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RESUMO

A fauna de pequenos mamíferos no norte do estado do Espírito Santo (ES) não é bem conhecida e nenhum estudo foi realizado na área da foz do rio Doce. Este rio corre no sentido oeste-leste nesta região do estado do ES, sudeste do Brasil, uma área que carece de conhecimentos sobre a fauna de pequenos mamíferos. Apresentamos nesse trabalho informações obtidas durante 25 anos de estudos intermitentes sobre pequenos mamíferos, no lado norte e no lado sul do rio Doce. As amostragens foram feitas em cinco fragnentos de Restinga, na Floresta National dos Goytacazes (FLONA) e em duas plantações sombreadas de cacau. Armadilhas do tipo gaiola, do tipo Sherman e *pitfalls* suspensos foram usados para a captura dos pequenos mamíferos. Quatro ordens, 8 famílias e 15 espécies foram registradas. O marsupial *Didelphis aurita* foi destacadamente a espécie mais comum. Um espécime da ordem Lagomorpha (*Sylvilagus tapetillus*) e um da ordem Primates (*Callithrix geoffroyi*) foram também capturados. A similaridade entre a Floresta Nacional dos Goytacazes e os fragmentos de Restinga alcançou 46%, enquanto a área de plantação de cacau na margem norte do rio Doce mostrou baixos níveis de similaridade (8% e 29%), quando comparada com as áreas preservadas (fragmentos de Restinga e FLONA). Baixa riqueza de roedores foi observada com a possibilidade de algumas espécies estarem localmente extintas por perda de habitat e fragmentação.

Palavras-chave: Mata Atlântica, biodiversidade, plantação de cacau, perda de habitat, composição de espécies

ABSTRACT

The small mammal fauna in the northern state of Espírito Santo (ES) is not very well known, and no study has been previously conducted at the mouth of the Doce River. This river runs west-east in this region of the state of ES, southeastern Brazil, an area that lacks knowledge on small mammals. Herein, we present information obtained during a 25-year intermittent survey on non- flying small mammals on the north bank of the Doce River, and another on the south side. Sampling took place in five patches of *Restinga*, the Floresta National dos Goytacazes (FLONA) and two shaded cacao plantations. Cage traps, Sherman-like traps and suspended pitfalls were used to capture the small mammals. Four orders, eight families, and 15 species were recorded. The marsupial *Didelphis aurita* was by far the most common species. One specimen from the order Lagomorpha (*Sylvilagus tapetillus*) and one from the order Primates (*Callithrix geoffroyi*) were also captured. The similarity between Floresta Nacional dos Goytacazes and the patches of *Restinga* reached 46%, and the area of cacao plantation on the north bank of the Doce River showed low levels of similarity (8% and 29%) when compared with the preserved areas (patches of *Restinga* and FLONA). A low richness of rodents was observed, with the possibility of some species locally extinct by habitat loss and fragmentation.

Keywords: Atlantic Forest, biodiversity, cacao plantation, habitat loss, Mammalia, species composition

INTRODUÇÃO

The state of Espírito Santo (ES), Brazil, was almost all covered by the Atlantic Forest in the past. The process of colonization and human development greatly increased the degradation of this biome; agriculture, livestocking, logging, charcoal production and population growth were the main causes of its devastation (THOMAZ, 2010). Nowadays, only small, medium and a few large fragments of the Atlantic Forest remain, comprising of only about 8 - 10% of the original cover (FUNDAÇÃO SOS MATA ATLÂNTICA; INPE, 2019).

Understanding how non-volant small mammals respond to Atlantic Forest fragmentation is an unsolved problem, because establishing the occupancy patterns and relate them to diversity and abundance of species in forest patches of various sizes is still a complex problem. Some studies have shown a positive relationship between small mammal abundance and richness in relation to the fragment size (PARDINI et al., 2005; PASSAMANI, FERNANDEZ, 2011), while others have revealed the opposite (MALCOLM, 1991; LAURANCE, 1994). Likewise, some species of small mammals depend on intact forest and have their abundance reduced in small forest fragments (FIGUEIREDO, FERNANDEZ, 2004). Otherwise, other species benefit from human-altered environments, which increase their abundance (OLIFIERS, 2002; PARDINI, 2004; VIVEIROS DE

CASTRO, FERNANDEZ, 2004; UMETSU, PARDINI, 2007; PARDINI et al., 2009; VIEIRA et al., 2009; PASSAMANI, FERNANDEZ, 2011). PARDINI et al. (2010) found that generalist species were not affected by differences in patch size, neither is their total abundance or richness. On the other hand, the total number of forest specialist species (gamma diversity) had 3-5 times less specialist taxa in most deforested landscape when compared with the most forested fragmented landscapes. Fragmented landscapes are complex and heterogeneous systems (PARDINI, 2004), which effects on abundance and richness are influenced by internal and external factors, such as food availability, predators, edge effect, size of the fragment, isolation degree of forest remnant, type of the matrix and disturbances from various sources.

Historically the small mammals of the Espírito Santo were catalogued under medium and large mammal categories in surveys that were mostly conducted from the late 1980s onwards. The volant and non-volant mammal fauna at the Duas Bocas Biological Reserve was firstly surveyed in 1987/88 (HELDER-JOSÉ et al., 2016). Then, two other studies on non-volant mammals were carried out in this reserve (PARESQUE et al., 2004; TONINI et al., 2010). Together, these three works reported 27 small mammal species. Surprisingly, only seven out of twenty-seven species of small mammals recorded for this reserve were common between the three studies (HELDER-JOSÉ et al., 2016). Vertical stratification (PASSAMANI, 1995), and richness and abundance of small mammals (PASSAMANI, 2000; PASSAMANI et al., 2000; PASSAMANI, FERNANDEZ, 2011) assessments were carried out in 1994, 1998, and from 1999 to 2001 at the Santa Lúcia Biological Station and adjacent forest fragments, in Santa Teresa municipality. The small non-flying mammals in Atlantic Forest fragments and agricultural areas in Viana municipality (ES) were surveyed in 1981 and 1982, and 2006 and 2007 by Pinto et al. (2009). In 2012 and 2013, non-volant mammals of the Mestre Álvaro Environmental Protection Area in the metropolitan area of Serra were surveyed by Guerra, Leite (2017). In 2006, in the north of Espírito Santo, Leite, Costa (2018) inventoried the mammalian fauna of Pontões Capixabas Natural Monument, while Srbek-araújo et al. (2014) reported the mastofauna of the Reserva Natural Vale. A state of knowledge study on Espírito Santo mammals based on museum records and published data was carried out by Moreira et al. (2008).

Existing studies are still not enough for the knowledge of the non-volant small mammal fauna of Espírito Santo, especially in the northern region, where the largest forest complex of this state stands (ROLIM et al., 2016). The mouth of the Doce River lies in this region, which is considered high priority for studies on mammal fauna (THOMAZ, 2010; IPEMA, 2011) due to the lack of knowledge and the impacts caused the Fundão mining dam breach (CASAR et al., 2020).

OBJECTIVES

From this perspective, several surveys were conducted over 25 years at the mouth of the Doce River with the aim of providing a list of species of small non-flying mammals for this region. In addition, other faunas associated with the different phytophysiognomies were compared by similarity analysis.

MATERIALS AND METHODS

Study area

The surveys were conducted at the mouth of the Doce River region in the municipality of Linhares, state of Espírito Santo (Fig. 1). This region belongs to the Hileia Baiana lowlands, called Mata de Tabuleiros, which stands from the north of the state of Espírito Santo to the south of the state of Bahia on the Brazilian coast. The term Tabuleiros refers to the topography of the region, which has large lowland areas up to 200 metres above sea level. The vegetation is characterized as Lowland Dense Ombrophilous Forest (PEIXOTO, GENTRY, 1990). It is a forest area of high floristic diversity (alpha diversity) with the presence of majestic sapucaias (*Lecythis* spp.), jequitibás (*Cariniana* spp.) and pequí-vinagreiro (*Caryocar edule* Casar) emerging over a canopy about 30 m high (SAITER et al. 2016). In this high forest the jueirama-branca (*Albizia pedicellaris* (DC.) L.Rico), the pau-sangue (*Pterocarpus violaceus* Vogel), the peroba-amarela (*Paratecoma peroba* (Record) Kuhlm.), the jacarandá-caviúna (*Dalbergia nigra* (Vell.) Fr. All. Ex Benth), the imbiruçú (*Eriotheca macrophylla* (K. Schum.) A. Robyns), araticum-bravo (*Annona dolabripetala* Raddi), the bitter palm (*Allagoptera caudescens* (Mart.) Kuntze) and the jequitibá-rosa (*Cariniana legalis* (Mart.) Kuntze) are common (Thomaz, 2010). In addition to this main forest, three other plant formations are part of the Tabuleiros forest: muçununga (shrubby vegetation), floodplain forest and native grasslands. The average annual rainfall in this region is nearly 1200 mm, presenting a rainy season running from October to March and a dry season from April to September. The minimum average temperature in this region is 14.8 °C and the average maximum temperature is 34.2 °C. The average annual temperature is 23.3 °C (FERREIRA-DA-SILVA, 2005).

The study was carried out in four different sites, all of them belonging to the Atlantic Forest biome domain. Site A comprised of five patches of *Restinga*, a sandy soil ecosystem derived from sea level regression. The vegetation of these fragments is structured by dense forests with trees of approximately 20 m in height. These patches stand near the district of Povoação. The structure of the vegetation of site B is a dense ombrophilous forest with tall trees and trunks covered by substantial amounts of epiphytes and creepers (ROSS, 2001). It is a Conservation Unit, the National Forest of Goytacazes (FLONA), the only remaining area of alluvial soil in the state of ES. Samplings encompassed the vegetation of its border, and central area. The site is a government-protected conservation unit and plays an important role in conserving local biodiversity. Sites C and D were

located in a shaded cacao plantation, on the south and north bank of the Doce River respectively.

This agroforest ecosystem known as *cabruca* consists of understory replacement by cacao trees (*Theobroma cacao* L.) after the removal of the understory forest and the maintenance of some tall trees to shade the cacao trees. Table 1 presents the sampling periods, sampling efforts, sizes, and geographical coordinates of the study areas. All these sites are close to sea level, around 3 m asl.

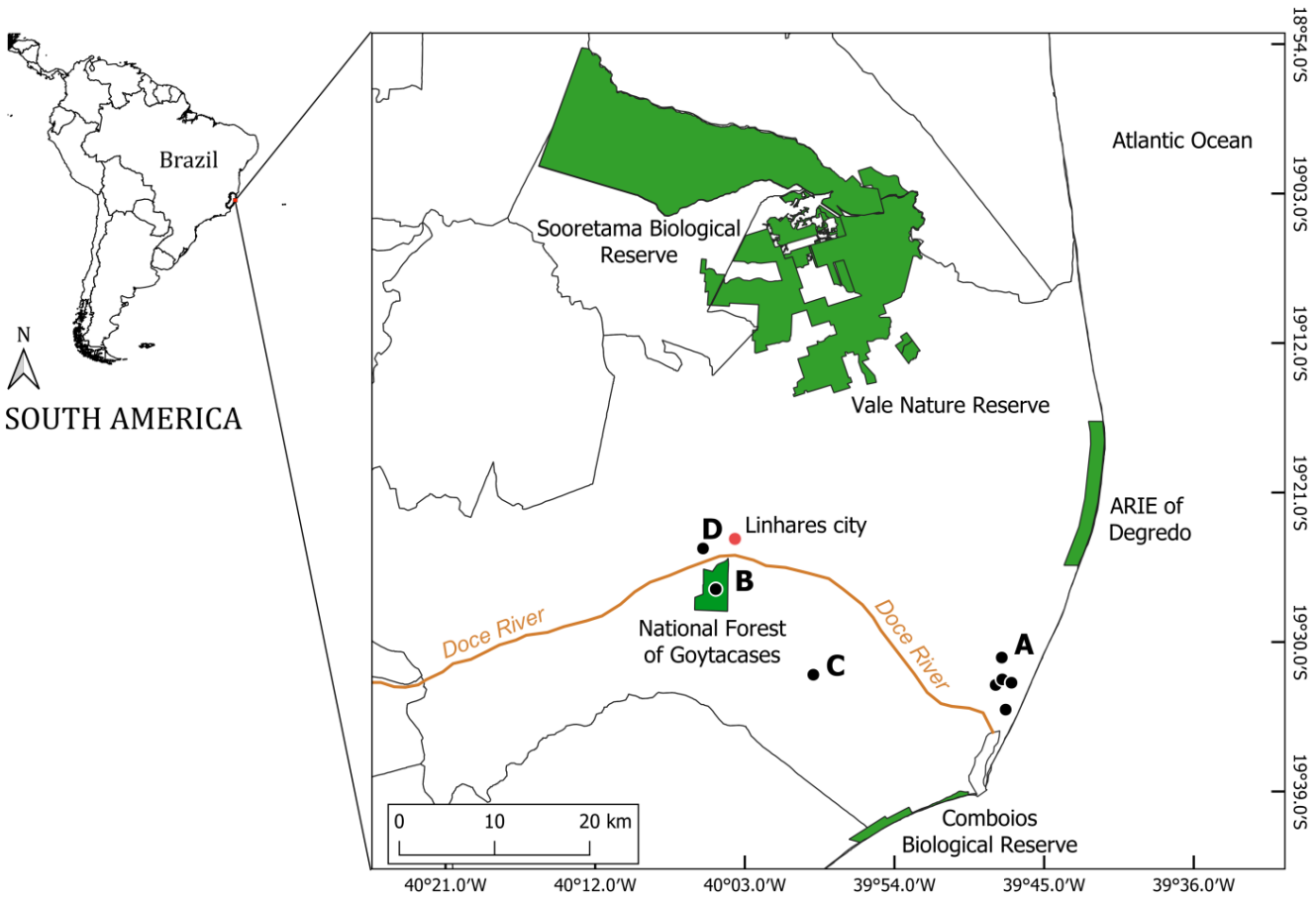

Figure 1 – Location of the mouth of the Doce River in the municipality of Linhares, state of Espírito Santo, Brazil. A, B, C and D indicate the studied areas. Green areas are Conservation Units. ARIE - Area of relevant ecological interest.

Table 1. Trapping periods, sampling efforts, sizes and coordinates of the sampling sites of small non-volant mammals at the mouth of the Doce River, Linhares, southeastern Brazil.

Sites	Sizes (ha)	Coordinates	Trapping periods	Sampling effort (traps-night)
Site A: *Restinga* ecosystem			December 1992 to January 1993 October to December 1993	6047
Fragment 1	~ 65	19°34'04.3" S 39°47'19.7" W	January and May 1994	
Fragment 2	~ 1	19°32'35.4" S 39°47'55.7" W	January and February 1995	
Fragment 3	~ 23	19°32'15.2" S 39°47'31.7" W	June and July 1995	
Fragment 4	~ 40	19°32'27.4" S 39°46'58.2" W	September and December 2000	
Fragment 5	~ 34	19°30'56.3" S 39°47'33.8" W	January to March 2001	
Site B: Floresta Nacional dos Goytacazes (FLONA)	1423.96	19°26'49" S 40°04'45" W	March to August 2006 March to October 2008 January to October 2009 and May to the beginning of October 2010 April to July 2011	1740 1405 2148 678
Site C: Cacao agroforestry ecosystem - cabruca (Sapucaia farm)	~ 254	19°31'58" S 39°58'53" W	August 2011 to August 2012 and December 2012 to August 2013	3632
Site D: Cacao agroforestry ecosystem - cabruca (Angélica farm)	~ 208	19°24'22" S 40°05'31" W	January to the beginning of February 2017	780
Total				**16430**

Data Collection

The surveys ranged from December 1992 to the beginning of February 2017. Table 1 shows the dates of the trapping periods at each site, as well as sampling efforts, sizes and coordinates of the sampling sites.

At site A, 11-35 galvanized wire traps (15x15x30 cm and 20x20x45 cm) were randomly arranged on the forest floor, and on the two largest patches they were placed in a linear transect. In both cases the traps were about 20 m apart. In one of these fragments, additional 567 traps-night were tied to tree branches up to 4 m high.

At site B, from March to October 2006, three 310 m-parallel linear transects, 100 m apart, were built from the west border of the FLONA toward its interior. Each line had nine capture points on the ground and five on trees at 2 m, 8 m

and 14 m high, raised on wooden platforms. The distances between them ranged from 10-50 m. From March to October 2008 and from January 2009 to October 2010, three linear transects of 240 m each were arranged in the form of a 'Y' in the core of FLONA. Each arm of the 'Y' had 12 capture points on the ground (20 m apart) and five in the understory up to 3 m high at alternating points. Additional 510 traps-night were raised between 8 to 15 m heights. The galvanized wire traps measured 21x21x41 cm.

At site C, sampling was conducted using cage-type traps (21x21x41 cm) and Sherman-like folding traps (23x9x8 cm) on the ground along three parallel linear transects (50 m apart) of 400 m, totaling 11 capture points of 40 m intervals per transect. At each capture point (33 in total) a 63-L suspended pitfall was set for the capture of small arboreal mammals, as described by Helder-José et al. (2019). The suspended pitfalls were installed between the heights of two to three meters in cacao tree branches. Arboreal traps totaled 1880 suspended pitfalls-night, while on the ground they totaled 1752 traps-night.

At site D, three parallel linear transects, 30 m apart, were built. Each transect had 20 capture points, 15 m equidistant of one another. Twenty traps of each type were used (60 in total). The types of traps were arranged alternately, following the order: cage-type trap with two entrances (42.5x12.5x12 cm), 63-L suspended pitfall and Sherman folding trap (41x10x13 cm). Cage traps and Shermans were tied to the branches of cacao trees with bungee cords at heights ranging from 1.6 to 3 m with the help of a ladder, while the suspended pitfalls were hung up to 5 m high, as previously described by Helder-José et al. (2019). The total trapping effort was 780 traps-night.

During all trapping periods (Table 1) of sites A and D, the traps were daily triggered, while in sites B and C the samplings were carried out for 2-3 days fortnightly, or sometimes weekly. Cavendish bananas were preferably used as bait because they seemed to be more effective for capture, pineapple and peanut butter were also utilized. Each captured specimen was analyzed, identified, sexed, had mass and biometric data recorded, and reproductive stage determined. We used external characters and measures, and geographical distribution for identification. The taxonomic identification followed Faria et al. (2019) for marsupials; Patton et al. (2015) for Cricetidae, Echimyidae, Erethizontidae and Sciuridae rodent families; Bonvicino et al. (2008) for Muridae rodent family; Ruedas et al. (2017) for the Lagomorpha order and Reis et al. (2015) for the Primates order. The nomenclature is in accordance with Quintela et al. (2020). Specimens were then photographed for further descriptions and comparisons. Since there were many unmarked individuals, only the number of captures as a whole was reported, afterwards, the animals were released. The relative abundance of each species was calculated by multiplying the number of (re)captures of each species by 100, divided by the total number of (re)captured individuals. The relative abundance of

each site was calculated by multiplying the total number of (re)captures of each site by 100, divided by the total number of (re)captured individuals. The capture success rate was calculated by multiplying the number of (re)captures by 100, divided by the number of traps triggered (capture effort). The program Past 2.09 was used to calculate the similarity between these areas, using the Jaccard index (HAMMER et al., 2001; MAGURRAN, 2004). We considered as small mammals all those with body mass up to 2 kg, including the genus *Sylvilagus*, *Callithrix* and *Coendou*.

RESULTS

A total of four orders, eight families, and 15 species were recorded (Table 2; Fig. 2). The whole sampling effort of 16430 traps-night yielded the (re)capture of 814 individuals and a capture success of 4.95%. Seven species of marsupials were recorded, with *Didelphis aurita* by far the most abundant species. It was present in all studied sites and periods except the cacao plantation of the site D (Table 2). *Metachirus myosuros* and *Marmosa paraguayana* were the two other most abundant species. The first was present only in the two forested sites (*Restinga* and FLONA), while the second was found in all four studied sites. The other captured marsupials were much less abundant (Table 3). Six rodent species were caught, and *Rhipidomys mastacalis* was the most abundant, although it only occurred in the cacao agroforest ecosystem of site C. The *Phyllomys pattoni* specimen was collected and recorded in the Mammals Collection of the Universidade Federal do Espírito Santo (UFES-MAM 2461).

FLONA and cacao plantation at site C had the greatest richness (Table 3) and similarity between species composition in both areas (Figure 3). The similarity analysis values between the study areas are shown in Table 4 and Figure 3. The cacao plantation at site D reached the lowest index value (8%) when compared to *Restinga* and FLONA sites. The similarity between the patches of *Restinga* and FLONA reached 46%, probably for being forested environments.

The species richness of cacao agroforestry at site C was similar to the patches of *Restinga*, although the species composition differed among them. Both cacao plantations showed a high level of dissimilarity (31% and 8%) when compared with the preserved areas (*Restinga* and FLONA). Cacao plantations have the understory forest replaced by cacao trees, and workers frequently walk throughout it. This makes it a human-altered environment not suitable for terrestrial small mammal species. Almost all the species captured in this ecosystem were scansorial preferably arboreal or strictly arboreal. On the other hand, the patches of *Restinga* and FLONA comprised several small mammals of terrestrial habits.

Table 2. Non-flying small mammal species recorded in a 25-year intermittent survey of the mouth of the Doce River in the municipality of Linhares, state of Espírito Santo, Brazil. The total number of captures of each species and their relative abundance are indicated. Conservation status of the species follows Costa et al. (2019) and ICMBio (2018). LC = Least Concern.

Species	**Total (re)captures (relative abundance)**	**Conservation status**
Order DIDELPHIMORPHIA		
Family Didelphidae		
Caluromys philander (Linnaeus, 1758)	13 (1.6)	LC
Didelphis aurita Wied-Neuwied, 1826	521 (64)	LC
Gracilinanus microtarsus (Wagner, 1842)	18 (2.2)	LC
Marmosa (Marmosa) murina (Linnaeus, 1758)	39 (4.79)	LC
Marmosa (Micoureus) paraguayana Tate, 1931	61 (7.49)	LC
Marmosops (Marmosops) cf. *incanus* (Lund, 1840)	9 (1.1)	LC
Metachirus myosuros (Temminck, 1824)	64 (7.86)	LC
Order LAGOMORPHA		
Family Leporidae		
Sylvilagus tapetillus Thomas, 1913	1 (0.12)	LC
Order PRIMATES		
Family Callitrichidae		
Callithrix geoffroyi (Humboldt, 1812)	24 (2.95)	LC
Order RODENTIA		
Famíly Cricetidae		
Nectomys squamipes (Brants, 1827)	19 (2.33)	LC
Rhipidomys cf. *mastacalis* (Lund, 1840)	41 (5.04)	LC
Family Echimyidae		
Phyllomys pattoni Emmons, Leite, Kock & Costa, 2002	1 (0.12)	LC
Family Erethizontidae		
Coendou insidiosus (Olfers, 1818)	1 (0.12)	LC
Famíly Muridae		
Rattus rattus Linnaeus, 1758	1 (0.12)	LC
Family Sciuridae		
Guerlinguetus brasiliensis (Gmelin, 1788)	1 (0.12)	LC
Total	**814**	

Figure 2. Non-volant small mammals at the mouth of the Doce River, southeastern Brazil. **A** *Caluromys philander*. **B** *Didelphis aurita*. **C** *Gracilinanus microtarsus*. **D** *Marmosa murina*. **E** *Marmosa paraguayana*. **F** *Marmosops* cf. *incanus*. **G** *Metachirus myosuros*. **H** *Sylvilagus tapetillus*. **I** *Callithrix geoffroyi*. **J** *Nectomys squamipes*. **K** *Rhipidomys* cf. *mastacalis*. **L** *Phyllomys pattoni*. **M** *Coendou insidiosus*. **N** *Guerlinguetus brasiliensis*. **O** *Marmosops* cf. *incanus*.

Table 3. Richness and abundance of small mammals of the mouth of the Doce River related to the studied sites.

Sites	Captured species	Number of (re)captured individuals by species	Total of individuals (relative abundance)	Capture success rate (%)
Site A: *Restinga*	*Didelphis aurita*	323	386 (47.4)	6.4
	Metachirus myosuros	43		
	Marmosa paraguayana	5		
	Nectomys squamipes	13		
	Guerlinguetus brasiliensis	1		
	Callithrix geoffroyi	1		
Site B: FLONA	*Didelphis aurita*	157	221 (27.2)	3.7
	Metachirus myosuros	21		
	Marmosa paraguayana	17		
	Marmosops cf. *incanus*	9		
	Marmosa murina	6		
	Caluromys philander	8		
	Nectomys squamipes	1		
	Guerlinguetus brasiliensis	Some visualized		
	Coendou insidiosus	1		
	Sylvilagus tapetillus	1		
Site C: cacao agroforestry	*Didelphis aurita*	41	188 (23.1)	5.2
	Marmosa paraguayana	30		
	Marmosa murina	28		
	Gracilinanus microtarsus	16		
	Caluromys philander	4		
	Rhipidomys cf. *mastacalis*	41		
	Nectomys squamipes	5		
	Phyllomys pattoni	1		
	Guerlinguetus brasiliensis	1 (visualized)		
	Callithrix geoffroyi	22		
Site D: cacao agroforestry	*Marmosa paraguayana*	9	19 (2.3)	2.4
	Marmosa murina	5		
	Gracilinanus microtarsus	2		
	Caluromys philander	1		
	Rattus rattus	1		
	Callithrix geoffroyi	1		
Total			**814**	**4.95**

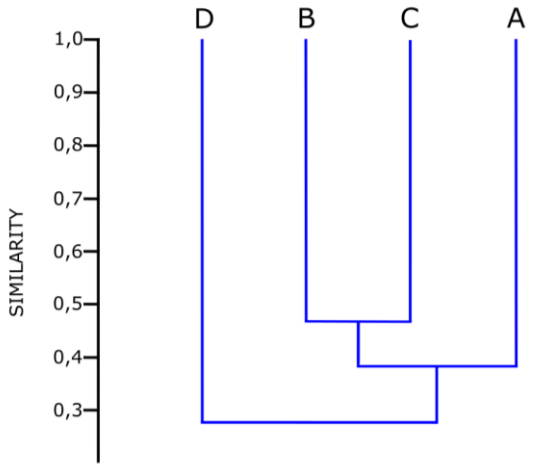

Figure 3. Dendrogram showing the similarity analysis, using the Jaccard index. A, B, C and D are the studied sites.

Table 4. Results of the similarity analysis values between the studied areas. The Jaccard indices were converted to percentages.

	Site A	Site B	Site C	Site D
Site A	100%	46%	31%	8%
Site B	46%	100%	47%	29%
Site C	31%	47%	100%	45%
Site D	8%	29%	45%	100%

Order Didelphimorphia, Family Didelphidae

The bare-tailed woolly opossum, *Caluromys philander* (Linnaeus, 1758) (Fig. 2A), were captured in all studied sites but not in the forest patches of *Restinga*. All specimens were captured in the vertical stratum, corroborating their already known strictly arboreal habit. This is the only species of the genus *Caluromys* present in the study area.

The brazilian common opossum or big-eared opossum, *Didelphis aurita* Wied-Neuwied, 1826 (Fig. 2B), is a medium-sized opossum, and it has black, large, hairless ears, different from *Didelphis albiventris*, which are white. Body coat periodically changes from black to gray. It is the only species of the genus *Didelphis* present in the study area.

The Brazilian gracile opossum, *Gracilinanus microtarsus* (Wagner, 1842) (Fig. 2C) is one of the smallest neotropical marsupials, their adult body mass ranges from 19-30 g. This measure differentiates them from the similar sympatric species *Marmosa murina*, which has double or triple the body mass. This species was only captured in the cacao agroforest, being absent in the forested habitats. It is of scansorial habit and omnivorous diet.

Adult specimens of Linnaeus's mouse opossum, *Marmosa (Marmosa) murina* (Linnaeus, 1758) (Fig. 2D), are larger than *G. microtarsus*, and body mass reaches 100 g. It is of arboreal habit and omnivorous diet.

Tate's woolly mouse opossum, *Marmosa (Micoureus) paraguayana* Tate, 1931 (Fig. 2E), was ubiquitous, the only species present in all sampled sites, and relatively abundant when considering the arboreal sampling. The average body mass is 136.5 g (n = 15; range: 62 - 177 g).

The grey slender mouse opossum, *Marmosops (Marmosops)* cf. *incanus* (Lund, 1840) (Fig. 2F, 2O), is the only species of this genus present in the sampling area (at sea level). *Marmosops paulensis* (Tate, 1931), known for being present in the state of Espírito Santo, inhabits the mountainous region above 800 m of Serra do Mar and Serra da Mantiqueira (MUSTRANGI, PATTON, 1997), and it was only recorded in the Caparaó National Park (COSTA et al., 2019).

The brown four-eyed opossum, *Metachirus myosuros* (Temminck, 1824) (Fig. 2G), is a medium-sized neotropical marsupial and the largest didelphid without a pouch. The two conspicuous pale spots above the eyes and the general brown pelage color gave them the popular name brown four-eyed opossum. When disturbed, the species of this genus make a conspicuous noise as they are cracking the teeth, as a defensive behavior. *M. myosuros* is the only species of the genus *Metachirus* found in the study area. Among the forested patches sampled, *M. myosuros* was much abundant in two of them, mainly in the smallest one, where it was found in higher density. All specimens were captured on the ground, confirming their terrestrial habit.

Order Lagomorpha, Family Leporidae

Just one specimen of dwarf cottontail, *Sylvilagus tapetillus* Thomas, 1913 (Fig. 2H) was trapped. It is likely it is a trap-shy species. This is the only species of Lagomorpha native to Brazil.

Order Primates, Family Callitrichidae

Some specimens of Geoffroy's tufted-ear marmoset, *Callithrix geoffroyi* (Humboldt, 1812) (Fig. 2I), were captured in the cacao plantations. However, many of them were visualized and their vocalizations heard. In this ecosystem they must occur in relatively high densities. It is diurnal, arboreal and omnivorous. This species is endemic to the central corridor of the Atlantic Forest in the states of Minas Gerais, Espírito Santo and Bahia (MMA, 2017).

Order Rodentia, Family Cricetidae

The Atlantic Forest water rat, *Nectomys squamipes* (Brants, 1827) (Fig. 2J) was recorded in both forested and cacao agroforestry habitats. Despite of being a semiaquatic species, the individuals found in the agroforest were not associated with any form of water body.

The Atlantic Forest climbing mouse, *Rhipidomys* cf. *mastacalis* (Lund, 1840) (Fig. 2K), was the most abundant rodent. Although it is known as arboreal rat, almost half of the captures occurred on the ground (18 out of 41) by cage like and Sherman traps. Arboreal individuals were trapped by suspended pitfalls. The mean body mass over time was 72.4 g (n = 21; range: 45 - 103 g).

Family Echimyidae

The rusty-sided Atlantic tree-rat, *Phyllomys pattoni* Emmons, Leite, Kock, Costa, 2002 (Fig. 2L), has thorny hairs on the dorsal surface. It is a nocturnal and arboreal species. This is the unique species of the genus *Phyllomys* occurring in the study area (LEITE, 2003).

Family Erethizontidae

The Bahian hairy dwarf porcupine, *Coendou insidiosus* (Olfers, 1818) (Fig. 2M), is stout with rounded head and mobile snout. Its conspicuous feature is a coat of thick, cylindrical spines. It is a nocturnal and predominantly arboreal species.

Family Muridae

The house rat, *Rattus rattus* (Linnaeus, 1758), presents a world-wide distribution, is invasive and highly damaging to natural environments.

Family Sciuridae

The tail of the Southeastern Squirrel, *Guerlinguetus brasiliensis* (Gmelin, 1788) (Fig. 2N), is hairy with the same color as the back and often positioned over the back. It is the only species of the genus occurring in the study area. It is of diurnal and has arboreal habits.

None of the species herein recorded is on any of the lists of threatened species for the state of ES and Brazil, and they are classified as least concern (ICMBio, 2014; COSTA et al., 2019). Most of these species are largely distributed throughout the Atlantic Forest, and some of them even throughout other biomes. In contrast, excluding *D. aurita*, *M. myosuros*, *M. paraguayana* and *Callithrix geoffroyi*, most of the species occurred in low or in relatively low abundance. It is noteworthy the scarcity of rodents. Only five native rodent species were captured throughout the sampling area. Just two species (*N. squamipes* and *G. brasiliensis*) occurred in the patches of *Restinga* ecosystem, and in three of the fragments terrestrial rodents were absent. The same 2 species plus *C. insidiosus* were present at the west border of the FLONA, but absent in the central area and in the east border.

DISCUSSION

The richness result of 15 species is below most of other works carried out in the Atlantic Forest nearby. The Vale Nature Reserve (31 km north) encompassed 21 small mammal species (SRBEK-ARAÚJO et al., 2014); in Pontões Capixabas Natural Monument (Pancas and Águia Branca municipality, 76 km northwest) 21 species were recorded (LEITE, COSTA, 2018); studies in the Mestre Álvaro Environmental Protection Area (85

km south) Guerra, Leite (2017) reported 15 species; in the Biological Station of Santa Lúcia (Santa Teresa municipality, 77 km southwest), Passamani, Fernandez (2011), found 20 species and in Duas Bocas Biological Reserve (103 km southwest) 27 species were recorded (PARESQUE et al., 2004; TONINI et al., 2010; HELDER-JOSÉ et al., 2016). The species recorded by us at the mouth of the Doce River were also reported in most of these localities. Since animals in most of the sampled sites were not tagged, it is likely that many of them were recaptured, which may have led to overestimates of local abundance.

Almost all the species cited in these studies occur on both sides (north and south) of the Doce River, and it seems that the river does not work as a geographic barrier. Most of these species have a broad geographic range. However, we highlight two species: *Trinomys paratus* and *Trinomys setosus*. The first species occurs on the south bank of the Doce River, while *T. setosus* is present only on the north bank (DALAPICOLLA, LEITE, 2015). In this case, the Doce River is the geographic limit between these two species acting as a barrier.

The high abundance of *D. aurita* in the study area might be explained by its omnivorous diet with great flexibility in eating habits (CÁCERES, MONTEIRO-FILHO, 2001; CARVALHO et al., 2005), the capability of exploiting disturbed environments, the high reproductive rate having one, two or three litters with many offspring per breeding season (CERQUEIRA, 1985; HELDER-JOSÉ et al., 2016), the use of the ground and the forest vertical strata (GRELLE, 2003) and the decrease of its natural predators in small and medium-sized fragments. In forest patches in this biome, *D. aurita* tends to be the dominant species (FONSECA, ROBINSON, 1990; SILVA, PASSAMANI, 2009), what is in agreement with our data. Its adaptability enables it to be found in peridomestic areas and even in urban areas (JARED et al., 2014). These features provide adaptive flexibility to the environment, making it an **r** strategist.

The second commonest species, *M. myosuros*, covers a fairly large South American range, including the Atlantic Forest and Amazonia (FARIA et al., 2019). It inhabits forested environments, both pristine and secondary forests (FARIA et al., 2019), avoiding anthropic areas. Individuals are usually found nesting in areas with a thick layer of forest litter and in bushy environments (LORETTO et al., 2005). This may explain the absence of this species in cacao agroforests in this study.

The medium-sized scansorial marsupial *M. paraguayana* prefers arboreal habitats. The Atlantic Forest and the Cerrado (Brazilian savannah) are its dwelling biomes (RODRIGUES et al., 2006; GARDNER, CREIGHTON, 2008). It has been captured in most studies of these biomes, but not in abundance, contradicting our results.

Although *Caluromys philander* and *Marmosa murina* were not captured in the forest patches of *Restinga*, these species must be present in this site.

Judging by the vegetation structure of these patches and the low arboreal sampling effort done, it is likely that they also occur in this habitat. *C. philander* is a strictly arboreal species and inhabits tropical and subtropical forests, including secondary forests, plantation areas and disturbed vegetation (IUCN, 2015a). *M. murina* is widespread throughout the Atlantic Forest, the Cerrado, Amazonia and the Pantanal biomes (IUCN, 2015b).

Only nine captures of seven individuals of *Marmosops* cf. *incanus* were made, which makes this species locally rare. It was only recorded on the west border of FLONA from March to August 2006. However, in other places of the Espírito Santo Atlantic Forest, such as in the Santa Teresa municipality (PASSAMANI, FERNANDEZ, 2011), Duas Bocas Biological Reserve (HELDER-JOSÉ et al., 2016) and Vale Nature Reserve (ROCHA et al., 2016) it was well sampled.

In a recent taxonomic revision of South American cottontail rabbits, Ruedas et al. (2017) restored *Sylvilagus tapetillus* Thomas, 1913 as a valid species, previously included in *Sylvilagus brasiliensis* (Linnaeus, 1758). These authors restricted *S. brasiliensis* to Northeastern Brazil and *S. tapetillus* as applicable to samples from Southeastern Brazil. The type locality of *S. tapetillus* is the municipality of Porto Real, Rio de Janeiro state, Brazil (ca. 22°24.68′S, 044°19.25′W). It is smaller than *S. brasiliensis*.

The small rodent *Rhipidomys* cf. *mastacalis* inhabits forested areas including primary and secondary forests (GEISE et al., 2004). Conversely, herein *R. mastacalis* was only recorded in cacao agroforestry (site C). It has also been reported in cacao plantations in the state of Bahia (ENCARNAÇÃO, 2001; GEISE, PEREIRA, 2008), where it causes serious damage to cacao production. These records indicate its adaptability to disturbed environments.

The quills of *Coendou insidiosus* are hidden and mixed with long, soft and pale hairs. Just above the head the thorns are exposed. They are short yellow-based and black-tipped bicolor quills. This species has pale to light-brown unicolor thin hairs covering the dorsal and lateral quills, as described by Caldara, Leite (2012). These characters differ from the congeneric *C. spinosus*, which has long tricolor quills (yellow-based and black intermediate bands longer than orange tip), and thick hairs covering the dorsal and lateral quills. These hairs are dark-brown at the base, and grayish, orange, yellow or light brown at the tip (CALDARA, LEITE, 2012).

Just one specimen of *Guerlinguetus brasiliensis* was trapped and a few others visualized. This may be a false idea of low abundance due to it being a trap-shy species, and thus rarely captured with traditional live-traps. It is likely that it also escapes from suspended pitfalls (HELDER-JOSÉ et al., 2019). In a 3-year capture-mark-recapture study at the Serra da Bocaina National Park, Delciellos et al. (2019) estimated that the population size ranged between 3.2 (± 2.4) and 51.3 (± 15.0) individuals.

Population density was 1.3 to 74.3 individuals/km^2, similar to other previous studies carried out in the Atlantic Forest. *G. brasiliensis* ranges along the Atlantic Forest from Espírito Santo state to Rio Grande do Sul state, and Misiones in Argentina (DE VIVO, CARMIGNOTTO, 2015). It is the only sciurid species occurring in the Atlantic Forest.

The absence of several rodent species, which are commonly found in other places of the Atlantic Forest nearby (e.g., *Akodon cursor* (Winge, 1887), *Oligoryzomys nigripes* (Olfers, 1818), *Oecomys catherinae* Thomas, 1909, *Euryoryzomys russatus* (Wagner, 1848), *Blarinomys breviceps* (Winge, 1887), *Trinomys paratus* (Moojen, 1948) and others), raises two possibilities: (1) these species have never occurred in the study area or (2) they are present in very low density.

The similarity analysis showed that the cacao plantation at site D was the most dissimilar, and this may have occurred because human activity in this place is more intense, with workers frequently walking along it. This makes it a human-altered environment, not suitable for small terrestrial mammal species. Almost all species captured in this ecosystem were scansorial preferably arboreal or strictly arboreal. On the other hand, the Restinga and FLONA patches included several small mammals of terrestrial habits, and they were similar to each other. The similarity analysis also showed that the cacao plantation in site C was more similar to the preserved areas, indicating that areas of this type, when less active, can be a refuge for wildlife.

CONCLUSION

In general, our results indicated that *D. aurita, M. myosuros and M. paraguayana* benefited from the fragmented environment, while most rodent species showed a negative relationship. In addition, the data presented in this paper contribute to the insights of the mouth of the Doce River, since other studies have not been conducted at this location according to the current literature. The similarity analysis contributed significantly to the knowledge of the fragmentation of the Atlantic Forest, since the diverse habitats and species with distinct habits could be compared within the same biome.

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