Oecologia Australis
21(2): 147-155, 2017
10.4257/oeco.2017.2102.05

SURVEY OF SMALL MAMMALS (RODENTIA AND DIDELPHIMORPHIA) IN A CERRADO RESERVE: CENTRAL ESPINHAÇO MOUNTAIN RANGE, BRAZIL

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ABSTRACT
Despite its high diversity, small mammals within the Cerrado (savanna) at the Central Espinhaço Range are poorly known, and precise information regarding the geographical distribution of all species is still scarce. Here we present data on terrestrial small-sized mammals (Didelphimorphia and Rodentia) from Parque Estadual do Rio Preto (PERP), a protected area in the Central Espinhaço and compare the species composition of this area with other protected areas in the Espinhaço Range. Over the course of 10,616 trap-nights, there were 700 captures of 245 individuals, being eight species from de order Didelphimorphia and eight from Rodentia, with an overall capture rate of 6.6%. We report both, *Gracilinanus agilis* and *G. microtarsus*, occurring in sympatry and the occurrence of *Thalpomys lasiotis*, known to be endemic to the Cerrado biome. We observed that the species composition of the Central Espinhaço contains a set of species different from those found in Southern Espinhaço (Serra de Ouro Branco). This may be most the result of vegetal physiognomies among the inventoried areas and less clearly the result of geographic distance between them. Considering that the conservation strategies focus basically on the richness and the occurrence of endemic species, we here emphasize the need for further research efforts in order to improve our knowledge about the Espinhaço fauna.
Keywords: inventory; Mammalia; species composition.

INTRODUCTION

The Espinhaço Mountain Range represents the most continuous Precambrian orogenic belt in the Brazil's territory and extends approximately 1,200 km between its north and south limits, delimiting a contact zone between Atlantic Forest and Cerrado at South and Caatinga, Cerrado and Atlantic Forest biomes at North (Giulietti *et al.* 1997, Almeida-Abreu *et al.* 2005). Although the Espinhaço Range has been the focus of studies of naturalists over the last two centuries, basic information about the small mammal's species richness and composition is still scarce (Lessa *et al.* 2008, Braga *et al.* 2016). The Central Espinhaço in Minas Gerais state is within the Cerrado (savanna), and the predominant vegetation type consists of "campos rupestres" (rock grassland), although the vegetation mosaic also includes semi-deciduous and dwarf forests (Mendonça-Filho 2005, Bünger *et al.* 2014). This complex biome holds the third highest mammal's diversity of Brazil (251 species) with many endemic and/or patchily distributed species (Paglia *et al.* 2012). The most diverse groups are Chiroptera (with 101 species), Rodentia (78 species) and Didelphimorphia (26 species) (Paglia *et al.* 2012) and part of this diversity is threatened due to human activities as agropastoral activities, mining and fire (Trolle *et al.* 2007, Lessa *et al.* 2008), making it one of the most threatened savanna-like biomes in the world (Myers *et al.* 2000, Klink & Machado 2005, Carvalho *et al.* 2009).

Despite its importance, in Minas Gerais state less than 2% of native Cerrado remnants are under legal protection as parks or other protection categories (Drumond *et al.* 2005, Klink & Machado 2005). Although some of these protected areas are recognized as priority sites for vertebrate biodiversity conservation (see Drumond *et al.* 2005), only a small portion has their mammalian fauna properly inventoried (Drumond *et al.* 2005, Leal *et al.* 2008, Câmara & Oliveira 2012, Lessa & Paula 2014). However, despite the limited information on the diversity of mammals across this

mosaic landscapes (Lessa *et al*. 2008), recent researches revealed the occurrence of species considered to be restricted to the Atlantic Forest (Geise & Astúa 2009, Loss *et al*. 2015) and even the description of a new genus of Sigmodontinae rodent (Pardiñas *et al*. 2014). The Parque Estadual do Rio Preto (PERP), one of the few Cerrado protected areas in the Central Espinhaço, harbors a great diversity of small mammals (Lessa & Paula 2014) and was highlighted in 2005 as one of the 52 priority sites for mammal conservation in Minas Gerais state (Drumond *et al*. 2005).

In this context, the aims of the present study were (1) presents updated data on small-sized mammals composition (Didelphimorphia and Rodentia) from Parque Estadual do Rio Preto, Minas Gerais; (2) compare the species composition of this area with other protected areas in the Espinhaço Mountain Rage to understand how this species composition is related to others.

MATERIAL AND METHODS

Study area

The Parque Estadual do Rio Preto (PERP: 18º05'20"S; 43º20'25"W), with an area of 12,000 hectares, is located in the Central Espinhaço Mountain Range, in São Gonçalo do Rio Preto municipality, Minas Gerais state, Brazil (Figure 1). Its vegetation is composed by different Cerrado physiognomies: riparian forest ("mata ciliar"), field rock ("campo rupestre"), Cerrado *stricto sensu*, and open grassland ("campo limpo") (Foresto 2008).

Climate is type *Cwb* according to the climatic classification of Köppen, with mild, wet summers in the period from October to March and cooler, dry winters from April to September. Annual precipitation ranges from 250-1,550 mm and the average annual temperature ranges from 17° to 19°C (Neves *et al.* 2005).

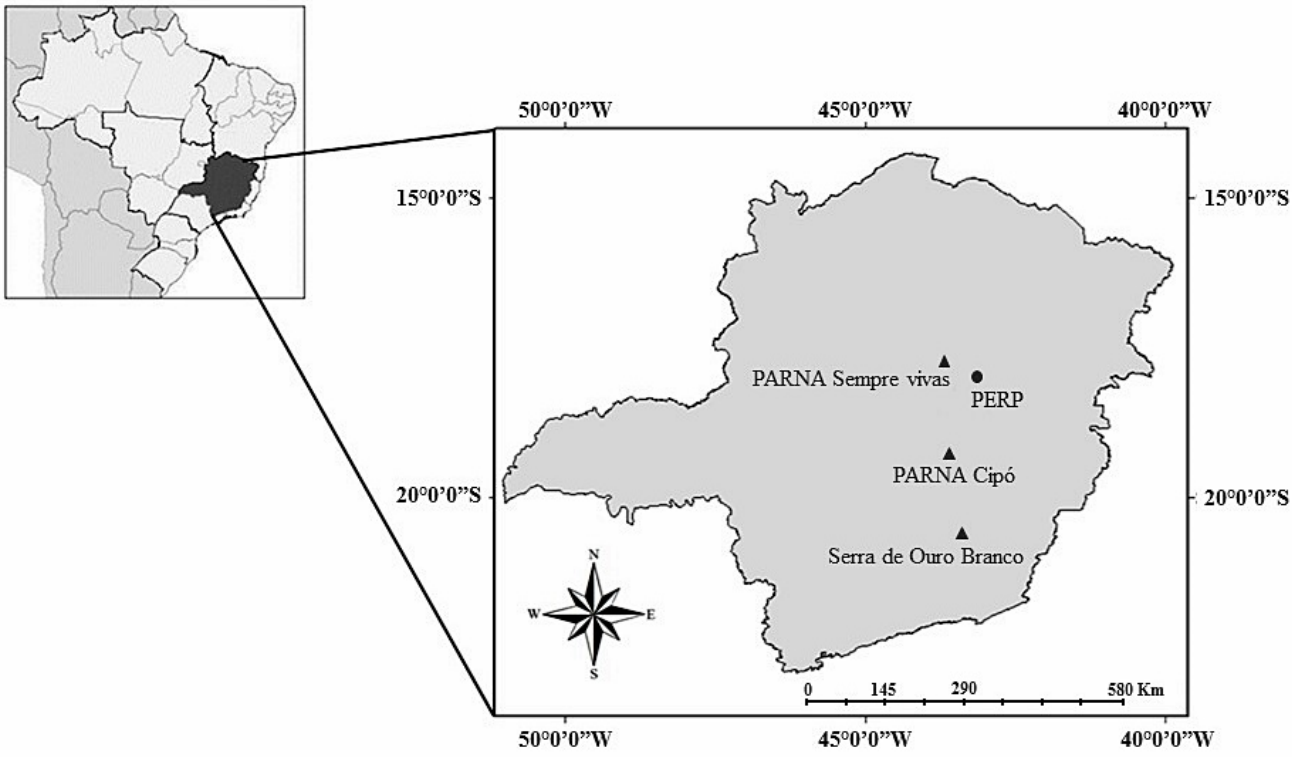

Figure 1. Geographic location of Parque Estadual do Rio Preto (PERP) and the other protected areas compared in the present study. PARNA Cipó = Parque Nacional da Serra do Cipó; PARNA Sempre Vivas = Parque Nacional das Sempre Vivas e Serra de Ouro Branco.

Sampling design and species inventory

We sampled small mammals (Rodentia and Didelphimorphia) in two periods, from November 2009 to October 2011 and from September 2013 to January 2014. The overall sampling effort was 10,616 trap-nights. During both sampling periods we used as bait orange or pineapple pieces, cotton impregnated in Scott emulsion® (the base of cod liver oil) and bacon bits. We checked all trap daily and captured individuals were tagged with numbered rings fixed to the ear (Zootech®). Trapping was conducted in areas with different Cerrado physiognomies and traps were set according topography and occurrence of trees (arboreal traps settled up to 2 m).

During the first period (2009-2011) sampling was monthly, with four trapping nights each, using 96 wire traps (300 x 160 x 160 mm), disposed in four parallel transects separated by 50 m. In each transect 12 trapping stations were settled, 15 m apart one from another, each one with two traps, one on the ground and one in the understory. In this first period, trapping was conducted in a transitional area among a riparian forest ("mata ciliar") and Cerrado *stricto sensu*. During the second period (2013-2014) two collecting efforts were carried out, each one with seven capture nights, one in the dry season (September 2013) and another in the rainy season (January 2014). The sampling design was according to the Sisbiota/ CNPq-ComCerrado Research Network (Research Thematic Networks to expand knowledge on the biota, the functional role, use and conservation of Brazilian Biodiversity) with two parallel lines of 5 km long separated by 1 km. To the right side of each line, every 1 km, one 250 m transect was installed, totaling five trapping stations per line. We used 100 wire live traps (300 x 16 x 16 mm) and Sherman (250 x 80 x 90 mm) traps in an 1:1 proportion alternately installed, one on the ground and one in the understory (about 2 m high). Trapping was conducted in seven areas with different vegetation types (Cerrado *sensu stricto* n = 2, "campo rupestre" n = 2, "campo limpo" n = 2 and "mata ciliar" n = 1). In the areas of "campo rupestre" and "campo limpo", two live-traps were set on the ground.

We considered morphological characters (skin and skull) for species identification according to Gardner (2008) for Didelphimorphia and Patton *et al.* (2015) for Rodentia. At least one individual of each morphotype captured was collected, identified in specific level, and deposited in the scientific collection of the Departamento de Ciências Biológicas/Universidade Federal dos Vales do Jequitinhonha e Mucuri (Appendix 1). The Chico Mendes Institute for Biodiversity Conservation - SISBIO/MMA provided the license to capture the animals (process number 19790-1).

Data analysis

We compared the species composition of our studied area (PERP) with the composition of other protected areas, Parque Nacional da Serra do Cipó (PARNA Cipó) and Parque Nacional das Sempre Vivas (PARNA Sempre Vivas), located in the central portion of the Espinhaço Mountain Range, and the Serra de Ouro Branco, located in the southern portion (Table 1). To do this, a cluster analysis was carried out using the Jaccard coefficient of similarity and a UPGMA algorithm. We use a Mantel test to correlate the composition dissimilarity matrix (based on the Jaccard coefficient) with a matrix of geographic distance (based on the coordinate data using Euclidian distance). The Mantel test was used to determine if linear correlation was present in the species composition. These analyzes were performed in the R program for statistical computing (R Development Core Team 2013) with the Vegan package (Oksanen *et al.* 2010).

The cumulative curve of mammal species was made in the software EstimateS 9.0 (Colwell 2013) with "1,000" randomizations and the sampling effort was evaluated from the overlap of the confidence interval of 95% of species richness.

RESULTS

We obtained a capture success of 6.6% and registered 16 species of small mammals being, eight Didelphimorphia and eight Rodentia (Table 2). Among the didelphids, the highest relative abundances were obtained for the species *Gracilinanus agilis* (22.44%) and *G. microtarsus* (21.22%), while *Cerradomys subflavus* and *Thrichomys apereoides* (5.71%) had the highest abundance among rodents. The species with lower relative abundance were *Cerradomys scotti*, *Necromys lasiurus* (0.81%) and *Talpomys lasiotis* (0.40%) (Table 2). The species accumulation curve shows a tendency to stabilize (Figure 2).

Table 1. Small mammal species composition in Parque Estadual do Rio Preto (PERP), and in three other protected areas: PARNA Cipó (Parque Nacional da Serra do Cipó), PARNA Sempre Vivas (Parque Nacional das Sempre Vivas), and Serra do Ouro Branco, Minas Gerais state, Brazil.

Taxon	PERP[1]	PARNA Cipó[2]	PARNA Sempre Vivas[3]	Serra de Ouro Branco[4]
Didelphimorphia				
Caluromys philander (Linnaeus, 1758)	30	1	0	0
Cryptonanus cf. *agricolai* (Moojen, 1943)	0	0	0	1
Cryptonanus sp.	0	2	0	0
**Didelphis albiventris* Lund, 1840	21	34	1	1
Gracilinanus agilis (Burmeister, 1854)	226	93	0	0
Gracilinanus microtarsus (Wagner 1842)	155	0	0	1
Marmosa paraguayana Tate, 1931	24	0	0	0
**Marmosops incanus* (Lund 1840)	93	221	19	12
Metachirus nudicaudatus (Desmarest, 1817)	16	0	0	0
**Monodelphis americana* (Müller, 1776)	0	0	1	19
**Monodelphis domestica* (Wagner, 1842)	1	85	17	1
Monodelphis kunsi Pine, 1975	0	1	0	0
Philander frenatus (Olfers, 1818)	0	36	0	0
Total	566	473	38	35
Rodentia				
Abrawayaomys ruschii Cunha & Cruz, 1979	0	0	0	1
Akodon cursor (Winge, 1887)	0	26	3	0
Castoria angustidens (Winge, 1887)	0	0	0	43
Bibimys labiosus (Winge, 1887)	0	0	0	2
Blarinomys breviceps (Winge, 1887)	0	0	0	4
Calomys tener (Winge, 1887)	0	112	2	4
**Cavia aperea* Erxleben, 1777	0	16	4	0
**Cerradomys scotti* (Langguth & Bonvicino, 2002)	2	15	1	0
**Cerradomys subflavus* (Wagner, 1842)	40	944	40	1
**Cerradomys* sp.	0	0	1	0
Euryoryzomys russatus (Wagner, 1842)	0	2	0	0
**Euryzygomatomys spinosus* (G. Fischer, 1814)	0	0	5	0
**Hylaeamys laticeps* (Lund, 1840)	0	0	2	0
**Hylaeamys* sp.	0	0	1	0
**Necromys lasiurus* (Lund, 1841)	2	2	3	3
**Nectomys squamipes* (Brants, 1827)	7	16	35	0
**Oligoryzomys nigripes* (Olfers, 1818)	20	223	27	242
**Oligoryzomys stramineus* Bonvicino & Weksler, 1998	0	0	1	0
Oxymycterus dasytrichus (Schinz, 1821)	0	1	0	0
**Oxymycterus delator* Thomas, 1903	0	23	1	0
Oxymycterus sp.	0	0	1	0
Pseudoryzomys simplex (Winge, 1887)	0	0	3	0
Rattus novergicus (Berkenhout 1758)	0	0	0	2
Rhagomys rufescens (Thomas, 1886)	0	0	0	2
**Rhipidomys mastacalis* (Lund, 1840)	38	667	13	1
Thalpomys lasiotis Thomas, 1916	2	124	1	0
**Thrichomys apereoides* (Lund, 1839)	23	336	194	0
**Trinomys albispinus* (I. Geoffroy, 1838)	0	0	169	0
Trinomys moojeni Pessoa, Oliveira & Reis, 1992	0	1	0	0
Trinomys setosus (Lund, 1841)	0	6	0	0
**Trinomys* sp.	0	0	61	0
Total	134	2.514	568	305
Overall total	700	2.987	606	340

[1]Present study; [2]Câmara & Oliveira 2012; [3]Leal *et al.* 2008; [4]Braga *et al.* 2016; *L. G. Lessa unpublished data.

Table 2. Small mammal species registered in Parque Estadual do Rio Preto, Minas Gerais state, Brazil, between November 2011 to January 2014.

Taxon	Captures	Individuals
Didelphimorphia		
Caluromys philander (Linnaeus, 1758)	30	14
Didelphis albiventris Lund, 1840	21	11
Gracilinanus agilis (Burmeister 1854)	226	55
Gracilinanus microtarsus (Wagner 1842)	155	52
Marmosa paraguayana Tate, 1931	24	2
Marmosops incanus (Lund 1840)	93	40
Metachirus nudicaudatus (Desmarest, 1817)	16	8
Monodelphis domestica (Wagner, 1842)	1	1
Total	566	183
Rodentia		
Cerradomys scotti (Langguth & Bonvicino, 2002)	2	2
Cerradomys subflavus (Wagner, 1842)	40	14
Necromys lasiurus (Lund, 1841)	2	2
Nectomys squamipes (Brants, 1827)	7	5
Oligoryzomys nigripes (Olfers, 1818)	20	10
Rhipidomys mastacalis (Lund, 1840)	38	13
Thalpomys lasiotis Thomas, 1916	2	2
Thrichomys apereoides (Lund, 1839)	23	14
Total	134	62
Overall total	700	245

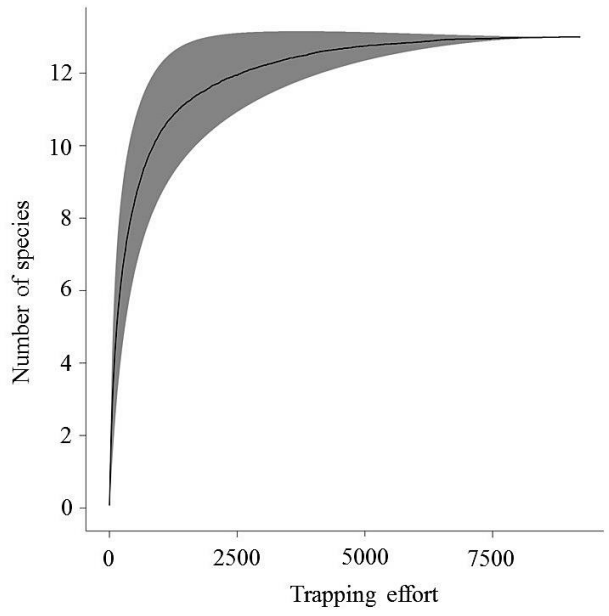

Figure 2. Cumulative number of species recorded per field trip in Parque Estadual do Rio Preto, Minas Gerais, Brazil. The gray band represents the Confidence Interval (CI) of 95%.

The cluster analysis revealed that all areas compared in the Espinhaço Moutain Range present high dissimilarity in species composition, the average value of dissimilarity was 72%. We found a distinguished group with a consistent similarity index (cophenetic correlation similarity = 0.92) (Figure 3). This group was comprised of the three protected areas located at the central portion of the Espinhaço Range (PERP, PARNA Cipó and PARNA Sempre Vivas) and had distinct Cerrado physiognomies from each other. This group presents a distinct small mammalôs composition from Serra de Ouro Branco, located at the southern portion of the Espinhaço. PERP, located at least 250 Km from Serra do Ouro Branco, presents a dissimilarity coefficient of 68%, with only eight species in common. The higher dissimilarity coefficient was found among PARNA Sempre Vivas and Serra do Ouro Branco (80%) (Table 3, Figure 3).

We found a high geographical correlation in species composition among the areas with the Mantel test, but this correlation was not significant ($r = 0.88$; $p = 0.083$). A high but not significant correlation indicates a high probability of this correlation occurring by chance or being influenced by a small sample size.

Table 3. List from the four areas used to compose the cluster analysis. Areas: PERP = Parque Estadual do Rio Preto; PARNA Cipó = Parque Nacional da Serra do Cipó; PARNA Sempre Vivas = Parque Nacional das Sempre Vivas. Traps: Tm - Tomahawk, Sh - Sherman, Pt - Pitfall. Habitats: C - open grassland, Ce - Cerrado *stricto sensu*, Cr - field rock, Fs -forest savanna, Rf - riparian forest, AF - Atlantic Forest.

Area	PERP[1]	PARNA Cipó[2]	PARNA SempreVivas[3,*]	Serra de Ouro Branco[4]
Location in the Espinhaço Range	Meridional	Meridional	Meridional	South
Geographic coordinates	18º05'20"S; 43º20'25"W	22°30' to 22°33'S; 42°15' to 42°19'W	17°54'47"S; 43°48'08"W	20°29'S; 43°37'W
Trap	Tm, Sh, Pt	Tm, Sh	Tm, Sh	Tm, Sh*, Pt
Habitat	C, Ce, Cr, Rf,	C, Ce, Cr, Fs, Rf	C, Ce, Cr, Fs, Rf	Cr, AF
Rodentia	8	16	22	11
Didelphimorphia	8	8	4	6
Richness	16	24	26	17
Total effort	10,616	21,360	9,008	6,664

[1]Present study; [2]Câmara & Oliveira 2012; [3]Leal *et al.* 2008; [4]Braga *et al.* 2016; *L. G. Lessa unpublished data.

DISCUSSION

There are currently 251 mammalian species assigned to the Cerrado biome, including 26 marsupials (Didelphimorphia) and 78 rodents (Rodentia) (Paglia *et al.* 2012) therefore, the Parque Estadual do Rio Preto, with the 16 species here reported, harbors 31% of Didelphimorphia and 10% of Rodentia known for this biome. Most species recorded shows large geographical distributions also occurring in other adjacent biomes such as the Caatinga (*e.g. G. agilis, Didelphis albiventris, Marmosops incanus, Necromys lasiurus* and *Oligoryzomys nigripes*) and the Atlantic Forest (*e.g. G. microtarsus, M. incanus, Metachirus nudicaudatus, Cerradomys subflavus, Nectomys squamipes* and *Rhipidomys mastacalis*) (see Bonvicino *et al.* 2002, Geise & Astúa 2009, Pereira & Geise 2009, Paglia *et al.* 2012, Nogueira *et al.* 2015, Patton *et al.* 2015). A similar pattern represented by species shared with Atlantic Forest, Caatinga and Cerrado was observed in other studies carried on the Espinhaço Range (see Pereira & Geise 2007, 2009, Câmara & Oliveira 2012, Braga *et al.* 2016) which is a contact zone between the Cerrado and Atlantic Forest to the south and a transition zone between the Cerrado, Atlantic Forest and Caatinga in the northern (Giulietti *et al.* 1997).

Among the 32 endemic mammalian species presently recognized for the Cerrado (Paglia *et al.* 2012), at least one was found in PERP, the terrestrial rodent *T. lasiotis*, trapped in a transitional area between riparian forest and open grassland. Capture sites of *T. lasiotis* in the Cerrado biome have mostly been in savanna-like formations such as open grasslands and open grasslands with scattered shrubs ("campo sujo") (Ribeiro *et al.* 2011, Rocha *et al.* 2011). This taxon is considered rare in scientific collections and seemingly rare in studies in all vegetation types of the Cerrado (Santos & Henriques 2010, Ribeiro *et al.* 2011, Rocha *et al.* 2011). In the Espinhaço Range, the only other known record of *T. lasiotis* is in a protected area in Parque Nacional da Serra do Cipó (Lessa *et al.* 2008, Câmara & Oliveira 2012). The PERP small-sized mammalian fauna also presents interesting components, such as the didelphid *M. incanus* and the sympatry between *G. microtarsus* and *G. agilis*. The first two species are best known from coastal Atlantic Forest localities with few inland samples in savanna habitats (Cerrado and Caatinga) of Minas Gerais and Bahia (Melo & Sponchiado 2012). The small Neotropical opossum *G. agilis* occurs predominantly in more open formations in the Brazilian Cerrado and Caatinga (Loss *et al.* 2011, Melo & Sponchiado 2012). *Gracilinanus microtarsus*, described to be endemic

to the Atlantic forest and *G. agilis*, considered to be endemic to Cerrado/Caatinga, are not frequently recorded in sympatry (Geise & Ástua 2009). In addition to this record, contact zones between these two small Neotropical arboreal opossums are known in only other three localities of the Cerrado, all in the state of Minas Gerais (Costa *et al.* 2003, Geise & Ástua 2009).

The number of species recorded in PERP (n = 16) is similar to other study carried out in the central portion of the Espinhaço Range with 15 species recorded (Leal *et al.* 2008). Furthermore, Câmara & Oliveira (2012) reported one of the largest species richness in the Central Espinhaço (n = 24), both studies using only wire traps. Indeed, the species composition of PERP was grouped with other areas at the Central Espinhaço (Leal *et al.* 2008, Câmara & Oliveira 2012), showing greater similarity in species composition in relation to the Serra de Ouro Branco (Braga *et al.* 2016), localized at the Southern Espinhaço. Despite the greater similarity in species composition between the three areas located in the Central Espinhaço, they present heterogeneous vegetation formations, composed of different physiognomies from Cerrado such as rock grassland, Cerrado *stricto sensu*, woodland savanna, and riparian forests. Comparing the species composition of PERP with those found in the other two cited parks, we observed that 12 species (five didelphids and seven rodents) are common to at least two parks (Leal *et al.* 2008, Câmara & Oliveira 2012, present study). *Marmosops incanus, Monodelphis domestica, C. subflavus, N. lasiurus, T. lasiotis* and *Thrichomys apereoides* were registered in all three parks, and, according to Paglia *et al.* (2012), all these species may occur in open formations of the Cerrado biome. The major difference in the species composition between these parks was observed between Didelphimorphia species. Some didelphid marsupials, characteristics of different forest physiognomies (*Marmosa paraguayana* and *M. nudicaudatus*) (Gardner 2008, Paglia *et al.* 2012) were recorded only in PERP, while the small arboreal opossum *G. microtarsus* has been registered only in PERP and Serra do Ouro Branco (Braga *et al.* 2016).

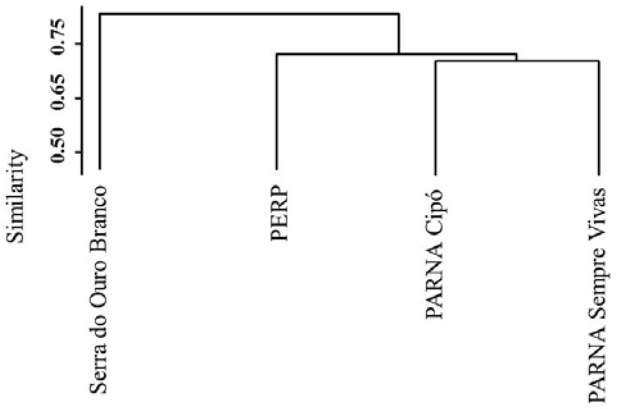

Figure 3. A cluster analysis showing the similarity in small mammal species composition among between the studied areas: PERP = Parque Estadual do Rio Preto; PARNA Cipó = Parque Nacional da Serra do Cipó; PARNA Sempre Vivas = Parque Nacional das Sempre Vivas and Serra de Ouro Branco. The tree was constructed based on Jaccard distance and a UPGMA algorithm.

In the Cerrado biome, forest formations usually present a higher complexity and habitat heterogeneity (Paglia *et al.* 1995, Graipel *et al.* 2006), being able to house a greater number of niches (Ribeiro & Marinho-Filho 2005) supporting higher species diversity compared to the open physiognomies of this biome, as the field rocks and open grasslands (Lessa & Paula 2014). This may also be the reason for the occurrence of didelphids commonly found in the Atlantic Forest in those forest formations in the PERP. A similar pattern was also observed by Pereira & Geise (2009), which reported the occurrence of species endemic to the Atlantic Forest in Cerrado forested physiognomies in the Chapada Diamantina, at the extreme northern border of the Espinhaço Mountain Range.

We observe that spatially closer populations are more similar in species composition, the analysis suggested that the Central Espinhaço contains a set of species different from those found in Southern Espinhaço (Serra de Ouro Branco). The more similar areas within the central group (PARNA Cipó and PARNA Sempre Vivas) are the two that presents a predominance of savanna-like formations ("campo rupestre", "campo limpo" and Cerrado *stricto sensu*) (IBAMA 2009), while the PERP presents a predominance of forest formations from Cerrado ("mata ciliar" and "cerradão") (Foresto 2008). On the other hand, the more dissimilar area in the south (Serra

do Ouro Branco) is more influenced by the nearby communities and physiognomy characteristics of Atlantic Forest (Braga *et al.* 2016). Despite those phytophysionomic differences among the compared areas, we do recognize, however, that the differences in trapping effort may also contribute to those dissimilarities in species composition, once Serra do Ouro Branco had the lower trapping effort compared to the other studied areas. According to Moura *et al.* (2008), the trapping effort is the most important variable influencing the number of species and individuals sampled.

Finally, although the species accumulation curve presented here shows an asymptotic tendency, additional surveys are still required which will allow a more precisely assessment of the Espinhaço richness and species composition. Over the last ten years, various studies have focused on the extraordinarily rich mammalian fauna throughout the Espinhaço, but have also emphasized that there are still many knowledge gaps (Lessa *et al.* 2008, Câmara & Oliveira 2012, Braga *et al.* 2016).

ACKNOWLEDGMENTS

We received financial support from Fundação de Amparo a Pesquisa do Estado de Minas Gerais (FAPEMIG - process no APQ01034/09) and Programa SISBIOTA/CNPq (process no 56314/2010.0). Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) provided the collecting license (no 19790-1) and the Instituto Estadual de Florestas (IEF) the authorization to develop the research in the PERP. Lena Geise receives CNPq, FAPERJ and Uerj/Prociência fellowships. We also thank Thiago Santos for comments on the manuscript and many colleagues who helped us in fieldwork.

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Submitted: 15 June 2016
Accepted: 14 December 2016