita* (100%), *A. montensis* (87.5%), *O. nigripes* (81.25%); and eight rare species: *M. iheringi* (18.75%), *M. americana*, *T. nigrita*, *G. microtarsus* and *J. pictipes* (12.5%), *B. breviceps*, *C. aperea* and *C. phylander* (6.25%). In general, the three most abundant species represented 93.7% of the captures and the remaining eight rare species represented only 6.3% (Table 2).

Nine species were captured during the dry period, five rodents and four marsupials, and six species during the rainy season, four rodents

Table 1. Capture of small mammals during the dry and rainy seasons inside four different phytophysiognomies formations of the Parque Estadual das Fontes do Ipiranga, São Paulo, Brasil. Ibot.1 - Instituto de Botânica 1; Ibot.2 - Instituto de Botânica 2; Cient.1 - Parque da Ciência e Tecnologia 1; Cient.2 - Parque da Ciência e Tecnologia 2

Species	Season	Location			
		Ibot.1	Ibot. 2	Cient. 1	Cient. 2
Rodentia					
Cricetidae					
<i>Akodon montensis</i> Thomas, 1913	Dry	1	5	31	17
	Rainy	5	10	12	15
<i>Oligoryzomys nigripes</i> (Olfers, 1818)	Dry	2	2	3	3
	Rainy	2	5	2	6
<i>Blarinomys breviceps</i> (Winge, 1887)	Dry	–	–	–	–
	Rainy	–	–	1	–
<i>Juliomys pictipes</i> (Osgood, 1933)	Dry	1	–	–	–
	Rainy	–	1	–	–
<i>Thaptomys nigrita</i> (Lichtenstein, 1829)	Dry	–	–	–	3
	Rainy	–	–	–	–
Caviidae					
<i>Cavia aperea</i> Erxleben, 1777	Dry	–	–	–	1
	Rainy	–	–	–	–
Didelphimorphia					
<i>Didelphis aurita</i> (Wied-Neuwied, 1826)	Dry	29	22	23	17
	Rainy	16	19	19	17
<i>Monodelphis americana</i> (Müller, 1776)	Dry	–	–	–	–
	Rainy	–	–	2	1
<i>Monodelphis iheringi</i> (Thomas, 1888)	Dry	–	–	2	4
	Rainy	–	–	–	–
<i>Caluromys philander</i> (Linnaeus, 1758)	Dry	1	–	–	–
	Rainy	–	–	–	–
<i>Gracilinanus microtarsus</i> (Wagner, 1842)	Dry	–	1	–	1
	Rainy	–	–	–	–
Total	Dry	34	30	59	46
	Rainy	23	35	36	39
Overall total		57	65	95	85
		302			

and two marsupials. Although more captures occurred during the dry months ($n = 167$) compared to the rainy months ($n = 135$), we found no significant difference in the total richness of small mammals (rodents and marsupials) between the two periods ($t = -1.275$; $p = 0.211$). Similarly, there was no significant difference in the richness of rodents ($t = 2.507$; $p = 0.120$) and marsupials ($t = -0.547$; $p = 0.340$) separately between the seasons. The total abundance of small mammals did not vary significantly between the dry and rainy periods ($t = 1.999$; $p = 0.147$), nor did it for rodents ($u = 0.480$; $p = 0.315$) and marsupials ($u = 0.626$; $p = 0.265$) separately.

In addition to the species of small non-volant mammals, field activities led to the record of four other non-target native taxa, namely: brown howler monkey (*Alouatta guariba* Humboldt, 1812), orange

dwarf porcupine (*Coendou spinosus* F. Cuvier, 1823), nine-banded armadillo (*Dasybus novemcinctus* Linnaeus, 1758) and three-toed sloth (*Bradypus variegatus* Schinz, 1825). Additionally, there were unintentional captures of alien species, such as the common marmoset (*Callithrix jacchus* Linnaeus, 1758), the black-tufted marmoset (*Callithrix penicillata* É. Geoffroy, 1812) and domestic animals, such as the common household cat (*Felis catus* Linnaeus, 1758). Taxonomic identification of non-target species followed Abreu et al. (2020).

3. Capture method assessment

With a sampling effort of 2,400 traps/night, the Tomahawk traps accounted for 69% of the total captures, detecting four of the 11 species. Despite this expressive value, 71.5% of the captures with this

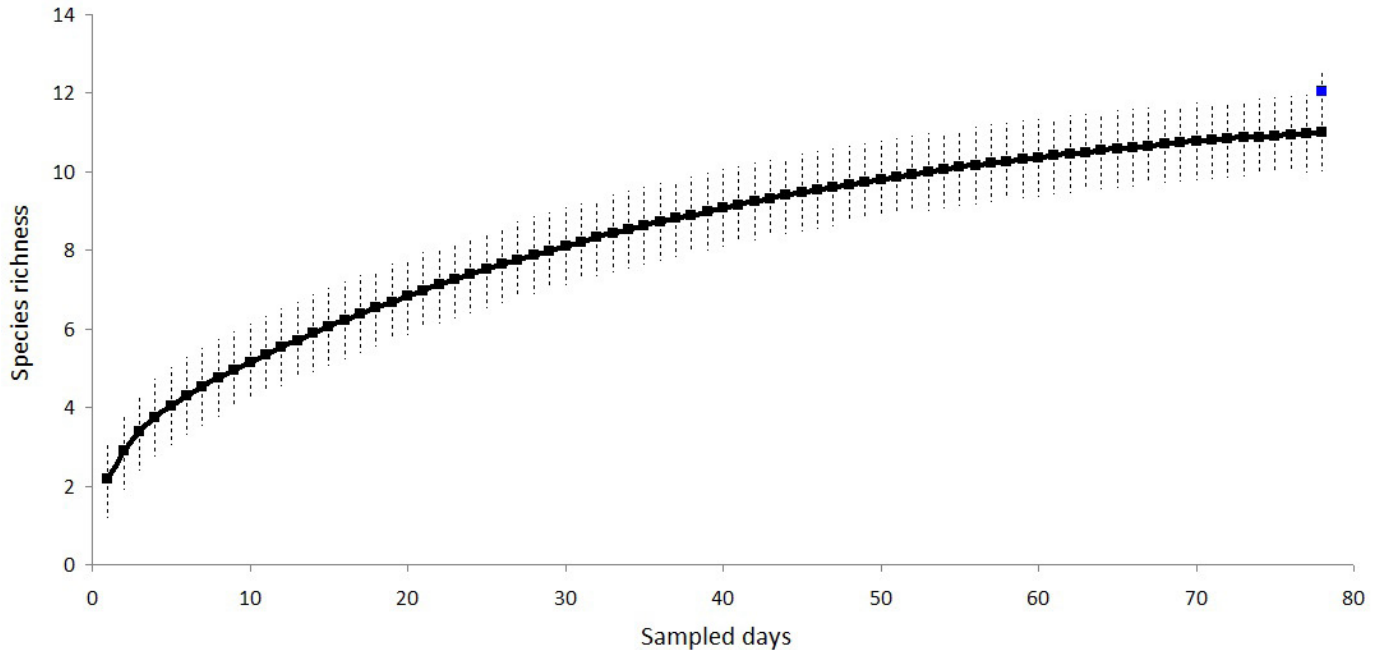


Figure 3. Species accumulation curve based on sampling effort in the Parque Estadual das Fontes do Ipiranga (PEFI), São Paulo, Brasil. Blue square corresponds to the jackknife 1 estimator for species richness

Table 2. Species of small non-volant mammals captured in the Parque Estadual das Fontes do Ipiranga and their respective values of relative abundance (Ar) and constancy index (C). Ptf = pitfall traps; sh = Sherman; t = Tomahawk

Species	No. of specimen captured	Ar (%)	C (%)	Capture method
Rodentia				
<i>Akodon montensis</i>	96	32.4	87.5	Common
<i>Oligoryzomys nigripes</i>	25	8.44	81.25	Common
<i>Blarinomys breviceps</i>	1	0.34	6.25	Rare
<i>Juliomys pictipes</i>	2	0.67	12.5	Rare
<i>Thaptomys nigrita</i>	3	1.01	12.5	Rare
<i>Cavia aperea</i>	1	0.34	6.25	Rare
Didelphimorphia				
<i>Didelphis aurita</i>	162	52.7	100	Common
<i>Monodelphis americana</i>	3	1.01	12.5	Rare
<i>Monodelphis iheringi</i>	6	2.03	18.75	Rare
<i>Caluromys philander</i>	1	0.34	6.25	Rare
<i>Gracilinanus microtarsus</i>	2	0.67	12.5	Rare
Total	302	100		

method were *D. aurita*, the most abundant species in the PEFI. With a sampling effort of 800 traps/night and accounting for only 16% of the total capture events, the pitfall trap was not the most effective method of capture, but it was responsible for detecting nine of the 11 species of small mammals. Despite its lower sampling effort and the absence of bait, this method proved to be the most efficient and was essential for the sampling of small mammals in the area. Box traps (Shermans) were the least successful in terms of capture events. With a 2,400 traps/night sampling effort, the same as the Tomahawk, they captured five of the 11 species and their capture events represented only 15% of the total.

Some species were captured exclusively with pitfall traps (forest layer 0): *T. nigrita*, *G. microtarsus*, *M. americana*, *M. iheringi*, *B. breviceps* and *C. aperea*. Others were captured only in the understory (forest layer 2): *C. philander*. Live traps on the forest substrate (forest layer 1) did not show any exclusive captures. Individuals of *D. aurita*, *A. montensis*, *O. nigripes* and *J. pictipes* were captured in all three of the forest strata sampled.

Concerning the captures in the different strata of the forest, pitfall traps (0) presented the most successful capture rate of 13.65%, followed by live traps (Sherman and Tomahawk) located in the forest substrate (1), with a

rate of 12.7%, and live traps in the understory (2), with a rate of 3.66%. Assessing the efficiency of the methods for capturing different species of the PEFI, we found a significant difference between the methods ($H = 30.24$; $p = 0.0001$). Post-test analysis showed a significant difference between pitfall *versus* Tomahawk from forest stratum 2 ($p = 0.05$) and pitfall *versus* Sherman from forest stratum 2 ($p = 0.05$). We found no significant difference between pitfall, Sherman (1) and Tomahawk (1). There was also no significant difference between Sherman (1), Sherman (2) and Tomahawk (2) methods.

Discussion

Environmental characteristics such as vegetation type, primary production and terrain directly impact the mammalian community present in a given area (Peres 2000, Haugaasen & Peres 2005, Galetti et al. 2009). Anthropogenic actions, such as habitat suppression and fragmentation, also affect the permanence of mammal populations in different environments (Chiarello 1999, Cullen-Junior et al. 2000, Peres 2000, Galetti et al. 2009, Brocardo & Cândido-Junior 2012). These factors in association with the size of the remaining natural area may determine the richness of mammal species (Chiarello 1999), as the absence of large protected areas has been directly related to the decrease in species, especially those of larger size (Chiarello 2000, Gurd et al. 2001, Ceballos et al. 2005, Cardillo et al. 2005, Jorge et al. 2013).

Large remnants of the Atlantic Forest are related to the viable maintenance capacity of several species of mammals (Chiarello 1999, 2000, Cullen-Junior et al. 2000). Contrarily, the PEFI is an example of the loss of vegetation cover and fragmentation which, due to its isolation as a small area inside the anthropic landscape of São Paulo, the most populous city in Brasil, presents a low richness of small non-volant mammals when compared with other areas of the Atlantic Forest found nearby and better preserved: 32 species found in the Estação Ecológica do Bananal (Abreu-Junior & Percequillo 2019); 23 in the Reserva Florestal do Morro Grande (Pardini & Umetsu, 2006); and 21 in the Parque Estadual Carlos Botelho (Brocardo et al. 2012). However, the number of species recorded in the PEFI is still compatible with the majority of the studies reported for the Atlantic Forest biome (Figueiredo et al. 2017). These results were expected, considering that a substantial reduction in mammal richness has been reported for small fragments of the Southern Atlantic Forest (Abreu-Junior & Köhler 2009, Brocardo & Cândido-Junior 2012) in Southeastern (Chiarello 1999, Briani et al. 2001, Pardini et al. 2005) and Northeastern Brazil (Silva Junior & Pontes 2008). In light of its loss of vegetation cover and isolation, it is possible that a defaunation process is occurring in the PEFI, affecting not only the small mammals, but mainly other mammals which are larger and/or have greater habitat requirements. In the PEFI no invasive rodents were captured, which is surprising considering all its anthropogenic modifications. According to Bovendorp et al. (2017), 24% of the Atlantic Forest fragments have at least one species of invasive rodent.

The forest types present in areas Ibot.1 and Ibot.2 are considered similar to each other according to Bicudo et al. (2002) and they show a relatively larger number of arboreal individuals compared to the other areas, with distinct aggregation patterns and dense understory. Fewer species were found in these areas. The Cient.1 area is comparable to Ibot.1 and 2 (Bicudo et al. 2002) and presented a similar number of species. These three areas are considered to be less degraded than Cient.2 (Bicudo et al. 2002).

Although we did not find significant differences in small mammal richness in the PEFI among four sampled areas, the Cient.2 had the highest number of species, where eight of the 11 species were captured. Of these eight, six were terrestrial or semi-fossorial (*C. aperea*, *T. nigrita*, *A. montensis*, *O. nigripes*, *M. americana* and *M. iheringi*). This area is comprised of continuous forest, degraded by fires that occurred in the late 1990s and early 2000s (Peccinini & Pivello 2002). Pardini & Umetsu (2006) suggest that younger or more altered forests, as found in Cient.2, lead to greater biomass production and, consequently, greater availability of fruits and arthropods which are the main items consumed by small non-volant mammals. In addition, this variety of phytophysiognomy has a relatively more opened canopy with a denser understory which favors the proliferation of terrestrial or understory species and minimizes the chance of occupation by forest canopy species (Pardini & Umetsu 2006).

The Ibot.1 site was the only one in which *C. philander*, an arboreal species commonly found in canopies but also in the understory (Delciellos et al. 2006), was captured. The exclusive capture at this site may be related to the fact that the species is described as arboreal of medium to high canopies (Aragona & Marinho-Filho 2009) and the site presents a large concentration of 4 to 6 m tall trees, due to its absence of recent major impacts.

Communities of small non-volant mammals are long considered to be generally composed of two or three dominant species and other species tend to be in greater rarity (Fleming 1975), a pattern largely considered to be a response to adaptive flexibility of dominant species. The results found in this study are in accordance with this expected pattern for a community of small non-volant mammals in degraded/recovering areas of the Atlantic Forest (Pardini et al. 2005, Puttker et al. 2008). Other characteristics of the PEFI such as isolation, secondary forest and urban surroundings might also promote this scenario of species occupation. These elements favored the establishment and predominance of three generalist species in the PEFI: *D. aurita*, *A. montensis* and *O. nigripes*, which accounted for a combined 93.7% of total captures. Seven of the 11 species captured in the PEFI are among the 22 species suggested as hyper-dominant in the Atlantic Forest (Bovendorp et al. 2017).

The process of forest regeneration and the impacts it suffers, such as fires, cause environmental changes that may reflect on the structure of the small mammal community, as observed by Oliveira (1995), creating new species dynamics to be later assessed. Pinotti (2010) suggests that both structural characteristics of the forest (biomass and depth of leaf litter, branch volume and number) as well as food availability (arthropod biomass in the soil, richness of fruiting plants and number of individuals fruiting in the understory) are liable to change as a result of the forest regeneration process and are strongly linked to favoring or disadvantaging species, either specialists or generalists. Generalist species such as *D. aurita*, *A. montensis* and *O. nigripes* also benefit from a greater availability of food resources found in areas at an earlier stage of regeneration. Specialized forest species have a higher occupancy capacity in more mature forests, where these resources are scarcer (Pinotti 2010). However, it is important to note that the absence of connectivity between the PEFI and other forest fragments prevents the recolonization of the area by other species, which could potentially increase the richness of the rodent and marsupial community (Pardini et al. 2005).

As *D. aurita* was the most abundant species in the PEFI, the low richness found may have been influenced by the presence of this species. Fonseca & Robinson (1990) suggested that the increase in the density of *D. aurita*, due to the absence or small abundance of predators, for example, could be related to the low richness of small terrestrial mammals in smaller fragments, either due to competition for resources or even predation (Graipel et al. 2003).

The absence of PEFI predators due to reduced vegetation cover and all the effects of isolation inside the anthropic landscape may also be related to the rates of recapture found in this study. The high recapture value (42.7%) suggests that the areas sampled were not occupied by new individuals during the study period. Such a low turnover of individuals may be related to the absence of medium and large predators, which play an important role in the dynamics and structure of the mammal community (Fonseca 1988). For the PEFI, there are no records of native carnivorous mammals and this absence can decrease the rate of predation, favor the permanence of individuals in the same area for a longer time and, consequently, decrease the turnover of individuals between adjacent territories thus resulting in spatial stability, a fact also observed by Lessa et al. (1999).

Regarding the species found in the different strata, the trapping method alone is not sufficient to estimate the use of vertical space by small mammals (Delciellos et al. 2006, Preveddello et al. 2008). The finding of species described as terrestrial (*A. montensis*) or arboreal (*J. pictipes*) (Paglia et al. 2012) on ground and understory may be related to physical characteristics of the area, such as connectivity due to the presence of lianas and fallen trunks, seasonal variations in food availability and interspecific competition (Begon et al. 2006, Lambert et al. 2006, Hannibal & Caceres 2010). *Didelphis aurita* and *O. nigripes* are considered scansorial and can be found on the ground and understory (Paglia et al. 2012). Although young individuals of *D. aurita* have been previously reported to be more prevalent in the upper strata (Preveddello et al. 2008), in this study, 62.83% (n = 71) of young individuals of *D. aurita* were captured on the ground and 37.17% (n = 42) in understory.

Whereas not significantly different, the capture success rate of this study was greater in the dry season (5.55%) than in the rainy season (3.85%). This can possibly be explained by the variation throughout the year in the availability of food resources. Higher rainfall is related to a greater supply of arthropods (Janzen 1973, Charles-Dominique 1983, Wolda 1993, Santos-Filho et al. 2008) and fruits in the environment (Foster 1982, Charles-Dominique 1983, Julien-Laferrière & Atramentowicz 1990, Bergallo & Magnusson 1999, 2002, Santos-Filho et al. 2008). This makes the animals more likely to find food while moving less (Stallings 1988), thus decreasing the efficiency of the baits and the probability of capturing small mammals (MacClearn et al. 1994). A higher relative rate of capture in the season of lower rainfall has previously been observed in other studies with determined seasonality (Mello 1980, O'Connell 1989, MacClearn et al. 1994, Vieira 2002, Alho 2003, Santos-Filho et al. 2008). Among the five species of marsupials captured, three were captured exclusively in the dry period (*M. iheringi*, *C. philander* and *G. microtarsus*), one was captured in both periods, but more often in the dry period (*D. aurita*), and one species was captured only in the rainy season (*M. americana*). For rodents, among the six species captured during the study, one was exclusively captured during the rainy season (*B. breviceps*), two during the dry season (*T. nigita* and *C. aperea*) and three were captured in both periods (*A. montensis*, *O.*

nigripes and *J. pictipes*). *A. montensis* was the most frequently captured species in the dry season and *O. nigripes* in the rainy season.

As there is no previous research on small non-volant mammals from the PEFI, this novel study can be a starting point for monitoring programs of this group, aiming to evaluate possible local ecological changes and advances in the defaunation process.

The different capture methods used in this study complemented each other, as they were responsible for the capture of different species, showing the importance of the use of diverse techniques to capture small non-volant mammals (Santos-Filho et al. 2006, Caceres et al. 2011, Bovendorp et al. 2017).

Even though baits are not used in pitfall traps, they have previously been associated with higher capture success rates (Hice & Schmidly 2002, Santos-Filho et al. 2006, Umetsu et al. 2006). In this study, the method with the greatest success in capturing small mammals was the use of cage-type traps (Tomahawk). The difference in the capture success rate of Tomahawks versus Shermans was probably due to the size of the traps. Since the most abundant animal species captured in this study reached around 2 kg, this size was probably incompatible with the Shermans culminating in a lower capture rate using this method.

Considering the great influence marsupials and small rodents have on forest dynamics, as well as their role as habitat quality indicators (Pardini & Umetsu 2006), the importance of knowing their community formation cannot be underestimated, as its understanding may direct conservation efforts of the forests and species.

Of the 11 species captured in this study, none were included in the national list of threatened species (ICMBio 2018), but six (54.55%) are endemic to the Atlantic Forest: *B. breviceps*, *J. pictipes*, *T. nigrita*, *D. aurita*, *M. iheringi* and *G. microtarsus* (Paglia et al. 2012). In the state of São Paulo, *M. iheringi* is on the list of threatened species in the "vulnerable" category, and five of the species captured are classified as "almost threatened" (*B. breviceps*, *J. pictipes*, *T. nigrita*, *M. americana* and *G. microtarsus*) (São Paulo 2018).

The results of this study add knowledge about the biodiversity of the Atlantic Forest in an urban fragment in São Paulo. Although species richness is not high and generalist species are predominant, the PEFI is important for the maintenance of different animal and plant species, which in turn, play important biological roles for the maintenance of ecological interactions. This demonstrates the great value of the PEFI to the city of São Paulo, due to its provision of rare ecosystem services for the anthropic landscape of the city.

Acknowledgements

The authors would like to thank the Fundação Parque Zoológico de São Paulo (FPZSP) for financing the study; Camilla di Nizo for carrying out cytogenetic analyses at the Laboratory of Special Ecology and Evolution at Instituto Butantan; and all FPZSP employees and associates who helped in different activities related to the study of small mammals of the PEFI.

Author Contributions

Caue Monticelli: contributed to the concept and design of the study, to data collection, analysis and interpretation; to manuscript preparation; with critical revision and adding intellectual content.

Thatiane Cristina Antunes: contributed to data collection and manuscript preparation.

Kauê Souza de Moraes: contributed to data collection, analysis and interpretation; to manuscript preparation and adding intellectual content.

Luan Henrique Moraes: contributed to data collection.

Amanda Alves de Moraes: contributed to the concept and design of the study, to data collection, to manuscript preparation; with critical revision and adding intellectual content.

Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

References

- ABREU-JUNIOR, E.F. & KÖHLER, A. 2009. Mastofauna de médio e grande porte na RPPN da UNISC, RS, Brasil. *Biota Neotrop.* 9(4):169-174. <https://doi.org/10.1590/S1676-06032009000400017> (last accessed on 01/10/2012)
- ABREU-JUNIOR, E.F. & PERCEQUILLO, A.R. 2019. Small Mammals of the Estação Ecológica de Bananal, Southeastern Atlantic Forest, Brazil, with Description of a New Species of *Brucepattersonius* (Rodentia, Sigmodontinae). *Arquivos de Zoologia.* 50(1):1–116.
- ABREU-JUNIOR, E.F., CASALI, D.M., COSTA, M.C., GARBINO, G.S.T., LORETO, D., LOSS, A.C., MARMONTEL, M., OLIVEIRA, M.L., PAVAN, S.E. & TIRELLI, F.P. 2020. Lista de Mamíferos do Brasil. Comitê de Taxonomia da Sociedade Brasileira de Mastozoologia (CT-SBMz). Disponível em: <https://www.sbmz.org/mamiferos-do-brasil/> (last accessed on 03/12/2020)
- ALHO, C.J.R. 2003. Conservação da biodiversidade da Bacia do Alto Paraguai: Monitoramento da fauna sob impacto ambiental. MS, Ed. UNIDERP, Campo Grande.
- ARAGONA, M. & MARINHO-FILHO, J. 2009. História natural e biologia reprodutiva de marsupiais no Pantanal, Mato Grosso, Brasil. *Zoologia-Curitiba.* 26(2):220-230.
- BARBOSA, L.M., POTOMATI, A., PECCININI, A. 2002. O PEFI: histórico e legislação. In: Parque Estadual das Fontes do Ipiranga (PEFI): unidade de conservação que resiste à urbanização de São Paulo (D.C. Bicudo, M.C. Forti & C.E.M. Bicudo, orgs.). Imprensa Oficial do Estado de São Paulo, São Paulo, pp.15-28.
- BARROS, F., MAMEDE, M.C.H., MELO, M.M.F., LOPES, E.A., JUNG-MENDAÇOLLI, S.L., KIRIZAWA, M., MUNIZ, C.F.S., WATANABE, H.M., CHIEA, S.A.C. & MELHEM, T.S.A. 2002. Flora Fanerogâmica do PEFI: composição, afinidades e conservação. In: Parque Estadual das Fontes do Ipiranga (PEFI): unidade de conservação que resiste à urbanização de São Paulo (D.C. Bicudo, M.C. Forti & C.E.M. Bicudo, orgs.). Imprensa Oficial do Estado de São Paulo, São Paulo, pp.93-110.
- BEGON, M., TOWNSEND, C.R. & HARPER, J.L. 2006. Ecology from individuals to ecosystems. 4a ed. Blackwell Publishing, Oxford.
- BENEDICTO, D.M. 2015. Área de vida, padrão de atividade, dieta e dispersão de sementes por *Alouatta clamitans* (Cabrera, 1940) em um fragmento urbano de Mata Atlântica da cidade de São Paulo. Master's dissertation, Universidade Federal de São Carlos, São Carlos.
- BERGALLO, H.G. & MAGNUSSON, W.E. 1999. Effects of climate and food availability on four rodent species in southeastern Brazil. *J Mammal.* 80:472-486.
- BERGALLO, H.G. & MAGNUSSON, W.E. 2002. Effects of weather and food availability on the condition and growth of two species of rodents in Southeastern Brazil. *Mammalia.* 66(1):17-31.
- BICUDO, D.C., FORTI, M.C. & BICUDO, C.E.M. 2002. PEFI: unidade de conservação que resiste à urbanização de São Paulo. Imprensa Oficial do Estado de São Paulo, São Paulo.
- BOVENDORP, R.S., VILLAR, N., ABREU-JUNIOR, E.F., BELLO, C., REGOLIN, A.L., PERCEQUILLO, A.R. & GALETTI, M. 2017. Atlantic small-mammal: a dataset of communities of rodents and marsupials of the Atlantic forests of South America. *Ecology.* 98:2226–2226.
- BRIANI, D.C., SANTORI, R.T., VIEIRA, M.V. & GOBBI, N. 2001. Mamíferos não-voadores de um fragmento de mata mesófila semidecídua do interior do Estado de São Paulo, Brasil. *Holos Environ.* 1(2):141-149.
- BRITO, D., OLIVEIRA, L.C., OPREA, M. & MELLO, M.A.R. 2009. An overview of Brazilian mammalogy: trends, biases and future directions. *Zoologia.* 26:67-73.
- BROCARD, C.R. & CÂNDIDO-JUNIOR, J.F. 2012. Persistência de mamíferos de médio e grande porte em fragmentos de floresta ombrófila mista no estado do Paraná, Brasil. *Rev. Arvore.* 36(2):301-310.
- BROCARD, C.R., RODARTE, R., BUENO, R.S., CULOT, L. & GALETTI, M. 2012. Non-volant mammals of Carlos Botelho State Park, Paranapiacaba Forest Continuum. *Biota Neotrop.* 12(4):198-208. <https://doi.org/10.1590/S1676-06032012000400021> (last accessed on 27/12/2020)
- BURNHAM, K.P. & OVERTON, W.S. 1979. Robust estimation of population size when capture probabilities vary among animals. *Ecology.* 60(5):927–936.
- CACERES, N.C., NÁPOLI, R.P. & HANNIBAL, W. 2011. Differential trapping success for small mammals using pitfall and standard cage traps in a woodland savannah region of southwestern Brazil. *Mammalia.* 75:45-52.
- CARDILLO, M., MACE, G.M., JONES, K.E., BIELBY, J., BININDA-EMMONS, O.R.P., SECHREST, W., ORME, C.D.L. & PURVIS, A. 2005. Multiple causes of high extinction risk in large mammal species. *Science.* 309:1239-1241.
- CEBALLOS, G., EHRlich, P.R., SOBERÓN, J., SALAZAR, I. & FAY, J.P. 2005. Global mammal conservation: What must we manage? *Science.* 309:603-606.
- CHARLES-DOMINIQUE, P. 1983. Ecology and social adaptations of didelphid marsupials: Comparison with eutherians of similar ecology. In *Advances in the study of mammalian behaviour.* (J.F. Eisenberg & D. Kleiman, eds.). Special Publication, The American Society of Mammalogists, Shippensburg, p.395-422.
- CHIARELLO, A.G. 1999. Effects of fragmentation of the Atlantic forest on mammal communities in south-eastern Brazil. *Biol Conserv.* 89:71-82.
- CHIARELLO, A.G. 2000. Conservation value of a native forest fragment in a region of extensive agriculture. *Revista Brasileira de Biologia.* 60(2):237-247.
- COLWELL, R.K. 2013. EstimateS: Statistical Estimation of Species Richness and Shared Species from samples. University of Connecticut, Connecticut.
- COSTA, L.P., LEITE, Y.L.R., MENDES, S.L. & DITCHFIELD, A.D. 2005. Mammal conservation in Brazil. *Conserv Biol.* 19(3):672-679.
- CULLEN-JUNIOR, L., BODMER, R.E. & PÁDUA, C.V. 2000. Effects of hunting in habitat fragments of the Atlantic Forest, Brazil. *Biol Conserv.* 95:49-56.
- DAJZO, R. 1983. *Ecologia geral.* 4a ed. Editora Vozes, Petrópolis.
- DE VIVO, M., CARMIGNOTTO, A.P., GREGORIN, R., HINGST-ZAHER, E., IACK-XIMENES, G.E., MIRETZKI, M., PERCEQUILLO, A.R., ROLLO JR., M.M., ROSSI, R.V. & TADDEI, V.A. 2011. Checklist dos mamíferos do Estado de São Paulo, Brasil. *Biota Neotrop.* 11(1a). <https://doi.org/10.1590/S1676-06032011000500007> (last accessed on 03/06/2019)
- DELICIELLOS, A.C., LORETTO, D. & VIEIRA, M.V. 2006. Novos métodos no estudo da estratificação vertical de marsupiais neotropicais. *Oecol Bras.* 10(2):135-153.
- FERNANDES, A.J., REIS, L.A.M. & CARVALHO, A. 2002. Caracterização do meio físico. In: Parque Estadual das Fontes do Ipiranga (PEFI): unidade de conservação que resiste à urbanização de São Paulo (D.C. Bicudo, M.C. Forti & C.E.M. Bicudo, orgs.). Imprensa Oficial do Estado de São Paulo, São Paulo, pp.49-60.
- FIGUEIREDO, M.S.L., BARROS, C.S., DELICIELLOS, A.C., GUERRA, E.B., CORDEIRO-ESTRELA, P., KAJIN, M., ALVAREZ, M.R., ASFORA, P.H., ASTÚA, D., BERGALLO, H.G., CERQUEIRA, R., GEISE, L., GENTILE, R., GRELE, C.E.V., LACK-XIMENES, G.E., OLIVEIRA, L.C., WESKLER, M. & VIEIRA, M.V. 2017. Abundance of small mammals in the Atlantic Forest (ASMAF): a data set for analyzing tropical community patterns. *Ecology.* 98:2981–2981.
- FLEMING, T.H. 1975. The role of small mammals in tropical ecosystems. In: *Small Mammals: their productivity and population dynamics* (K.P. Golley, K. Petruszewicz & L. Ryszkowski, eds.). Cambridge Univ. Press, New York, pp.269-298.
- FONSECA, G.A.B. 1988. Patterns of small mammal species diversity in the Brazilian Atlantic Forest. PhD thesis. University of Florida, Gainesville.
- FONSECA, G.A.B. & ROBINSON, J.G. 1990. Forest size and structure: Competitive and predatory effects on small mammal communities. *Conserv Biol.* 53:265-294.

- FOSTER, R. 1982. The seasonal rhythm of fruitfall on Barro Colorado Islands. In: *The Ecology of a Tropical Forest: Seasonal Rhythms and long-term Changes* (E.G. Leigh, A.S. Rand & D.M. Windsor, eds.). Smithsonian Press. Washington DC, p.151-172.
- GALETTI, M., GIACOMINI, H.C., BUENO, R.S., BERNARDO, C.S.S., MARQUES, R.M., BOVENDORP, R.S., STEFFLER, C.E., RUBIM, P., GOBBO, S.K., DONATTI, C.L., BEGOTTI, R.A., MEIRELLES, F., NOBRE, R.A., CHIARELLO, A.G. & PERES, C.A. 2009. Priority areas for conservation of Atlantic Forest large mammals. *Biol Conserv.* 142:1229-1241.
- GALINDO-LEAL, C. & CÂMARA, I.G. 2005. Mata Atlântica: biodiversidade, ameaças e perspectivas. Fundação SOS Mata Atlântica, Conservação Internacional, Belo Horizonte.
- GARDNER, A.L. 2007. *Mammals of South America, Volume 1: Marsupials, Xenarthrans, Shrews, and Bats*. University of Chicago Press, Chicago.
- GOMES, E.P.C., MANTOVANI, W. & KAGEYAMA, P.Y. 2003. Mortality and recruitment of trees in a secondary montane Forest in southeastern Brazil. *Braz. J. Biol.* 63(1):47-60.
- GRAIPEL, M.E., MILLER, P.R.M. & GLOCK, L. 2003. Padrão de atividade de *Akodon montensis* e *Oryzomys russatus* na reserva Volta Velha, Santa Catarina, sul do Brasil. *Mastozoología Neotropical: J. Neotrop. Mammal.* 10(2):255-260.
- GURD, D.B., NUDDS, T.D. & RIVARD, D.H. 2001. Conservation of mammals in eastern north American wildlife reserves: How small is too small? *Conserv. Biol.* 15(5):1355-1363.
- HANNIBAL, W. & CACERES, N.C. 2010. Use of vertical space by small mammals in gallery forest and woodland savannah in south-western Brazil. *Mammalia.* 74:247-255.
- HAUGAASEN, T. & PERES, C.A. 2005. Mammal assemblage structure in Amazonian flooded and unflooded forests. *J. Trop. Ecol.* 21:133-145.
- HICE, C.L. & SCHMIDLY, D. 2002. The effectiveness of pitfall traps for sampling small mammals in the Amazon basin. *Mastozool. Neotrop.* 9:85-89.
- HIROTA, M.M. 2018. Atlas dos remanescentes florestais da Mata Atlântica. Período 2016 a 2017. Relatório técnico, Fundação SOS Mata Atlântica e Instituto de Pesquisas Espaciais. https://www.sosma.org.br/wp-content/uploads/2019/05/Atlas-mata-atlantica_17-18.pdf (last accessed on 07/22/2020)
- IAG. 2017. Instituto de Astronomia, Geofísica e Ciências Atmosféricas. Informações sobre as Estações do Ano na Cidade de São Paulo. <http://estacao.iag.usp.br/seasons/index.php> (last accessed on 05/20/2017)
- INSTITUTO CHICO MENDES DE CONSERVAÇÃO DA BIODIVERSIDADE (ICMBio). 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume II - Mamíferos. In: Instituto Chico Mendes de Conservação da Biodiversidade. (Org.). Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. ICMBio, Brasília.
- JANZEN, D.H. 1973. Sweep samples of tropical foliage insects: effects of seasons, vegetation types, elevation, times of day and insularity. *Ecology.* 54:687-708.
- JENKINS, C.N., PIMM, S.L. & JOPPA, L.N. 2013. Global patterns of terrestrial vertebrate diversity and conservation. *P Natl Acad Sci USA.* 110(28):E2602-2610.
- JORGÉ, M.S.P., GALETTI, M., RIBEIRO, M.C. & FERRAZ, K.P.M.B. 2013. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. *Biological Conservation.* 163:49-57.
- JULIEN-LAFERRIÈRE, D. & ATRAMENTOWICZ, M. 1990. Feeding and reproduction of three didelphid marsupials in two Neotropical forests (French Guiana). *Biotropica.* 22(4):404-415.
- LAMBERT, T.D., MALCOLM, J.R. & ZIMMERMAN, B.L. 2006. Amazonian small mammal abundances in relation to habitat structure and resource abundance. *J Mamm.* 87:766-776.
- LESSA, G., GONÇALVES, P.R., JUNIOR, M.M.M., COSTA, F.M., PEREIRA, R.F. & PAGLIA, A.P. 1999. Caracterização e monitoramento de fauna de pequenos mamíferos terrestres de um fragmento de mata secundária em Viçosa, Minas Gerais. *Caderno do Departamento de Ciências Biológicas da PUC Minas.* 7(7):41-49.
- LISBOA, C.S., VAZ, R.I., MALAGOLI, L.R., BARBO, F.E., VENTURINI, R.C. & BRASILEIRO, C.A. Herpetofauna from an Atlantic Forest Fragment in São Paulo, Brasil. *Herpetological Conservation and Biology*. In press.
- MACCLEARN, D., KOHLER, J., MCGOWAN, K.J., CEDEÑO, E., CARBONE, L.G. & MILLER, D. 1994. Arboreal and terrestrial mammal trapping on Gigante Peninsula, Barro Colorado Nature Monument, Panama. *Biotropica.* 26(2):208-213.
- MALAGOLI, L.R., BAJESTEIRO, F.B. & WHATELY, M. 2008. Além do concreto: contribuições para a proteção da biodiversidade paulistana. Instituto socioambiental, São Paulo.
- MELLO, D.A. 1980. Estudo populacional de algumas espécies de roedores do Cerrado (norte do município de Formosa, Goiás). *Revista Brasileira de Biologia.* 40(4):843-860.
- MINISTÉRIO DO MEIO AMBIENTE (MMA). 2002. Biodiversidade brasileira - Avaliação e identificação de áreas e ações prioritárias para a conservação, utilização sustentável e repartição dos benefícios da biodiversidade nos biomas brasileiros. Brasília – DF.
- MITTERMEIER R.A., GIL P.R., HOFFMAN M., PILGRIM J., BROOKS T., MITTERMEIER C.G., LAMOREUX J., FONSECA G.A.B. (2005) Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. Washington, Conservation International
- MITTERMEIER, R.A., GIL, P.R., HOFFMAN, M., PILGRIM, J., BROOKS, T., MITTERMEIER, C.G., LAMOREUX, J. & DA FONSECA, G.A.B. 2004. Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. Conservation International.
- MITTERMEIER, R.A., RYLANDS, A.B., PADUA, C. & BUTYNSKI, T.M. 2006. Primates in peril: The world's 25 most endangered primates 2004-2006. Report to IUCN/SSC Primate Specialist Group, International Primatological Society and Conservation International, Washington DC.
- MONTICELLI, C. & MORAIS, L.H. 2015. Impactos antrópicos sobre uma população de *Alouatta g. clamitans* (Cabrera 1940) em um fragmento de Mata Atlântica no Estado de São Paulo: apontamentos de medidas mitigatórias. *Revista Biociências.* 21(1):14-26.
- MONTICELLI, C. & ANTUNES, T.C. 2018. Novo registro de *Blarinomys breviceps* (Winge, 1888) (Rodentia: Sigmodontinae) na Mata Atlântica do sudeste de São Paulo. *Boletim da Sociedade Brasileira de Mastozoologia.* 81:10-13.
- MONTICELLI, C. 2019. Diversidade genética de uma população isolada de bugio-ruivo (*Alouatta guariba clamitans*) (Cabrera, 1940) no Parque Estadual das Fontes do Ipiranga, São Paulo – SP. Brasil. Master's dissertation, Universidade Federal de São Carlos, São Carlos.
- MORAES, A.A. 2017. Ecologia alimentar e estudo do comportamento de termorregulação de preguiça comum, *Bradypus variegatus* Schinz, 1825, no Parque Estadual Fontes do Ipiranga (São Paulo). Master's dissertation, Universidade Federal de São Paulo, São Paulo.
- O'CONNELL, M.A. 1989. Population dynamics of neotropical small mammals in seasonal habitats. *J Mamm.* 70(3):532-548.
- OLIVEIRA, P.P. 1995. Ecologia de comunidades de pequenos mamíferos em áreas em diferentes estágios de sucessão na Reserva Biológica de Poço das Antas, RJ. Master's dissertation, Universidade Federal de Minas Gerais, Belo Horizonte.
- PAGLIA, A.P., FONSECA, G.A.B., RYLANDS, A.B., HERRMANN, G., AGUIAR, L.M.S., CHIARELLO, A.G., LEITE, Y.L.R., COSTA, L.P., SICILIANO, S., KIERULFF, M.C.M., MENDES, S.L., TAVARES, V.C., MITTERMEIER, R.A. & PATTON J.L. 2012. Lista anotada dos mamíferos do Brasil /Annotated checklist of Brazilian Mammals 2nd edn. *Occasional Papers in Conservation Biology.* 6:1-76.
- PARDINI, R., SOUZA, S.M., BRAGA-NETO, R. & METZGER, J.P. 2005. The role of forest structure, fragment size and corridors in maintaining small mammal abundance and diversity in an Atlantic forest landscape. *Biol Conserv.* 124:253-266.
- PARDINI, R. & UMETSU, F. 2006. Non-volant small mammals from the Morro Grande Forest Reserve – distribution of species and diversity in an Atlantic Forest area. *Biota Neotrop.* 6(2):1-22. <https://doi.org/10.1590/S1676-06032006000200007> (last accessed on 04/18/2019)

- PATTON, J.L., PARDIÑAS, U.F.J. & ELÍA, G.D. 2015. Mammals of South America, Volume 2: Rodents. University of Chicago Press, Chicago.
- PECCININI, A.A. & PIVELLO, V.R. 2002. Histórico do uso das terras e condição da vegetação no PEFI. In: Parque Estadual das Fontes do Ipiranga (PEFI): unidade de conservação que resiste à urbanização de São Paulo (D.C. Bicudo, M.C. Forti & C.E.M. Bicudo, orgs.). Imprensa Oficial do Estado de São Paulo, São Paulo, pp.251-258.
- PERES, C.A. 2000. Effects of subsistence hunting on vertebrate community structure in Amazonian Forests. *Conserv Biol.* 14(1):240-253.
- PERES, C.S. 2010. A previsão constitucional do bioma mata atlântica. *Revista Brasileira de Direito Constitucional.* 16:109-119.
- PERRELLA, D.F. & GUIDA, F.J.V. 2013. Aspectos da história natural de *Ramphastos dicolorus* (Piciformes – Ramphastidae) no Parque Estadual das Fontes do Ipiranga. Unpublished monograph, Fundação Parque Zoológico de São Paulo, São Paulo.
- PERRELLA, D.F., FERRARI, D.S., KATAYAMA, M.V., PAIVA, R.V. & GUIDA, F.V. 2018. A Avifauna do Parque Estadual das Fontes do Ipiranga, um remanescente de Mata Atlântica imerso na área urbana de São Paulo, SP. *Ornithologia.* 10(1):4-16.
- PINOTTI, B.T. 2010. Pequenos mamíferos terrestres e a regeneração da mata atlântica: influência da estrutura do habitat e da disponibilidade de alimento na recuperação da fauna. Master's dissertation, Instituto de Biociências da Universidade de São Paulo, São Paulo.
- PREVEDELLO, J.A., FERREIRA, P., PAPI, B.S., LORETTO, D. & VIEIRA, M.V. 2008. Uso do espaço vertical por pequenos mamíferos no Parque Nacional Serra dos Órgãos, RJ: um estudo de dez anos utilizando três métodos de amostragem. *Espaço & Geografia.* 11(1):95-119.
- PUTTKER, T., PARDINI, R., MEYER-LUCHT, Y. & SOMMER, S. 2008. Responses of five small mammal species to micro-scale variations in vegetation structure in secondary Atlantic Forest remnants, Brazil. *BMC Ecol.* 8(9).
- RANCURA, K.G.O. & CERATI, T.M. 2020. A Mata Atlântica e o Parque Estadual das Fontes do Ipiranga – PEFI. In: Parque Estadual das Fontes do Ipiranga: Biodiversidade, Conservação e Educação. (N.F. da Silva & K.G.O. Rancura, orgs.). 1a ed. Fundação Parque Zoológico de São Paulo, São Paulo, p.12-27.
- RIBEIRO, M.C. 2009. The Brazilian Atlantic forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biol Conserv.* 142(6):1141-1153.
- ROSSI, H.R.S. 2017. Comunidade de morcegos e análise de grãos de pólen em pelagem de Phyllostomidae (Chiroptera, Phyllostomidae) no Parque Estadual Fontes do Ipiranga - PEFI, São Paulo, Brasil. Master's dissertation, Universidade Federal de São Carlos, São Carlos.
- ROSSI, H.R.S., CORRÊA, A.M.S., MONTICELLI, C., MORAIS, L.H. & ROCHA, V.J. 2020. Análise de pólen em pelagem de morcegos Phyllostomidae (Chiroptera) no Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. *Hoehnea.* 47:1-15.
- SANTOS, A.C.L. 2008. Composição florística e estrutura da comunidade de epífitas vasculares associadas a trilhas no Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. Master's dissertation, Instituto de Botânica, São Paulo.
- SANTOS-FILHO, M., SILVA, D.J. & SANAIOTTI, T.M. 2006. Efficiency of four trap types in sampling small mammals in forest fragments, Mato Grosso, Brazil. *Mastozoología Neotropical.* 13(2):217-225.
- SANTOS-FILHO, M., SILVA, D.J. & SANAIOTTI, T.M. 2008. Variação sazonal na riqueza e na abundância de pequenos mamíferos, na estrutura da floresta e na disponibilidade de artrópodes em fragmentos florestais no Mato Grosso, Brasil. *Biota Neotrop.* 8(1):115-121. <http://dx.doi.org/10.1590/S1676-06032008000100014> (last accessed on 04/04/2017)
- SÃO PAULO. 2008. Secretaria do Meio Ambiente. Parque Estadual Fontes do Ipiranga. Plano de Manejo: Resumo Executivo. São Paulo. 35 p.
- SÃO PAULO. 2018. Lista vermelha de fauna ameaçada do estado de São Paulo. Decree no. 63.853 from November 27, 2018.
- SILVA JUNIOR, A.P. & PONTES, A.R.M. 2008. The effect of a mega-fragmentation process on large mammal assemblages in the highly-threatened Pernambuco Endemism Centre, north-eastern Brazil. *Biodivers Conserv.* 17:1455-1464.
- STALLINGS, J.R. 1988. Small mammals communities in an eastern Brazilian Park. Unpublished PhD thesis. University of Florida, Gainesville.
- UMETSU, F., NAXARA, L. & PARDINI, R. 2006. Evaluating the efficiency of pitfall traps for sampling small mammals in the Neotropics. *J Mamm.* 87:757-765.
- VIEIRA, M.V. 2002. Seasonal niche dynamics in coexisting rodents of the Brazilian Cerrado. *Studies on Neotropical Fauna and Environment.* 38(1):7-15.
- VILLAGRA, B.L.P. 2008. Diversidade florística e estrutura da comunidade de plantas trepadeiras no Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. Master's dissertation, Instituto de Botânica, São Paulo.
- VILLAGRA, B.L.P. & ROMANIUC-NETO, S. 2010. Florística de trepadeiras no Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. *Revista Brasileira de Biociências.* 8(2):186-200.
- WHATELY, M., SANTORO, P.F., GONÇALVES, B.C., GONZATTO, A.M. 2008. Parques urbanos municipais de São Paulo: subsídios para a gestão. Instituto Socioambiental. São Paulo.
- WOLDA, H. 1993. Trends in abundance of tropical forest insects. *Oecologia.* 89:47-52.

Received: 08/09/2020

Revised: 08/03/2021

Accepted: 23/03/2021

Published online: 26/04/2021