Floresta e Ambiente 2019; 26(3): e20180416
https://doi.org/10.1590/2179-8087.041618
ISSN 2179-8087 (online)

Original Article

Conservation of Nature

Population Fluctuation of Termitofauna (Blattodea: Isoptera) in Six Forest Fragments of the Mata Atlântica

Cleber Vinicius Vitorio[1], Acacio Geraldo de Carvalho[1], Karina Arruda Silva[2], Olavo Araujo Tomas Junior[3], Carlos Domingos da Silva[1], Edson Luiz Carvalho Lima[4], Fábio José Esper[3]

[1]Universidade Federal Rural do Rio de Janeiro – UFRRJ, Rio de Janeiro/RJ, Brasil
[2]Faculdade de Americana – FAM, Americana/SP, Brasil
[3]Universidade Estácio de Sá – ESTÁCIO, São Paulo/SP, Brasil
[4]Helium Corporation Engenharia, Seropédica/RJ, Brasil

ABSTRACT

The objective of this work was to evaluate the forest restoration of the basin of Guapiaçu river in Cachoeiras de Macacu, Rio de Janeiro state, using the families of Termites as tools for environmental assessment. We analyzed the population fluctuation and feeding guilds of the families of Termites: Kalotermitidae, Rhinotermitidae and Termitidae. Six sampling points were arranged along Guapiaçu river, five points being inferred in reforestation carried out in the basin and a point in a regeneration control area. Quantitative and qualitative surveys followed standard protocols and the samples were obtained directly, without baits. Thirty species within 25 genera were identified and the family Termitidae was the most frequent. The termite fauna of the control point P06 was the richest. From the frequencies of occurrence of the species related to their trophic guild, an ecological evaluation table of the environments was proposed. The P05 area, rich in plant species, presented the greatest similarity to the natural regeneration area P06. The majority of the species was classified as xilophagous.

Keywords: forest entomology, conservation of natural areas, ecology of forest ecosystems.

1. INTRODUCTION AND GOAL

The termites belong to the order Blattodea and have a cosmopolitan distribution, occurring both in places of temperate and tropical areas, with a large diversity of species in the neotropical region, as happens with several orders of insects (Cabrera Dávilla & Cancello, 2009; Reis et al., 2009; Krishna et al., 2013a). There are more than 3,300 species described, distributed in nine families: Mastotermitidae, Archotermopsidae, Hodotermitidae, Stolotermitidae, Stylotermitidae, Kalotermitidae, Rhinotermitidae, Serritermitidae and Termitidae (Rocha et al., 2012; Krishna et al., 2013b). In Brazil, there are approximately 300 species contained in four families: Kalotermitidae, Rhinotermitidae, Serritermitidae and Termitidae. This diversity is certainly underestimated since the data for many regions of Brazil, mainly the North and Northeast is scarce. Most of the data come from the Atlantic Forest and the Cerrado Biomes, both acknowledge as *hot spots* (Constantino, 1998, 2002).

The insects can be used to determinate the anthropic interference in various ecosystems in bio-monitoring. Therefore, there has been an interest to obtain information about their dynamics, thus gaining insight about the ecosystem quality (Cristo et al., 2018).

The termitofauna is globally recognized for its ecosystem engineering services. However the termite fauna of the neotropical region has been poorly studied, when compared to the termites in the regions of the old world, as the Eastern and African regions. There are few studies in the literature about the termites of the Atlantic Forest. Even smaller is the amount of studies addressing auto-ecology and sin-ecology of these species. Thus, Bandeira et al. (1998) mapped the termitofauna in forest fragments of the city João Pessoa, Paraíba state. They found that 65% to 88% of the identified species were not known by the scientific community, which enriches the literature about the biome. Brandão (1998) mapped the termitofauna at the Reserva Florestal de Linhares, Espírito Santo state. The author verified a decrease in richness with the change of floristic and pedological structure in the areas of study. Termites are ecologically relevant to tropical ecosystems, especially when considered the changes they cause to the environment, in particular the forest ecosystem, from landscape changes to changes in physical and chemical properties of the soil, effects in the process of decomposition, nutrient cycling, among others (Krishna et al., 2013b).

Several authors have made various attempts to classify the species of termites in trophic guilds according to their use of resources (Rocha et al., 2012; Constantino, 1992; Eggleton et al., 1995). As the biology of many species of termites is still unknown, there are difficulties to classify them in different guilds. Eggleton et al. (1995) compared diversity and richness of termites between primary forest areas and areas where there was a mischaracterization of the original vegetation with sampling techniques and different results. The authors observed a dramatic difference between an area of primary forest and pasture. As expected, the fauna of the primary forest was the most diverse and complex.

In the state of Rio de Janeiro, forest restoration actions are carried out in the basin of Guapiaçu river in Cachoeiras de Macacu (Azevedo et al., 2018). The headwaters of the river is located in a preserved area at 1,200 m altitude in the midst of the hilly slopes of the Serra do Mar (Azevedo et al., 2018). The basin has a territorial extension of 573.54 km^2, having as main soil covered with Dense Ombrophilous Forest (Azevedo et al., 2018), very diverse, forming three strata: emerging with canopy trees, reaching about 45 m of height, on the main canopy of 5 to 10 m and smaller trees their shadows (Azevedo et al., 2018). Ecosystems such as altitude fields, swamps, lakes and rivers were also observed in the basin. The main river of the basin, the river Guapiaçu, used to be navigable. According to Azevedo et al. (2018), the rivers of the region were important logistical pathways of agricultural products and raw materials derived from forest extraction in the 18th century. Currently, a large part of restoration actions of the basin follows the guidelines of the Atlantic Forest Restoration Pact (Calmon et al., 2009). One example of this is the actions of forest restoration in the Ecological Reserve of Guapiaçu (REGUA).

Therefore the objective of this work was to use the fluctuation of the sampled species in the families of termites Kalotermitidae, Termitidae and Rhinotermeitidae during summer and winter of 2013 to 2015, as a way of assessing the ecological quality of reforestation in that area.

2. MATERIAL AND METHODS

2.1. Characterization of the study area

The sample space is located within the geographical limits of the 7380 ha of the Ecological Reserve of Guapiaçu - REGUA, between the coordinates UTM 23K 728783 7515700 m N and M L. located in the periurban area of Guapiaçu, district of the municipality of Cachoeiras de Macacu, Rio de Janeiro state. It encompasses part of the basin of the river Guapiaçu and block of forest remnants of the Serra do Mar. According to Köppen, the climate of the region is tropical with a rainy summer and a dry winter, classified as type AF. The work developed by Azevedo et al. (2018) on the same reservation determined the average annual temperature of 22.4 °C, with maximum in the months of January and February and minimum in June. The average annual rainfall is 2095 mm. December and January are the wettest months and June and July the driest ones. During this study, the average temperature was 23.1 °C with an average annual rainfall of 1307 mm. July was the driest month with 32 mm. The wettest month was December, with an average of 208 mm.

Six sampling points were allocated in the basin of the River Guapiaçu (Figure 1). P01 was the closest to the area of pastures and agricultural zones; reforestation has been happening in this area for approximately six years. P02 had great density of zoochoric dispersal species, with a focus on the attraction of ornithon and chiropteran fauna; the reforestation had been carried out in this area for eight years. P03 had the most recent reforestation area, that is, five years, secondary species and pioneers were found in this area. P04 is the area that has the highest density of pioneer species; in this area the deployment of fast-growing species as *schinus terebinthifolia* Raddi, *Casearia sylvestris* Sw. and *Cecropia glaziovii* Snethl was maximized; reforestation has been happening in this area for six years. P05 is the area in which it the methodological framework of the Atlantic Forest Restoration Pact (Calmon et al., 2009) was applied; it is an area with a high density of non-pioneer and climax species arranged in rows of quincunx, reforestation has been happening there for seven years.

The control area is the P06, composed by those whose ecological characteristics are closer to the original, not affected by anthropic pressure. Additionally, that is the area with the most difficult access and the highest hipsometry.

All sampling areas have a history of being pasture and livestock for dozens of years. It is noteworthy that in P05, the perennation of a large body of water with lotic characteristics has been occurring, probably due to the reforestation.

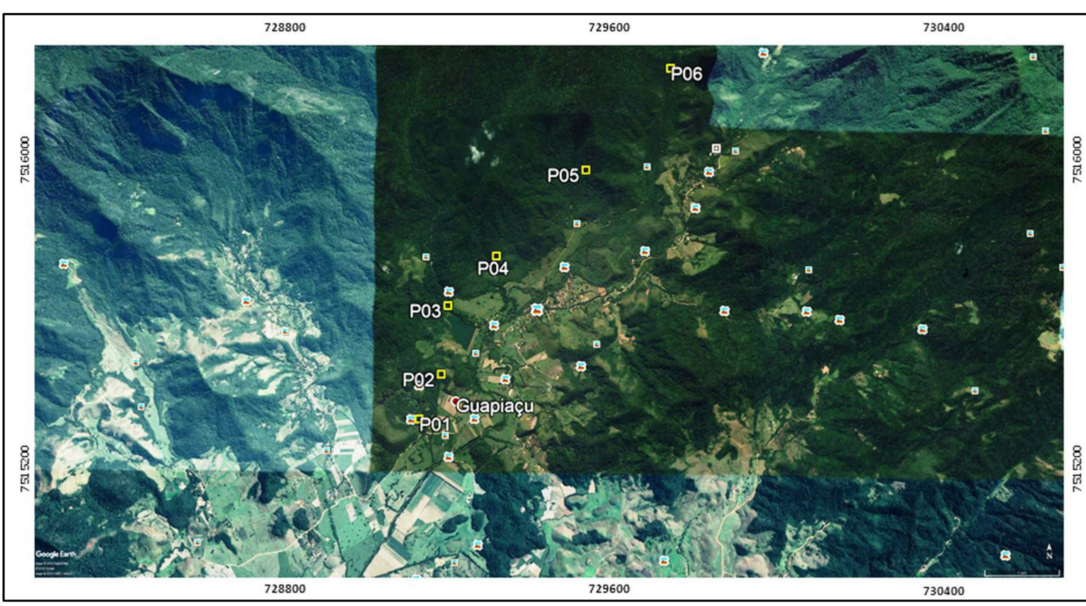

Figure 1. Sampling points in the Guapiaçu River basin. P01 = area P01; P02 = area P02; P03 = area P03; P04 = area P04; P05 = area P05; P06 = area P06.

3. SAMPLE DESIGN AND ANALYSIS

The protocol used to survey the richness of termite species was an adaptation of the sampling per quincunx. The quantitative samplings were marked in six transects, one at each sample point, at least 100 m apart from each other; each sub-parcel in five plots of 5 × 2 m, arranged on the left and the right, intermittently and with spacing of 10 m between them, for a total of 30 plots per locality. A distance of 250 m was kept from the edge of the forest to avoid the "edge effects". The termites were searched in the soil, litter, under or inside of the fallen trunks, in dead trunks, under the bark of the trees up to a height of 1.5 m, under rocks, in galleries, on the ground through holes of 15 cm and in the roots of grasses or shrubs, therefore virtually in all micro-habitats where they could be found. The team took notes in codes for subsequent classification of species in trophic groups. As temporal scale pattern and sample effort, each plot was prospected during 1 hour/collector.

For the 3 years of collection, two annual collections were performed: one for the dry season of the year (winter) and another for the wet season of the year (summer). Always between 9:00 and 17:00. The total sampled area was 10,000 m^2, for a sampling effort of 480 h per campaign. The termites collected were identified to the lowest taxonomic level possible and preserved in alcohol 70%.

The guild food of termites was analyzed by direct observation in the field, in addition to the data from the literature. The classification of the Termites in trophic groups was made according to the work of Eggleton et al. (1995): humivores or geofagos (termites that feed on organic particles of soil); intermediaries, known as "soil/wood interface-feeders" (termites that feed the soil/wood interface, collected with the aid of tweezers, predominantly in the soil immediately beneath the fallen trunk or colonized them, or even inside of trunks in high stage of decomposition, where the soil is mixed with wood very degraded); Wood-eaters (termites that feed on dead wood); and the reapers or litter eaters (termites that cut sheets or feed on small pieces of wood and/or other items of litter). The termites collected were identified to the lowest taxonomic level possible and preserved in alcohol 70%.

The bibliographical references of the works of descriptions of species mentioned here are in Constantino (1998). All the collected material was deposited in the zoological collection of the Laboratory of Environmental Mapping of UFRRJ (LAMAGEDENASA).

We plotted curves of accumulation of species for the six collection sites and compared them to estimate the accumulated abundance of species per sample location and season in which the collection occurred. We analyzed the composition of species through multivariate models to facilitate and enable the use of variables related to bioindicator species.

In regard to the number of specimens collected per campaign, because of the intrinsic characteristics of the group studied, we can hardly estimate it since the statistics will be done by sampling effort, and not by the number obtained. The number of sampled insects varied and it was unlikely to be estimated for a site without a prior collection that informing the densities of the ecological community. We could have an estimate after the first year, but prior to it it would be merely a guess. The sampling efforts in Ecological Entomology work with probabilistic comparisons of densities and frequencies, being the *n* sampled unlikely to be gauged to places never before sampled.

We analyzed the Ecological parameter Relative Frequency (RF) adapting it to the average number of seasons of collection, which is the percentage of the occurrence of the taxon i by the sum of occurrences for all taxa of the component analyzed, where FO = (Oci/Σ x 100 OC). For the seasons of collection, the results found for the parameter frequency were essential for the creation of a table of evaluation of ecological quality, i.e., correlating the frequency of taxa with its auto-ecology.

Biological indexes should be sensitive to a range of biological impacts, not just narrow indicators, since the biological attributes chosen as measures must be capable of discriminating the impacts caused by man of variations from those of natural origin (temperature, speed of current) (Cristo et al., 2018). Therefore, the results were analyzed in a two-dimensional fashion, over time for each sampling point, and in a general way, with the aim of trying to discriminate against potential impacts on termite fauna. In this study, the communities were described according to the following indexes:

Shannon index (H’): The system of transects with subdivisions allows an indirect measure of abundance through the number of encounters (frequency) in which the species was recorded in the plots (Brandão, 1998). The presence of species in a plot was defined as a meeting, and the total number of encounters per species treated as the measure of abundance. Thus, it was possible to calculate the diversity from the Shannon-Wiener index (logarithm in base 2) by H’ = Σ pi * Ln (pi), where pi corresponds to the relative abundance of species i (or ratio between the abundance of species i and all individuals in the sample), and Ln is the natural logarithm.

Pielou Evenness Index (J’): It is derived from the diversity of Shännon index, which represents the uniformity of the distribution of individuals among the existing species apud. Its value has a range of 0 (minimum uniformity) to 1 (maximum uniformity). It is calculated by J’=H’/ ln (S), where N corresponds to the richness of the sample and H’ to the Shannon index of the same sample.

The multivariate analyses aim to reduce a large number of variables to a few dimensions with minimal loss of information, allowing the detection of main patterns of similarity and association between the sample units. With this purpose, we employed indirect ordination through the non-metric multidimensional scaling (MDS). The MDS is a sorting method that employs an iterative optimization algorithm to graphically represent (in one to three dimensions) the relations of similarity between the sample units. It differs from all other methods eigen (PCA, PCOA, CCA, etc.) by not assuming linear relationships between the variables and by better preservation of the relations of distances between the sampling units, often lost when reduced to orthogonal axes of greatest variation.

Stress is an index resulting from the analysis of MDS. It represents the degree of adjustment of graphical distances between points to ecological distances between sample units. A stress ≤ 0.1 corresponds to a good ordination.

In this study the chart MDS was elaborated from the bray-curtis similarity matrix, which in turn was derived based on data from seasonal abundance and frequency of each taxon raised by sampling unit. The Bray-Curtis index varies from 0 to 1, with lower values indicating more similar samples. This standardization in the interval between one and zero facilitates the interpretation and comparison. For the preparation of analyzes, it was used the statistical software Past and the multiplatform spreadsheet open source software Calc, distributed for free with the suites OpenOffice.org and NeoOffice.

4. RESULTS AND DISCUSSION

The protocol proposed with sampling per quincunx, adapted for this study, proved to be adequate for the study of thermite biodiversity. The results are similar to those of Bandeira et al. (1998), where a total of 43 species were collected in an area of 0.4 ha in the Buraquinho forest. In the same area, using the protocol (0.03 ha), which corresponds to only 7.5% of the sampled area, 38 species were found in the rainy season and 36 species in the dry season, corresponding to 88.3% and 83.7% of the total species found by Bandeira et al. (1998).

In the dry season of 2013 there were found 411 occurrences of termites distributed in 30 species. For the wet season of the same year the record was of 420 occurrences also distributed in 30 species (Table 1).

For the dry season of 2014 there was an increase of 50 occurrences in relation to the year 2013, whence the peak record was of 461 occurrences. However there were 28 species, i.e., two less than the previous year. As for the wet season of 2014, the record was of 467 occurrences distributed in 30 species.

For the dry season of 2015 the record was of 478 occurrences distributed in 29 species. For the wet season of 2015 the record was of 565 occurrences distributed in 30 species. This had the largest number of occurrences compared to the previous years in this study.

However, the fluctuation in the number of species was 28 to 30 species, with a reduction of species for the dry season. The taxa that presented frequency of occurrence equal to 0 in some dry season of collection were: *Atlantitermes* sp. and *Crepititermes verruculosus* that are humivore, and *Convexitermes manni*, which is considered a reaper.

In areas P01, P02 and P03 there was a high frequency of *Coptotermes gestroi*, an exotic species and xylophage common and of great economic importance in the urban and peri-urban regions, where it is one of the most frequent urban plagues (Bandeira et al., 2003).

Table 1. Frequency of occurrence (FO %) of the Taxa of termites to all areas and seasons.

Taxa	2013		2014		2015		Guild food
	Dry season (%)	Wet season (%)	Dry season (%)	Wet season (%)	Dry season (%)	Wet season (%)	
KALOTERMITIDAE							
Cryptotermes brevis (Walker, 1853)	4.08	4.26	4.17	3.85	3.68	4.23	Wood-eater
Coptotermes gestroi (Wasmann, 1896)	4.08	4.26	4.17	3.85	3.68	4.23	Wood-eater
Calcaritermes rioensis (Krishna, 1962)	2.72	3.55	4.17	3.21	4.41	3.52	Wood-eater
Eucryptotermes sp.	3.40	3.55	2.78	3.21	3.68	4.23	Wood-eater
Rugitermes Rugosus (Hagen, 1858)	3.40	3.55	4.17	3.21	4.41	3.52	Wood-eater
RHINOTERMITIDAE							
Heterotermes longiceps (Snyder, 1924)	2.72	2.84	3.47	3.85	4.41	4.23	Wood-eater
Dolichorhinotermes sp.	2.04	2.13	2.78	1.92	4.41	2.82	Wood-eater
Heterotermes sp.	3.40	3.55	3.47	2.56	2.94	3.52	Wood-eater
Rhinotermes sp.	3.40	4.26	3.47	3.85	3.68	4.23	Wood-eater
TERMITIDAE							
Apicotermitinae							
Anoplotermes sp. 1	2.04	2.13	2.78	3.21	2.21	2.11	Humivore
Anoplotermes sp. 2	3.40	2.13	3.47	1.92	2.21	3.52	Humivore
Tetimatermes sp.	3.40	2.84	2.78	1.92	2.94	1.41	Humivore
Nasutitermitinae							
Angularitermes pinocchio (Cancello et al., 1996)	4.08	3.55	4.17	3.85	2.94	2.82	Humivore
Agnathotermes sp.	4.08	4.26	3.47	3.85	2.21	2.82	Humivore
Araujotermes sp.	3.40	4.26	3.47	3.85	3.68	2.82	Humivore
Atlantitermes sp.	0.68	2.13	0.00	3.21	1.47	4.23	Humivore
Armitermes euamignathus (Silvestri, 1901)	4.08	3.55	4.17	3.85	3.68	4.23	Wood-eater
Convexitermes manni (Emerson, 1925)	1.36	2.13	0.00	3.21	0.74	2.11	Intermediary
Embiratermes neotenicus (Holmgren, 1906)	2.04	2.13	2.08	3.85	2.21	3.52	Intermediary
Labiotermes labrali (Holmgren, 1906)	4.08	3.55	4.17	3.85	4.41	2.11	Humivore
Nasutitermes ephratae (Holmgren, 1910)	4.08	3.55	4.17	2.56	2.94	2.11	Wood-eater
Nasutitermes callimorphus (Mathews, 1997)	4.08	4.26	4.17	3.21	4.41	3.52	Wood-eater
Nasutitermes corniger (Motschulsky, 1855)	4.08	4.26	4.17	3.85	4.41	2.82	Wood-eater
Nasutitermes macrocephalus (Silvestri, 1903)	4.08	4.26	3.47	3.85	3.68	3.52	Wood-eater
Nasutitermes minor (Holmgren, 1906)	3.40	4.26	3.47	3.85	4.41	4.23	Wood-eater
Subulitermes sp.	4.08	2.84	3.47	3.21	3.68	4.23	Humivore
Velocitermes sp.	4.08	3.55	4.17	3.21	3.68	2.82	Reapers or litter eaters
Termitinae							
Amitermes amifer (Silvestri, 1901)	4.08	4.26	4.17	3.85	4.41	4.23	Wood-eater
Microcerotermes exiguus (Hagen, 1858)	2.72	3.55	2.78	3.85	4.41	4.23	Humivore
Crepititermes verruculosus (Emerson, 1925)	3.40	0.71	2.78	2.56	0.00	2.11	Humivore

According to Constantino (2002), *Coptotermes gestroi* is one of the most important pest species in South America. Like almost any pest species, it presents certain plasticity including nests, which may be polygalic, increasing the foraging area of each colony. Bandeira et al. (2003) report that this species was not recorded in primary forest and was the most frequent in areas where there was some type of disturbance. The P05 area presented very low occurrence of this species and the P06 area had no occurrence.

The behavior of the Shannon index (H') was of consistent increase for the humid campaigns in relation to the dry campaigns. This fact is due to the higher density of humivore and reaper termites during the wet season. The Pielou Evenness (J'), with the exception of the dry season of 2013, presented a homogeneous distribution of species for all areas. The Pielou Evenness of the dry season of 2013 may have a relation with a possible dominance of wood-eating termites recorded in this year's seasonal period (Figure 2).

Regarding the behavior of the curve of the manifold (Figure 3), the only sample area in which there was no stabilization of accumulated richness of species was the control area P06. The other 5 areas presented curve stabilization, indicating that the sampling were sufficient for these sample areas. The areas P01 and P02 showed a level of 28 species and the areas P03, P04 and P05 showed a level of 27 species.

The areas P04 and P03 presented a higher level of wood consumption. However, P05 presents more similar values to the control area P06. Incidentally, that was the only sample area in which the percentage of humivores was greater than 40%, similar to the control area P06, thus highlighting its successful reforestation process attributed to the methodological framework the Atlantic Forest Restoration Pact (Table 2).

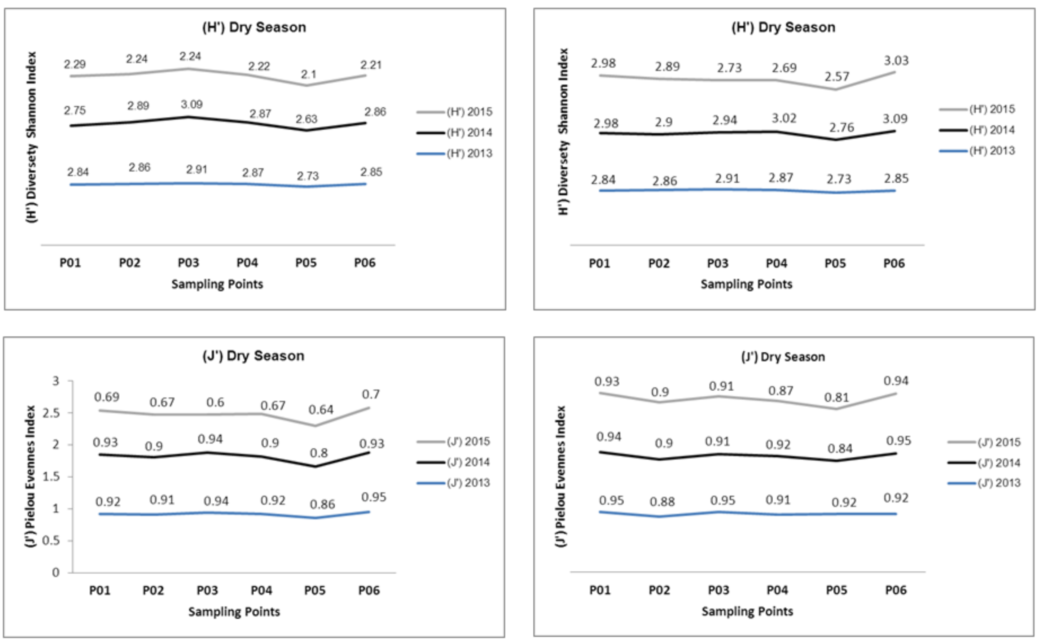

Figure 2. Shannon index (H') and Pielou evenness (J') for all sampling areas and seasons.

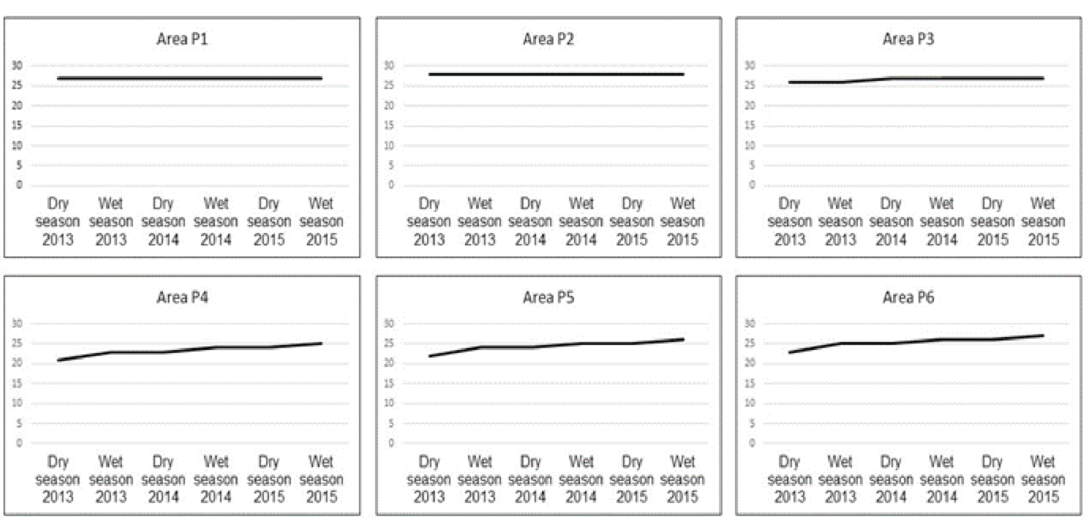

Figure 3. Accumulated abundance of species for the six sampling areas and collection stations.

Table 2. Frequency of occurrence (FO%) as the guild food by area of study.

Guild food to dry Campaign 2013						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	**61.54**	57.69	**66.67**	54.17	54.17	42.86
Humivore	26.92	34.62	29.17	37.50	**41.67**	**47.62**
Reapers or litter eaters	3.85	3.85	4.17	4.17	4.17	4.76
Intermediary	7.69	3.85	0.00	4.17	0.00	4.76
Guild food for wet Campaign 2013						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	58.33	64.00	**80.00**	**66.67**	58.33	44.00
Humivore	33.33	24.00	20.00	23.81	37.50	**44.00**
Reapers or litter eaters	4.17	4.00	0.00	4.76	4.17	4.00
Intermediary	4.17	8.00	0.00	4.76	0.00	8.00
Guild food to dry Campaign 2014						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	**75.00**	53.85	59.26	**66.67**	55.56	50.00
Humivore	15.00	38.46	37.04	25.00	37.04	**45.45**
Reapers or litter eaters	5.00	3.85	3.70	4.17	3.70	4.55
Intermediary	5.00	3.85	0.00	4.17	3.70	0.00
Guild food for wet Campaign 2014						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	58.33	**64.00**	**60.00**	51.85	48.15	46.15
Humivore	29.17	24.00	36.00	37.04	**40.74**	**42.31**
Reapers or litter eaters	4.17	4.00	0.00	3.70	3.70	3.85
Intermediary	8.33	8.00	4.00	7.41	7.41	7.69
Guild food to dry Campaign 2015						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	**72.73**	**60.87**	**68.18**	**69.57**	58.33	55.00
Humivore	22.73	26.09	27.27	21.74	33.33	**45.00**
Reapers or litter eaters	4.55	4.35	4.55	4.35	4.17	0.00
Intermediary	0.00	8.70	0.00	4.35	4.17	0.00
Guild food for wet Campaign 2015						
	P01 (%)	**P02 (%)**	**P03 (%)**	**P04 (%)**	**P05 (%)**	**P06 (%)**
Wood-eater	59.09	**65.22**	**76.19**	56.52	50.00	51.85
Humivore	31.82	21.74	23.81	34.78	38.46	**40.74**
Reapers or litter eaters	4.55	4.35	0.00	4.35	3.85	0.00
Intermediary	4.55	8.70	0.00	4.35	7.69	7.41

P01 = area P01; P02 = area P02; P03 = area P03; P04 = area P04; P05 = area P05; P06 = area P06. In bold are the areas with high gradient of wood-eaters (> 60%) and with high gradients of humivores (> 40%).

Regarding the abundance and frequency of species, the similarity synthesized by the multivariate method of non-metric multidimensional scaling (Figure 4) indicated that the sample area that has greater similarity with the control area P06 was the P05. The areas P01 and P03, which showed the highest frequency of wood-eating termites, also demonstrated some similarity. Multivariate analysis opposed the frequency of occurrence for the guilds food.

Areas of clearings and edges are determinant to the population growth of wood-eater and reaper termites (Reis et al., 2009). Moreover, larger amounts of litter and stabilization of the organic matter favors the humivores and intermediaries (Rocha et al., 2012). Thus, it was understood that the area P05, which has a higher density of non-pioneer forest species and planted in rows of quincunx, creates environments more similar to natural areas with high levels of preservation, providing a greater similarity with the control area P06.

The Atlantic Forest is a hot spot of biodiversity, many are the actions of forest restoration carried

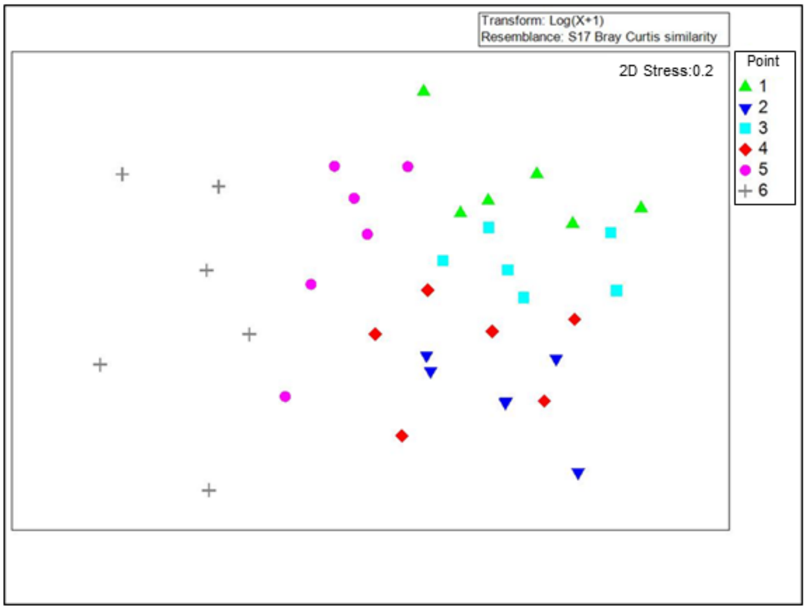

Figure 4. Graph of non-metric multidimensional analysis (MDS) drawn from the bray-curtis similarity matrix on the basis of FO % and the abundance of species of termites. 1 = area P01; 2 = area P02; 3 = area P03; 4 = area P04; 5 = area P05; 6 = area P06.

out in their ecosystems, therefore a biome of priority to conservation and environmental preservation. The recovery of degraded areas becomes relevant to have the proper provision of environmental services. However the methodologies deployed in this restoration must be reassessed, since this study indicated that the large deployment of pioneer species might compromise the ecological health of their ecosystems.

5. CONCLUSIONS

Compared to other surveys following protocols similar to the use of quincunx, this work has proved to be relevant to the use of termites as environmental assessment tools.

New species can be raised. Further studies are still needed, such as the structure of the jaws and the digestive tract of workers of many species, the contents of the tube digestive system of the workers, and especially careful and direct observations in the field, so that the diet of individuals of many species can be confirmed.

For the seasons of collection, the results found for the parameter frequency were essential for the creation of a table of evaluation of ecological quality. It can be used in forest restoration activities in the Mata Atlântica biome, which is totally unheard of and may still be a reference for other biomes.

The presence of the exotic specie *Coptotermes gestroi* species in high-density areas of pioneer species demonstrates how important the selection of climatic species in reforestation is. It deserves to be warned and pointed out that this species of termite is found in the Atlantic Forest.

ACKNOWLEDGEMENTS

I thank the faculty of the Postgraduate Program in Environmental and Forest Sciences at UFRRJ for their teaching especially to Dr. Acacio Geraldo de Carvalho my advisor, I thank the egregious council of PPGCAF of which I was a part, Thank you for all your support during the synthesis of my academic master's degree and thank the funding of this academic research by CNPQ.

SUBMISSION STATUS

Received: 22 oct., 2018
Accepted: 4 feb., 2019

CORRESPONDENCE TO

Cleber Vinicius Vitorio
Universidade Federal Rural do Rio de Janeiro – UFRRJ, Rodovia BR 465, Km 07, s/n, Zona Rural, CEP 23890-000, Seropédica, RJ, Brasil
e-mail: clebervitorio88@gmail.com, klebervinicius88@gmail.com

FINANCIAL SUPPORT

Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (Grant/Award Number: 04870001).

REFERENCES

Azevedo AD, Camara R, Francelino MR, Pereira MGG, Leles PSS. Estoque de carbono em áreas de restauração florestal da Mata Atlântica. *Floresta* 2018; 48(2): 183. http://dx.doi.org/10.5380/rf.v48i2.54447.

Bandeira AG, Pereira JCD, Miranda YCS, Medeiros LGS. Composição da fauna de térmitas (Insecta: Isoptera) em áreas de Mata Atlântica em João Pessoa, Paraíba, Brasil. *Revista Nordestina de Biologia* 1998; 12(1-2): 9-17.

Bandeira AG, Vasconcellos A, Silva MP, Constantino R. Effects of habitat disturbance on the termite fauna in a highland humid forest in the caatinga domain, Brazil. *Sociobiology* 2003; 42: 117-127.

Brandão D. Patterns of the termite (Isoptera) diversity in the Reserva Florestal de Linhares, State of Espírito Santo, Brazil. *Revista Brasileira de Entomologia* 1998; 41(2-4): 151-153.

Cabrera Dávilla G, Cancello EM. Termitas (Insecta: Isoptera) de Topes de Collantes, provincia de Sancti Spíritus, Cuba central. *Boletin de la SEA* 2009; 44: 567-568.

Calmon M, Nave AG, Lino CF, Pinto LP. Pacto pela restauração da Mata Atlântica: um movimento pela restauração da floresta. In: Fujihara MA, Cavalcanti R, Guimarães A, Garlipp R, editors. *O valor das florestas*. São Paulo: Terra das Artes; 2009.

Constantino R. Abundance and diversity of Termite (Insecta: Isoptera) in two sites of primary rain forest in Brazilian Amazonia. *Biotropica* 1992; 24(3): 420-430. http://dx.doi.org/10.2307/2388613.

Constantino R. Catalog f the living termites of the New World (Insect: isoptera). *Arquivos de Zoologia* 1998; 35(2): 135-260. http://dx.doi.org/10.11606/issn.2176-7793.v35i2p135-230.

Constantino R. The pest termites of South America: taxonomy, distribution and status. *Journal of Applied Entomology* 2002; 126(7-8): 355-365. http://dx.doi.org/10.1046/j.1439-0418.2002.00670.x.

Cristo SC, Vitorino MD, Carvalho AG. Leaf-litter entomofauna as a parameter to evaluate areas under ecological restoration. *Revista Floresta e Ambiente* 2018; 26: 1-11.

Eggleton P, Bignell DE, Sands WA, Waite B, Wood TG, Lawton JH. The species richness (Isoptera) under differing levels of forest disturbance in the Mbalmayo Forest Reserve, southern Camerron. *Journal of Tropical Ecology* 1995; 11(1): 85-98. http://dx.doi.org/10.1017/S0266467400008439.

Krishna K, Grimaldi DA, Krishna V, Engel MS. Treatise on the Isoptera of the world: 1. Introduction. *Bulletin of the American Museum of Natural History* 2013a; 377(1): 1-200. http://dx.doi.org/10.1206/377.1.

Krishna K, Grimaldi DA, Krishna V, Engel MS. Treatise on the Isoptera of the world: 5 Termitidae (part two). *Bulletin of the American Museum of Natural History* 2013b; 377(5): 1499-1987. http://dx.doi.org/10.1206/377.5.

Reis YT, Delabie J, Cancello EM. Térmites (Insecta: Isoptera) da Reserva Zoobotânica do Centro de Pesquisa do Cacau, Ilhéus, Bahia, Brasil. *Agrotrópica* 2009; 21: 103-108.

Rocha M, Cancello EM, Carrijo TF. Neotropical termites: revision of Armitermes Wasmann (Isoptera, Termitidae, Syntermitinae) and phylogeny of the Syntermitinae. *Systematic Entomology (Print)* 2012; 37(4): 793-827. http://dx.doi.org/10.1111/j.1365-3113.2012.00645.x.