Non-volant small mammals in the different vegetation types of two protected restinga areas, Southeastern Brazil

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Abstract

Recent environments, such as restingas, present high habitat heterogeneity, with different vegetation types throughout its geographic range. In this study, we provided the first assessment of how the composition and abundance of non-volant small mammals are influenced by the habitat heterogeneity of the different vegetation types in the restinga of the Paulo César Vinha State Park and the Environmental Protection Area of Setiba, state of Espírito Santo. We used live traps in 24 sampling sites distributed over four vegetation types from April to October 2019 to capture mammals. We found a pattern in the assemblage's composition, showing a difference in richness and abundance of species among vegetation types. We recorded 21 species of small mammals. The restinga forest showed the highest richness and abundance of species, in contrast the beach vegetation zone showed the lowest richness and abundance. Our results pointed to a high richness of small mammals for the two protected restinga areas in general. This was the first study with non-volant small mammals in the restinga environment that assessed the habitat's heterogeneity and how species change their composition in different vegetation types. We noted the veracity of the hypothesis of habitat heterogeneity, with higher richness and abundance of species in vegetation types with higher heterogeneity. In addition to verifying the specificity of habitat of species recorded exclusively in forest environments. These results represent the first step to assist in actions for the conservation of mammals in a coastal environment with high anthropogenic pressure.

Keywords Atlantic forest · Heterogeneity · Species richness · Rodents · Marsupials

Introduction

The habitat heterogeneity's hypothesis (MacArthur and MacArthur 1961), postulates that more heterogeneous environments would provide more resources, potentially increasing the number of niches, maintaining a higher species diversity than comparatively simpler environments (Bazzaz 1975). In different vegetation types, the levels of luminosity, humidity and temperature vary between environments according to the levels of habitat structural heterogeneity (Li and Reynolds 1994). These factors can be determinant to favor or not the occurrence of species in different sites, because they are basic characteristics for a species be successful to obtain food resources, reproduction, and nesting (August 1983). The habitat heterogeneity plays an important role in structuring assemblages (Tews et al. 2004; Ferreguetti et al. 2017), as a result, species richness and abundance can be proportional to the heterogeneity and complexity of the local environment (Grelle 2003; Sukma et al. 2019).

The Atlantic Forest has a heterogenous set of ecosystems and one of the most biodiverse biomes in Brazil, with a high degree of endemism and a high threat of extinction to local species due to the intense anthropic action (Escarlate-Tavares et al. 2016). Currently, the Atlantic Forest has approximately 26% of native vegetation cover (Rezende et al. 2018) and one of its geological formations are the restingas (Araújo et al. 2017). The restingas are formed by a vegetation types mosaic that despite being a highly threatened environment due to intense urban expansion (Rocha et al. 2003), present a high diversity (Bigarella 2001).

The restingas are coastal plains environments with predominantly sandy terrains formed mainly during regressions and

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Fig. 1 Different vegetation types of Paulo César Vinha State Park and Environmental Protection Area of Setiba in Guarapari, Espírito Santo, Brazil, being, (RF) Forest Formation, (OCZ) Clusia Open Shrub Formation, (SVZ) Shrub Formation and (BVZ) Post-beach formation

transgressions at sea level (Coutinho 2016), harboring sets of different plant communities such as trees, shrubs, and herbaceous vegetation (Magnago et al. 2011). The restingas present an intense degradation process resulted in an accentuated alteration and loss of this habitat (Rocha et al. 2004). A limitation in monitoring the restinga habitat loss rate is the lack of information about the location and extension of the restinga remnants and about the main degradation factors in each one. Additionally, we also lack information on the conservation state of these remnants to support actions for their protection. The extensive presence along the Brazilian coast and despite being located in areas with comparatively high human density, the restingas are still relatively poorly-understood scientifically in several aspects of their biodiversity and state of conservation (s). The restinga environment has a high habitat heterogeneity, as there are different vegetation types, such as forest formations, shrubs vegetation, open Clusia formation, and beach vegetation zone (Magnago et al. 2011).

One of the first steps towards conservation is knowing the assemblage's composition and structure and evaluating how they respond to the environment variation in the landscape (Santos 2003). Considering the importance of knowing the mammalian composition in such a threatened coastal environment (such as the restingas) to assist in conservation measures,

we assessed how the richness and abundance of non-volant small mammals would be influenced by habitat heterogeneity in each of the four major vegetation types. Specifically, we aimed to: (1) identify the species composition in the different vegetation types of Paulo César Vinha State Park (PEPCV) and Setiba EPA; (2) compare the species richness and abundance in the different vegetation types of PEPCV and Setiba Environmental Protection Area (Setiba EPA); and (3) define which vegetation type would have the highest richness and abundance of species. Our hypothesis was that there would be higher richness and abundance in forest environments that are supposed to be more heterogenous, therefore having a higher variability of niches that, in turn, could potentially hold more species, compared to open formations that would be less heterogenous.

Material and methods

Study area

We conducted the study in two protected areas (hereafter PA), the Paulo César Vinha State Park (PEPCV) and the Setiba Environmental Protection Area (Setiba EPA) located in the
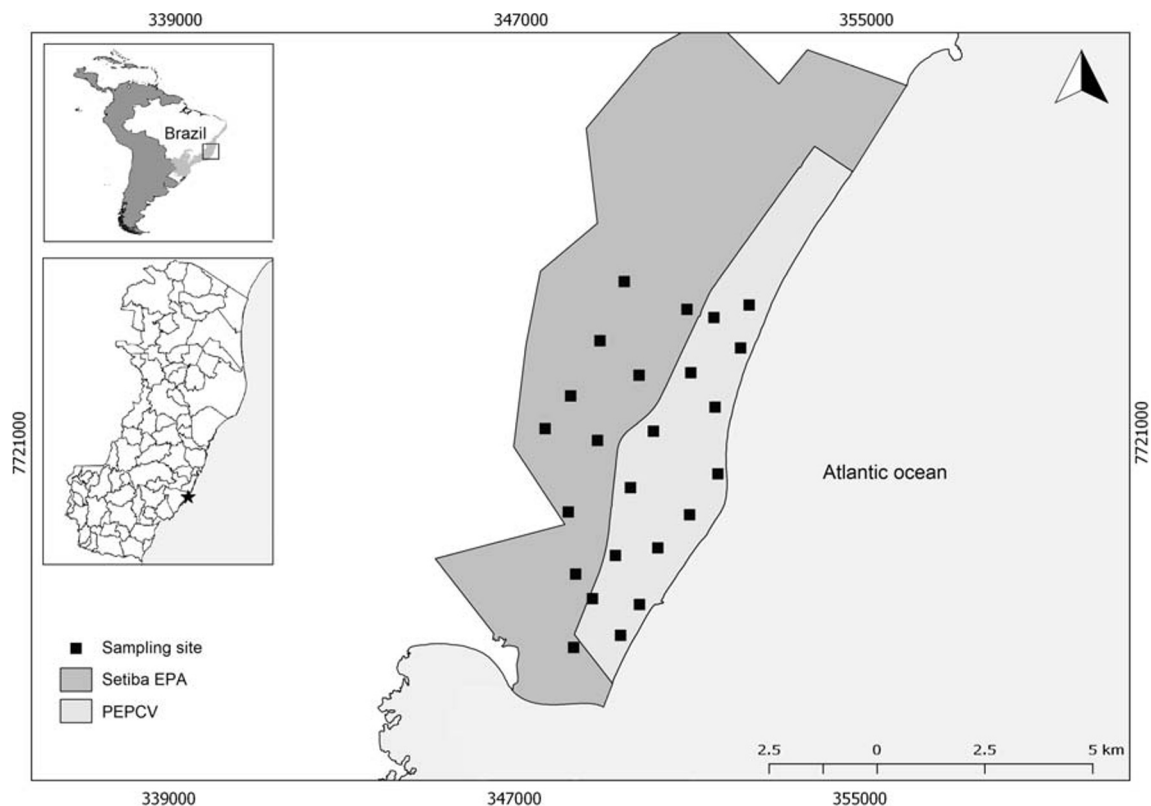
Fig. 2 Location of Paulo César Vinha State Park (PEPCV) in Guarapari, Espírito Santo, Brazil, with 14 sampling sites and the Environmental Protection Area of Setiba (Setiba EPA) in Guarapari, Espírito Santo, Brazil, with 10 sampling sites

Espírito Santo state, southeastern Brazil. The two PAs are separated only by the "Rodovia do Sol" (ES-060 road) connecting the Guarapari and Vila Velha municipalities. The PEPCV (20°33′-20°38'S, 40°23′-40°26'W) covers an area of approximately 1500 ha, and the Setiba EPA (20°32′-20°39'S, 40°22′-40° 32'W) has approximately 12,960 ha (IEMA 2016a, b).

These two PAs present four different vegetation types, as following: beach vegetation zone (BVZ, closer to the sea, with herbaceous vegetation), shrub vegetation zone (SVZ, with low shrubs, usually cacti and bromeliads), open Clusia formations (OCZ, composed of higher shrubs, high density of bromeliads and presence of tree species, Clusia spp.) and restinga forests (RF, dominated by tree species) (Oprea et al. 2009; Oliveira et al. 2017; Fig. 1).

The RF, with a predominance of trees, which can be classified in terms of canopy coverage (open or closed) and also in terms of flooding (Lima et al. 2017), OCZ that manifests interleaving islands of vegetation with white and sandy soil with sparse vegetation and high salinity (Pereira et al. 2004) with a predominance of *Clusia spiritusanctenses* and *Clusia hilariana* species (IEMA 2016a, b). Shrub vegetation zone that basically consists of thickets with a height of around 1.5 m and in the areas between thickets we find outcropping of sandy sediment (Martins 2012) and BVZ that occurs after the reptive vegetation of the tide line, in this formation we can

observe a sudden transformation to the bush vegetation (Braz et al. 2013) (Fig. 1).

Data sampling

We collected data weekly from April to October 2019. We defined 14 sampling sites in the PEPCV and 10 sampling sites in the Setiba EPA (Fig. 2) with 500 m between sampling sites. In each sampling site, we defined six sampling stations that consisted in a 10 × 10 m plot with a minimum distance of 50 m between stations. In each sampling station, we installed five live-traps, one Tomahawk (size: 45 X 21 X 21 cm) and four Shermans (size: 25 X 8 X 9 cm). We arranged the live-traps as follows: four Sherman traps at the corners of the sampling station plot (two placed 1.5 m high on lianas or tree trunks in the understory and two placed on the ground) and a Tomahawk trap in the center placed on the ground. All stations were sampled five times.

We used a bait composed of banana, sardines, ground peanuts and cornmeal, mixed until it became a homogeneous paste. We left the live-traps open for three consecutive nights in each campaign and checked every morning. For each captured animal, we recorded the date of capture, the sampling site at which it was captured, and identified the species. We marked the individuals with numbered ear tags to make it possible to recognize if the

Table 1 Species of non-volant small mammals found in the Paulo César Vinha State Park and in the environmental protection area of Setiba, Guarapari, Espírito Santo, Brazil

Order	Captured individuals	Degree of threat
Rodentia		
Caviidae family		
Cavia fulgida (Wagler, 1831)	8	LC
Cricetidae family		
Hylaeamys laticeps (Lund, 1840)*	6	NT[IUCN]
Oligoryzomys nigripes (Olfers, 1818)	5	LC
Nectomys squamipes (Brants, 1827)	11	LC
Rhipidomys mastacalis (Lund, 1840)	4	LC
Necromys lasiurus (Lund, 1841)	5	LC
Akodon cursor (Winge, 1887)	7	LC
Echimyidae family		
Phyllomys pattoni (Emmons, Leite, Kock & Costa, 2002)*	3	LC
Trinomys setosus (Desmarest, 1817)*	12	LC
Muridae family		
Mus musculus (Linnaeus, 1758)[a]	13	LC
Rattus rattus (Linnaeus, 1758)[a]	11	LC
Rattus norvegicus (Berkenhout, 1769)[a]	9	LC
Order Didelphimorphia		
Didelphidae family		
Didelphis aurita (Wied-Neuwied, 1826)*	17	LC
Caluromys philander (Linnaeus, 1758)	3	LC
Marmosa murina (Linnaeus, 1758)	9	LC
Metachirus nudicaudatus (Desmarest, 1817)	11	LC
Gracilinanus microtarsus (Wagner, 1842)*	5	LC
Marmosa paraguayana (Tate, 1931)	7	LC
Marmosops incanus (Lund, 1840)	12	LC
Philander frenatus (Olfers, 1818)	9	LC
Monodelphis americana (Müller, 1776)	3	LC

*Endemic species

[a] exotic species

individual had been recaptured. After all the information was collected, the individual was released in the same site where it was captured.

For identification, we used mammalian guides (Emmons and Feer 1997; Pine 1999; Bonvicino et al. 2008). To classify species in terms of endemism, we used the annotated list of mammals by Paglia et al. (2012) and, for the degree of threats, we used the International Union for Conservation Red List (IUCN 2019) and the Brazilian List of Threatened Fauna (ICMBio 2018).

Data analysis

We used the Non-Metric Multidimensional Scaling (NMDS) to order the data of composition and number of individuals captured (abundance) of the non-volant mammals' species in the PEPCV and Setiba EPA. We used the Bray-Curtis index in the NMDS to estimate the dissimilarity in species composition and the number of individuals captured in each sampling site. This analysis aimed to assess the existence of some pattern ordering the mammalian assemblage. We performed the analyzes in the R version 3.4.4 program using a "metaMDS" function in the Vegan package version 2.5–4 for community analysis (Oksanen et al. 2013). We used a one-way analysis of variance (ANOVA) to assess whether there were differences in the richness and abundance of small mammals, among vegetation types using the R version 3.4.4 program.

Results

We recorded 170 individuals of 21 species, 12 species of the Order Rodentia and nine species of the Order Didelphimorphia (Table 1). Among the recorded species, five
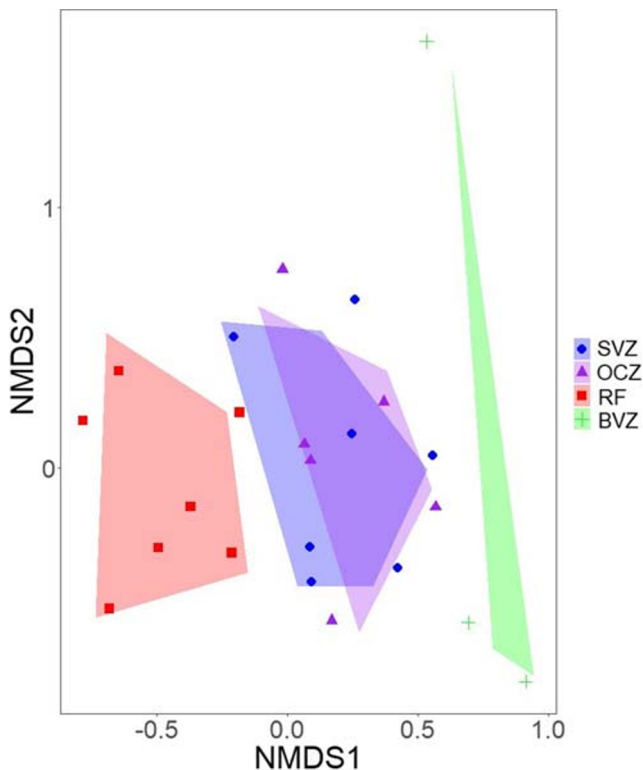
Fig. 3 Non-Metric Multidimensional Scaling (NMDS) showing the dissimilarity between the sample areas in the composition of non-volant small mammals recorded in the Paulo César Vinha State Park and the Environmental Protection Area of Setiba, Guarapari, Espírito Santo, Brazil. Caption: SVZ = Shrub vegetation zone; OCZ = open Clusia zone; RF = Restinga forest and BVZ = beach vegetation zone

are endemic to the Atlantic Forest. Among the endemic species of the Atlantic Forest are the rodents *Phyllomys pattoni*, *Hylaeamys laticeps*, *Trinomys setosus*, and the Brazilian Common Opossum *Didelphis aurita* and the Brazilian Gracile Opossum *Gracilinanus microtarsus* (Table 1). *Hylaeamys laticeps* is listed as almost threatened on the IUCN list.

The non-volant small mammals' composition from PEPCV and Setiba EPA differed between the four vegetation types, constituting three main groups regarding the dissimilarity between the sampling sites (Fig. 3). The areas with the lowest dissimilarity to each other were the SVZ and OCZ, which constituted a grouping and, the most dissimilar to each other, were the RF and BVZ areas, constituting two distinct groups (Fig. 3).

We found a significant difference in the richness (ANOVA, F = 13.8, p = <0.001, degree of freedom = 20) and in the abundance of species (ANOVA, F = 13.87, p = <0.001, degree of freedom = 20) in the four different vegetation types studied (Fig. 4). The richness and abundance of the species captured were higher in RF when compared to OCZ, SVZ and BVZ (Fig. 4).

We found that small mammals assemblage differed in the different vegetation types, with higher species richness in the Restinga Forest (RF). Approximately 61% of the species found in the RF were also present in Shrub Formations (OCZ and SVZ). In the BVZ, only two species were captured, *Didelphis aurita* and *Cavia fulgida* (Fig. 5). Only *D. aurita* was captured in all vegetation types. We captured seven species exclusively to the forest formation, they were the *Marmosa paraguayana*, *Caluromys philander*, *Gracilinanus microtarsus*, *Monodelphis americana*, *Necromys lasiurus*, *Rhipidomys mastacalis* and *Phyllomys pattoni* (Fig. 5).

Discussion

We recorded a high species richness in the sampled areas of PEPCV and Setiba EPA, with a total of nine marsupials and 12 rodents distributed in four different vegetation types. Our results indicate a high species richness for both PAs, when compared with other studies carried out in other restinga areas of Brazil. Of the 21 species found in PEPCV and Setiba EPA,
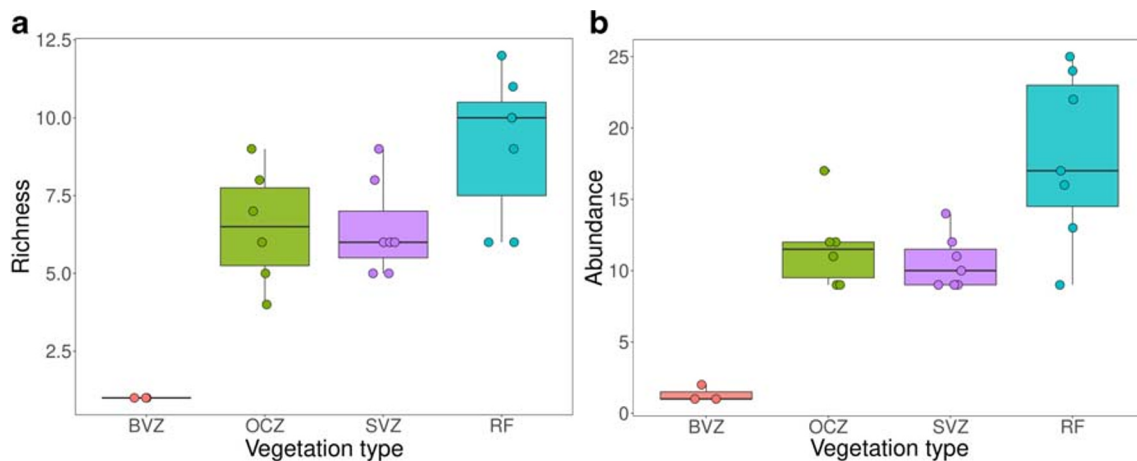
Fig. 4 a Richness and b abundance of non-volant small mammals in each vegetation type of Paulo César Vinha State Park and the Environmental Protection Area of Setiba in Guarapari, Espírito Santo, Brazil
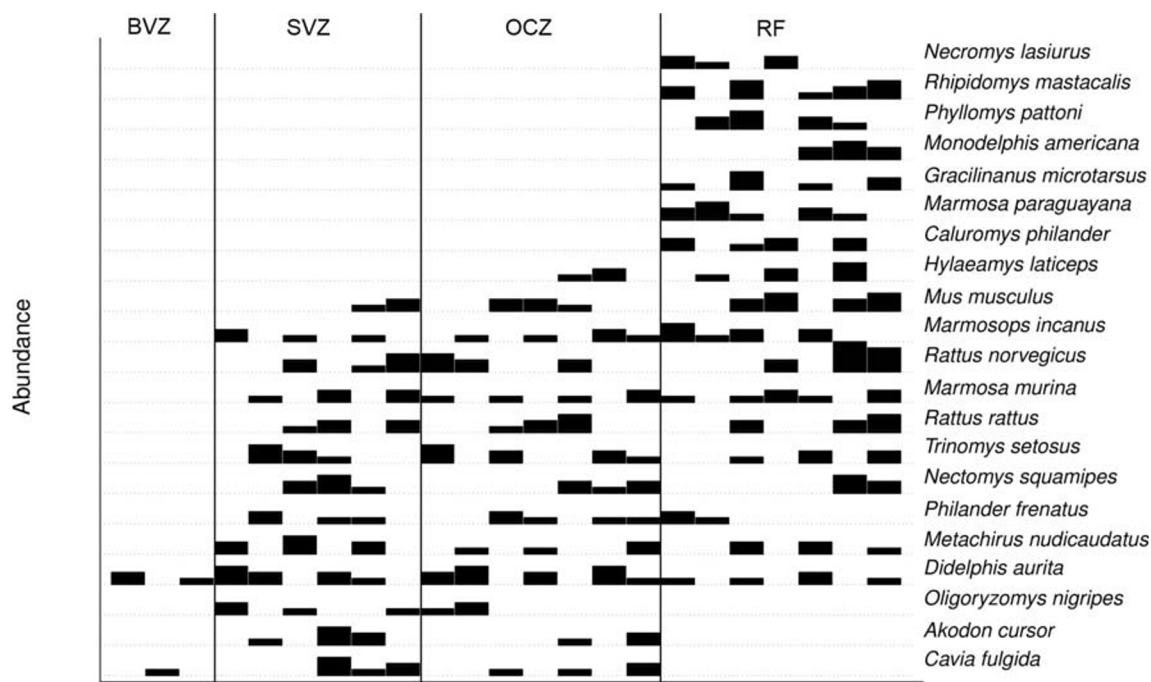
Fig. 5 Abundance of species of non-volant small mammals ordered by the vegetation types sampled in the Paulo César Vinha State Park and in the Environmental Protection Area of Setiba, Guarapari, Espírito Santo, Brazil

five are endemic to the Atlantic Forest, which represents 23.8% of the rate of endemism of small mammals to this biome among local species (Paglia et al. 2012). This result represents about 16% of all species of non-volant small mammals occurring in the Atlantic Forest (Paglia et al. 2012; Graipel et al. 2017) and 43.75% of species of the Rodentia Order and Didelphimorphia of the State of Espírito Santo listed by Moreira et al. (2008). A study at the Morro Grande Forest Reserve, in the State of São Paulo (Pardini and Umetsu 2006) recorded eight species of marsupials and 15 of rodents. On the other hand, in fragments of restinga forest in Rio Grande, in the coastal plain of Rio Grande do Sul, recorded three species of marsupials and eight rodents (Quintela et al. 2012). Another study conducted in the restinga of the Acaraí State Park in the south of Brazil recorded 126 individuals of small mammals, one species of the Order Didelphimorphia and three species of the Order Rodentia (Balieiro et al. 2015). In the Restinga de Jurubatiba National Park, Bergallo et al. (2004) recorded four species of marsupials and seven species of rodents in five vegetation types.

The small mammals' composition differed between the vegetation types of PEPCV and Setiba EPA. Only the *Didelphis aurita* was captured in all vegetation types. This may be related to the fact that this opossum is an animal with a high ecological plasticity and with omnivorous feeding habits and can be found in the most different types of habitat from the interior of forests to urban areas (Graipel and dos Santos-Filho 2006). *Cavia fulgida* was recorded in all vegetation types except for forest environments. In fact, it has been

argued that the species is terrestrial and inhabit tunnels in low and closed vegetation, such as grasslands (Silva 1994), which is in line with what was found in PEPCV and Setiba EPA. Of the species recorded exclusively in the forest environment, the species *Rhipidomys mastacalis* and *Phyllomys pattoni*, are exclusively arboreal rodents (Bonvicino et al. 2008; Paglia et al. 2012). *Necromys lasiurus* is a terrestrial rodent that occupies open and forested formations in the Cerrado, but also transits the ecotone Atlantic Forest-Cerrado (Bonvicino et al. 2008). The marsupials recorded only in forest environments were *Caluromys philander*, *Gracilinanus microtarsus* and *Marmosa paraguayana*, which are arboreal species (Rossi et al. 2012; Graipel et al. 2017). In forest formations, we also register *Monodelphis americana*, which is a species of semi-fossorial marsupial (Vieira et al. 2012).

The higher richness found in the forest environment could be related to the greater complexity of the vertical space, expanding the availability of different niches, increasing resources and protection against terrestrial predators (Vieira et al. 2012). Banasiak and Shrader (2016) suggest that communities of small mammals prefer more complex environments, because in addition to the higher resource's availability, these environments still offer protection against predation through their vegetation cover. A study in South Africa found differences in the composition of small mammals in different habitats and recorded a higher richness and abundance in forest areas (Simelane et al. 2018). Our results recorded this same pattern because forest environments provide higher plant diversity, thus presenting the highest richness and abundance of

all other formations evaluated. In the areas of OCZ and SVZ, a similar pattern of richness and abundance was observed, and this can be explained due to the similarity of this environments, because both are composed of thickets of vegetation (Martins 2012). However, in the BVZ sampling sites we recorded the lowest richness and abundance, with only plant species that are adapted to the actions of the winds, increased salinity, and greater water restriction, with a very characteristic undergrowth (reptile) prevailing (Martins 2012). These factors reduce the chances of rodents and arboreal marsupials transiting in these environments because the ideal conditions for these species occur are vegetation types with the presence of a more diversified vegetation with lianas that form an understory. In the Jurubatiba sandbank, Bergallo et al. (2004), found similar results regarding the habitat heterogeneity and the richness of species.

The results obtained in this study indicate a high small mammals' richness for two PAs of restinga, which are important environments for conservation due to their intense exploitation for sand extraction and high real estate speculation due to urban expansion. These results represent the first step to assist in actions for the conservation of mammals in a coastal environment with high anthropogenic pressure. Our results corroborate the hypothesis of habitat heterogeneity in the restinga environments. In addition, we verified the plasticity of the species *D. aurita* and the specificity of habitat of species recorded exclusively in forest environments. We also noticed that although the forest vegetation types showed the higher richness in the resting, some species occurred only in open vegetation formations, emphasizing the importance of the irreplaceable nature of different vegetation types for the conservation of species. We hoped that our results will be able to contribute with important data on the distribution of the species of small mammals of PEPCV and Setiba EPA, helping in the decision making for actions related to the conservation of this ecosystem.

Compliance with ethical standards

Disclosure statement   We have no conflicts of interest to declare.

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