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ZOOLOGY

Medium-sized mammals in peri-urban environments in southern Brazil

Carla Denise Tedesco[1], Douglas Machado da Silva[2*] and Noeli Zanella[1]

*[1]Programa de Pós-Graduação em Ciências Ambientais, Instituto de Ciências Biológicas, Universidade de Passo Fundo, Passo Fundo, Rio Grande do Sul, Brazil. [2]Programa de Graduação em Ciências Biológicas, Instituto de Ciências Biológicas, Universidade de Passo Fundo, BR 285, 99052-900, Passo Fundo, Rio Grande do Sul, Brazil. *Author for correspondence. E-mail: 145318@upf.br*

ABSTRACT. Anthropic effects on natural environments caused by urban expansion or agriculture have been identified as one of the causes for the decline in species richness. In southern Brazil, the urbanization process affects the local fauna and reduces the diversity of mammalian species**.** This study was conducted from 2012 to 2015 with the objective of gathering information on mammalian species in a peri-urban area. Data was collected four consecutive days each month for 42 months using sand plots and visual searches. Occasional encounters and camera traps complemented were used to complement the data. We recorded 15 mammal species belonging to 10 families. The species with the highest abundance, taking into account all the applied methods, were *Didelphis albiventris*, *Mazama gouazoubira* and *Cerdocyon thous.* Four species were listed as endangered (*Puma yagouaroundi*, *Leopardus guttulus*, *Nasua nasua*, and *Dasyprocta azarae*).

Keywords: Atlantic Forest; endangered species; inventory; fragmentation; mammalian fauna.

Mamíferos de médio porte em ambientes periurbanos no sul do Brasil

RESUMO. A antropização de ambientes naturais, pela expansão urbana ou pela agricultura, tem sido apontada como uma das causas da redução da riqueza de espécies. No sul do Brasil, esses processos afetaram a diversidade, extinguindo diversas espécies da mastofauna. Este estudo foi conduzido de 2012 a 2015, com o objetivo de conhecer as espécies de mamíferos presentes em uma área periurbana. A coleta de dados foi realizada durante quatro dias por mês durante 42 meses, utilizando plots de areia e procura visual. Encontros ocasionais e armadilhas fotográficas complementaram os dados. Foram registradas 15 espécies de mamíferos, distribuídas em 10 famílias. As espécies com a maior frequência, utilizando todos os métodos, foram *Didelphis albiventris, Mazama gouazoubira* e *Cerdocyon thous*. Quatro espécies estão listadas como ameaçadas regionalmente (*Puma yagouaroundi*, *Leopardus guttulus*, *Nasua nasua* e *Dasyprocta azarae*).

Palavras-chave: Mata Atlântica; espécies ameaçadas; inventário; fragmentação; fauna de mamíferos.

Introduction

The Atlantic forest is one of the most threatened biomes, with only 12% of its original natural cover (Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009); it has high species-richness with strong levels of endemism in animal and plant groups (Myers, Mittermeier, Mittermeier, Fonseca, & Kent, 2000). Biological diversity is threatened by the expansion of agricultural activity and increased population density (Ribeiro et al., 2009; Pires & Cademartori, 2012).

Anthropized environments, due to agriculture or urbanization, invariably result in a mosaic of different land use patterns; this leads to fragmentation of the original vegetation, which is the main cause of habitat loss for native fauna (Santos, Pellanda, Tomazzoni, Hasenack, & Hartz, 2004; Ribeiro et al., 2009; Brocardo & Cândido-Júnior, 2012). When vegetation areas are isolated, it creates a barrier for species dispersal (Liu, Zhang, Wei, & Xie, 2016; Yong, Barton, Okada, Crane, & Lindenmayer, 2016) that favors generalist species (Bernardo & Melo, 2013). Previous studies revealed that mammals in altered landscapes include species that can tolerate anthropic impact (Dotta & Verdade, 2011; Ribeiro & Melo, 2013; Dias & Bocchiglieri, 2016).

Another element is the quality of the matrix surrounding habitat fragments, as verified in several studies as stated by Cassano, Barlow, and Pardin (2012); the anthropized matrices of higher quality (agroforests) modify the structure of mammalian communities, but maintain diversity. The manner in which species live in fragmented habitats and perceive the matrix defines the impact of these fragmented mosaics on a species' populations (Caryl, Quine, & Park, 2012).

The abundance and distribution of mammals is reflected by different variables relative to the biology of the species (e.g., degree of specialization and interaction). Urban matrices can cause negative and positive effects on the species, as those with high levels of specialization and larger carnivores that avoid fragmented environments (Pires & Cademartori, 2012). The ecological plasticity of mammalian communities in the original vegetation areas relate to many factors. We evaluated the frequency and richness of medium-sized mammals using different methods in an area with fragments of habitats in the process of regeneration. Our objective was to collect information about mammalian species in a peri-urban area. We also identified species and their trophic category and compared the abundance of mammalian records.

Material and methods

Study site

The study area has springs of water resources along permanent preservation areas (PPAs), with different degrees of conservation, and lies at the border of the urban area with the rural area of the municipality of Passo Fundo (028° 13' 51.6" S, 051° 22' 49.9" W; Datum = WGS84). The area was composed of three different APPS environments (Figure 1), covering an area of 15% of 136 hectares, in a mixed matrix of urbanized blocks (low density buildings) with asphaltic streets, green wooded areas, small fragments of forest native crops, and annual crops. Original vegetation is characterized as mixed ombrophilous, with the typical vegetation mosaic of the Araucaria Forest (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2012), one of the most important phytophysiognomies in southern Brazil. Altitudes range from 630 to 740 m.

Data collection

Sampling occurred from March 2012 to December 2015, for four consecutive days each month, excluding January, February, and December 2012 and January, February, and March 2013, when sampling was interrupted due to logistic issues, 42 months in total.

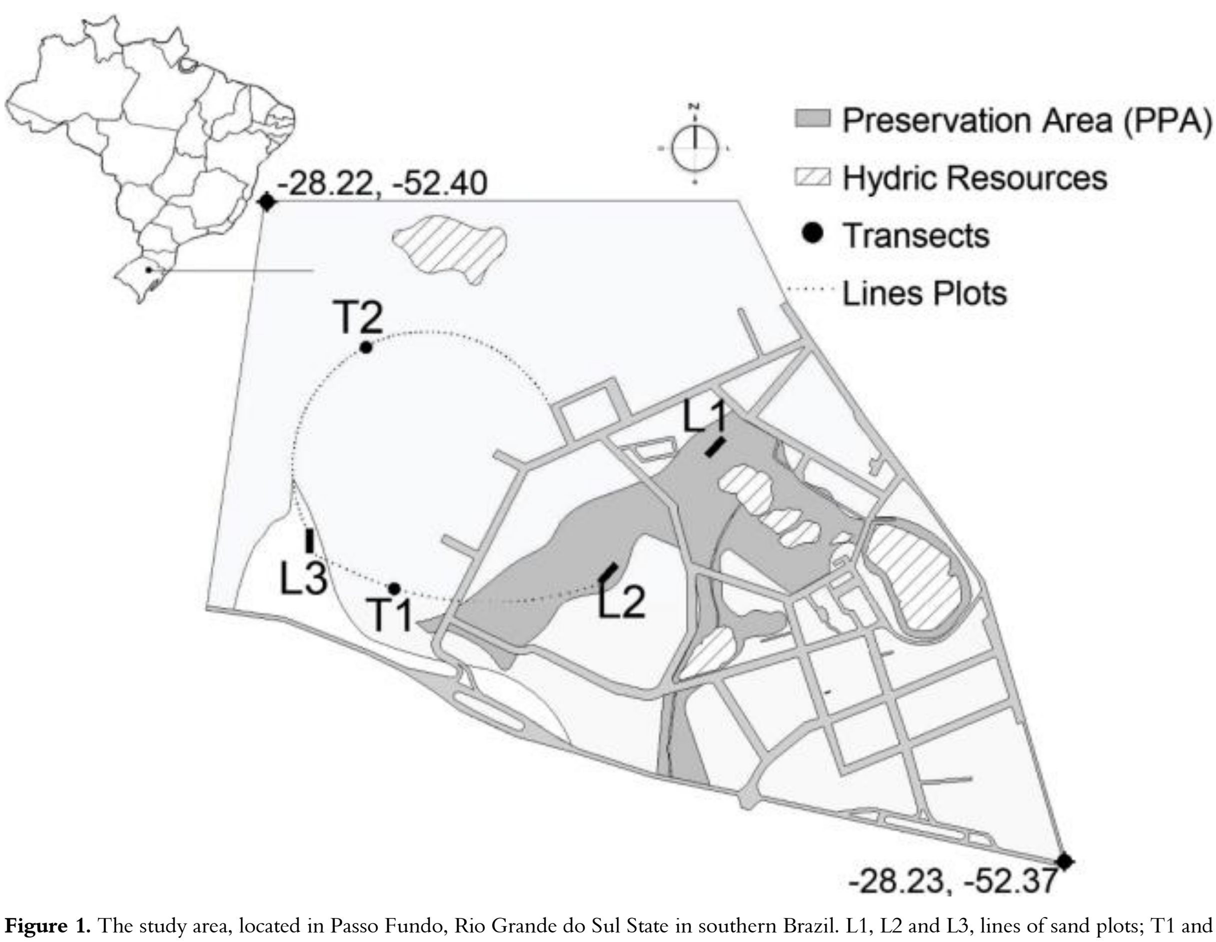

Figure 1. The study area, located in Passo Fundo, Rio Grande do Sul State in southern Brazil. L1, L2 and L3, lines of sand plots; T1 and T2, transects of visual searches.

We used distinct methods for sampling: (1) sand plots (plots); (2) visual searches (Vs); (3) casual encounters (Cs); and (4) camera traps (Cts). Vs occurred along two delimited transects, between plot lines, where at least two researchers spent a minimum of two hours per day, in the humid, successional vegetation, and open areas. Transects were traveled coinciding with the inspection of the traps, in the morning (8:00 - 11:00). Transect lines varied between 0.3 and 0.6 km per environment. Total walked distance varied between 50.4 and 100.8 km per sampling unit, totaling 151.2 km and 336 hours. Species were detected by direct sightings or by indirect evidence, such as footprints, fecal material, burrows, predation marks, and carcasses.

Sand plots consisted of bottomless wooden frames 50 × 50 cm, installed in three transects 300 m apart from each other. In each transect we installed 10 plots with 10 m in between each. Plots were baited with fruits and meat (Santos, Bueno, & Casella, 2013; Bernardo & Melo, 2013) and maintained for five working days per month, totaling 4.032 hour. Plots were examined in the morning to search for footprints and remove remaining baits. New baits were placed in the evenings (during autumn, spring, and summer) or in the mornings during winter.

Cs were mammal sightings by the research team that occurred before or after the Vs or detections made by study helpers, used to increase the species-richness estimate for the area.

Six Cts (Bushnell® E2) were installed in PPA (L1 and L2) (Figure 1) from March 2015 to February 2016 at a height of 40 cm from the ground. Cts were maintained through the study period and cameras were systematically reviewed monthly. Records obtained this way confirmed the species from the study area, as they enabled precise identification of the Felidae, Cervidae, and Canidae families, which are difficult to determine using footprints.

We determined that footprints in the plots, among the wild canids, belonged to *Cerdocyon thous* as only this species was detected by the team in areas adjacent to the plots. We assumed that *M. gouazobira* was the recorded species in plots, as it was identified on camera traps.

We adopted the definition of mammal size patterns, identifying animals ≥ 1.0 kg as adults (Wilson & Reeder, 2005; Bocchiglieri, Mendonça, & Henriques, 2010). Small rodents were included in the non-identified category. Non-identified footprints, domestic species (dogs and cats), and small rodents were recorded and removed from the analysis.

Footprints identification was based on previous experience field staff. Footprints which were difficult to identify became measures and photographs compared with material from a specialized bibliography (Travi & Gaetani, 1985; Becker & Dalponte, 1999).

Data analysis

The sampling effort was evaluated using a species accumulation curve with 1,000 simulations, to evaluate sampling efficiency (Colwell & Coddington, 1994). Each field campaign (one week/month) corresponded to a sample unit. Accumulation curves were obtained using non-parametric Jackknife 1 and Bootstrap estimators to confirm the validation of the sampling. The number of samples to estimate any total species in the community (Santos, 2003) was obtained using EstimateS 9.1.0 software (Colwell, 2013).

Since records in each plot were not independent, it was difficult to use this method to calculate species abundance. Thus, we calculated frequency in plots, i.e., Vs and Cs with occurrence records of the species. Constancy of species occurrence was calculated by an index (Silveira-Neto, Nakano, Barbin, & Nova, 1976), with the constant defined as the percentage of samples in which a certain species was present. Based on plot data, species in more than 50% of samples were considered constant; species identified in 25 to 50% of samples were classified as accessories; and species observed in less than 25% of samples were considered occasional.

The nonparametric Kruskal-Wallis (H) test was used to compare the efficiency of each sampling method (Cs, Plots, and Vs) for species-richness (Zar, 1999).

Results and discussion

We recorded 15 mammal species, belonging to 10 families (Table 1, Figure 2), with Carnivora accounting for 46.6%, Rodentia for 20%, and Didelphimorphia for 13.3%. When sampling methods were analyzed, *Mazama gouazoubira*, *Lepus europaeus*, and *Myocastor coypus* were the most frequent in Vs; *Didelphis albiventris*, *Cerdocyon thous*, and *Dasypus novemcinctus* the most frequent in plots; and *M. gouazoubira*, *C. aperea,* and C. *thous* the most frequent in Cs. Given the sum of all methods, *D. albiventris* was the most frequent species (Figure 2).

Table 1. Mammals in the study area using all methods, from March 2012 to December 2015. Vs = visual search; Plots = sand plots; Cs = casual encounters.

Taxon	Species	Common name	Method			Category trophic
			Cs	Plots	Vs	
Carnivora						
Canidae	*Cerdocyon thous* (Linnaeus, 1766)	Crab-eating fox		x		Omnivorous
	Lycalopex gymnocercus (Fischer, 1814)	Pampas fox	x		x	Insectivorous/omnivorous
Felidae	*Puma yagouaroundi* (Geoffroy Saint-Hilaire, 1802)	Jaguarundi	x			Carnivorous
	Leopardus guttulus (Hensel, 1872)	Southern tigrina			x	Carnivorous/Insectivorous
Procyonidae	*Nasua nasua* (Linnaeus, 1766)	Coati		x		Insectivorous/Frugivorous
	Procyon cancrivorus (Cuvier, 1798)	Crab-eating raccoon	x	x	x	Frugivorous/Omnivorous
Mephiltidae	*Conepatus chinga* (Molina, 1782)	Andeam hog-nosed skunk	x	x		Insectivorous/omnivorous
Cetartiodactyla						
Cervidae	*Mazama gouazoubira* (Fischer, 1814)	Brown brocket deer	x	x	x	Frugivorous/Herbivorous
Cingulata						
Dasypodidae	*Dasypus novemcinctus* (Linnaeus, 1758)	Armadillo	x	x	x	Insectivorous/omnivorous
Rodentia						
Dasyproctidae	*Dasyprocta azarae* (Lichtenstein, 1823)	Agouti		x	x	Frugivorous/Granivorous
Caviidae	*Cavia aperea* (Erxleben, 1777)	Cavies	x	x	x	Herbivorous
	Hydrochaeris hydrochaeris (Linnaeus, 1766)	Capybara	x	x		Herbivorous
Didelphimorphia						
Didelphidae	*Didelphis albiventris* (Lund, 1840)	White-eared opossum	x	x	x	Frugivorous/Omnivorous
Echimyidae	*Myocastor coypus* (Molina, 1782)	Coypu	x	x		Frugivorous/Omnivorous
Lagomorpha						
Leporidae	*Lepus europaeus* (Pallas, 1778)	European hare	x	x	x	Herbivorous
Total species			11	12	9	

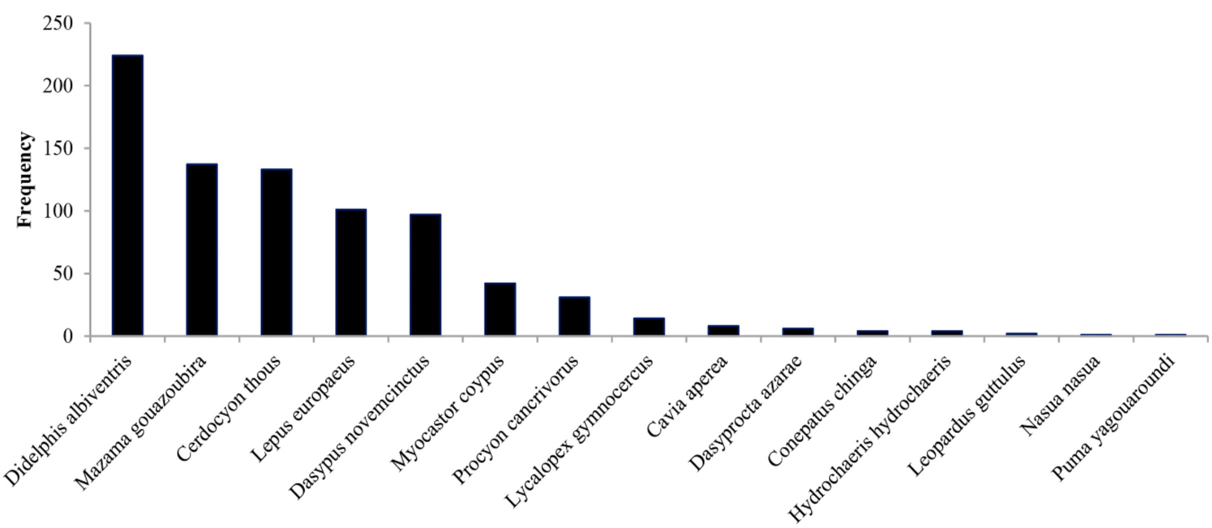

Figure 2. Frequency of mammals using Plots, Cs and Vs, from March 2012 to December 2015.

Four species (26%) were listed as endangered for the state of Rio Grande do Sul *Puma yagouaroundi*, *Leopardus guttulus*, *Nasua nasua*, and *Dasyprocta azarae* (Brasil, 2014). Recorded richness corresponds to 9.5% of the 158 species for Rio Grande do Sul (Fontana, Bencke, & Reis, 2003). Despite the small size of the PPAs, the environmental impact caused by vehicle traffic, suppression of original vegetation, and the presence of conventional crops, maintains the area with a number of species consistent with previous studies in southern Brazil: 16 spp, (Abreu-Júnior & Köhler, 2009); 16 spp, (Pires & Cademartori, 2012); 14 spp, (Guaragni, Lima, Zanella, & Paula, 2014). In altered landscapes, there may be variation in observed richness regarding the number and composition of mammalian species, reflecting the influence of size of the area, type and degree of anthropic change, and influence of adjacent biomes (Oliveira, Câmara, & Oliveira, 2009; Bocchiglieri et al., 2010). It is possible that more extensive areas with mosaics of environments contribute to the increase of local wealth, since larger species need larger areas in which to forage and tend to use different environments in the landscape to explore a greater variety of resources (Bocchiglieri et al., 2010).

The majority of the recorded species are considered widely distributed, usually associated with open areas, and tolerant to human disturbances (Alves, Fonseca, & Engel, 2012; Bernardo & Melo, 2013; Dias & Bocchiglieri, 2016). Carnivora represented the highest richness, similar to that found in other studies in the Atlantic forest (Negrão & Valladares-Pádua, 2006; Kasper, Mazim, Soares, Oliveir, & Fabián, 2007; Abreu-Júnior & Köhler, 2009; Santos et al., 2013) where medium- and large-sized mammals tend to present the highest richness indices in Brazil (Paglia et al., 2012). In fragmented landscapes, this group was observed frequently and did not exhibit habitat preferences, which occurred across the entire area, given that the majority of its representatives have high mobility and the ability to explore anthropogenic environments and areas close to native vegetation patches (Lyra-Jorge, Ciocheti, & Pivello, 2008). We highlight the presence of *Puma yagouaroundi* and *Leopardus guttulus*, both endangered species. These carnivores occurred in low density with few detection records (Lyra-Jorge et al., 2008; Dias & Bocchiglieri, 2016). Many have extensive home ranges and habitat fragmentation can influence the use of habitat and the size of home range of this species (Kasper, Schneider, & Oliveira, 2016). *Didelphis albiventris* was found in high frequency in this study area, and is considered a generalist species that feeds on fruits, small vertebrates, eggs, insects, and other invertebrates (Silva, Forneck, Bordignon, & Cademartori, 2014). The traps may have favored the recording of a greater frequency of this species, since we used bait, which are considered generalist and opportunistic. Our observations showed that species such as *Cerdocyon thous* and *N. nasua* have environmental plasticity, managing to survive in forest fragments sparse and small next to the study area. The ease of adaption of *N. nasua* to modified environments can lead to an increase in population size in disturbed areas (Bisbal, 1993). Dogs and cats were frequently registered during the study; records were obtained by footprints, photographic traps, and direct sightings. The presence of these species may exert a negative effect on wild species, as a potential disease vector, predator, or those competing for resources with wild carnivores (Santos, 2003; Campos, Esteves, Ferraz, Crawshaw-Jr., & Verdade, 2007).

Using data from the plots and Vs, 26.7% of the species were considered constant (*Cerdocyon thous*, *Didelphis albiventris, Dasypus novemcinctus*, and *Mazama gouazoubira*), 46.7% were considered occasional (*Cavia aperea, Conepatus chinga, Dasyprocta azarae, Hydrochaeris hydrochaeris, Lepus europaeus*, *Myocastor coypus*, and *Nasua nasua*), and 6.7% were accessory (*Procyon cancrivorus*). The highest richness result was obtained using plots with 12 recorded species. Cs recorded eleven species, and Vs 9 species. There was a significant difference between these methods ($H = 40.34$; $p < 0.0001$). In Vs, *Mazama gouazoubira* was the most frequent species with 88 records (38.6%). *Didelphis albiventris* was the most frequent in plots with 213 records (36.8%). Cameras traps recorded 8 species, probably due to the short time this survey was used in comparison with other methods (Figure 3). Species richness estimator Jacknife 1 determined 9.98 ± 0.98, 13.93 ± 2.16 and 13.93 ± 1.36 species for Vs, Cs, and plots, while Bootstrap estimated 9.58 ± 0, 12.25 ± 0 and 13.03 ± 0 species for Vs, Cs, and plots, respectively (Figure 4).

Using different sampling methods proved adequate to record mammals in the study area. The methods can present limitations, such as highly similar footprints in sand plots (e.g., canids, small cats), so collecting accurate data depends on a researcher's ability to correctly identify species based on footprints (Lyra-Jorge et al., 2008). In future studies, an increase in the number of camera traps could help with detecting other species not recorded in this study. There are other limiting factors related to weather conditions; torrential rains can obscure footprints, and during certain periods of the year, the substrate may be dry, preventing formation of footprints. Despite the limitations of these methods, we found them to be important instruments for mammal detection. Their use corroborated various studies using different complementary methods for sampling (Kasper et al., 2007; Lyra-Jorge et al., 2008; Pires & Cademartori, 2012; Santos et al., 2013; Carvalho, Oliveira, & Pires, 2014; Dias & Bocchiglieri, 2016).

Camera traps were used for a shorter period than other methods to confirm species occurrence, resulting in detection of low richness. Ct is an important method to detect cryptic species, which are rarely detected by other methods, and their use is considered a good strategy for surveying mammalian diversity (Melo, Sponchiado, & Cáceres, 2012; Santos et al., 2013; Espinosa, Galiano, Kubiak, & Marinho, 2016; Fleschutz et al., 2016). Since we were unable to assess the total number of species in the area, the accumulation curves rarely stabilize for data from sand plots and occasional meetings, but show a tendency to stabilize for visual searches. Similar data was found in other studies, which showed that curves did not stabilize and more species may be detected with increased sampling effort (Bocchiglieri et al., 2010; Dias & Bocchiglieri, 2016). Thus, richness estimators for the area corroborate that more species are recorded for the study area with an increased sampling effort. In a nearby protected area, using similar methodologies, Guaragni et al. (2014) recorded species not found in this study, such as *Coendou spinosus* and *Sapajus nigritus*.

Figure 3. Camera traps installed in the study area. 1. *Nasua nasua*; 2. *Puma yagouaroundi*; 3. *Didelphis albiventris*; 4. *Mazama gouazoubira*.

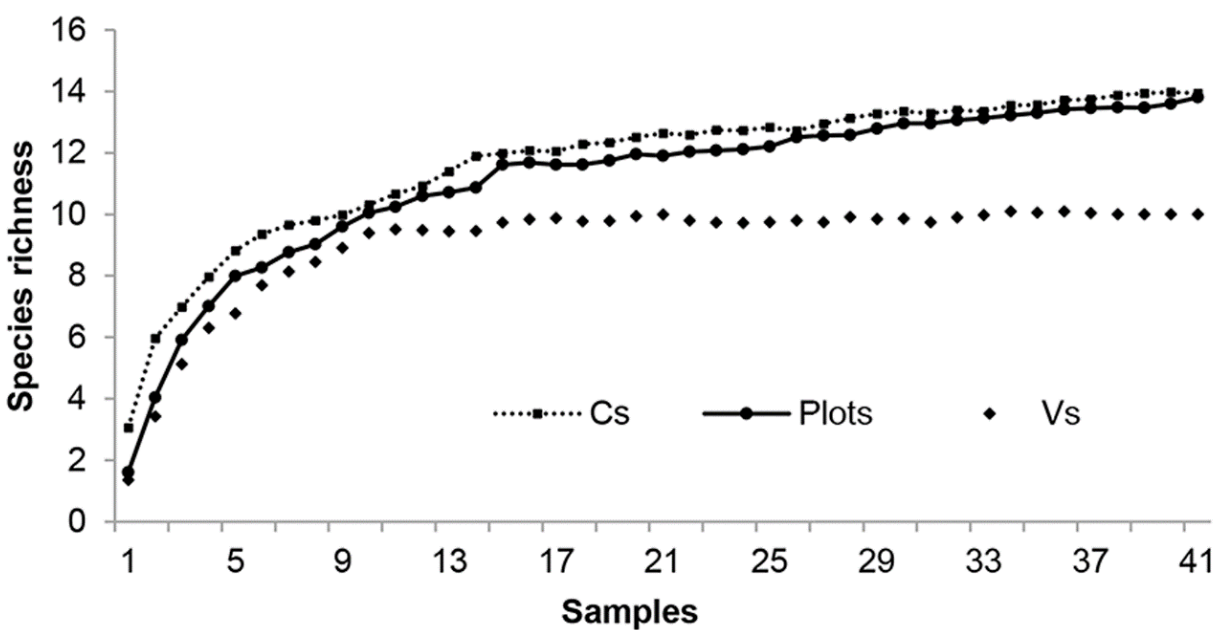

Figure 4. Species accumulation curves using the Jackknife 1 estimator, from March 2012 to December 2015. Vs = visual search; Plots = sand plots; Cs = casual encounters.

The richness was probably the result of the conservation state of the areas (peri-urban), the fragmentation and sampling methods used, which prioritized terrestrial species. Analyzing the trophic categories, 5 species were herbivorous (33.3%), 4 were insectivores/omnivores (26.6%), 3 were frugivorous/omnivorous (20%), 2 were carnivorous (13.3%), and 1 was omnivorous (6.6%) (Table 1). The predominance of herbivores can be explained by the high availability of food items in this group. Omnivorous species, such as crab-eating fox, agoutis, and cavies eat mainly leaves, fruits, and seeds when small mammals, birds and amphibians are not available (Faria-Corrêa, Balbueno, Vieira, & Freitas, 2009; Rocha, Aguiar, Silva-Pereira, Moro-Rios, & Passos, 2008). Carnivorous species, such as *P. yagouaroundi* and *L. guttulus* and those with high potential for hunting (*N. nasua*, *L. gymnocercus*, *C. thous* and *D. albiventris*) may be associated with food resources (Rocha et al., 2008; Rocha-Mendes, Mikich, Quadros, & Pedro, 2010; Ferreira, Nakano-Oliveira, Genaro, & Lacerda-Chaves, 2013), such as small rodents in the study area. *L. guttulus* is specialized in hunting small rodents and *P. yagouaroundi* preys on small rodent marsupials and medium-sized mammalian species (Canepuccia, Martinez, & Vassallo, 2007; Rocha-Mendes et al., 2010; Bisceglia, Pereira, Teta, & Quintana, 2011).

Habitat loss and fragmentation may affect mammalian communities, especially by modifications in landscape matrix, which act as a selective filter for fauna (Ceballos & Ehrlich, 2002). The size, structure and shape of small fragments may contribute to form a mosaic of qualitatively different habitats throughout the landscape, providing greater heterogeneity and structural complexity (Bernardo & Melo, 2013; Fleschutz et al., 2016; Melo et al., 2016). Species show many kinds of responses to habitat fragmentation: some are advantaged and increase in abundance, while others decline and become locally extinct (Bennett & Saunders, 2010). Species that need a greater living range are more sensible to the effects of habitat fragmentation, disappearing from smaller fragments (Woodroffe & Ginsberg, 1998, Kosydar, Rumiz, Conquest, & Tewksbury, 2014). In this study, the register of medium-sized species may be associated with the landscape in this peri-urban environment. The absence of species in nearby areas such as *Sapajus nigritus* (Guaragni et al., 2014), *Alouatta guariba clamitans*, *Lontra longicaudis,* and *Eira barbara* (Abreu Júnior & Köhller, 2009) is probably related to the needs of larger and more preserved fragments. Maintenance of preserved areas in periurban environments can contribute to a refuge for mammals that transit the agricultural matrix and provide additional resources for the survival of many species.

Conclusion

Our results demonstrate species maintenance potential in peri-urban areas with water resources, surrounded by a predominantly agricultural landscape with native vegetation fragments. We emphasize the use of different methods to learn about fauna in the area, and the importance of a relatively long registration period, allowing us to increase the wealth of species of the mastofauna. Conservation strategies include fragmented areas, especially in the Atlantic Forest, and can play an important role in conserving threatened mammals. Knowledge of the mammals recorded in the disturbed areas may aid in devising conservation strategies.

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