Sociobiology 60(2): 190-197 (2013)   DOI: 10.13102/sociobiology.v60i2.190-197

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - TERMITES

Species Composition of Termites (Isoptera) in Different Cerrado Vegetation Physiognomies

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Article History
Edited by:
Alexandre Vasconcellos, UFPB - Brazil
Received 12 December 2012
Initial acceptance 24 January 2013
Final acceptance 25 March 2013

Keywords
termite assemblage, biodiversity, forest, savanna, feeding guilds

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Abstract

Little is known about the termite fauna of the different vegetation physiognomies in the Cerrado biome. It is suggested that the species compositions in grassland and savanna areas are closely related to each other, and quite distinct from those of forests. This study compared the species composition from five different physiognomies of Cerrado, and tested the hypothesis that the termite faunas of savannas and grasslands form a distinct group from that of forests. The study was conducted in the Parque Estadual da Serra de Jaraguá, state of Goiás, Brazil. Termites were sampled from two physiognomies of savanna, one natural grassland, one pasture, and one gallery forest. A transect with 10 parcels of 5x2 m was established in each physiognomy. The relative abundance was inferred by the number of encounters, termites were classified in feeding guilds, and the dissimilarity in the species composition between the physiognomies was calculated. A total of 219 encounters, of 42 species of two families were recorded. The most abundant feeding guilds were the humivores (98) and xylophages (55). The physiognomies with the largest number of species were rupestrian cerrado (23 species) and cerrado *sensu stricto* (21). The physiognomies had a similar species composition (less than 55% dissimilarity), mainly the natural open areas. The hypothesis of a distinct fauna of termites in forest vegetation was refuted. The termite fauna of gallery forest is very different from that of pasture, but most species also occur in natural open areas. The impact of pasture on the diversity and composition of termites seems to be significant, but the impact is even greater on the proportion of the feeding guilds, reducing the proportion of xylophages and intermediates.

Introduction

Termites (Isoptera) are one of the most abundant soil invertebrates in tropical ecosystems (Wilson, 1971; Wood & Sands, 1978; Eggleton et al., 1996) and the most important soil ecosystem engineers of these environments (Bignell, 2006; Jouquet et al., 2011). In some arid and semi-arid tropical savannas, during the dry season, termites are the only active group of invertebrates able to decompose organic matter (Jouquet et al., 2011) and provide ecosystem services such as soil formation and aeration (Lavelle et al., 2006). Most species of termites are tropical, and among more than 2800 described species, approximately 500 occur in the Neotropical region (Kambhampati & Eggleton, 2000; Constantino, 2012). With about 150 species, 50% of them endemic (Constantino, 2005), the Cerrado biome in central Brazil probably harbors the most diverse and highly endemic savanna termite fauna (Domingos et al., 1986).

The Cerrado is the largest and richest tropical savanna in the world, and is also probably the most threatened one (Silva & Bates, 2002). Ranked among the 25 most important biodiversity hotspots (Myers et al., 2000), the Cerrado is the second most extensive biome in Brazil (Klink & Machado, 2005), and the most strongly affected by human disturbance.

During the past 50-60 years, with the evolution of agricultural techniques, this savanna also has become the largest agricultural frontier in Brazil (Sano et al., 2010). The latest analysis of the conservation status of the Cerrado showed that only 20% of the original area remained relatively undisturbed, and only 6.2% was preserved in protected areas (Myers et al., 2000).

The Cerrado biome is a mosaic of 10 different kinds of vegetation formations (physiognomies) (Ribeiro & Walter, 1998). The development of these physiognomies depends on the soil, groundwater, and other environmental variables. The physiognomies can be distinguished from one another mainly by the species composition, richness pattern, and relative abundance of plant species (Eiten, 1983). The termite faunas of most of these habitats are still little known, and for some of them no published information is available.

The majority of termite surveys in the Cerrado biome have been conducted in the cerrado *sensu stricto* physiognomy (Mathews, 1977; Coles, 1980; Brandão & Souza, 1998; Constantino & Schlemmermeyer, 2000; Constantino, 2005; Cunha et al., 2006; Carrijo et al., 2009). Some surveys have also described local faunas in the cerradão (Mathews, 1977; Constantino & Schlemmermeyer, 2000; Cunha et al., 2006), gallery forest (Mathews, 1977; Constantino & Schlemmermeyer, 2000; Cunha et al., 2006), and interfluve mesophytic forest (Brandão & Souza, 1998; Cunha et al., 2006).

The diversity of animals is often linked to the type of vegetation where they live or breed, and often differs between forests and grassy (grasslands and savannas) environments (Bond & Parr, 2010); termites can be expected to follow these patterns. Constantino (2005) remarked that in the Cerrado biome there are two termite faunas, one closely related to those of grasslands and savannas, and another one, quite distinct, related to forests. Constantino (2005) also suggested that the species composition of termites from Cerrado forests resembles faunas of the Amazon and Atlantic Forest biomes. Also, Mathews (1977) observed a gradient in the species composition of termites that build epigeal (above-ground) nests, from grasslands and savannas to forests.

The present study aimed to 1) compare the species composition, richness, and abundance of termites in five Cerrado physiognomies including three types of savanna (ranging from shortgrass savanna to woodland), one forest, and one pasture, all situated in the Parque Estadual da Serra de Jaraguá, Goiás, Brazil; and 2) test if there are two different groups of termite species related to the vegetation in the Cerrado biome: one in open areas (grasslands and savannas), and another in forests.

Material and Methods

This study was carried out at the Parque Estadual da Serra de Jaraguá, municipality of Jaraguá, state of Goiás, Brazil (15.75º to 15.85º S and 49.27º to 49.37º W). The park covers an area of about 2,860 ha, ranging in altitude from 640 to 1,140 m. The predominant soil type is Litolic Neosol, and the Köppen-Geiger climate type is "Aw" (Agência Ambiental, 2004). The park is surrounded by cattle grazing land and is mostly covered by cerrado *sensu stricto* (a vegetation type composed of tropical xeromorphic semideciduous broadleaf trees and scrub woodland of cerrado), which is more or less dense depending on the location. At higher altitudes (above 1,000 m) some rupestrian cerrado is present (tropical rupestrian semideciduous broadleaf trees and scrub woodland on rocky soil). Also, gallery forests (tropical mesophytic semideciduous broadleaf gallery forest) extend along the permanent water courses. Near the border of the park are some open shortgrass savannas (tropical xeromorphic, semideciduous broadleaf scrub with seasonal shortgrass).

Termites were sampled in these four physiognomies, and in a cattle pasture that was described by Carrijo et al. (2009) as "a 7-year-old pasture cultivated with *Brachiaria brizantha* Stapf. (Poaceae), originally covered by cerrado *sensu stricto* and cleared and turned into pasture approximately 50 years ago". We used the same methods as Carrijo et al. (2009), that is: in each physiognomy we established one linear transect with 10 plots of 5 x 2 m and 2 m height. Each plot was 30 m distant from the next one, and the transect was at least 50 m distant from the border of the particular physiognomy. The plots were carefully searched for termites in all possible places where these insects can be found: epigean nests, litter, plant stalks, fallen branches, soil surface, and to a depth of 20 cm below ground. Each plot was sampled by two collectors during 30 min. A total of 50 plots were sampled, comprising an area of 500 m².

Because of the difficulty of estimating the number of colonies (relative abundance) with this protocol, all individuals of the same species that were collected in the same plot were considered as one encounter. Thus, the maximum abundance of each species in each plot is 1 (one), and for all plots combined, 50 encounters (following Bignell and Eggleton, 2000).

Samples from all colonies were identified using appropriate literature and/or comparing with the Termitological Collection of the Universidade Federal de Goiás (UFG), where the vouchers were deposited. Species were classified in four functional groups (feeding guilds) according to field observations and literature information (Mathews, 1977; Gontijo & Domingos, 1991; DeSouza & Brown, 1994): xylophages, humivores, grass/litter feeders and intermediates.

The statistical analyses were performed with the software R (R Development Core Team, 2010), using the packages 'vegan' (Oksanen et al., 2011) and 'vcd' (Meyer et al., 2006, 2011). The sampling effort for each physiognomy was evaluated using a species accumulation curve, constructed using the function 'specaccum'. The number of species of termites was estimated by the estimators Jackknife 1 and Bootstrap, which are two of the best-known richness estimators (Colwell & Coddington, 1994; Magurran, 2004); for this, we used the function 'poolaccum'. A Pearson Chi-square test was performed between the number of encounters observed for each feeding guild, and that estimated based on a Poisson distribution; the results of this test were presented in a Cohen-Friendly association plot, generated by the function 'assoc' (Meyer et al., 2006). The dissimilarity in species composition between the five physiognomies was assessed using the Chao-Jaccard index (Chao et al., 2005), with the function 'vegdist', 1,000 permutations and method 'chao'. The cluster was performed with the function 'hclust' and method 'average'.

Results

In the five physiognomies, a total of 42 species and 27 genera of termites from the families Termitidae and Rhinotermitidae were collected (Table 1). Rhinotermitidae was represented by two species, *Coptotermes* sp. and *Heterotermes tenuis*. Of the four subfamilies of Termitidae, Apicotermitinae was the richest, with 15 species, followed by Nasutitermitinae, with nine species. A slight tendency toward stabilization can be observed in the species accumulation curve (Fig 1). The number of observed species was closer to the Bootstrap estimate (48 species) than to the Jackknife 1 estimate (58). The sampling completeness was 87.5% if we use the first estimator, and 72.4% for the latter (Fig 1).

The savannas (cerrado *sensu stricto* and rupestrian cerrado) were the physiognomies with higher numbers of species, followed by the grasslands (shortgrass savanna and pasture), and the gallery forest, respectively (Fig 2). None of the accumulation curves from the five physiognomies showed a stabilization tendency, which means that the numbers of species are certainly higher (Fig 2).

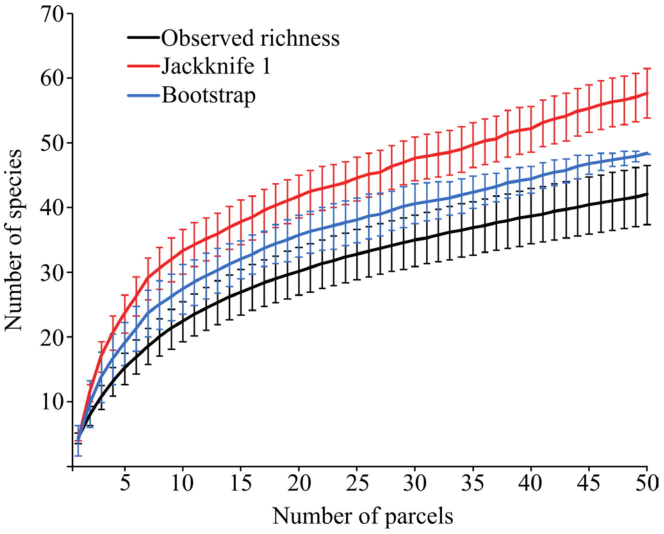

Figure 1 Accumulation curves with the observed termite richness and the estimates from Bootstrap and Jackknife 1 of five physiognomies pooled together from the Parque Estadual da Serra de Jaraguá. Vertical lines are the standard deviations.

The relative abundance of termites in all physiognomies was 219 encounters, with 5.214 ± 5.542 (average ± standard deviation) encounters per species (Table 1). However, a strong dominance of some species was found. The most common species, *Amitermes* sp., *Anoplotermes* sp. 3 and *Nasutitermes* sp. 1, had 23, 21 and 17 encounters, respectively, while 16 species were found only once, comprising 38% of the total pool of species surveyed. The subfamily Apicotermitinae was the most abundant both in absolute number (90 encounters) and in number of encounters per species (six encounters per species). Rhinotermitidae was the least abundant by both measurements: six in absolute number, and three encounters per species.

The cerrado *sensu stricto* showed the highest abundance of termites, both absolute (61), and per species (2.9); while the gallery forest had the lowest absolute abundance (25), and the shortgrass savanna had the lowest abundance per species (1.8). The most abundant species in the savannas (cerrado *sensu stricto* and rupestrian cerrado) was *Armitermes* sp., while *Anoplotermes* sp. 3 was the most abundant in the pasture and gallery forest, and *Nasutitermes* sp. 1 in the shortgrass savanna (Table 1).

Considering all physiognomies together, the most abundant and diverse guild was the humivores (98 encounters and 20 species) followed, in number of encounters, by the xylophages (55 encounters and six species) and, in number of species, by the intermediates (25 encounters and nine species). The grass/litter feeders had 41 encounters and seven species. Humivorous and xylophagous species were the most abundant in all the physiognomies considered separately; except in the pasture, where the grass/litter feeders had 18 encounters, against three of xylophagous species. The proportion of feeding guilds in cerrado *sensu stricto* and rupestrian cerrado was similar, with more humivores and xylophages, but also with a high proportion of intermediates, compared to the other physiognomies (Fig 3).

The Pearson Chi-square test showed that the shortgrass savanna had a lower proportion of grass/litter feeders than that expected by chance (Fig 3). The gallery forest showed a higher proportion of humivores, while the proportions of the other guilds were lower than those expected by chance. The pasture was the most singular physiognomy; the proportions of humivores and, mainly of grass/litter feeders were much higher, while those of intermediates and xylophages were much lower than those expected by chance (Fig 3).

Regarding the species composition, all physiognomies were very similar to each other (Fig 4). All the open areas had a dissimilarity index less than 0.5. The gallery forest and pasture were the most dissimilar areas (Chao-Jaccard Index = 0.8426). In fact, only three species were shared between gallery forest and pasture, and two of them (*Anoplotermes* sp. 3 and *Nasutitermes* sp. 1) were the only species that were present in all physiognomies.

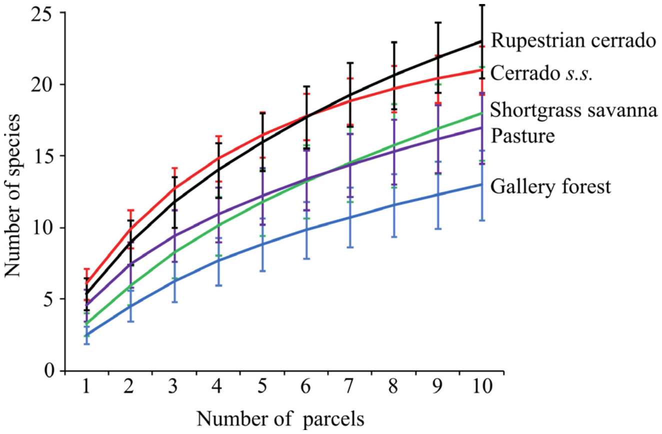

Fig 2 Accumulation curves with the observed termite richness for each physiognomy present in the Parque Estadual da Serra de Jaraguá. Vertical lines are the standard deviations.

Discussion

The species richness at the Parque Estadual da Serra de Jaraguá was as expected, as the local richness of termites in the Cerrado biome is about 40 to 60 species (Constantino, 2005), ranging from 15 (Cunha et al., 2006) to 114 (Mathews, 1977). In previous surveys in the Cerrado, the subfamily Nasutitermitinae was frequently the richest and most common group, but in these studies the species of Apicotermitinae were frequently pooled together due to limitations of identification (Constantino, 2005; Cunha et al., 2006). The true richness and abundance of Apicotermitinae is expected to be very high (Eggleton, 1999), which was the case in the present study. However, most previous studies in the Cerrado cannot be properly compared, since the protocols used are not standardized.

The gallery forest had the second smallest proportion of xylophages (6 species of a total of 25). This was an unexpected result, since the amount of wood is expected to be higher in forests than in the other physiognomies, and, consequently, more xylophagous species were expected in this environment. The reason is probably that, in the savannas, most of the wood needed by the xylophages is in shrubs, below two meters (the maximum height collectable by the protocol used), while in the forest the xylophages are situated much higher, in the canopy, and out of reach of our collections. In forests, a vertical gradient of termite species occurs and the xylophagous species found on the ground are only a subsample of those on the canopy (Roisin et al., 2006).

The grass/litter feeders were the most abundant termites in the pasture. This was expected, since grass is the most abundant food resource for termites in this environment. Moreover, litter-feeding species occur in higher proportions in Cerrado than in forest biomes (Constantino & Acioli, 2008). However, the high proportion of grass/litter feeders led to a skewed pattern in the feeding-guild proportions. Compared to the other physiognomies, the pasture had fewer xylophages and intermediates, and many more grass/litter feeders. This pattern was not as evident for the shortgrass savanna, the other grassland studied, which suggests that this is linked to human activity, turning cerrado *sensu stricto* into pasture, and not only the coverage of grass. The effects of pasture formation on termite communities are well known and include a reduction of richness and abundance of humivores and mostly xylophages, leading to high rates of local extinctions and an increase in the abundance of grass-feeders, which transforms some species into aesthetic pests (Brandão & Souza, 1998; Constantino, 2002; Cunha & Orlando, 2011).

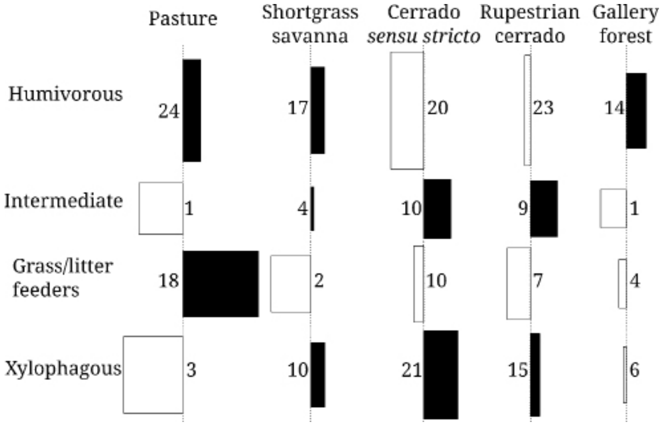

Fig 3 Cohen-Friendly association plot for the alimentary guilds of termites for each physiognomy of the Parque Estadual da Serra de Jaraguá. The bar length is proportional to the contribution to the Pearson Chi-Squared; and the bar area is proportional to the difference between the observed and expected frequencies. The independence values for each physiognomy are the vertical dashed lines. The black bars, to the right, are the values higher than expected by chance, and the white bars, to the left, are the values lower than the expected.

The termite fauna studied here had a very similar composition between all physiognomies. Although previous studies have concluded that each physiognomy has a different termite species composition (e.g., Constantino & Acioli, 2008), the natural open areas (rupestrian cerrado + cerrado *sensu stricto* + shortgrass savanna) investigated here have about the same termite species pool. Mathews (1977) also found a gradient of termite species from open areas to forests, with a high number of shared species of two or more physiognomies. Eiten (1983) observed a continuum of plant species between cerrado *sensu stricto* and rupestrian cerrado. In an inventory of plant species of the Parque Estadual da Serra de Jaraguá (unpublished data), the present authors found a continuum of plant species between all the natural open areas, with some exclusive species in each physiognomy.

The gallery forest and the pasture each had a distinct

Table 1 List of the number of termite encounters in different physiognomies of Cerrado in Parque Estadual da Serra de Jaraguá, state of Goiás, Brazil. (Feeding group X – xylophagous; H – humivorous; G – grass/ litter feeder; I – intermediate).

Family/subfamily/species	Feeding group	Pasture	Shortgrass savanna	Cerrado *sensu stricto*	Rupestrian cerrado	Gallery forest
Rhinotermitidae						
Coptotermes sp.	X	0	0	1	0	0
Heterotermes tenuis	X	0	2	1	0	2
Termitidae: Apicotermitinae						
Anoplotermes sp.1	H	0	3	5	5	3
Anoplotermes sp.2	H	1	1	2	1	0
Anoplotermes sp.3	H	7	4	4	2	4
Anoplotermes sp.4	H	0	3	3	2	4
Anoplotermes sp.5	H	0	1	2	1	1
Anoplotermes sp.6	H	6	1	0	2	0
Anoplotermes sp.7	H	3	2	0	0	0
Anoplotermes sp.8	H	1	0	0	0	0
Anoplotermes sp.9	H	0	1	0	0	0
Aparatermes sp.	H	1	0	1	0	1
Grigiotermes sp.1	H	1	0	0	0	0
Grigiotermes sp.2	H	1	0	0	0	0
Grigiotermes sp.3	H	0	0	0	1	0
Ruptitermes sp.	G	6	0	1	0	0
Tetimatermes sp.	H	0	0	1	0	0
Termitidae: Nasutitermitinae						
Agnathotermes sp.	H	1	0	0	0	0
Anhangatermes sp.	H	0	0	0	1	0
Atlantitermes stercophilus	I	0	1	0	0	0
Nasutitermes sp.1	X	1	5	4	6	1
Nasutitermes sp.2	X	0	0	5	1	2
Nasutitermes sp.3	X	0	0	0	0	1
Parvitermes bacchanalis	G	0	0	1	0	0
Subulitermes sp.	H	0	0	0	0	1
Velocitermes heteropterus	G	0	1	5	1	1
Termitidae: Syntermitinae						
Silvestriermes euamignathus	I	1	0	2	3	0
Cornitermes silvestrii	G	2	0	3	3	0
Cornitermes villosus	G	0	0	0	0	3
Curvitermes minor	I	0	1	0	1	0
Cyrilliotermes cupim	H	0	1	0	0	0
Embiratermes festivellus	I	0	0	3	2	0
Labiotermes emersoni	H	1	0	2	6	0
Procornitermes araujoi	G	4	0	0	2	0
Syntermes nanus	G	6	1	0	1	0
Termitidae: Termitinae						
Amitermes sp.	X	2	3	10	8	0
Dihoplotermes cf. *inusitatus*	I	0	0	0	1	0
Neocapritermes araguaia	I	0	1	2	1	0
Neocapritermes opacus	I	0	1	0	0	0
Neocapritermes talpa	I	0	0	0	0	1
Spinitermes trispinosus	H	0	0	0	2	0
Termes sp.	I	0	0	3	1	0
Encounters (total = 219)		45	33	61	54	26
Species richness (total = 42)		17	18	21	23	13

subsample of termite species from the natural open areas, plus some exclusive species. For example, of all the termite species found in the gallery forest, four were exclusive to this physiognomy and the other nine species were also found in cerrado *sensu stricto*. In spite of their high overall similarity, the pasture and gallery forest had very different species compositions, with only three shared species. This is an expected result, since the vegetation structure in gallery forest is very different from pasture. In gallery forest there is an abundant amount of wood and a comparatively small stock of grass, and the opposite in pasture. In fact, two species of xylophages were found for each species of grass/litter feeders termites in the gallery forest. In pasture the opposite occurred, with two species of grass/litter feeders found for each species of xylophagous termites.

Although the gallery forest had a different species composition pool, there is no evidence in the present study to support the hypothesis that this physiognomy hosts species from the Amazon and Atlantic Forest biomes. As mentioned above, the species pool of the gallery forest is a subsample of that in cerrado *sensu stricto* plus some exclusive species (*Nasutitermes* sp. 1, *Subulitermes* sp. 1, *Cornitermes villosus* and *Neocapritermes talpa*). Of these species, *Cornitermes villosus* only occurs in forests of the Cerrado biome; *Nasutitermes* and *Subulitermes* have species occurring in open areas of Cerrado; and only *Neocapritermes talpa* occurs in both the Amazon and Cerrado forests.

In the last decade, different physiognomies have undergone different rates of deforestation, and those with denser vegetation (i.e., forests and savannas) have been most affected (Rocha et al., 2011). It is alarming that gallery forests, which have a relatively depauperate but little-known termite fauna, are among the physiognomies that are most affected by deforestation.

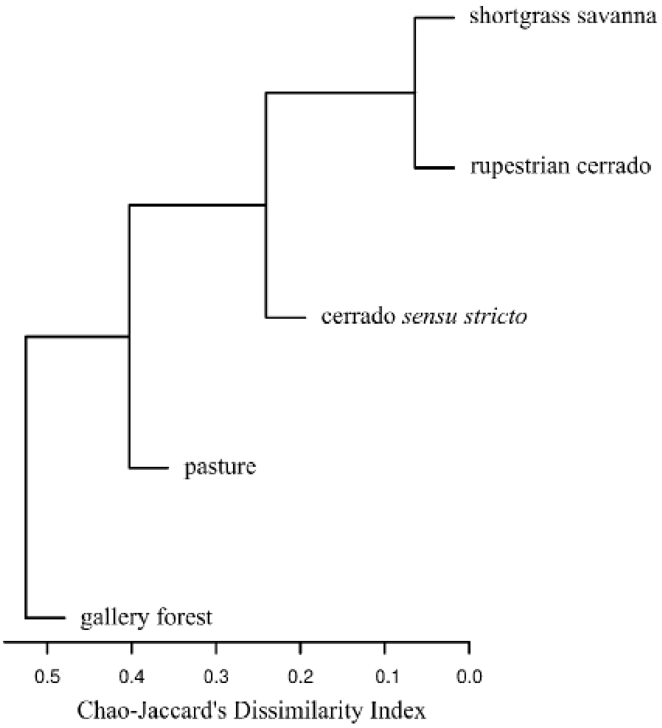

Fig. 4 Dendrogram with the dissimilarity (Chao-Jaccard's Index) between termite species composition for each physiognomy present in the Parque Estadual da Serra de Jaraguá.

This study showed that termites have a high number of species and abundance in Cerrado areas, mainly in the savanna physiognomies. The physiognomies have a similar species composition, mainly the natural open areas, and there is no support in the present study for the hypothesis of a distinct fauna of termites in forest. As expected, the termite fauna of gallery forest is very different from pasture, but most of the species also occur in natural open areas. The implantation of pasture seems to impact the termite diversity and, mainly, the species composition and proportions of the feeding guilds. However, this statement should be reinforced by future studies, with a greater sampling effort.

Acknowledgements

We thank our friends Diogo A. Costa and Thiago Santos for their help in discussing the project and also for their essential help in the fieldwork. This study was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil, and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES, Brazil. The Secretaria do Meio Ambiente e dos Recursos Hídricos, SEMARH, Brazil, for granting a collecting permit. We also thank two anonymous reviewers for valuable comments that improved this article.

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