Available online at:

http://www.italian-journal-of-mammalogy.it

Research Article



doi:10.4404/hystrix-00662-2023

How forest amount and bioclimatic factors shape small mammal communities in Atlantic Forest fragments?

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Keywords: rodents marsupials diversity fragmentation temperature precipitation

Article history: Received: 15 September 2023 Accepted: 21 March 2024

Acknowledgements

We thank to CAPES for the Ph.D. fellowship and a post-doctoral fellowship (#88882.314922/2019-01), PROPP-UESC (n. 073.6764.2019.0002700-48) and PROAP— UESC for the financial support. We thank the Atlantic Series Initiative for the open data for Scientists. We are deeply in debt to FG, GM, PRR, Lucas A. Wauters, Editor-In-Chiefcolombo.joly.2010 and Olivia Dondina Section Editor of *Hystrix*, and two anonymous reviewers who made their suggestions in the earlier versions to improve the quality of this manuscript.

Introduction

Community assembly at multiple spatial scales has been an essential topic in community ecology (Fukami and Morin, 2003). Assessments of how species diversity is distributed has become relevant due to provision of ecosystem services (Tscharntke et al., 2012; Whittaker et al., 2001). Changes in environmental variables and habitat amount can occur together with anthropogenic disturbances at multiple spatial and temporal scales (Chase et al., 2019). These have been shown to influence community composition (Dambros et al., 2015; Delciellos et al., 2016; Gaston, 2000; Melo et al., 2017). The native Atlantic Forest in Brazil is experiencing significant habitat loss and deforestation due to human activities such as cultivation of crops, grazing of livestock and general overexploitation of natural resources (FAO, 2018). As a result, habitat loss and deforestation have been identified as the main drivers of the decline in biodiversity in Atlantic Forest regions (Cassano et al., 2014; Galetti et al., 2021; Pardini et al., 2017; Rios et al., 2021).

The Brazilian Atlantic Forest covers 1.5 million km² along the country's coast to northeastern Argentina and eastern Paraguay (Tabarelli et al., 2005). After hundreds of years of deforestation due to anthropogenic disturbances (Joly et al., 2014; Lapola et al., 2014; Marcilio-Silva and Marques, 2017), the Atlantic Forest has lost around 77 % of its original vegetation cover (Vancine et al., 2024). Today, remnants surrounded by several different anthropogenic matrices can be found throughout the original Atlantic Forest biome (Lira et al., 2012). Even so, the remaining Atlantic Forest fragments are noted for high biodiversity, including endemic species (Mittermeier et al., 2011), and are

Hystrix, the Italian Journal of Mammalogy ISSN 1825-5272 ©© ©© ©2024 Associazione Teriologica Italiana doi:10.4404/hystrix-00662-2023

Abstract

Understanding how the mammalian diversity responds to anthropogenic disturbances on local and landscape scales is an urgent task. The Atlantic Forest biome, with only 12% of its original area remaining, still harbors great diversity of small mammals (Rodentia and Didelphimorphia), a key group that responds quickly to disturbances. Here, using the largest dataset of Atlantic Forest small mammals, we evaluate how forest amount and bioclimatic variables affect the non-volant small mammal diversity. For this purpose, we use 214 small mammal assemblages across the Atlantic Forest domain. Our results show that forest amount, with a positive relation, was the most important predictor explaining the diversity of small mammals in Atlantic Forest remnants. We also found that the bioclimatic variables (temperature and precipitation) can positively and/or negatively affect small mammal biodiversity, depending on the region analyzed. This is the first study that has assessed diversity across the entire Atlantic Forest biome, showing the importance of large-scale assessment and of forest amount and bioclimatic variables in shaping the diversity of small mammals regardless of the biogeographic context.

considered global hotspots of biodiversity (Myers et al., 2000). Within its rich biodiversity, these Atlantic Forest remnants harbor substantial diversity of mammals, comprising more than 41 % of all Brazilian species and most of the non-volant mammals belong to the orders Rodentia and Didelphimorphia (Bovendorp et al., 2017; Paglia et al., 2012).

Rodents and Didelphimorphs are composed of more than 200 species within Atlantic Forest remnants (Bovendorp et al., 2017). They occupy several habitat strata (underground, ground and arboreal) and have different habitat requirements (Abreu and De Oliveira, 2014; Estavillo et al., 2013; Umetsu and Pardini, 2007). Compared to medium and large mammals, rodents and marsupials are less vulnerable to extinction from anthropogenic disturbances due to their small size and rapid reproductive rates (Gardner, 2008; Keesing, 2000; Pardini et al., 2010; Smith, 2001). However, many species are sensitive to fragmentation and loss of landscape connectivity (Banks-Leite et al., 2014; Pardini et al., 2010), land use changes (Cassano et al., 2014; Ferreira et al., 2020; Silva et al., 2019; Vieira et al., 2009), variation in food availability (Taitt, 1981; Taitt and Krebs, 1981) and climate change (Loyola et al., 2012). Anthropogenic disturbances in natural habitats lead to defaunation (Bovendorp et al., 2019; Cardillo et al., 2008; Fritz et al., 2009; Galetti et al., 2015; Lira et al., 2012). Therefore, small mammals are ideal models for investigating how diversity is shaped by bioclimatic variables and forest amount in the biogeographic context.

The diversity of small mammals has been associated with the amount and composition of the landscape elements (forest remnants and matrices) (Palmeirim et al., 2019; Pardini et al., 2010; Vieira et al., 2018). Large forest remnant is associated with greater small mammal richness in different biomes as well as for some assemblages in the Atlantic Forest (Palmeirim et al., 2019; Pardini et al., 2010; Vie-

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ira et al., 2018). In addition, the matrix composition can positively or negatively influence small mammals' richness and abundance, depending upon the species' response to the matrix composition (Brady et al., 2011; Delciellos et al., 2016; Paise et al., 2020).

Studies have shown that factors such as temperature and precipitation can influence small mammal assemblages locally (Bergallo and Magnusson, 1999; Dambros et al., 2015; Ferreguetti et al., 2021; Graipel et al., 2006). Thus, the spatial variation of climate can shape small mammal assemblages by imputing dispersion limits (Dambros et al., 2015). Precipitation can also shape small mammal assemblages due to the positive effects on primary productivity (i.e., food availability) (Ferreguetti et al., 2021).

Using the largest dataset of Atlantic Forest small mammals, we evaluate how bioclimatic variables and forest amount affect non-volant small mammal diversity in Atlantic Forest fragments. Furthermore, this is the first study aiming to ascertain how the effects of these factors differ among the tree main Atlantic Forest regions (northeast, southeast and south) (see detailed explanation in Material and Methods -Small mammal assemblages) because of geographic barriers (rivers and mountains) and heterogeneous species pools (Costa et al., 2000; DaSilva et al., 2015; Prance, 1982; Leite et al., 2016). The physical characteristics of remnants (size, forest amount and landscape heterogeneity) are frequently mentioned as the primary drivers of species diversity (da Fonseca, 1989; Hortal et al., 2008; Banks-Leite et al., 2014; Magioli et al., 2021), and based on studies in the Atlantic Forest (Pardini, 2004; Pardini et al., 2005, 2010; de la Sancha et al., 2020), we hypothesized that small mammal diversity would be more affected by forest amount than by bioclimatic variables. Thus, we expect small mammal diversity to increase as the forest amount expands due to the area effect, since a larger total forest amount will contain more individuals and for a given abundance distribution, this will imply more species available to colonize the forest area (Fahrig, 2013). Nonetheless, previous studies have demonstrated this relationship locally for small mammals in the Cerrado, Amazon Forest and some areas in the Atlantic Forest biome (Melo et al., 2017; Palmeirim et al., 2018; Pardini et al., 2005, 2010). Also, we hypothesized that factors that affect the diversity of small mammals in the whole Atlantic Forest will be different from ones that affect regional pools (de la Sancha et al., 2020), since the remaining Atlantic Forest fragments (ranging from 3° S to 31° N in latitude) contain diverse habitats and environmental conditions at, both on large and small scales, and this heterogeneity can lead to factors influencing small mammal assemblages at different scales (Fuentes-Montemayor et al., 2020).

Materials and methods

Small mammal assemblages

We gathered information about small mammals (rodents and marsupials) available in the most recent and complete studies (Bovendorp et al., 2017 and Figueiredo et al., 2017. We only included studies providing appropriate geographic coordinates, richness, abundance, taxonomic identification, sampling year and trapping effort (Fig. 1), and we removed any duplicated data.

We classified the dataset into three subgroups (northeast, southeast and south), creating a non-homogeneous pool due to geographic barriers (mainly rivers, in particular to Rio Doce (Leite et al., 2016)). These three main regions are widely accepted for systematic studies of small mammals by taxonomists and also identify different areas of Atlantic Forest endemism, highlighting the different and unique species composition across Atlantic Forest fragments (Dalapicolla et al., 2021) and the factors that affect small mammals in these three main regions (see Bovendorp et al., 2019).

Forest amount

For the landscape variables, we obtained land use information from MapBiomas (Souza et al., 2020) (https://mapbiomas.org/en), which covers the period from 1985 to 2017 for Brazil. Given that our small mammal assemblage data span several years of sampling (from 1986 to



Figure 1 – Geographic distribution of the 214 small mammal assemblages in the Atlantic Forest fragments in Brazil. Gray shows the historical Atlantic Forest distribution, green shows the remaining patches.

2015) and that land use has changed substantially over time, we tried to obtain the most accurate information by extracting land use data for the average years of sampling. By matching the time of both sampling and land use data we reduced potential bias due to the temporal trends in land use change. Land use data for each year of sampling was extracted using QGIS 3.18 (QGIS Development Team, 2020).

Our analysis focused on forest, pasture and agriculture land uses, which were the predominant categories of our sampling sites. We combined pastures and cropped areas into one category (farming) since they are both unnatural plantations with a production objective. We did not consider other land cover types, such as urban infrastructure, rivers, lakes, mangroves, beaches, dunes and mining areas, due to their low prevalence in our dataset. Using the geographic coordinates and sampling year provided in each study, we quantified the proportion of forest and farming amount around each sampling site within multiple spatial scales (100, 250, 500, 1000, 1500, 2000, 3000, 4000 and 5000 m radius). For example, a single sampled site can have a large amount (e.g., 90%) of forest cover at a 100 m radius because it is located in the middle of a fragment. However, this fragment can be isolated from other forest patches, so at 5000 m radius, the forest cover can be only 10%. Then, we selected the appropriate spatial scale for the subsequent analyses using the AIC value with the 'multifit' R package (Huais, 2018). For each variable, the package fits multiple models, i.e., one model for each scale. With a set of candidate models across all scales, the appropriate scale is selected according to the lowest AIC value (Huais, 2018). In our analyses, the forest amount was expressed as percentages. Since the amount of forest cover and farmed areas were strongly negatively correlated (-0.95), we only maintained forest amount. We only included assemblages with complete land cover use information for the largest radius (5 km), which we determined using Diva-Gis version 7.5 (Hijmans et al., 2012).

Bioclimatic variables

Unfortunately, bioclimatic variables were not available for each sampling site due to the lack of information in published studies. In most cases, climatic information for sampling sites simply does not exist. To standardize the metric for all sampling sites, we used the bioclimatic variables from the nearest pixel accessed from the WorldClim database (www.worldclim.org) as a proxy for local (site) conditions. To ensure that the variables used in our analyses were not highly correlated and were statistically independent, we performed a correlation test with the 19 bioclimatic variables using the 'ENMwizard' package (Heming et al., 2019). After that step, we just used seven bioclimatic variables (mean diurnal range, isothermality, maximum temperature of warmest month, annual precipitation, precipitation seasonality, precipitation of wettest quarter, and precipitation of coldest quarter).

Data analysis

We calculated the Shannon index for each small mammal assemblage using the function 'diversity' of the vegan package (Oksanen, 2017). In addition, we conducted Mantel correlation analysis using the 'mantel' function of the vegan package (Oksanen, 2017) to certify that the assemblages were not correlated spatially (t= 0.969; df= 3445; p= 0.33) and/or temporally (t= -0.338; df= 3445; p= 0.73). Note that the data assembled by us only allow a single diversity estimate to be obtained for each study site.

We utilized the iNEXT package (Hsieh et al., 2016) to estimate the completeness of assemblages through interpolation/extrapolation analysis. This approach was necessary due to variations in sampling efforts and species pools in the available literature (Hsieh et al., 2016). For each assemblage, we provided species richness as input to the package, which then extrapolated the estimates to predict the total number of species and the percentage of the dataset represented. This rarefaction/extrapolation curve-based analysis allowed us to estimate the expected number of species as sampling effort increased and the proportion of the assemblage that was sampled. The analysis involves systematically increasing the number of individuals or samples collected from the community and calculating the cumulative number of observed species at each sampling effort level. By analyzing the rarefaction/extrapolation curves, we were able to make inferences about the species diversity and richness of the community. We estimated how many additional species would likely be observed if more sampling effort was applied and assessed the level of completeness of the actual sampling. Following these steps, were included 214 assemblages were included, with sample completeness of 80 % or higher the analysis.

Because diversity indices combine species richness and evenness in a single number, frequently they do not reflect differences in species richness, so biological or statistical interpretations can be misleading (Gotelli and Colwell, 2001). Therefore, we tested the correlation between species richness and the Shannon index (r(212) = 0.837, t = 22.3, p < 0.005) to make sure that our interpretation of the Shannon diversity index was straightforward (Fig. 2).



Figure 2 – Relationship between the Shannon index estimates and the species richness of small mammals across sampled sites in northeast (NE), southeast (SE) and south (S) regions of the Atlantic Forest.

To understand the relationship between the Shannon index and various predictor variables (forest amount, mean diurnal temperature range, isothermality, max temperature of the warmest month, annual precipitation, precipitation seasonality, precipitation of wettest quarter and precipitation of coldest quarter), we built linear models (LMs) using the function 'lm', because the variance of the residuals was constant. We generated a model selection table using the 'dredge' function and limited the number of predictor variables to two per model. We ranked the models using second order AICc weights and built an average model (Anderson, 2008; Burnham and Anderson, 2002) using the 'model.avg' function, based on the weights of the models (≥ 0.001). To check for uninformative parameters, we used the 85 % confidence interval of each variable in the averaged models (Arnold, 2010). For model building comparison and averaging, we used the R package "MuMIn" (Barton, 2019).

Due to the different species pools in the Atlantic Forest fragments, we split the dataset into three subsets representing the regions (south, southeast and northeast — see above) and analyzed them separately. We used the average model for the subsets as well, under the same terms, to verify if the factors that affected the diversity of small mammals differed among all the Atlantic Forest remnants in the three regions. The landscape variable (forest amount) was used in linear and polynomial (quadratic) form (Edwards, 2002). The consideration of a quadratic effect can help identify potential threshold effects in the relationship between forest cover and the amount of forested area. Thresholds represent points at which the impact of forest cover on the variable undergoes a qualitative change. This can be crucial to understand critical levels of habitat for certain species of as small mammals (Pardini et al., 2010; Banks-Leite et al., 2014). The model was fitted using the normal distribution. We also assessed the statistical evidence of the variables (variable importance) by summing the AICc weights (W) of the model in which the explanatory variables were present (Burnham and Anderson, 2002). All analyses were performed with the R platform version 4.2.3 (R Core Team, 2023).

Results

The final dataset included 214 assemblages, with 45,195 individuals from 104 species, and the average number of individuals per assemblage was 186 (2 to 5,188 individuals; SD = 429). The most abundant species in these assemblages were *Akodon montensis* (n = 6401), *Oligoryzomys nigripes* (n = 4826), *Akodon cursor* (n = 3650), *Didelphis aurita* (n = 3582) and *Nectomys squamipes* (n = 2236).

The appropriate spatial scale of our data was 5 km radius, and all variables in the model selection analysis were performed within this size. The most informative variables were forest amount (quadratic, w = 0.58, estimate = 0.00004, p = 0.001 and linear, w = 0.41, estimate = 0.005, p = 0.003) and maximum temperature of warmest month (w = 0.42, estimate = -0.004, p = 0.004), with negative effects on diversity of small mammals, and precipitation of coldest quarter (w = 0.27, estimate = -0.001, p = 0.007) and precipitation of wettest quarter (w = 0.25, estimate = 0.001, p = 0.008) having negative and positive effects on diversity of small mammals, respectively (Tab. 1; Fig. 3). The other variables had importance of less than 0.05.

In the northeast region, none of the variables had statistical significance. In the southeast region, precipitation of wettest quarter (w = 0.42, estimate = 0.001, p = 0.012), forest amount (linear, w = 0.34, estimate = 0.005, p = 0.004; quadratic, w = 0.40, estimate=0.00004, p = 0.003) and annual precipitation (w = 0.09, estimate = 0.0005, p = 0.019) had positive effects on the diversity of small mammals (Tab. 2 and 3). On the other hand, maximum temperature of warmest month (w = 0.50, estimate = -0.006, p = 0.001), mean diurnal temperature range (w = 0.19, estimate=-0.009, p = 0.014) and isothermality (w = 0.4, estimate=-0.025, p = 0.046) had negative effects (Tab. 2 and 3).

In the south region, forest amount (linear, w=0.46, estimate=0.007, p=0.022; quadratic, w=0.54, estimate=0.0007, p=0.016) and mean diurnal temperature range (w=0.29, estimate=0.008, p=0.046) had a positive effect on the diversity of small mammals (Tab. 2 and 4).

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Table 1 – Variables, model averaged estimates (Estimate), standard errors (SE), z values (z) an p-value given by the Z-statistic (p) across the model-average linear mixed model (LM) and the importance of each variable (W) to testing the variation of the small mammal Shannon index with data from studies carried out in the Atlantic Forest. The importance value (W) was obtained by the sum of the weights of each variable in the global models. The spatial scale used was 5 km radius.

	Estimate	SE	Z	p	W
(Intercept)	1.671	0.750	2.227	0.026	
Max temperature of warmest month	-0.004	0.001	2.855	0.004*	0.42
Forest amount quadratic	0.00004	0.00001	3.265	0.001*	0.58
Precipitation of coldest quarter	-0.001	0.0002	2.695	0.007*	0.27
Forest amount	0.005	0.002	3.014	0.003*	0.41
Precipitation of wettest quarter	0.001	0.0002	2.673	0.008*	0.25
Isothermality	0.012	0.006	1.762	0.078	0.03
Mean diurnal temperature range	-0.001	0.003	0.193	0.847	0.01
Annual precipitation	-0.00001	0.0001	0.065	0.948	0.01

Significance code: *p < 0.05



Figure 3 – Relationship between Shannon index (small mammal diversity) and (A) forest amount, (B) max temperature of warmest month, (C) precipitation of coldest quarter and (D) precipitation of wettest quarter. The spatial scale used was 5 km radius.

Table 2 – Variables and importance of each variable (*W*) for each region. The importance value for small mammal diversity (Shannon index) was obtained by the sum of the weights of each variable in the global models. The spatial scale used was 5 km radius.

Variables	W	W	W
	Northeast	Southeast	South
Annual precipitation	0.13	0.09	0.04
Isothermality	0.44	0.04	0.25
Max temperature of warmest month	0.11	0.50	0.10
Mean diurnal temperature range	0.14	0.19	0.29
Precipitation of coldest quarter	0.17	0.01	0.12
Precipitation of wettest quarter	0.22	0.42	0.08
Forestry amount	0.16	0.34	0.46
Forestry amount quadratic	0.16	0.40	0.54

Discussion

As hypothesized, our findings reveal that forest amount exerted a significant influence on the small mammal diversity in the of Atlantic Forest fragments studied. Additionally, our analyses demonstrate that bioclimatic variables (temperature and precipitation), have a discernible impact on the biodiversity of small mammals in this region. This is the first study assessing diversity across the entire Atlantic Forest biome, showing the importance of large-scale assessment and forest amount

Table 3 – Variables, model averaged estimates (Estimate), standard errors (SE), z values (z) and the *p*-values given for the Z-statistic (*p*) across the model-average linear mixed model (LM) testing the variation of the Shannon index for small mammals with data from studies carried out in the Atlantic Forest (for the southeast dataset). The spatial scale used was 5 km radius.

Variable	Estimate	SE	Z	p
Intercept	2.076	1.373	1.511	0.131
Max temperature of warmest month	-0.006	0.002	3.176	0.001*
Forest amount quadratic	0.00004	0.00002	2.934	0.003*
Forest amount	0.005	0.002	2.849	0.004*
Precipitation of wettest quarter	0.001	0.0004	2.515	0.012*
Mean diurnal temperature range	-0.009	0.004	2.446	0.014*
Annual precipitation	0.0005	0.0002	2.355	0.019*
Isothermality	-0.025	0.013	1.993	0.046*
Precipitation of coldest quarter	0.0008	0.0013	0.639	0.523

Significance code: *p < 0.05

Table 4 – Variables, model averaged estimates (Estimate), standard errors (SE), z values (z) and the *p*-values given for the Z-statistic (*p*) across the model-average linear mixed model (LM) testing the variation of the Shannon index for small mammal with data from studies carried out in the Atlantic Forest (for the south dataset). The spatial scale used was 5 km radius.

	Estimate	SE	Z	р
(Intercept)	0.405	1.019	0.394	0.694
Forestry amount quadratic	0.0007	0.0003	2.407	0.016*
Forestry amount	0.007	0.003	2.288	0.022*
Mean diurnal temperature range	0.008	0.004	1.995	0.046*
Isothermality	0.028	0.016	1.737	0.082
Precipitation of coldest quarter	0.001	0.0007	1.434	0.152
Max temperature of warmest month	-0.004	0.003	1.275	0.202
Precipitation of wettest quarter	-0.0005	0.0005	0.957	0.338
Annual precipitation	0.0002	0.0003	0.073	0.942
Significance code: $*p < 0.05$				

and bioclimatic variables in shaping the diversity of small mammals, regardless of the biogeographic context.

The diversity of small mammals increases in proportion to the amount of forest cover in the landscape (5 km radius), across all levels of analysis, including per region and in all the Atlantic Forest remnants. This relationship has also been observed in previous studies of small mammals in the Cerrado and Amazon Forest biomes (Melo et al., 2017; Palmeirim et al., 2019), where amount of forest cover was associated with high species diversity (Pardini et al., 2010) based on the variety of habitat types and levels of habitat complexity (Umetsu and Pardini, 2007). It is important to note that this positive correlation is not universal, and small mammal assemblages inhabiting small fragments (Pardini et al., 2005, 2010) or an inhospitable matrices (Estavillo et al., 2013) may be negatively impacted. But the significant relation-

ships between the amount of forest cover and species diversity of small mammals in Atlantic Forest patches have also been observed in various studies in the last 20 years (Pardini et al., 2005; Püttker et al., 2011; Estavillo et al., 2013).

Our analyses indicate that bioclimatic variables, specifically temperature and precipitation, can have a significant impact on small mammal diversity. Indeed, changes in temperature and precipitation are expected to induce species range shifts and alter diversity and distribution patterns in the Atlantic Forest, since the region is projected to become warmer and drier (Brown et al., 2020; Almazroui et al., 2021). Based on this unique dataset, we observed a negative correlation between the maximum temperature of the warmest month and precipitation in the coldest quarter with small mammal diversity, while precipitation in the wettest quarter was found to have a positive relationship with small mammal diversity. Some studies investigating the relationship of temperature and precipitation with small mammal abundance and richness have reported contrasting findings (Barros-Battesti et al., 2000; Ferreguetti et al., 2021). Bioclimatic variables can indirectly influence small mammal diversity and abundance by increasing the availability of food resources (Bergallo and Magnusson, 1999; Graipel et al., 2006; Passamani and Ribeiro, 2009), leading to higher reproduction rates (Barros, 2013; Bonecker et al., 2009; Graipel et al., 2006). Such indirect impacts can help explain the complex and varied relationships between bioclimatic variables and small mammal biodiversity observed in different studies.

Upon analyzing the three regions of the Atlantic Forest, we observed that none of the variables investigated in this study were statistically significant in the northeast region. The protected areas in this region are considered to have the "worst state of conservation" compared to other regions where Atlantic Forest fragments are present (SOS Mata Atlântica and INPE, 2023). The northeast region also has the lowest number of forest fragments (Dalapicolla et al., 2021), which are typically small (<50 ha) and isolated from one another (Ribeiro et al., 2009; Vancine et al., 2024). Due to these landscape characteristics, it is likely that much of the original mammal diversity in these areas has become extinct, since there are not enough large forest patches left to support their populations (de la Sancha et al., 2020). Furthermore, our investigation of the bioclimatic variables found no effect on small mammal diversity in the northeast Atlantic Forest region. This lack of effect may be due to the low variance in precipitation and temperature in the area (Carvalho et al., 2020).

For the southeastern region, we discovered that the maximum temperature of the warmest month and precipitation of coldest quarter had a negative impact on small mammal diversity. Conversely, precipitation of wettest quarter, and quadratic and linear forest amount were positively correlated. The temperature and precipitation are closely related to the geographic and latitude conditions of regions. In this region, the summer is generally characterized by high temperatures and abundant rainfall, which enhances food availability, and consequently small mammal abundance (Corrêa et al., 2017). Warmer temperatures and precipitation in the coldest periods can affect the availability of suitable microhabitats, food resources and water sources for small mammals, potentially leading to negative impacts on their population and diversity (Bergallo and Magnusson, 1999). Despite historical disturbances caused by agriculture and urban encroachment (Joly et al., 2014), the southeast region has the largest Atlantic Forest fragments (Vancine et al., 2024), which can promote small mammal conservation and reinforce the importance of forest amount in this group (Pardini et al., 2010).

In the south region, mean diurnal temperature and the quadratic and linear forest amount has a positive relationship with small mammal diversity. The southern region has the lowest temperatures in the Atlantic Forest biome, reflecting also the geographic and latitude conditions of the region (Oliveira-Filho and Fontes, 2000; Colombo and Joly, 2010). Indeed, the mean diurnal temperature can have positive impacts on small mammal populations and diversity, not only on microhabitat, food and water resources (Bergallo and Magnusson, 1999), but also on furthermore in the individuals' activities and foraging (Kenagy, 1973; Milling et al., 2017). Moreover, the southern region contains the second and third largest Atlantic Forest fragments (Vancine et al., 2024), contributing to small mammal conservation in these areas. The positive relationship between small mammal diversity and forest amount can be attributed to the legally protected forest remnants in the region (protected areas), which have the capacity to support a high richness of non-volant small mammal species within the southern Atlantic Forest. This underscores the presence of areas characterized by high endemism among small mammal species (Dalapicolla et al., 2021).

Conclusions

This is the first study assessing diversity in the entire Atlantic Forest biome (214 small mammal assemblages), showing the importance of large-scale assessment. The results of this study also reveal the importance of forest amount in the landscape for small mammal diversity in the Atlantic Forest, regardless of the biogeographic region. Future research should focus on investigating the variation in bioclimatic variables (temperature and precipitation), climate change and the characteristics of the surrounding land cover, since these factors can also contribute to small mammal diversity. By better understanding the factors that influence this diversity, conservation efforts can be targeted more effectively to protect these important and often overlooked members of the ecosystem (Asfora and Pontes, 2009; Dalmagro and Vieira, 2005; Lima et al., 2010; Püttker et al., 2008).

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Associate Editor: O. Dondina