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Article

Influence of altitude and seasonality in the termite species richness and nests density in a hill environment of the Brazilian Caatinga

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ABSTRACT. The variation in altitude drives the richness and density of species in tropical ecosystems. The diversity and richness of termites are influenced by the variations in temperature, humidity, and soil properties according to altitude elevation. This is well known for rainy forests and little information is found for semiarid areas of Brazil. In this study, we aimed to identify species richness and encounters density of termites in a hill inserted in the Caatinga Brazilian forest. We found variation in the composition of species as a function of altitude (in a comparison of top and foot of the hill) and in periods of the wet and dry, with an increase in the season wet. The increase the diversity in this period and altitude elevations can be explained by the increases in humidity after rainfalls and maintenance of temperature enabled by the conditions in the hill's top. Our findings provide valuable information regarding termite diversity in semiarid areas as a function of elevation and contribute to other studies that are expanding our understanding of how elevation can affect these organisms.

KEYWORDS. Semiarid, ecology of termites, assemblages, dry forest.

RESUMO. Influência da altitude e sazonalidade na riqueza de espécies e densidade de ninhos de cupins em um ambiente de serra da Caatinga Brasileira. As variações na altitude modulam a riqueza e densidade de espécies em ecossistemas tropicais. A densidade e riqueza de cupins são influenciadas por variações na temperatura, umidade, e propriedades do solo de acordo com a elevação da altitude. Isso é bem conhecido para florestas úmidas, e pouca informação é encontrada para áreas semiáridas do Brasil. Neste estudo, tivemos por objetivo identificar a riqueza de espécies e densidade de encontros de cupins em uma serra localizada em floresta brasileira de Caatinga. Encontramos variação na composição de espécies em função da altitude (em comparação de topo e base da serra), e em períodos de seca e chuva, com aumento na estação chuvosa. O aumento na diversidade nesse período e nas elevações da altitude pode ser explicada pelo aumento na umidade após as chuvas, e a manutenção da temperatura propiciada pelas condições do topo da serra. Nossos dados fornecem informações importantes a respeito da diversidade de cupins no semiárido em função de elevações na altitude, e contribui com outros estudos que expandem o nosso conhecimento a respeito de como a elevação pode afetar esses organismos.

PALAVRAS-CHAVE. Semiárido, ecologia de cupins, assembleias, floresta seca.

Understanding patterns of species distribution and diversity is now one of the most important areas of ecology (Gill *et al*., 2016). It is well known that the diversity of species increases towards the Equator line (Cancello *et al*., 2014), and the index associated with the diversity includes some variables that are connected to the structure of the communities, being the species richness one of those variables (Begon & Townsend, 2020). However, when it comes to richness and variety, altitude is a key gradient to consider because of the great environmental variation over short distances in mountain habitats (Zhang *et al*., 2016). The changes in the altitude gradients domify the density and diversity of organisms such as butterflies, bees, waps, ants and termites (Perillo *et al*., 2020; Viana-Junior *et al*., 2020; Beirão *et al*., 2021). Understanding biodiversity standards across altitude elevations can help to fundamental and applied ecological aims, one of which is knowledge on insect populations.

Termites are eusocial insects that represent an expressive parcel of the biomass in fields, forest, and savanna environments and other tropical regions habitats (Dahlsjö *et al*., 2014), being found in a wide range of microhabitats, such as soil, decaying logs, litter (leaves and twigs), inactive or active nests, inside living trees or even its canopy (Vasconcellos, 2010). In the neotropical environment, termites fauna constitutes about 42% of the total termite species known, with higher diversity found in Amazon forest, Brazilian Atlantic forest, and Cerrado (Constantino, 1998). Although, in comparison to the Oriental and African regions, the diversity of termites in the Neotropics is smaller (Reis & Cancello, 2007; Tuma *et al*., 2020). Despite their great influence and abundance in the ecosystem in which they dwell, termite species richness is far lower than that of mega-diverse insect orders (Davies *et al*., 2003; Bourguignon *et al*., 2011). In contrast to other tropical invertebrates, the diversity of termites species generally declines according to altitude elevations (Palin *et al*., 2011). Besides, their abundance and biomass decrease with increasing elevations (Eggleton, 2000).

Caatinga is a little-known vegetation variety in Brazil, and its biodiversity protection is ignored (Farias *et al*., 2016). Caatinga dry forest region is one of the most deteriorated areas in the country and its degradation has been associated with the exploitation of wood for fuel and clearing of native vegetation for the usage of the area in agricultural activities (Velloso *et al*., 2002; Creão-Duarte *et al*., 2016). The impact of disturbance of caatinga domain has been studied in termites communities and their species encounters have decreased according to the disturbance gradient (Bandeira *et al*., 2003; Vasconcellos *et al*., 2010) and the understanding of termites communities in caatinga mountain areas becomes important in light that its diversity decline, which is attributed to the fragility character of that communities.

Aside from the uniqueness of semiarid mountain altitude gradients and the critical role of termites in the maintenance of the natural ecosystems, little is known about the link between altitude and the fauna of termites in these areas. It should be noted that, despite lower values, termite diversity and abundance in semiarid locations are just as important for the dynamic of biological processes as in humid forests (Bravo & Calor, 2014). In this context, the current study investigated termite diversity in a caatinga hill's area and confirmed the presence of variations in termite richness in top and foot habitats, as well as nest density and activity state.

MATERIAL AND METHODS

This study was conducted in the Bodocongó hill, located in the municipality of Caturité, Paraíba, Brazil (07°27'S/35°59'W). The local area presents annual averages temperature ranging between 25 to 27° C, annual rainfall ranging between 400 mm to 600 mm (Paraíba, 2017). Soil is classified as shallow and stony, and the climate is hot semi-arid of *Bsh* (hot arid steppe) type (Köppen, 1918; Kottek *et al*., 2006). The plant diversity in this area differs from the overall pattern found in other fragments of Caatinga plane areas and the vegetation in the base and surrounding region is characterized as open steppe savanna but closed arboreal caatinga prevails at the peak (Da Silva *et al*., 2014).

The data were collected during the dry season (between January and February of 2010) and the wet season (between June and September of 2011). We separated the elevation into two levels to compare termite richness in hills top and foot: (A1) 390 m m.a.s.l. and (A2) 525 m m.a.s.l. Termite sampling followed an adaptation of the standardized sampling fast protocol of biodiversity (Jones & Eggleton, 2000). At each elevational level, six transects of 65x2 m were established. Each transect was subdivided into blocks of 5 x 2 m spaced by 10 m. The transects were disposed in a linear arrangement of each region of the hill, with a minimum distance of 50 m between them. Transects arranged over rock outcrops were excluded.

During one hour, termites were sought in the soil to a depth up to 30 cm, in the litter, epigeous and arboreal nests (actives and inactive), twigs and fallen or fixed logs; herbaceous roots and young trees, beneath that could be removed, in reentrant of the trees stalks. Samplings collected were preserved in alcohol 70% and posteriorly identified by specialist Dr Alexandre Vasconcellos. The density of conspicuous nests was measured through ten transects of 100 m x 20 m, evenly divided between hill top and foot, totaling one hectare in each sample site. The present nests were counted and classified as either active or inactive.

The Shannon index was used to compare existing species on top and foot of each season (dry and wet). Rarefaction curves were created to observe and compare the equitability that exists in the foot and top communities. The termites encountered between transects were used to generate a NMDS (dimensions=2) from a Bray Curtis distance matrix. Following, an Analysis of Similarity (ANOSIM) was performed to examine the similarity of foot and top assemblages. The amount of active and inactive nests encountered in the foot and top of the hill were compared using Wilcoxon rank-sum test for unpaired samples. The tests of Shapiro-Wilk and Levene were used to inspect the data for significant deviation from a normal distribution and homogeneity, respectively. All the analyses were conducted using R software (R Core Team, 2021).

RESULTS

The list of termites found in the hill environment presents differences in the top and foot (Tab. I). On the foot, we found only representatives of Rhinotermitidae and Termitidae. In the top of the hill termites of both these families were found, as well as species of Kalotermitidae.

According to our results, the top of the hill had higher species richness values greater than the foot and there were increases in the termites encounters between the wet and dry seasons. Shannon index revealed differences of diversity in the elevations between periods of the observations (Tab. II). The number of encounters was higher at the top (130), whereas the number of encounters at the foot was a little more than half the number at the top (58.46%).

The rarefaction curves showed that the assemblage of termites in the hill's foot is more equitable. When comparing climatic seasons, the data suggest that the communities at the top and foot have disparities across stations, whereas the dry season has higher equability (Fig. 1). The frequency of encounters varied significantly according to elevation and season. Hill's top shows slightly more encounters (Fig. 1), although it was not very different from the seasoning influence on the number of encounters. The NMDS results show the establishment of two distinct groupings (Fig. 2). The ANOSIM revealed difference in the composition of top and foot communities (r=0.55, p=0.003).

Tab. I. The number of encounters of termite species founded in top and foot in a hill environment in dry forest, Paraíba, Northeastern Brazil.

Family/species	Foot	Top
Kalotermitidae		
Neotermes fulvescens (Silvestri, 1901)	0	1
Rugitermes sp.	0	2
Tauritermes sp.	0	4
Rhinotermitidae		
Heterotermes longiceps (Snyder, 1924)	4	12
Heterotermes sulcatus (Mathews, 1977)	11	1
Termitidae		
Amitermes amifer (Silvestri, 1901)	7	10
Anoplotermes sp. 1	23	16
Anoplotermes sp. 2	5	1
Anoplotermes sp. 3	0	1
Aparatermes sp.	0	1
Apicotermitinae sp. 1	0	2
Apicotermitinae sp. 2	0	1
Constrictotermes cyphergaster (Silvestri, 1901)	7	9
Cylindrotermes sapiranga Rocha & Cancello, 2007	0	2
Diversitermes sp.	5	2
Inquilinitermes fur (Silvestri, 1901)	0	1
Microcerotermes indistinctus (Mathews, 1977)	1	5
Microcerotermes strunckii (Sörensen, 1884)	2	2
Nasutitermes corniger (Motschulsky, 1855)	1	13
Procornitermes sp.	1	17
Aparatermes cingulatus (Burmeister, 1839)	1	2
Ruptitermes sp.	0	4
Spinitermes cf. *trispinosus*	1	0
Termes fatalis Linnaeus, 1758	7	21
Encounters	76	130

Tab. II. Values of species richness, and Shannon index between elevations in a hill environment of a dry forest, Paraíba, Brazil.

	Foot	Top
Richness	14	23
Shannon index	2.20	2.62

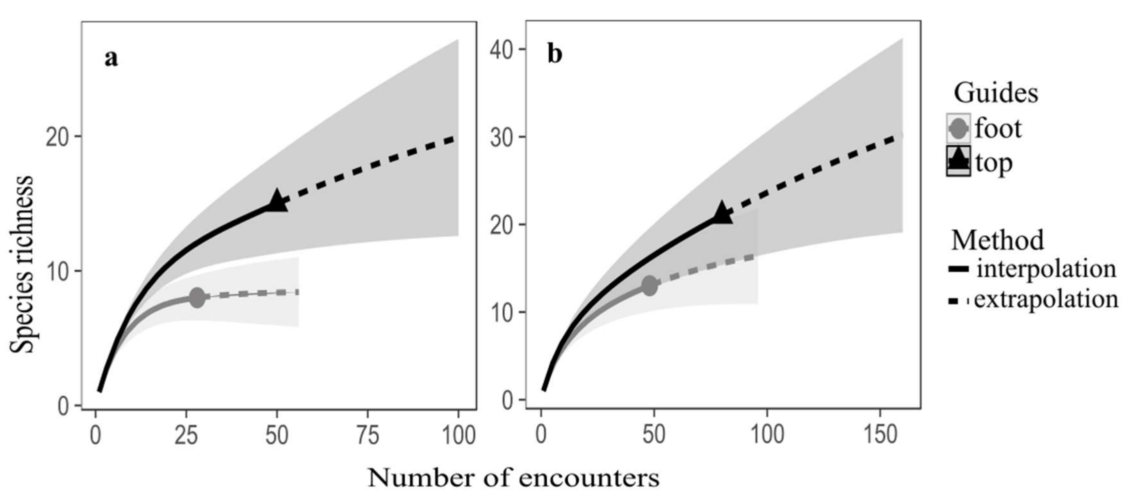

Fig. 1. Rarefaction curves of the richness of termites and number of encounters in a hill environment of a dry forest, Paraíba, Brazil. a) dry and b) wet seasons.

There was no statistical difference between the number of conspicuous nests in the top and foot of the hill (W=18, p=1) or the number of active/inactive nests (W=12, p=0.36). The average density of conspicuous nests in the hill was 36 nests/ha, with 34/ha on top and 38/ha on the foot (Fig. 3). On the top, there were arboreal nests of *Constrictotermes cyphergaster* (55 nests actives), *Microcerotermes* spp. (16), and *Nasutitermes corniger* (4). All the nest arboreal were present on the top. On the foot, *C. cyphergaster* stood out as the specie with the highest number of active nests (32), while on the top it had a lesser count of active nests (23). *Microcerotermes* sp. had the greatest abundance of nests on the top (13) and only three on the foot.

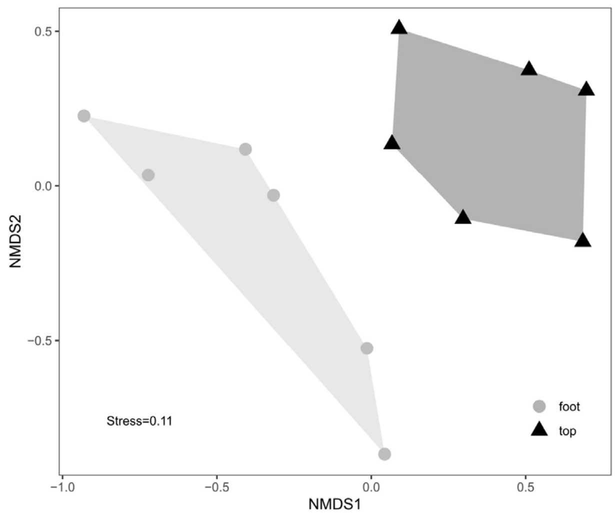

Fig. 2. NMDS of species composition in foot and top of a hill environment in a dry forest, Paraíba, Brazil (dimensions = 2).

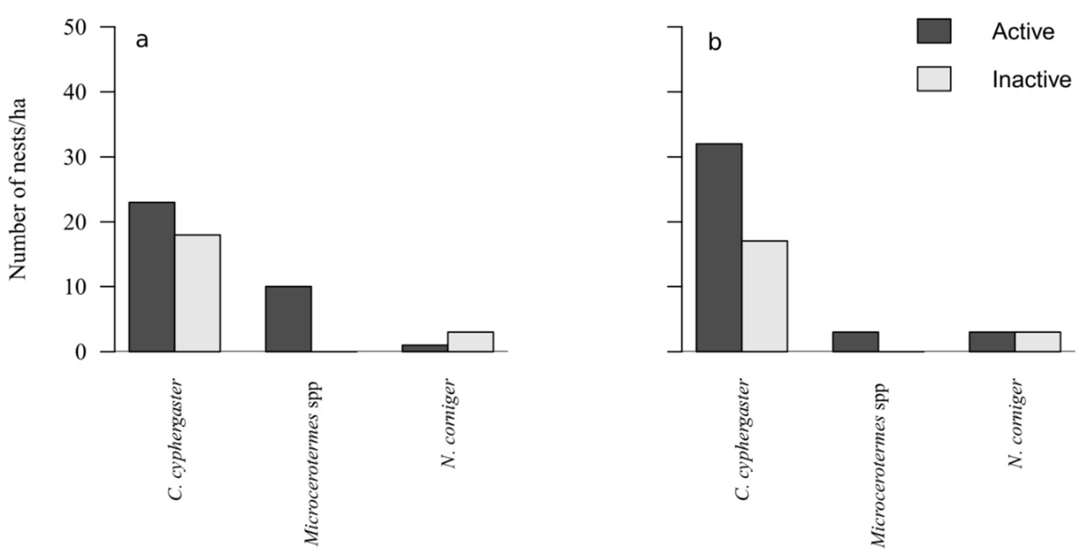

Fig. 3. Number of active and inactive nests of termites (Blatodea: Isoptera) in the top (a) and foot (b) in a hill environment of a dry forest, Paraíba, Brazil.

DISCUSSION

In comparison to other research, our data demonstrate a higher species richness of termites in a Caatinga ecosystem. The overall species richness (23) at the top of the hill was more than observed by Alves *et al*. (2011) and Couto *et al*. (2015) who linked these fluctuations to the habitat heterogeneity prevalent in similar areas of the Caatinga environment, as documented by Velloso *et al*. (2002). Given that the elevation gradients are great models to test hypotheses about the increases in species diversity as a result of changes in environmental conditions (Nunes *et al.*, 2017), the comparison between top and foot of Bodocongó hill provides information to improve databases and, even though our study used a discrete design, changes in species composition allow the idea that elevation gradients might impact termites communities in Caatinga environments.

The results of ANOSIM support the idea that the termite assemblage varies between the two sample locations. Nonetheless, the difference in species richness suggests that the compositional disparity is not related to species turnover. Shannon index places a higher weight on rare species, making it more sensitive to subtle changes within the assemblages, so this statistic test highlights disparities between the foot and top. Termites, as pointed out by Eggleton (2000), are an extreme example of the variety of groups founded based on the sample site. This variation may be seen in the habitats of the foot and top of the Bodocongó hill.

The family Termitidae is dominant in richness, corroborating prior research in northeastern Brazilian habitats (Bandeira *et al.*, 2003; Vasconcellos, 2010; Alves *et al.*, 2011). The presence of Apicotermitinae exclusively at the top deserves attention, given that they are largely described as humus feeding (Constantino, 2002; Da Cunha *et al.*, 2006), with this guild seen as a sign of preserved regions or in the regeneration stage (De Souza & Brown, 1994; Bandeira *et al.*, 2003). This finding suggests that the hill provides excellent circumstances for the dynamics of termite assemblages, emphasizing the necessity of studying and conserving mountain habitats.

The increase in termites diversity in the rainy period and altitude elevations can be explained by the increases in humidity after rainfalls and maintenance of temperature enabled by the conditions in the hill's top. We believe that excessive warmth, water scarcity, and soil compaction are all strongly connected to the termite's abundance and richness in Caatinga environments. Dambros *et al.* (2017) corroborated that the species richness and distribution of termites can be associated with environmental variables in the Amazon region and we suggest that this effect is similar in Caatinga, most likely in altitude gradients, as shown by Da Silva *et al*. (2019) for wood-feeding and soil-feeding termites in montane forests. Vasconcellos *et al*. (2010) and Bravo & Calor (2014) showed similar results for other semiarid environments, associating the modifications in the termite assemblages to the altitude variations.

The density of nests did not show significant differences between any of the parameters studied, which we believe can be attributed to the lower density found, highlighting *C. cyphergaster* with a higher nest density than other constructor species. This pattern is expected for areas of caatinga due to the high dominance of this specie in the Neotropical dry forests (Bandeira & Vasconcellos, 1999; Melo & Bandeira, 2004).

In conclusion, our findings provide valuable information regarding termite diversity in semiarid areas as a function of elevation and contribute to other studies that are expanding our understanding of how elevation can affect these organisms. The increased richness of the Bodocongó hill's top grounds the need to preserve mountain environments and areas with vegetation preserved in higher altitudes, so that these areas can function as islands of specific conditions that can shelter species that require less environmental pressures to survive.

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