Check List 8(4): 718–721, 2012
© 2012 Check List and Authors
ISSN 1809-127X (available at www.checklist.org.br)

Check List
Journal of species lists and distribution

Termite species list in a terra firme and ghost forest associated with a hydroelectric plant in Presidente Figueiredo, Amazonas, Brazil

Cristian de Sales Dambros [1*], Daniel Reis Maiolino de Mendonça [2], Tatiane Gonçalves Rebelo [3] and José Wellington de Morais [3]

1 University of Vermont. Department of Biology. 109 Carrigan Drive 120A Marsh Life Science Bld. 05405 Burlington, VT, USA.
2 Chico Mendes Institute of Nature Protection (ICMBio). Travessa Dom Pedro II, Nossa senhora Auxiliadora. CEP 69280-000 Manicore, AM, Brazil.
3 National Institute of Amazonian Research. Coordination of Biodiversity. Department of Entomology. Av. André Araújo, 2936, Petrópolis. CEP 69083-000. Manaus, AM, Brazil.
* Corresponding author. E-mail: Cristian.Dambros@uvm.edu

Abstract: Termites are among the most important groups to maintain tropical forests but despite their importance they are poorly studied. Termites were sampled in the trunks left over from the flood period in the Balbina Hydroelectric plant (UHB). The trunks are in the water and just partially submersed without contact with the mainland. We compared the species composition with the surrounding terra firme forest. This is the first list of species provided for this area from a standardized sampling and we provide some insights into how these degraded areas can be important to study species distribution and have potential for the discovery of new species of termites. We found that the change in the environment can drastically change the species composition and some rare species in the natural landscape can be more easily detectable in these areas.

Introduction

Termites are among the most important organisms in tropical forests promoting the physical and chemical modification of the soil and are linked to the improvement of soil drainage and aeration (Wood 1988). Despite their importance, there are few researchers working with termites and, consequently, a lack of studies on this group. For example, while the Check List Journal has provided valuable species records for many taxonomical groups, a search for an exclusive termite species list (access in May 2012) provides no results. The list of species of ants by Riera-Valera *et al*. (2009) is the only one that also includes termites. While species description and lists can be more easily found in other sources (such as Google Scholar and Scopus), the underrepresentation of termites in general is evident.

The Balbina Hydroelectric dam was built in the 1980s flooding about 300,000 ha of land and causing considerable devastation. In spite of the large change in the species composition and biological dynamics in this area, the remaining dead trees have provided a new source of food for termites in an area usually called ghost forest in hydroelectric flooding. While in the primary forest some species are rare or can be excluded from many areas by competition with others for resources, or by not finding the ideal conditions to survive (Ter Braak and Colin 1988), these species can be predominant and detected easily in disturbed regions, such as in urban areas (Fontes 1995).

The creation of such a large area as the UHB flooding, with exposed dry wood in the middle of the Amazonia, promoted a new environment that favored wood-feeder species making it possible for rare species to become more common and more easily detectable. The aim of this study, besides merely providing a species list, was to compare these two environments and understand how important they can be for ecological and taxonomic studies in the future. Our main hypothesis is that the ghost forest has a distinct species composition when compared to the adjacent forest, favoring the emergence of species that are too rare to be easily sampled in terra firme forests. We found a strong change in species abundance distribution, with some rare species becoming more common as predicted. We also showed that the species composition is easily distinguishable between the terra firme and the ghost forest. Finally we provide the first list of species of termites in the area from a standardized survey.

Materials and Methods

The study was performed in the Balbina Hydroelectric Plant (UHB) located in Presidente Figueiredo, central Amazonia (Figure 1). The original vegetation is characteristic of terra firme forest, not subject to periodical flooding. The reservoir has a flooding area of approximately 1,000,000 ha and in the shallow waters, close to islands and the mainland, the dead trees form an area called the ghost forest in which tree trunks still appear above the water surface. This region provides an important source of food for termites and virtually all trees are colonized by wood-feeder termites. We sampled termites both in the terra firme forest that surrounds the lake and in the trees in the lake (from 01°25’40” S, 59°32’40.2” W to 01°50’47.3” S, 59°37’16.1” W).

Termites were sampled in five distinct areas at least 1 km away from one another in the ghost forest and in adjacent transects in the neighboring terra firme forest. Inside the lake, the termites were sampled in the tree trunks above the water level. To refine our description of species composition in the ghost forest, which was the main purpose of this study, we performed three additional transects in this area.

The lake transects included trunks in a range of 500m x 30m and the sampling area was delimited using a GPS device with a minimum precision of 3m. The sampling started 30 meters away from the margins to avoid the sampling on those trees that eventually have contact with the terra firme forest due to variations in the water level. The mainland transects were 100m long and 2m wide and the termites were sampled in five 5x2m subsamples 20m equidistant from one another , following a modification of the original Jones and Eggleton's transect (Jones and Eggleton 2000). Termites were sampled manually by three people for 20 minutes in each subsample in the terra firme forest and in all trunks in the ghost forest. The samples were taken in September 2010 in the ghost forest and in November in the terra firme forest. Differences in the methods for terra firme and ghost forest are due to different density of nests as they are much more densely distributed in the terra firme forest.

The termite identification was carried out following Constantino (1999) at the generic level and by comparing the specimens with material in the Invertebrate collection of the National Institute of Amazonian Research (INPA) and by comparing the specimens with species descriptions. All collected termites are deposited in the Invertebrate collection of INPA. Species were assigned to feeding guilds based on morphological and nesting traits previously described (see Table 1; Mathews 1977; Constantino 1999).

We recorded the number of species in each transect and compared the terra firme and ghost forests in this respect. Based on the ratio of unique specimens and duplicates in each sample we used the Chao-2 estimator of species richness (Chao 1987) to estimate the extent to which species richness is underestimated.

To determine if the plots in each area had a distinct and estimated number of species, we performed a Wilcoxon signed-rank test comparing the two groups of samples (terra firme and ghost forest).

To compare the species composition in the areas (using transects as units) we performed the same test using as a measure the ordination scores of the first axis of the Principal Component Analysis (PCoA) by means of the Jaccard Similarity index. In this test, we were able to evaluate if the species composition is distinct between the two areas and if, using only the species composition, we would be able to predict whether the area is a terra firme or ghost forest transect.

All analyses were performed in R program version 2.12 (R Development Core Team, 2010).

Results and Discussion

In a total of 192 colonies surveyed in the ghost forest and 79 nests in the terra firme forest, we found a total of 26 species – 16 in the terra firme forest and 16 in the ghost forest (Table 1; Figure 2). We found a surprisingly high number of species in the ghost forest, including species that are too rare to be detected in most surveys in terra firme forests, as species from *Rugitermes* and *Gliptotermes* genus (not detected by Apolinário and Martius 2004; Ackerman *et al*. 2009 and Barros *et al*. 2002, for example). However, the overall number of species recorded in the terra firme forest was lower than the estimated for both areas (17 and 22, respectively) and far lower than detected in many previous studies in Central Amazonia (Martius *et al*. 1996; Davies *et al.* 2003; Ackerman *et al.* 2009). This is due to two main reasons. First, the sampled area was smaller than in most studies and our intention here was not to intensively sample in the terra firme forest, but to compare against the ghost forest species composition. Second, all the sample areas in the terra firme forest are in the same altitudinal level because the areas are all at the same distance from the margin of the lake. We have found, in other areas in central Amazonia, that the turnover of species is associated with the altitudinal gradient (*data not published*) because many environmental conditions that cause species turnover (Davies *et al.* 2003; Roisin and Leponce 2004) are associated to elevation (Magnusson *et*

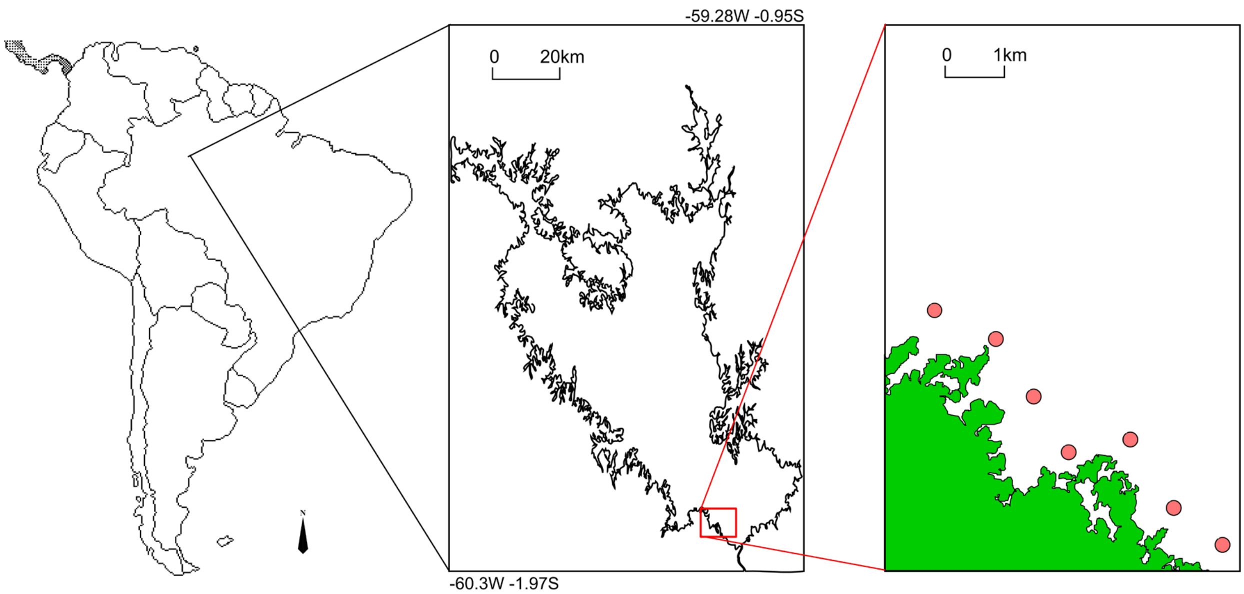

Figure 1. Localization of the Balbina Hydroelectric plant and the sampling points in the ghost forest. The green area represents the terra firme forests and the red dots represent the sampling areas. The terra firme sampling plots are not represented but are in the same areas as the five ghost forest samples.

al. 2005) and, consequently, the species composition tend to be similar in the same isoclines. Moreover, the effects of the fragmentation due to flooding must be affecting the surrounding forest, reducing the number of species that can be found close to the margins and increasing the similarities between all portions. It is worth noting, in this respect, that we could not find humus feeders in the terra firme forest and this group is likely to be more affected by fragmentation processes (Davies 2002).

The richness per plot, comparing the local plots, was higher in the terra firme areathan in the ghost forest (W=41; d.f.=10.825; P=0.01). Compared to the surrounding terra firme forest, the total number of species were the same, but the ghost forest areas tend to be less rich in the per plot comparison. Moreover, in the ghost forest, the identity of species tend to change more from one area to another (high turnover) while in the terra firme forest almost all found species tend to be present in all plots (low turnover). Finally, the number of colonies found in the ghost forest (192) was much higher than in the terra firme forest (79) because it is much easier to sample and find termites in the ghost forest, but the density of nests is much lower.

The most common species in the terra firme forest were *Syntermes molestus* (Burmeister, 1839) and *Nasutitermes* sp. 7, which we were not able to recognize among the *Nasutitermes* species inhabiting Central Amazonia. Many species were found in both areas, mainly of the *Nasutitermes* genus, including *N*. sp. 7, but the most common species in the ghost forest was *Termes hispaniolae* (Banks, 1918) followed by *Coptotermes testaceus* (Linnaeus, 1758) (Table 1; Figure 2). In general, the species composition was clearly distinct between the areas (W=45; d.f.=8.98; P<0.001; Figure 2). Our method, as any other, is not able to capture all species present in the terra firme forest due to the lower probability of detection of some species (MacKenzie 2005). Besides the clear differences between the habitats and we expect, with a higher sampling effort, that all species found in the ghost forest could be found in the terra firme forest, because the species in the ghost forest are a subset of the original species that lived in these areas, or came from the terra firme forest in a posterior colonization process.

In agreement with all differences in species richness, we detected a higher turnover of species in the ghost forest than in the terra firme forest. One surprising find of our study was that a degraded area, such as the ghost forest, at the same time that is an unsuitable environment for most species, may turn out to be an important tool for finding new wood-feeder species for the region since it is easy to detect very rare species. Moreover, this region can be an important area to study ecological dynamics because it is possible to detect all individuals in a biological community with almost 100% of certainty in a huge area absent of main predators (such as predator ants) and highly dependent on dispersion. Future studies carried out by taxonomists could also increase the number of known species for the region by providing the description of new species or broadening the range of distribution for many species additionally to those we were able to identify and list here. For example, most of the *Nasutitermes* species did not match any species found in this portion of Amazonia and/or already described species. More than provide a list of species, we extended the range of distribution of all species identified here to this area in central Amazonia and showed that some species have a higher potential of being found in open areas. This information can be used in the future to predict species distribution and potential species that can survive in open areas.

Table 1 shows a list of all species, the location, and the feeding groups. All species in the ghost forest were wood-feeders and, in terra firme areas, the wood-feeders were the most common group but other groups were also sampled.

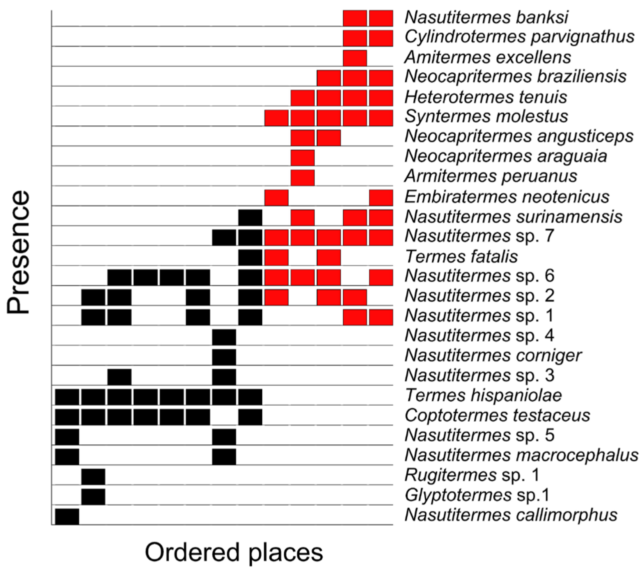

Figure 2. Species distribution in the ghost and terra firme forests. The red and black squares represent the presence of a species in a ghost or terra firme forest transect respectively. The transects were ordered using the Jaccard similarity index in the PCoA analysis without previous separation of ghost and terra firme forest.

Table 1. Termite species abundance and trophic group from the ghost forest and terra firme transects in the Balbina Hidroeletric Plant (UHB), Presidente Figueiredo, Brazil. Wood feeders: feed preferentially on dry wood; intermediate: feed on material between wood and humus or partially decayed wood; leaf-litter: feed preferentially on leaves and small branches. We didn't found humus feeders.

SPECIES	GHOST FOREST	TERRA FIRME FOREST	TROPHIC GROUP
Amitermes excellens Silvestri		2	Intermediate
Armitermes peruanus Holmgren		1	Intermediate
Coptotermes testaceus (Linnaeus)	22		Intermediate
Cylindrotermes parvignathus Emerson		2	Wood-feeders
Embiratermes neotenicus (Holmgren)		2	Wood-feeders
Glyptotermes sp. 1	1		Wood-feeders
Heterotermes tenuis (Hagen)		4	Wood-feeders
Nasutitermes banksi Emerson		2	Wood-feeders
Nasutitermes callimorphus Mathews	1		Wood-feeders
Nasutitermes corniger (Motshulsky)	1		Wood-feeders
Nasutitermes macrocephalus (Silvestri)	11		Wood-feeders
Nasutitermes sp. 1	15	2	Wood-feeders
Nasutitermes sp. 2	5	5	Wood-feeders
Nasutitermes sp. 3	2		Wood-feeders
Nasutitermes sp. 4	1		Wood-feeders
Nasutitermes sp. 5	7		Wood-feeders
Nasutitermes sp. 6	4	17	Wood-feeders
Nasutitermes sp. 7	75	17	Wood-feeders
Nasutitermes surinamensis (Holmgren)	1	4	Wood-feeders
Neocapritermes angusticeps (Emerson)		2	Intermediate
Neocapritermes araguaia Krishna & Araujo		1	Intermediate
Neocapritermes braziliensis (Snyder)		5	Intermediate
Rugitermes sp. 1	2		Wood-feeders
Syntermes molestus (Burmeister)		10	Leaf Litter-feeders
Termes fatalis Linnaeus	1	3	Intermediate
Termes hispaniolae (Banksi)	43		Intermediate
Total	192	79	

Acknowledgments: We acknowledge the Amazonas State Research Foundation (FAPEAM) for providing resources for laboratory and field supplies, the Chico Mendes Institute for the Biodiversity Conservation for the logistic support and authorization for collecting in the field work area. We also thank the Minister of Science and Technology (MCT) for providing a scholarship for the first author that allowed us to develop the project while working for the National Institute of Science and Technology – CENBAM.

Literature Cited

Ackerman, I.L., R. Constantino, H.G. Gauch Jr., J. Lehmann, S.J. Riha., E.C.M. Fernandes. 2009. Termite (Insecta: Isoptera) species composition in a primary rain forest and agroforests in central Amazonia. *Biotropica* 41: 226-233.

Apolinário, F.E., and C. Martius. 2004. Ecological role of termites (Insecta, Isoptera) in tree trunks in central Amazonian rain forests. *Forest Ecology and Management* 194: 23-28.

Barros, E., B. Pashanasi, R. Constantino, P. Lavelle. 2002. Effects of land-use system on the soil macrofauna in western Brazilian Amazonia. *Biology and Fertility of Soils* 35: 338-347.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. *Biometrics* 43:783–791.

Constantino, R. 1999. Chave ilustrada para identificação dos gêneros de cupins (Insecta: Isoptera) que ocorrem no Brasil. *Papéis Avulsos de Zoologia* 40: 387-448.

Davies, R. 2002. Feeding group responses of a Neotropical termite assemblage to rain forest fragmentation. *Oecologia* 133: 233-242.

Davies, R.G., P.Eggleton, D.T. Jones, F.J. Gathorne-Hardy, L.M. Hernández. 2003. Evolution of termite functional diversity: Analysis and synthesis of local ecological and regional influences on local species richness. *Journal of Biogeography* 30: 847-877.

Fontes, L.R. 1995. Cupins em áreas urbanas; p. 57-75 *In* E. Berti Filho and L. R. Fontes (ed.). *Alguns aspectos atuais da biologia e controle de cupins*. Piracicaba: Fundação Escola de Agricultura Luiz de Queiroz.

Jones, D.T. and P.Eggleton. 2000. Sampling termite assemblages in tropical forests: testing a rapid biodiversity assessment protocol. *Journal of Applied Ecology* 37: 191-203.

MacKenzie, D.I. 2005. What are the issues with presence-absence data for wildlife managers? *Journal of Wildlife Management* 69: 849-860.

Magnusson, W.E., A.P. Lima, R. Luizão, F. Luizão, F. Costa, C.V. Castilho, and V.F. Kinupp. 2005. RAPELD: A modification of the Gentry method for biodiversity surveys in long-term ecological research. *Biota Neotropica* 5: 1-6.

Martius, C., P.M. Fearnside, A.G. Bandeira and R.Wassmann. 1996. Deforestation and methane release from termites in Amazonia. *Chemosphere* 33: 517-536.

Mathews, A. G. 1977. Studies *on termites from the Mato Grosso State, Brazil*. Rio de Janeiro: Academia Brasileira de Ciencias. 267p.

R Development Core Team. 2010. *R: A language and environment for statistical computing*. Acessible at http://www.r-project.org/.

Riera-Valera, M.A., A.J. Perez-Sanchez, J. Perozo. 2009. Ants (Hymenoptera: Formicidae) and termites (Termitidae: Isoptera), Moron River basin, Carabobo, Venezuela: Preliminary data. *Check List* 5(4): 855-859.

Roisin, Y., and M. Leponce. 2004. Characterizing termite assemblages in fragmented forests: A test case in the Argentinian Chaco. *Austral Ecology* 29: 637-646.

Ter Braak, C.J.F. and I.C. Prentice. 1988. A Theory of Gradient Analysis. *Advances in Ecological Research* 34: 271-317.

Wood, T.G. 1988. Termites and the soil environment. *Biology and Fertility of Soils* 6: 228-236.

Received: March 2012
Accepted: July 2012
Published online: August 2012
Editorial responsibility: Ricardo Solar