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Article

Small mammals from the lasting fragments of Araucaria Forest in southern Brazil: a study about richness and diversity

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ABSTRACT. Rodents and marsupials together, form the most rich group of mammals in Brazil, they are distributed in all biomes, including Atlantic Forest, and can be used to analyze environmental quality. The Araucaria Forest is a threatened formation of the Atlantic forest with few areas remaining intact and a huge lack of knowledge about the potential of its secondary forest fragments to act as habitat refuges to native fauna. This study evaluated the species richness and diversity of non-volant small mammals among five vegetation types within a protected area in an Araucaria Forest area from southern Brazil. The sampling was made in six bimonthly campaigns during a year, by pitfall and live traps. This effort resulted in 875 captures of 625 individuals from 16 species. The most common species in Pine Plantation was *Oligoryzomys nigripes*, in Natural Regeneration forest was *Thaptomys nigrita* and *Akodon montensis* was most often captured in the other vegetation. Although differences in species composition were found among the different vegetation types, there was no significant difference in species richness. Nevertheless, true diversity values were significantly lower in the Pine Plantation. The results demonstrated that the substitution of native for exotic vegetation generated a negative impact on the group diversity. More studies, in other Araucaria Forest areas are necessary to allow better understanding of the processes driving this loss of diversity in this biome threatened by antropic action.

KEYWORDS. Didelphimorphia, Mixed Rain Forest, Sigmodontinae, species composition.

The Atlantic Forest in considered a world's hotspot for biodiversity (Myers *et al.*, 2000). Originally, the Brazilian Atlantic Forest covered 1227600 km^2 but after years of urbanization, industrialization, and agricultural expansion the biome was reduced to 28% of its original area (Myers *et al.*, 2000; Rezende *et al.*, 2018).

Ombrophilous Mixed Forest, or Araucaria Forest, is an Atlantic Forest formation, characterized by the predominance of Brazilian pine (*Araucaria angustifolia*) in the upper stratum. It occurs mainly in the Brazilian Southern Plateau, above 500-600 meters of altitude, in Paraná, Santa Catarina and Rio Grande do Sul states (MMA, 2010). Originally, this sub-region covered 253793 km^2 and, in 2009, it was narrowed to 32021 km^2 (12.6%) of fragmented patches and only 3.1% of that are located within protected areas (Ribeiro *et al.*, 2009), current this number can be even lower. Because of its management history few areas remain intact and little is known about the potential of the secondary forest fragments to act as habitat refuges to native fauna.

As the most rich group of mammals in Brazil (Paglia *et al.*, 2012), non-volant small mammals has been investigated for responding to different forms of environmental impacts as agricultural and mining activities, fragmentation and loss of habitat complexity (Martin *et al.*, 2012; Ardente *et al.*; 2016; Paise *et al.*, 2020; Hannibal *et al.*, 2020), therefore they can be used to analyze environmental quality. This group is formed by Sigmodontinae rodents and Didelphimorphia marsupials because they weigh less than 2 kg and are captured and studied by similar methods (Voss & Emmons, 1996; Eisenberg & Redford, 1999).

In the present study we used non-volant small mammals to compare assemblages from five secondary vegetation physiognomies in Piraí do Sul National Forest, a forest mosaic inserted in a matrix of forestry and livestock, located in the Araucaria Forest domain. Recently two rodent species, *Juliomys ossitenuis* and *Bibimys labiosus*, were recorded for the first time in this locality expanding their knowing home ranges (Grazzini *et al.*, 2015a,b) and suggesting Piraí do Sul National Forest to be an interesting refuge not studied enough. This National Forest has areas in different conservation contexts such as *Araucaria angustifolia* reforestation, *Pinus elliottii* plantation, and native Araucaria Forest in different successional stages which allowed us to assess how much diversity each vegetation retained after its unique management history.

Based on the fact that in a semi-deciduous mosaic area of the Atlantic Forest, the low diversity of small mammals in the *Eucalyptus* plantation indicates that these homogeneous plantations have low aptitude for endemic species (Umetsu & Pardini, 2007). Our hypothesis is that (1) the planting of exotic trees (here *Pinus elliotti*) will be the least suitable area for the native fauna of the Araucaria Forest and will present the least wealth and diversity among the sampled areas and (2) due to its homogeneous characteristic, reforestation with *Araucaria angustifolia* will be less diverse than natural regeneration.

MATERIALS AND METHODS

Study area. The study took place in the Piraí do Sul National Forest ("Floresta Nacional de Piraí do Sul", hereafter SPNF) (24°38'01"S, 49°53'25"W) (Fig. 1). SPNF is a conservation unit for sustainable use in the state of Paraná, southern Brazil, located in areas of Forest with Araucaria and covers an area of approximately 153 ha.

Sampling of non-volant small mammals took place in five sites representative of the vegetation classes within SPNF. These vegetation classes were defined as: (1) *Pinus elliotti* reforestation (Pine Plantation or PP), (2) natural regenerating Riparian Forest (RF), (3) *Araucaria angustifolia* reforestation (Araucaria Plantation or AP), (4) naturally regenerating secondary Ombrophilous Forest (Natural Regenerationor NR) and (5) Early-stage high altitude forest (HA) (Fig. 1).

The Pine Plantation comprised trees planted 30 to 40 years ago and has never been managed. It has a semi-structured understory with practically nonexistent herbaceous extract and soil covered by the needles of the species.

The Riparian Forest is anearly- to mid-successional secondary forest bordering a river (approximately 2 m wide). The IBGE (2012) classifies this as Mixed Flooded Ombrophilous Forest ("Floresta Ombrófila Mista Aluvial"). The species composition can vary greatly according to geographic location and elevation. At higher elevations *Podocarpus lambertii* and *Drimys brasiliensis* are found, and as the altitude decreases, *Araucaria angustifolia* is associated with several Angiosperm ecotypes dominated by the Lauraceae family, with a prominence of *Ocotea*, *Cryptocarya* and *Nectandra*. In southern Brazil this formation is dominated by *Araucaria angustifolia*, *Luehea divaricata*, *Blepharocalyx salicifolius* and *Sebastiania commersoniana* (IBGE, 2012).

The Araucaria Plantation also contains 30 to 40 year old trees and is characterized as a medium successional stage. The richest families (with almost 40% of the species) are Flacourtiaceae, Lauraceae, Rubiaceae and Aquifoliaceae. The families with most individuals (excluding Araucariaceae) are Flacourtiaceae, Aquifoliaceae, Rubiaceae and Lauraceae, with nearly half the sampled angiosperms. The most representative species in the forest structure, after *Araucaria angustifolia* are *Casearia sylvestris*, *Ilex paraguariensis* and *Rudgea jasminoides* (Moro *et al.*, 2009).

The Natural Regeneration forest is at a mid successional stage. The families with higher species richness (accounting for almost half of the species found) are Lauraceae, Myrtaceae, Sapindaceae, Rubiaceae and Flacourtiaceae. In terms of number of individuals, the most abundant families are Rubiaceae, Lauraceae, Sapindaceae, Myrtaceae and Flacourtiaceae, and those with highest importance value in the plant community are Lauraceae, Rubiaceae, Araucariaceae and Sapindaceae (Moro *et al.*, 2009).

The High Altitude forest is approximately 1250 meters above sea level and is in an initial successional stage. It is a low (average height of 2 m) closed shrub, size, and herbaceous extract consisting of several species of Poaceae, terrestrial bromeliads, epiphytes, and mosses and lichens, pteridophytes and several scandent species of Asclepiadaceae, Malpiguiaceae and Sapindaceae, together with species of terrestrial Orchidaceae. The families with the greatest number of species and individuals are Myrtaceae, Asteraceae, Melastomataceae and Myrsinaceae (Moro *et al.*, 2009).

Data collection. Data were collected between September 2012 and September 2013, in six bimonthly campaigns. During each campaign, traps were open for five nights, with exception of the first campaign when they remained open six nights. Traps were checked every early morning.

In each site three lines of pitfall traps were installed, with four 60 L buckets connected in each line by black plastic (approximately 80 cm heigh), 10 m distant from each other and approximately 30 m a row from another. Each line was approximately 40 m long. Additionally, in each site three lines containing six live traps each were installed approximately 5 m distant from each other, and baited with a paste made with bananas, sardines, bacon, oatmeal, peanut butter and corn flour. The live traps models included: Sherman (small: 250 x 90 x 90 mm; large: 310 x 95 x 95 mm) and Tomahawk (small: 350 x 145 x 180 mm; large: 450 x 145 x 180 mm). Each line was approximately 25 m long and lines were separated by approximately 30 m. This provided a total of 30 traps (12 pitfalls and 18 live traps) installed per campaign in each site. The live traps were placed preferentially on the ground.

All captured individuals received either a field number or a numbered tag, and had their specific identification, sex, reproductive condition, capture location, trap type and position recorded. To provide precise taxonomic identification at least one male and one female per species were collected for cytogenetic procedures and morphological analysis based on external and skull morphology, the results of these procedures are better described in Grazzini *et al.* (2015c). The classification of Sigmodontinae species followed Carleton & Musser (2005), with the exception of species of the Tribe Oryzomyini, which were identified based on Weksler & Percequillo (2011). Didelphimorphia were identified following Gardner (2005).

All captures were made according to the Brazilian federal environment agency license no. 35534-1SISBIO.

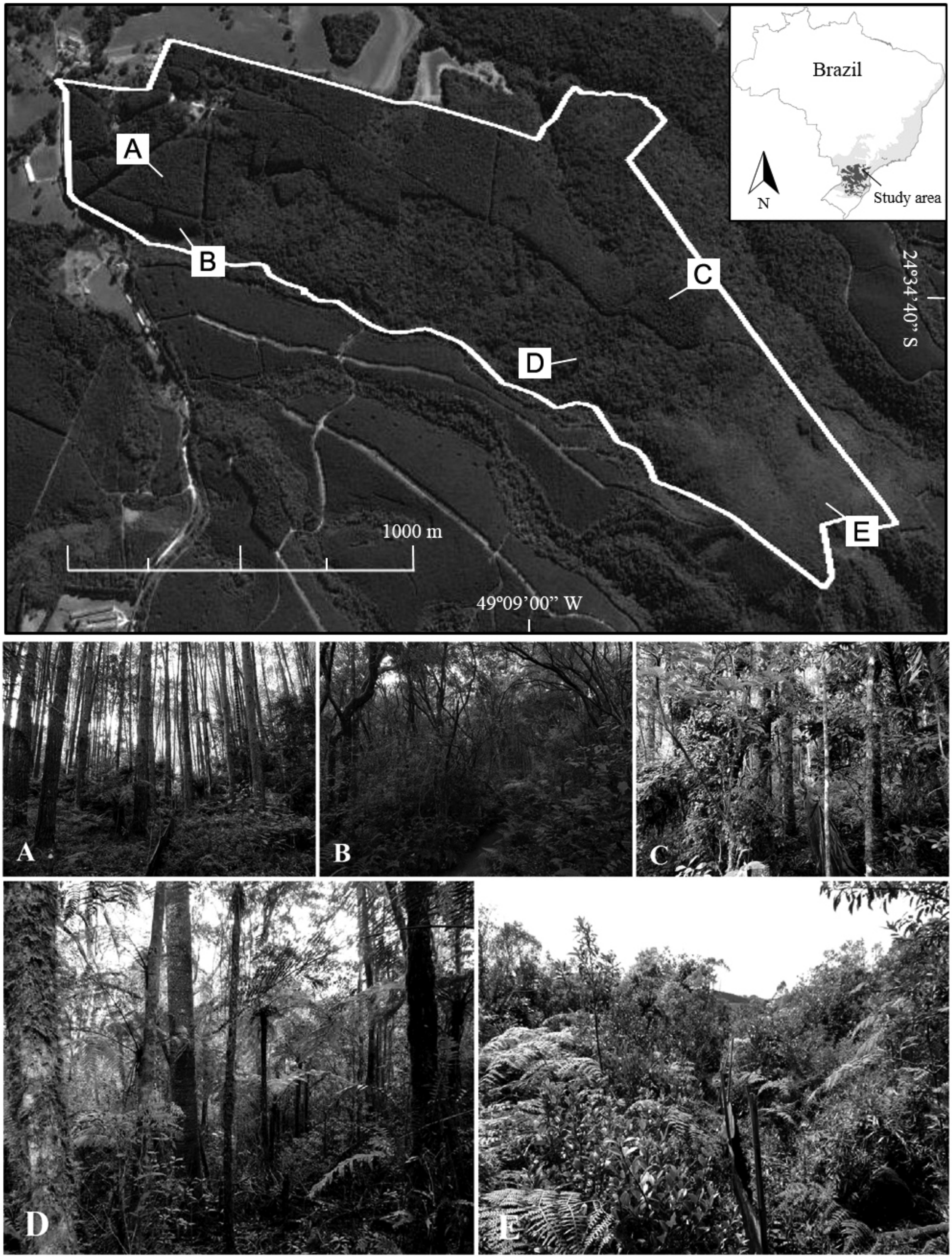

Fig. 1. Location and vegetation types where small mammals were sampled between November 2012 and September 2013, at Piraí do Sul National Forest, Paraná state, Brazil (A, Pine Plantation; B, Riparian Forest; C, Araucaria Plantation; D, Natural Regeneration forest; E, High Altitude forest). Original distribution of Atlantic Forest biome (light gray) and Araucaria forest (dark gray).

Data analysis. To compare the species richness per site rarefaction curves were calculated based on individuals using a Poisson model in EstimateS 9.1.0 (Colwell *et al.*, 2012).

To measure diversity we adopted the concept of true diversity (Jost, 2006), measured by the effective number of species. Thus, true diversities (TD) were calculated of order $q = 0$ (counts species equally without regard to their relative abundances) and $q = 1$ (counts individuals equally and thus weighs species in proportion to their abundances) using maximum likelihood estimators (MLE) for vegetation types (α diversity), and the SPNF (γ diversity) (Jost, 2006; Chao *et al.*, 2012), through software SPADE (Chao & Shen, 2010). Additive and multiplicative diversity components were calculated from the obtained result. The β+ (additive partition approach) component was calculated from the equation: $\beta+ = \gamma - \alpha$; and β* (multiplicative partition approach) using the equation: $\beta^* = \gamma / \alpha$ (Chao *et al.*, 2012).

The β+ component of $q = 0$ order partition was divided by (N - 1), where N is the number of communities, to quantify the number of unique species per vegetation type (Chao *et al.*, 2012). Relative species turnover per vegetation type (*i.e.* effective number of species not contained in the typical local community) was calculated from the use of β* from $q = 0$ in the equation $(\beta - 1) / N – 1$ (Chao *et al.*, 2012). This measure of differentiation is 0 when there is no difference between the turnover units, and is equal to 1 when each unit is completely distinct from all other units (Jost, 2007). The result was used to indicate the effect of vegetation type on the regional diversity of the group.

The TD of order $q = 1$ was used to compare the diversity among vegetation types by overlapping of 95% confidence intervals. In addition, the relative number of individuals of the species was obtained by dividing the total number of sampled individuals of each species by the total number of individuals recorded in the vegetation types (Magurran, 2011).

Finally a cluster analysis was performed using a matrix of Bray-Curtis similarity index values, as tested and recommended by Clarke and Warnick (cited in Magurran, 2011), using the UPGMA algorithm with 200 bootstrap repetitions in PAST 3 (Hammer *et al.*, 2001).

RESULTS

A total of 875 captures (19.4% capture success) were obtained from a sampling effort of 4500 trap.nights (900 per vegetation type). This included 625 individuals belonging to 16 species (Tab. I). Pine plantation and Araucaria plantation presented the lowest richness with eight species each while other vegetation types registered 10 species each. However, interval of confidence in rarefaction curves indicated no significant difference in species richness between the vegetation types (Fig. 2).

The species richness average between the sampled sites in SPNF was 9.2, resulting in $\beta+ = 6.8$ and $\beta^* = 1.74$. The number of unique species per vegetation type was 1.7 and the turnover (or species not contained in the typical local community) was 0.18 (Tab. I). Looking at the calculated turnover of each vegetation type PP and AP had higher indexes than NR, HA and RF indicating those two vegetation types had more distinct compositions. The TD ($q = 1$) was higher in NR, intermediate in RF, AP and HA, and significantly lower in PP compared to NR (Fig. 3).

The rodent *Akodon montensis* was the most abundant (*i.e.* the species with most individuals captured) in three of the five vegetation type. The exceptions were PP and NR where *Oligoryzomys nigripes* and *Thaptomys nigrita* were more abundant respectively. *Bibimys labiosus* and *Didelphis albiventris* were captured exclusively in PP; *Oxymycterus nasutus* exclusively in NR; and *Cryptonanus* sp. and *Monodelphis scalops* exclusively in HA (Tab. II).

The result of the cluster analysis of species similarity among vegetation types indicated next to the 90% similarity between HA and AP followed by RF (approximately 85%) and NR (approximately 70%). The species composition in PP was the most dissimilar to that of the other vegetation types with approximately 55% (Fig. 4).

DISCUSSION

The number of individuals and capture success obtained in the study were high when compared to other efforts conducted in the Atlantic Forest biome (*e.g.* Pires *et al.*, 2002; Dalmagro & Vieira, 2005; Astúa *et al.*, 2006;

Tab. I. Capture indexes of small mammals sampled at five vegetation types of Piraí do Sul National Forest, Paraná state, Brazil. Number of individuals, number of captures, relative capture success (%), true diversity order $q = 0$ (*i.e.* species richness), additive partition approach (*β+*), multiplicative partition approach (*β**), unique species per vegetation (*β+/N-1*), species not contained in the typical local community or turnover (β* -1/N-1), true diversity in order $q = 1$.

Vegetation	Individuals	Captures	Capture success (%)	q = 0					q = 1
				TD	*β+*	*β**	*β+/N-1*	β* -1/N-1	TD
Pine Plantation	103	118	13.1	8	8.0	2.00	2.0	0.25	3.75
Araucaria Plantation	120	183	20,3	8	8.0	2.00	2.0	0.25	4.54
Riparian Forest	102	154	17.1	10	6.0	1.60	1.5	0.15	4.26
High Altitude forest	125	180	20.0	10	6.0	1.60	1.5	0.15	4.58
Natural Regeneration forest	175	240	26.7	10	6.0	1.60	1.5	0.15	5.34
Piraí do Sul National Forest (Total)	625	875	19.4	16	6.8	1.74	1.7	0.18	5.33

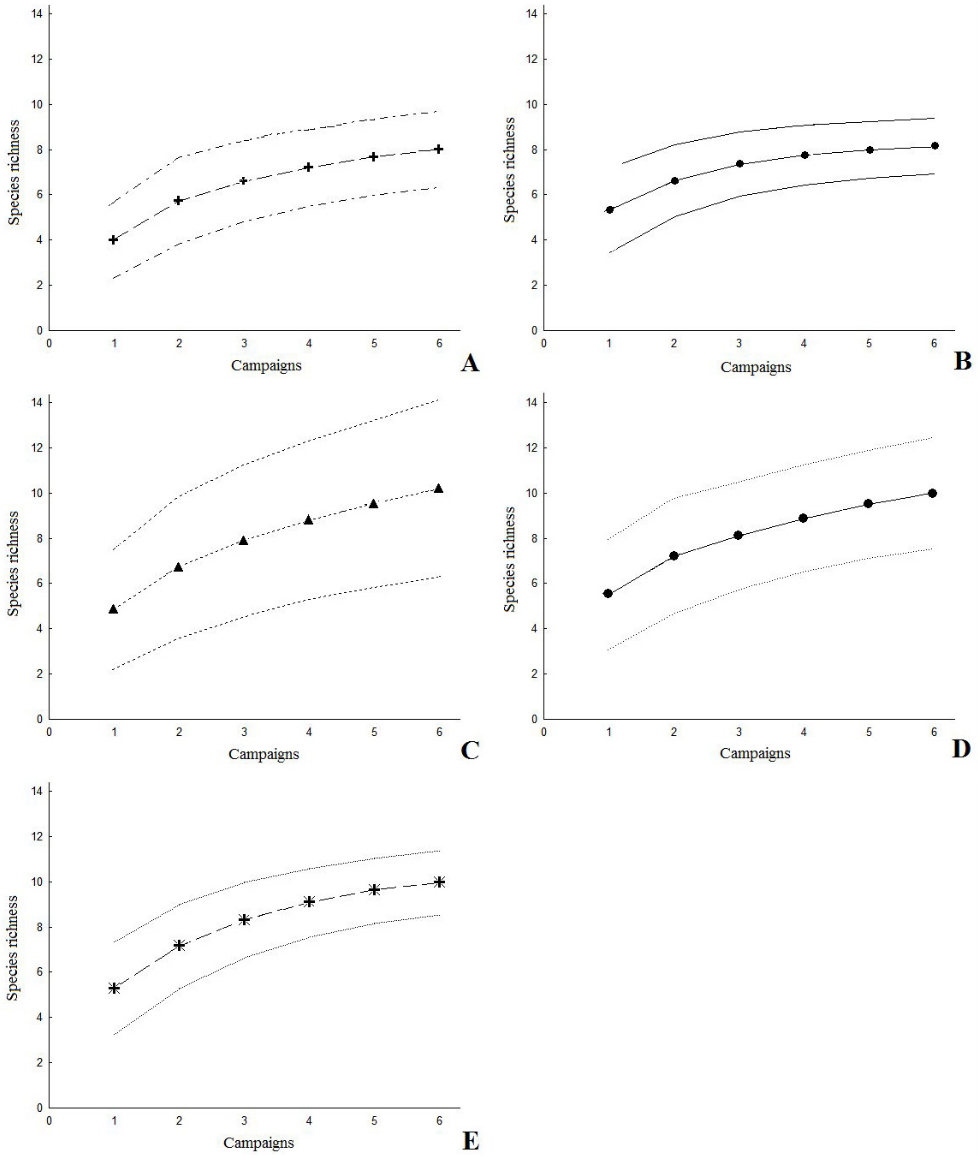

Fig. 2. Rarefaction curves of small mammals sampled at five vegetation types of Piraí do Sul National Forest, Paraná state, Brazil, with a 95% confidence interval (A, Pine Plantation; B, Riparian Forest; C, Araucaria Plantation; D, Natural Regeneration forest; E, High Altitude forest).

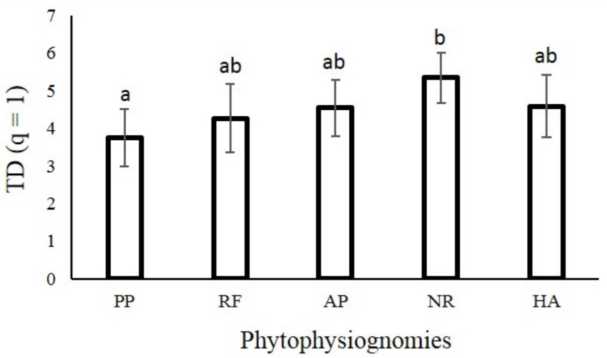

Fig. 3. True diversity values (TD), order q = 1, of small mammals sampled at five vegetation types of Piraí do Sul National Forest, Paraná state, Brazil. Equal letters indicate overlap of the 95% confidence intervals (PP, Pine Plantation; RF, Riparian Forest; AP, Araucaria Plantation; NR, Natural Regeneration forest; HA, High Altitude forest).

Pardini & Umetsu, 2006; Pessôa *et al.*, 2009; Lima *et al.*, 2010; Pedó *et al.*, 2010; Gatto-Almeida *et al.*, 2016). For the species, the fact that *Akodon montensis* and *Oligoryzomys nigripes* were the most abundant (*i.e.* more individuals captured) was expected and Quintela *et al.* (2012) even state that these are the most abundant non-volant small mammals in most studies in forest formations from Southern Brazil. The third ranked species in terms of number of individuals captured was *Thaptomys nigrita*, which was also common in a study in Mixed Rain Forest close to SPNF (Oliveira *et al.*, 2005), which reinforces the suggestion that this species is associated with this vegetation type in Paraná. The rarest species were *Bibimys labiosus*, *Monodelphis scalops* and *Oxymycterus nasutus*, which had not been registered in many of the previous studies in the Araucaria Forest (Cademartori *et al.*, 2002, 2004, 2008a,b; Oliveira *et al.*, 2005; Pedó *et al.*, 2010; Marques *et al.*, 2011).

Tab. II. Individuals (Nº) and relative number of individuals (%) of small mammals sampled at five vegetation types of Piraí do Sul National Forest (PSNF), Paraná state, Brazil (PP, Pine Plantation; RF, Riparian Forest; AP, Araucaria Plantation; NR, Natural Regeneration forest; HA, High Altitude forest).

Species	PP		RF		AP		NR		HA		PSNF (Total)	
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
DIDELPHIMORPHIA												
Cryptonanus sp.	0	0	0	0	0	0	0	0	2	2	2	<1
Didelphis albiventris Lund, 1940	2	2	0	0	0	0	0	0	0	0	2	<1
Didelphis aurita Wied-Neuwied, 1826	2	2	6	6	5	4	2	1	3	2	18	2.8
Gracilinanus microtarsus (Wagner, 1842)	0	0	1	1	1	1	1	<1	0	0	3	<1
Monodelphis americana (Muller, 1776)	0	0	0	0	2	2	0	0	1	<1	3	<1
Monodelphis scalops (Wagner 1847)	0	0	0	0	0	0	0	0	1	<1	1	<1
RODENTIA												
Akodon montensis Thomas, 1913	19	19	52	51	56	47	51	29	61	50	239	38.2
Bibimys labiosus Winge, 1887	1	1	0	0	0	0	0	0	0	0	1	<1
Brucepattersonius iheringi (Thomas, 1896)	6	6	6	6	9	8	7	4	5	4	33	5.3
Juliomys ossitenuis Costa, Pavan, Leite & Fagundes, 2007	0	0	1	1	0	0	2	1	0	0	3	<1
Nectomys squamipes (Brants, 1827)	0	0	2	2	0	0	7	4	0	0	9	1.4
Oligoryzomys nigripes (Olfers, 1818)	59	57	27	26	28	23	25	14	25	20	164	26.2
Oxymycterus judex (Thomas, 1909)	0	0	1	1	0	0	0	0	2	2	3	<1
Oxymycterus nasutus (Waterhouse, 1897)	0	0	0	0	0	0	1	<1	0	0	1	<1
Sooretamys angouya (Fisher, 1814)	2	2	3	3	5	4	21	12	5	4	36	5.8
Thaptomys nigrita (Lichtenstein, 1829)	12	12	3	3	14	12	58	33	20	16	107	17.1
TOTAL	103		102		120		175		125		625	

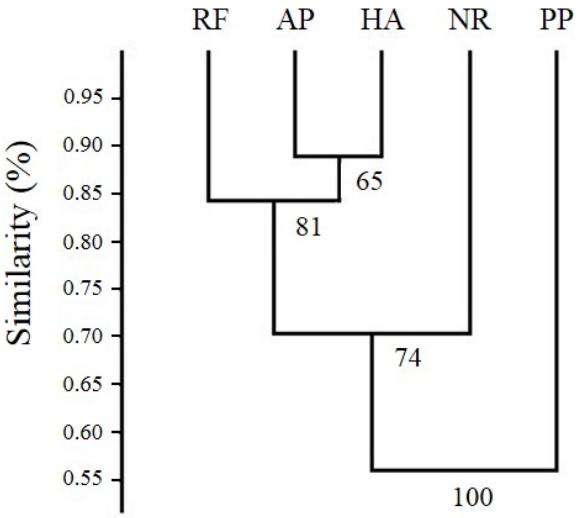

Fig. 4. Dendrogram from the cluster analysis of the similarity of small mammals sampled at five vegetation types of Piraí do Sul National Forest, Paraná state, Brazil (PP, Pine Plantation; RF, Riparian Forest; AP, Araucaria Plantation; NR, Natural Regeneration forest; HA, High Altitude forest).

We expected PP to present lower richness as reported Umetsu & Pardini (2007), Fonseca *et al.* (2009), Pardini *et al.* (2009), Rosa & Vieira (2010) in their study sites. However, we only found slightly higher richness in natural regenerating vegetation types *i.e.* RF, NR and HA sites, which might not be real if confidence of interval in rarefaction curves is considered. The same pattern was observed for AP.

In the specific case of the present study, it may be important to note that the reforestation areas (*i.e.* PP and AP) are surrounded by native vegetation types at a good level of conservation, the areas are not managed for 40 years and there are other native species growing within them. The results of Stallings (1991) and Rosa & Vieira (2010) emphasize the importance of this aspect: the first of which found a richer and more abundant assemblage of non-volant small mammals in a *Eucalyptus* plantation with an understory composed of native species compared to areas where there was only exotic species, and the second recorded only four species in a pine reforestation area without understory in the state of Rio Grande do Sul, Brazil. Either way, richness measure does not seem to be appropriate to assess the differences between areas sampled in SPNF.

Regarding species composition, some studies showed distinctions in the composition of assemblages of reforested environments (Umetsu & Pardini, 2007; Fonseca *et al.*, 2009; Pardini *et al.*, 2009; Rosa & Vieira, 2010) which led us to expect that PP and AP would present different species composition. This hypothesis was only partially met once no exclusive species were registered for AP area, while *Bibimys labiosus* and *Didelphis albiventris* were recorded only in PP. On the other hand, AP area register *Gracilinanus microtarsus* and *Monodelphis americana* two species captured in others areas of SPNF and not in PP. There is not much information about *Bibimys labiosus* or *Monodelphis americana* sensibility to environmental quality but *Didelphis albiventris* (actually the genus *Didelphis*) is considered ecologically generalist and frequently is found in disturbed environments (Olifiers *et al.*, 2005; Cantor *et al.*, 2010; Beatty *et al.*, 2014) while *Gracilinanus microtarsus* has been showed to not be sensible to a variety of atrophic disturbs (*e.g.* Pardini *et al.*, 2005; Püttker *et al.*, 2008).

The turnover indexes (q = 0) that measured the effective number of species not contained in the typical local community showed higher values of differentiation (0.25) for both reforestation areas (*i.e.* PP and AP) while the natural regenerating areas showed similar and lower indexes (0.15) meaning these last are more similar in composition to the general community of PSNF. This result helps to corroborate our initial hypothesis that the reforested environments would have different species composition.

Furthermore, TD (q = 1) analysis found higher values in RF, AP, NR and HA, and significant difference between the PP and NR confirming our initial hypothesis that native environments have greater diversity of non-volant small mammals. In a comparison made between pine reforestation and native area of coastal forest ("restinga"), Rosa & Vieira (2010) found no significant difference in diversity. However, the analysis was based on the Shannon-Wiener index, which may have masked the true diversity of the assemblages, besides the fact that the coastal forest is very different from a forest environment. When compared to the AP, the values found in RF and HA were very similar, suggesting that they are structurally similar assemblages. Although not statistically significant, the diversity of NR was somewhat larger, a result similar to that found by Umetsu & Pardini (2007) using as a basis the richness, abundance and species composition of the analyzed assemblages, suggesting that among the different management histories evaluated in PSNF, the natural regenerating area holds the higher diversity.

The cluster analysis showed similar results to those of TD (q = 1), in that the most distinctive assemblage (in terms of structure) is the PP, a result that is in line with its lower TD and the large number of *Oligoryzomys nigripes* captured. The second most distinct assemblage was found in NR, which was also expected due to its higher TD and the large number of *Thaptomys nigrita*. The assemblages of RF, AP and HA were much more similar to each other, a result also reflected in the TD values.

Together, the results of the TD (q=1) and cluster analysis showed that there were differences in the structure of the assemblages among the physiognomies that are all secondary and with a history of 40 years of regeneration, but different in their floral composition. Furthermore, our results confirm that the replacement of native by exotic vegetation negatively influenced some components of the local diversity. The importance of the result is not restricted to the SPNF, but the group's conservation in the Araucaria Forest. This is a phytophysiognomy of the Atlantic Forest biome that retains only 12.6% of its original forest, with only 3.1% of these protected by Integral Protection Conservation Units (Ribeiro *et al.*, 2009). Most of these unprotected forests are small forest fragments inserted into matrices of various human activities. The results demonstrated the potential of these secondary forest fragments to act as true habitat refuges for the group, provided they retain a certain degree of conservation of native vegetation and structure.

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REFERENCES

Ardente, N. C.; Ferreguetti, A. C.; Gettinger, D.; Leal, P.; Mendes-Oliveira, A. C.; Martins-Hatano, F. & Bergallo, H. G. 2016. Diversity and impacts of mining on the non-volant small mammal communities of two vegetation types in the Brazilian Amazon. **PLoS One 11**(11):1-16.

Astúa, D.; Moura, R. T., Grelle, C. E. V.& Fonseca, M. T. 2006. Influence of baits , trap type and position for small mammal capture in a Brazilian lowland Atlantic Forest. **Boletim do Museu de Biologia Mello Leitão**, Nova Série **19**:31-44.

Beatty, W. S.; Beasley, J. C. & Rhodes, O. E. 2014. Habitat selection by a generalist mesopredator near its historical range boundary. **Canadian Journal of Zoology 92**(1):41-48.

Cademartori, C. V.; Fabián, M. E. & Menegheti, J. O. 2004. Variações na abundância de roedores (Rodentia, Sigmodontinae) em duas áreas de floresta ombrófila mista, Rio Grande do Sul, Brasil. **Revista Brasileira de Zoociências 6**(2):147-167.

Cademartori, C. V.; Marques, R. V. & Pacheco, S. M. 2008a. Estratificação vertical no uso do espaço por pequenos mamíferos (Rodentia, Sigmodontinae) em área de Floresta Ombrófila Mista, RS, Brasil .**Zoociências 10**(3):189-196.

Cademartori, C. V.; Marques, R. V.; Pacheco, S. M.; Baptista, L. R. M. & Garcia, M. 2002. Roedores ocorrentes em Floresta Ombrófila Mista (São Francisco de Paula, Rio Grande do Sul) e a Caracterização de seu Habitat. **Comunicações do Museu de Ciências e Tecnologia PUCRS 15**(1):61-86.

Cademartori, C. V.; Saraiva, M.; Saraiva, C. & Miranda, J. A. 2008b. Nota sobre a fauna de pequenos roedores em mosaico antropogênico com remanescente florestal do domínio Mata Atlântica. **Biodiversidade Pampeana 6**(2):34-38.

Cantor, M.; Ferreira, L. A.; Silva, W. R. & Setz, E. Z. F. 2010. Potencial dispersão de sementes por *Didelphis albiventris* (Marsupialia, Didelphidae) em ambiente altamente perturbado. **Biota Neotropica 10**(2):45-51.

Carleton, M. D. & Musser, G. G. 2005. Order Rodentia. *In*: Wilson, D. E. & Reeder, D. M. eds. **Mammal Species of the World - A Taxonomic and Geographic Reference.** Baltimore, Johns Hopkins University Press, p.745-752.

Chao, A.; Chiu, C. H. & Hsieh, T. C. 2012. Proposing a resolution to debates on diversity partitioning. **Ecology 93**(9):2037-2051.

Chao, A. & Shen, T.-J. 2010. **User's Guide for program SPADE (Species Prediction And Diversity Estimation**). 71p.

Colwell, R. K; Chao, A.; Gotelli, N. J.; Lin, S.; Mao, C. X.; Chazdon, R. L. & Longino, J. T. 2012. Models and estimators linking rarefaction , extrapolation and comparison of assemblages. **Plant Ecology 5**(1):3-21.

Dalmagro, A. D. & Vieira, E. M. 2005. Patterns of habitat utilization of small rodents in an area of Araucaria forest in Southern Brazil. **Austral Ecology 30**(4):353-362.

Eisenberg, J. F. & Redford, K. H. 1999. **Mammals of the Neotropics**, Volume 3: Ecuador, Bolivia, Brazil. Chicago, Chicago University Press. 624p.

Fonseca, C. R.; Ganade, G.; Baldissera, R.; Beckera, C. G.; Boelter, C. R.; Brescovit, A. D.; Campos, L. M.; Fleck, T.; Fonseca, V. S.; Hartz, S. M.; Joner, F.; Käffer, M. I.; Leal-Zanchet, A. M.; Marcelli, M. P.; Mesquita, A. S.; Mondin, C. A.; Paz, C. P.; Petry, M. V.; Piovensan, F. N.; Putzke, J.; Stranz, A.; Vergara, M.; Vieira, E. M.; 2009. Towards an ecologically-sustainable forestry in the Atlantic Forest. **Biological Conservation 142**(6):1209-1219.

Gardner, A. L. 2005. Order Didelphimorphia. *In*: Wilson, D. E. & Reeder, D. M. eds. **Mammal Species of the World - A Taxonomic and Geographic Reference.** Baltimore, Johns Hopkins University Press, p. 3-18.

Gatto-Almeida, F.; Pontes, J. S.; Sbalqueiro, I. J.; Hass, I.; Tiepolo, L. M. & Quadros, J. 2016. Diversidade, Biogeografia, Caracterização Cariotípica e Tricológica dos pequenos mamíferos não voadores do Parque Estadual Rio da Onça, Litoral Sul do Paraná. **Papéis Avulsos de Zoologia 56**(7):69-96.

Grazzini, G.; Mochi-Junior, C. M.; Oliveira, H.; Pontes, J. S.; Gatto-Almeida, F.; Sbalqueiro, I. J.; Hass, I. & Tiepolo, L. M. 2015a. First record of *Juliomys ossitenuis* Costa, Pavan, Leite & Fagundes, 2007 (Rodentia, Sigmodontinae) in Paraná state, southern Brazil. **Check List 11**(2):1-5.

Grazzini, G.; Rezini, J. A.; Santos, B. S. B.; Venâncio, F. J.; Gatto-Almeida, F.; Sbalqueiro, I. J.; Hass, I. & Tiepolo, L. M. 2015b. *Bibimys labiosus* Winge, 1887 (Mammalia: Rodentia: Sigmodontinae): New records in Paraná state, southern Brazil, and update of the known geographic distribution. **Check List 11**(3):1632.

Grazzini, G.; Mochi-Jr., C. M.; Oliveira, H.; Pontes, J. S.; Gatto-Almeida, F. & Tiepolo, L. M. 2015c. Identidade, riqueza e abundância de pequenos mamíferos (Rodentia e Didelphimorphia) de área de Floresta com Araucária no estado do Paraná, Brasil. **Papéis Avulsos de Zoologia 55**(15):217-230.

Hammer, Ø.; Harper, D. A. T. & Ryan, P. D. 2001. PAST : Paleontological statistics software package for education and data analysis. **Palaeontologia Electronica 4**(1):1-9.

Hannibal, W.; Cunha, N. L.; Figueiredo, V. V.; Teresa, F. B. & Ferreira, V. L. 2020. Traits reveal how habitat-quality gradients structure small mammal communities in a fragmented tropical landscape. **Austral Ecology 45**(1):79-88.

IBGE. 2012. **Manual Técnico da Vegetação Brasileira**. Rio de Janeiro, IBGE. 272p.

Jost, L. 2006. Entropy and diversity. **Oikos 2**(113):363-375.

Jost, L. 2007. Partitioning diversity into independent alpha beta concepts. **Ecology 88**(10):2427-2439.

Lima, D. O.; Azambuja, B. O.; Camilotti, V. L. & Cáceres, N. C. 2010. Small mammal community structure and microhabitat use in the austral boundary of the Atlantic Forest, Brazil. **Zoologia 27**(1):99-105.

Magurran, A. E. 2011. **Medindo a Diversidade Biológica**. Curitiba, Editora UFPR. 260p.

Marques, R. V.; Cademartori, C. V. & Pacheco, S. M. 2011. Mastofauna no Planalto das Araucárias, Rio Grande do Sul, Brasil. **Revista Brasileira de Biociências 9**(3):278-288.

Martin, P. S.; Gheler-Costa, C.; Lopes, P. C.; Rosalino, L. M. & Verdade, L. M. 2012. Terrestrial non-volant small mammals in agro-silvicultural landscapes of Southeastern Brazil. **Forest Ecology and Management 282**:185-195.

MMA. 2010. **Mata Atlântica: patrimônio nacional dos brasileiros**. 2ed. Brasilia, Ministério do Meio Ambiente. 408p.

Moro, R. S.; Kaczmarech, R.; Pereira, T. K.; Chaves, C. C.; Milan, E.; Gels, M.; Moro, R. F. & Mioduski, J. 2009. **Perfil fitossociológico da vegetação da Floresta Nacional de Piraí do Sul, PR**. Relatório técnico.

Myers, N.; Mittermeier; R. A.; Mittermeier, C. G.; Fonseca, G. A. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. **Nature 403**(6772):853-858.

Olifiers, N.; Gentile, R. & Fiszon, J. T. 2005. Relation between small-mammal species composition and anthropic variables in the Brazilian Atlantic Forest. **Revista Brasleira de Biologia 65**(3):495-501.

Oliveira, J. A.; Silveira, G.; Rocha, V. J. & Silva, C. E. F. 2005. Ordem Rodentia. *In*: Reis, N. R.; Peracchi, A. L.; Fandiño-Mariño, H. & Rocha, V. J. eds. **Mamíferos da Fazenda Monte Alegre**. Londrina, EdUEL, p.161-191.

Paglia, A. P.; 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.** 2ed. Belo Horizonte, Conservation International. 82p.

Paise, G.; Vieira, E. M. & Prado, P. I. 2020. Small mammals respond to extreme habitat fragmentation in the Brazilian Atlantic Forest according to the landscape continuum model. **Mammal Research 65**:308-322.

Pardini, R.; Faria, D.; Accacio, G. M.; Laps, R. R.; Mariano-Neto, E.; Paciencia, M. L. B.; Dixo, M. & Baumgarten, J. 2009. The challenge of maintaining Atlantic forest biodiversity: A multi-taxa conservation assessment of specialist and generalist species in an agro-forestry mosaic in southern Bahia. **Biological Conservation 142**(6):1178-1190.

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. **Biological Conservation 124**(2):253-266.

Pardini, R. & Umetsu, F. 2006. Pequenos mamíferos não-voadores da Reserva Florestal do Morro Grande – distribuição das espécies e da diversidade em uma área de Mata Atlântica. **Biota Neotropica 6**(2):1-22.

Pedó, E.; Freitas, T. R. O. & Hartz, S. M. 2010. The influence of fire and livestock grazing on the assemblage of non-flying small mammals in grassland-Araucaria forest ecotones, southern Brazil. **Zoologia 27**(4):533-540.

Pessôa, F. S.; Attias, N. & Bergallo, H. D. G. 2009. Non-volant mammals, Reserva Particular do Patrimônio Natural (RPPN) Rio das Pedras, municipality of Mangaratiba, state of Rio de Janeiro, Brazil. **CheckList 5**(3):577-586.

Pires, A. S., Koeler, P. L.; Fernandez, F. A. S.; Schittini, G. M. & Oliveira, L. C. 2002. Frequency of movements of small mammals among Atlantic Coastal Forest fragments in Brazil. **Biological Conservation 108**(2):229-237.

Püttker, 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 Ecology 8**(9):1-10.

Quintela, F. M.; Santos, M. B.; Christoff, A. U. & Gava, A. 2012. Pequenos mamíferos não-voadores (Didelphimorphia, Rodentia) em dois fragmentos de mata de restinga de Rio Grande, planície costeira do Rio Grande do Sul. **Biota Neotropica 12**(1):261-266.

Rezende, C. L.; Scarano, F. R.; Assad, E. D.; Joly, C. A.; Metzger, J. P.; Strassburg, B. B. N.; Tabarelli, M.; Fonseca, G. A. & Mittermeier, R. A. 2018. From hotspot to hopespot: An opportunity for the Brazilian Atlantic Forest. **Perspectives in Ecology and Conservation 16**(4):208-214.

Ribeiro, M. C.; Metzger, J. P.; Martensen, A. C.; Ponzoni, F. J. & Hirota, M. M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. **Biological Conservation 142**(6):1141-1153.

Rosa, A. O. & Vieira, E. M. 2010. Comparação da diversidade de mamíferos entre áreas de floresta de Restinga e áreas plantadas com *Pinus elliotti* (Pinaceae) no sul do Brasil. *In*: Pessôa, L. M.; Tavares, W. C. & Siciliano, S. eds. **Mamíferos de Restingas e Manguezais do Brasil**. Rio de Janeiro, Sociedade Brasileira de Mastozoologia, p. 224-242.

Stallings, J. R. 1991. The Importance of Understorey on wildlife in a Brazilian eucalypt plantation. **Revista Brasileira de Zoologia 7**(3):267-276.

Umetsu, F. & Pardini, R. 2007. Small mammals in a mosaic of forest remnants and anthropogenic habitats — evaluating matrix quality in an Atlantic forest landscape. **Landscape Ecology 22**:517-530.

Voss, R. S. & Emmons, L. H. 1996. Mammalian diversity in Neotropical lowland Rainforests: a preliminary Assessment. **Bulletin of American Museum of Natural History 230**:1-115.

Weksler, M. & Percequillo, A. R. 2011. Key to the genera of the tribe Oryzomyini (Rodentia: Cricetidae: Sigmodontinae). **Mastozoología Neotropical 18**(2):281-292.