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RESEARCH ARTICLE - TERMITES

Influence of Flood Pulse on Termite Diversity (*Insecta: Isoptera*) in the Pantanal

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Abstract

This research aimed to associate termite diversity to flood pulse by Paraguay River, and with savannas and pasture areas. The study was conducted nearby the town of Cáceres, in Pantanal - Mato Grosso, on six livestock farms subject to the flood pulse of Paraguay River. The types of land use sampled were native savanna and cultivated pasture. Flooded and dry plots were selected, both from the savanna and the pasture in each sampling area. Termite richness and abundance was analysed based on the environments as an explanatory variable (FP – flooded pasture, DP – dry pasture, FS – flooded savanna, DS – dry savanna) through GLM; Tukey's test was subsequently performed to determine whether land use and/or flood pulse can significantly affect the termite community. There were 37 termite species and 19 genera. Richness and abundance of termite species cannot be explained by flooding pulse, but were explained only by land use (pasture and savanna). We identified a greater richness and abundance of arboreal species in flooded environments. In conclusion, flood pulse is not a determining factor for savannas or pasture termite richness, but it changes the composition of the termite fauna in the environment.

Introduction

Termites are crucial organisms for the maintenance of ecosystems for they play a role in structuring the environment because of their underground behaviour, which largely accounts for the nutrients' flow in the soil (Lopez-Hernandez, 2001; Ruckamp et al., 2009).

The termite diversity in the flood areas is still poorly known. In the literature only some authors have published in Brazil about the Pantanal or Amazonia (Mill, 1982; Polato & Alvez Jr, 2009; Cunha et al., 2015) but there is still a lack of information about the relationship and strategies to survive in the flood areas (Martius, 1994; Forschler & Henderson, 1995; Plaza et al., 2014).

The Pantanal is a sedimentary plain, which covers an area of 138,183 km², filled with alluvial deposits from the Upper Paraguay rivers basin. It is considered one of the world's largest flooded plains (Junk & Da Silva, 1999),

and it is an extremely important area for biodiversity and conservation, since the flora and fauna of the Pantanal are influenced by the Brazilian biomes, the Amazon, Cerrado, Chaco and Atlantic forest (Alho & Gonçalves, 2005).

This region is typically flooded annually in the plain, between January and May, after the beginning of the rainy season, due to the Paraguay River overflow and groundwater elevation (Junk et al., 1989). This seasonal flooding in the Pantanal directly influences the diversity of flora and fauna (Rizzini et al., 1988; Ab'Saber, 1988).

The Pantanal is considered a big ecotone (Alho & Gonçalvez, 2005), and it is expected that ecotones have a greater diversity than the environments that originate it (Odum, 1971), but some studies at the Pantanal region indicate a lower termite diversity in relation to the biomes that make up the Pantanal, such as Cerrado and Amazônia (DeSouza & Brown, 1994; Gontijo & Domingos, 1991; Polato & Alvez Jr, 2009; Cunha et al., 2015).

Since the termites are social animals that live in community and are fixed or foraging near their nests (Fontes & Araújo, 1999) the flooding state of areas could be a determining factor for the presence or absence of certain species in the environment, eliminating individuals out of the nest during flooding (Forschler & Henderson, 1995). The presence of arboreal nests in flooded environments has been documented in other groups, such as ants (Adis, 1997), but we have a lack of information about the life strategies of termites in these environments or the relation of diversity in this areas.

The Pantanal in Mato Grosso is subjected not only to floods but also to man-made disturbances as a result of changes in natural pasture landscape, especially after the beginning of the 1980s (Zanine et al., 2005; Vitousek et. al., 1997). It must be emphasized that on Pantanal northern region there is only one termite study (Plaza et al., 2014), lacking information about this biome's termite fauna.

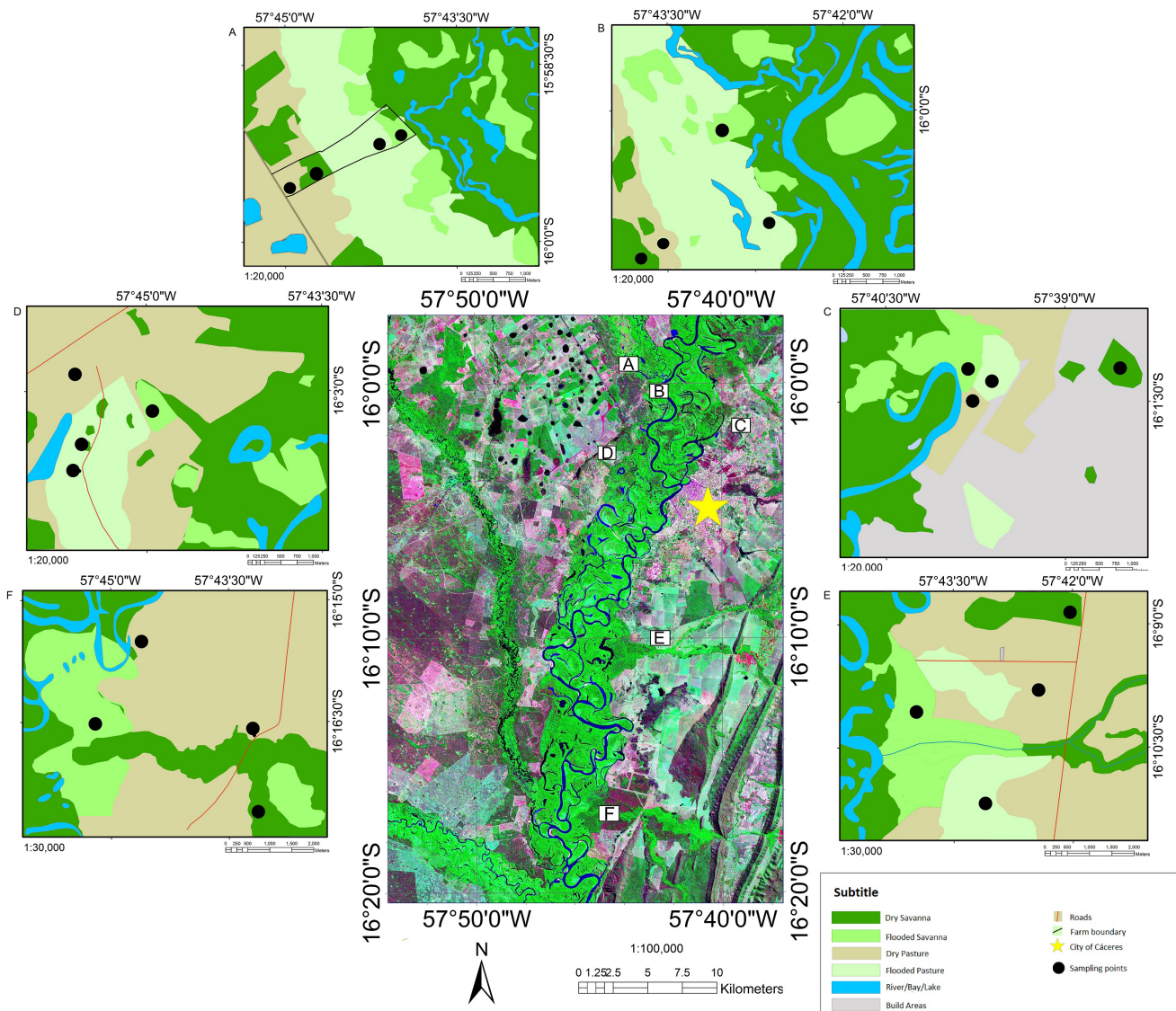In this context, the objective of the present study was to associate richness and abundance of termite species with different flooding regimes found in the Pantanal in Cáceres; it has been hypothesized that floods are determining factors for termite diversity in the environment.

Materials and Methods

Study Site

The study area is located near the town of Cáceres, 230 km away from the capital of Mato Grosso State, in Brazil centre-south of Mato Grosso state, micro-region of Alto Pantanal, near the border between Brazil and Bolivia (IBGE, 2005).

Six areas were sampled in the present study; they are flooded by the Paraguay River on a regular basis, and are located in six separate farms, at least 10 km distant from one another. The plots sampled, in the six farms, are located between the following coordinates: S 15º59'18.7'' - O 57º44'21.9'', S 16º01'24.6'' - O 57º39'40.3'', S 16º3'37.7'' - O 57º45'34.4'', S 16º0'10.53" - O 57º43'1.38", S 16°10'2.72" - O 57°43'56.43" and S 16°16'23.36" - O 57°45'9.52". (Fig 1)

Fig 1. Map of land use and occupation of the sampled areas in different Paraguay River bays in the Pantanal of Cáceres, Mato Grosso state, Where the areas are determined by the letters(A – F).

According to the Köppen classification, the climate in the region is Tropical Savanna (Aw), with dry winters and rainy summers. Average annual rainfall ranges between 1000 and 1400 mm, with maximum peaks in January and minimum peaks in July. Rainfall varies during the year, causing a regular drought and flood cycle (PCBAP, 1997).

Sampling of Termites and Observation of Different Environments

Termite samples were collected between March and May 2012, in six areas in the municipalities of Cáceres. Two types of environment were sampled in each area: savanna and cultivated pasture. For each type of land use, the samples were collected in transects that were either flooded by flood pulse or non-flooded, totalling 24 transects in the six farms (six transects in each environment: non-flooded (dry) savanna, flooded savanna, non-flooded (dry) pasture and flooded pasture).

To avoid many variables, we establish that pastures must be with *Brachiaria* (Griseb, 1853) and according to the following criteria: homogeneous vegetation cover, plant height of approximately 20 cm, and absence of exposed soil, which characterizes degraded pasture. The selected grazing areas were close to the studied savanna, 2 km away within the same sampling area (farm).

The savannas' transects were selected with vegetation fragments of Cerrado *stricto sensu*, with primary or secondary vegetation, at least 2 km away from one another. The *stricto sensu* savanna are characterized by a herbaceous layer dominated by grasses, a stratum with shrubs and tortuous trees with coverage less than 50%, and it is the most present phytophysiognomy in cerrado (Eiten, 1994).

The limits of flood pulse influenced by transects of both savanna and cultivated pasture, were determined through information from the residents and farm owners, where collections were held, and through observation of georeferenced information.

Termite sampling in each point within each transect was carried out based on the sampling protocol of termite richness (Jones & Eggleton, 2000), which consists in a transect measuring 200 m^2 (100 x 2 m), divided into 20 subplots measuring 10 m^2 (5x 2 m). Each termite species collected in the subplots, regardless of the amount of specimens, was treated as a sample.

The samples' sum, collected at subplot scale, represented species abundance in each transect (Davies, 2003). Abundance of social insects, such as termites and ants, are often estimated relatively, whereas the occurrence of a species in a particular small area, e.g. a 5x2m subplot, is considered to be a colony, and abundance equals 1 (Abensperg-Traun & Milewski, 1995; Davies, 2003; Gibb & Hochuli, 2002). Thus, for each subplot there was data on the presence and absence of species, and the maximum abundance of a given species in a transect equals 20.

The sampling effort, within the subplots (i.e, 5x2 m) was based on two collectors along 30 minutes of sampling. The termites were sampled with active gathering in leaf litter,

organic matter in various stages of decomposition, tree trunks, roots and arboreal and epigeal nests.

Each study site characteristics were categorised, these being determined as types of land use and flood pulse properties of the Pantanal, and four possible combinations were made: flooded pasture (FP), dry pasture (DP), flooded savanna (FS) dry savanna (DS).

The collected material was identified by Dr. Reginaldo Constantino at the University of Brasilia. The specimens were deposited in the termite collections of the laboratory in the Centre for Apiculture Studies (CETApis) in University of Mato Grosso State, Cáceres (UNEMAT) and the laboratory of Termite Biology, Department of Zoology, University of Brasilia (UnB).

Data Analysis

In order to test the hypothesis that species richness in the environments is explained by environment, a GLM (General linear model) was used with the statistical model whereby the response variable was the species richness (y) and the different environments, such as FP, DP, FS and DS (x). The same statistical model was used to test the hypothesis of abundance of specimens in the sampled environments. Tukey's test was later performed to find out which specific groups's means are diferente, based on the studentized range distribution (FP, DP, FS, DS).

To saw if we have some differences between behaviour species, we used a statistical model where response variable was the arboreal species richness (y) and the different environments, such as FP + DP and FS + DS (x) and arboreal species abundance (y) with the same (x).

Poisson distribution was used in GLM models, because the samples had count data for both species richness and species abundance. The statistical analysis was carried out with the free software R version 2.13.0 (R Core Team, 2014).

Results

Our study collected 451 samples of 37 termite species in 19 genera (Table 1). There were 26 species in the savanna with the presence of flood pulse, totalling 166 samples, 25 species in the dry savanna, totalling 152 samples, 20 species in pasture with flood pulse in 69 samples, and 19 species in dry pasture in 64 samples (Table 1).

Species richness is different between the types of studied environments (DF-20; P = 0.003); however, dry pasture showed no significant difference compared with flooded pasture (Tuckey, p = 0.86), and the dry savanna was not different from the flooded savanna (T, p = 0.142) (Fig 2-A).

The result for termite abundance was similar to that of richness: there were differences between the sampled environments (DF = 20; p = 0.001), but this result is more associated with land use, as there is no significant difference between the pastures (Tukey, p = 0.778) and between the savannas (T, p = 0.107). (Fig 2-B).
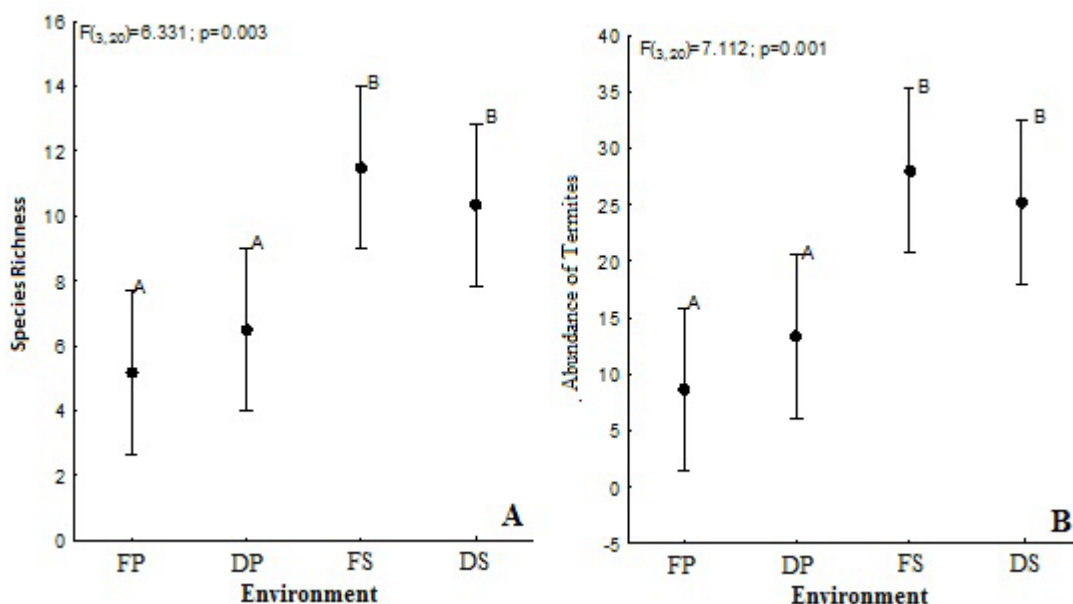
Fig 2. Demonstration using GLM analisys of richness of termite species based on environments (A) and abundance of termites based on different environments (B) in the town of Cáceres, MT. FP - flooded pasture, DP - dry pasture, FS - flooded savanna and DS - dry savanna.

The savannas seems to be more similar, this can be associated to species *Anoplotermes* sp. 8 (13 samples), *Coptotermes* sp.1 (6) and *Procornitermes triacifer* (5) all exclusive from this type of environment (Table 1).

For pastures, exclusive species from this type of environment study were found *Cornitermes bequaerti* (3 samples), *Nasutitermes ephratae* (3), *Spinitermes brevicornutus* (1) and *Spinitermes robustus* (1).

Exclusive species from the pasture without the flood pulse could be identified, such as *Anoplotermes* sp.2 (5 samples), *Nasutitermes kemneri* (3), *Termes nigritus* (2) and others.

All the arboreal species that we found in this paper are in savanna areas (10 species), and only seven are in the pasture areas too, but we don't find differences (DF = 20, p = 0.41), but the abundance is significant, we discovery 110 individuals on savanna formation and 24 individuals in pasture (DF = 20, p<0,05). The more abundant arboreal species are *Nasutitermes corniger* 83 individuals (78 in savanna and 5 in pasture).

Discussion

The results in this paper cannot claim that the pulse flood in the Pantanal has had a direct effect in the termite's communities, neither in the savanna nor in the grazing. To identify the possible causes of this response, we stablished some different adaptations to floods observed in termites and other insects in this discussion.

Initially this condition can be assigned to some factors/ answers in the termites periodic distribution, like arboreal or subterranean distribution. This characteristic has been observed in social insects nest builders, such as ants (Marques et al., 2006).

Another theory we think could be happening is the termites' resilience to flood disturbance, remaining inside their nests. The study with *Coptotermes formosanus*, the influence of periodic flooding in foraging places lessen the specimen abundance, however stablished colonies can survive inside the branches and repopulate the region, because of the alate production don't show reduction (Osbrink et al., 2008).

Termites could possibly remain in the flooded environment by building nests and staying inside them during the pulse, characteristic already observed in ants' specimen (Adis, 1997) and in a termite specie *Anoplotermes banski* (Martius, 1994).

The species *Cornitermes silvestrii* is an example for a modification in the behaviour for the environment of frequent floods in the Pantanal in Cáceres by building taller rather than wider nests, while the opposite occurs in other environments (Plaza et al., 2014), but this is only tested in *C. silvestrii*.

Another strong explanation can be related to arboreal termites nesting, since that preserved savannas areas are influenced by flood pulse tend to have more trees than areas without the influence of pulse (Adis, 1997). Due to this characteristic, the basal area of trees in areas influenced by flood pulse increases and determines microclimatic changes, and may influence the amount of food and nesting sites of termites (Vasconcellos et al., 2008).

The theory of arboreal species are more abundant in the flood areas have a strong place here, we did not test this, but the idea converges with the one found by Martius (1994). He found a greater amount of arboreal termite species and a greater number of arboreal nests in flooded environments in the Amazon.

Table 1. Abundance of termite species (Insecta: Isoptera) collected in environments of flooded pasture (FP), dry pasture (DP), flooded savanna (FS) and dry savanna (DS) and the place of their nests (Un – Underground, Ar – Arboreal, Ep – Epigeal, Nf – Not Found) in the Pantanal, in the town of Cáceres, MT.

Family/Sub-Family/ Species	Environments				Nests
	FP	DP	FS	DS	
Rhinotermitidae					
Heterotermes tenuis (Hagen, 1858*)*	6	4	13	22	Un
Coptotermes sp.1	-	-	4	2	Un
Coptotermes sp.2	-	1	2	2	Un
Termitidae					
Apicotermitinae					
Anoplotermes sp.1	5	3	4	9	Un
Anoplotermes sp.2	5	-	6	1	Un
Anoplotermes sp.3	7	2	-	2	Nf
Anoplotermes sp.4	1	2	-	-	Un
Anoplotermes sp.5	2	-	1	-	Un
Anoplotermes sp.6	7	2	8	8	Nf
Anoplotermes sp.7	6	3	14	17	Nf
Anoplotermes sp.8	-	-	-	13	Un
Nasutitermitinae					
Diversitermes sp.1	-	-	3	2	Nf
Diversitermes sp.2	-	-	1	1	Nf
Nasutitermes corniger (Motschulsky, 1855)	-	5	50	28	Ar
Nasutitermes ephratae (Holmgren, 1910)	1	2	-	-	Ar
Nasutitermes kemneri Snyder and Emerson in Snyder, 1949	3	-	6	7	Ar
Nasutitermes macrocephalus (Silvestri, 1903)	3	2	5	-	Ar
Subulitermes microsoma (Silvestri, 1903)	-	2	-	1	Ar
Velocitermes cf. velox (Holmgren, 1906)	-	-	1	1	Ar
Velocitermes melanocephalus (Snyder, 1926)	-	-	-	1	Ar
Syntermitinae					
Cornitermes bequaerti Emerson, 1952	2	1	-	-	Ep
Cornitermes silvestrii Emerson, 1952	3	21	13	12	Ep
Labiotermes emersoni (Araujo, 1954)	2	-	1	1	Un
Labiotermes longilabius (Silvestri, 1901)	-	-	-	1	Un
Labiotermes orthocephalus (Silvestri, 1901)	-	-	2	-	Un
Procornitermes triacifer (Silvestri, 1901)	-	-	3	2	Ep
Rhynchotermes nasutissimus (Silvestri, 1901)	-	-	3	-	Ar
Silvestritermes euamignathus Silvestri, 1901	4	3	3	3	Ep
Termitinae					
Amitermes amifer (Silvestri, 1901)	4	5	4	3	Nf
Cylindrotermes sapiranga Rocha and Cancello, 2007	3	3	6	4	Nf
Dentispicotermes globicephalus (Silvestri, 1901)	-	-	2	-	Nf
Microcerotermes sp.1	-	1	2	-	Nf
Microcerotermes strunckii (Soerensen, 1884)	1	-	4	1	Nf
Spinitermes brevicornutus (Desneux, 1904)	-	1	-	-	Nf
Spinitermes robustus (Snyder, 1926)	-	1	-	-	Nf
Syntermes molestus (Burmeister, 1839)	2	-	-	8	Un
Termes nigritus (Silvestri, 1901)	2	-	5	-	Nf
Total	69	64	166	152	

The permanence of termites in flooded locations can also be made possible by vertical migration, as previously observed in ants during flood pulse (Adis, 1997). For termites, all species of *Coptotermes*, *Microcerotermes*, *Nasutitermes* and the species *Cylindrotermes sapiranga* were found in the flooded areas; all of them are xylophagous species that use trees and stumps for foraging and building nests (Mathews, 1977), enabling migration to dry areas in branches and trunks.

This work provides a new taxonomic knowledge about the termites in the Pantanal area. We found 37 species of termites, more than any other work in this region. Cunha (2015) saw 13 species while Pollato and Alves-Junior (2012) only looked for Nasutitermes, this two works also deal with the south region of Pantanal and Pantanal of Cáceres is located to the north, about 500 km of distance.

In our study, we found that there is a strong negative relationship between anthropic impact and termite diversity; however, flood pulse was not a determining factor for on-site termite diversity because termite species could have different mechanisms of permanence in the environment; monitoring approaches are needed to check whether this modification is due to flooding or other environmental factor not yet observed.

Acknowledgements

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