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Importance of protected areas for biodiversity conservation in south Côte d'Ivoire: case of National Floristic Center of F.H.B University of Abidjan

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Abstract

To show the impact of human activity on biodiversity in humid equatorial region, termites, insects recognized as bio-indicators of climate change in the tropics were studied in two habitats: The National Center for Floristic (CNF), a preserved habitat for 51 years and the Campus of Cocody (CC), a strongly anthropic environment. Termites were sampled using a standardized method designed for rapid assessment of termite. In both areas, 18 species were collected, 17 species in CNF and 7 species in the Campus area. Significant change in diversity was found between the CNF and the Campus area. In addition, the relative abundance of termites showed a significantly greater decline in the Campus area. The highest abundance of termites was obtained in the CNF (2.95 ind./sections) unlike the Campus area where the relative abundance was 1.55 ind./section. Shannon and Simpson diversity index recorded in the CNF was higher than those of the Campus area. The low similarity index calculated (0.38) showed that these two areas were strongly different. The soil feeders seem to be the most sensitive group to human activities. The CNF preserved of human activities allowed reconstituting different species of termite colonies, unlike the Campus area which still subject to strong anthropogenic activities.

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Introduction

One of the most conspicuous aspects of contemporary global change is the rapid decline of the extraordinary diversity of the earth, estimated to include about 10 million different species diversity in many ecosystems (Soulé, 1991; Dale, 1997). On a global scale, even at the lowest estimated current extinction rate, about half of all species could be extinct within 100 years (NRC, 2000; Achard *et al.,* 2002; Barbault, 2002; Darkoh, 2003; Wright, 2005). On local and regional scales, biodiversity declines are already pronounced in many areas, especially where natural ecosystems have been converted to croplands, timber plantations, aquaculture and other managed ecosystems (Fahrig, 2002; Brooks *et al.*, 2002, Dosso *et al.*, 2010, 2012, 2013). The diversity of these managed ecosystems is often low, and species composition very different, compared with those of the natural systems they have replaced.

Therefore, early detection mechanisms that rapidly identify changes in ecosystem conditions must be made. Early detection can be performed using a group of organisms in an ecosystem or habitat that describes the response to these changes. An organism that can give respond, indication, early warning, information and evaluation of the condition and/ or changes that occur in an ecosystem called bioindicator (Jones and Eggleton, 2000; Dale, 2001; Carignan and Villard, 2002; Weissman *et al.,* 2006). One group of insects that could potentially be used as a bioindicator to assess the condition of ecosystems is termite (Pribadi *et al.,* 2011). Termites have a key role in tropical ecosystems function (Bignell and Eggleton, 2000). Termites are one of the main decomposer in tropical terrestrial ecosystems (Bignell and Eggleton, 2000), and ecosystem engineers through their activities which help improve soil structure and nutrient cycling (Jones *et al.*, 1994: Levelle *et al.,* 1997). In addition, termite species richness showed a high correlation to the diversity of other taxon groups in the same habitat (Vanclay, 2004), and the complexity of vascular plants (Gillison *et al.,* 2003). Termites also showed high sensitivity to environmental conditions, both biotic and abiotic that exposed them, as well as on ecosystem processes (Jones and Eggleton, 2000). While a few studies have demonstrated that termites are sensitive to habitat disturbance (Bignell and Eggleton, 2000; Eggleton *et al.,* 2002), only a very limited number of such studies have compared the communities living in areas exposed to different levels of disturbance (Dosso *et al.*, 2010, 2013). In general, research on termite community response to habitat disturbance was mostly conducted in Côte d'Ivoire.

The National Center for Floristic (CNF), object of our study is a botanical forest. It was established in 1963 by Professor Ake Assi with the aim of conserving plant diversity and especially of plant species threatened with extinction. Today, in addition to the conservation and preservation of biodiversity of plant species, the CNF could almost constitute an ecological niche of some animal species, including insects, in particularly the termites compared to the Campus area. These two different habitats, the CNF protected from human activities and the Campus of Cocody (CC), a high entropic area have really favored or not the restoration of the termite colonies? To address this question, it was aimed to examine the impact of these two differently disturbed habitat types on the termite assemblages. In this study, the sampling of termites was done by using a standardized method designed for rapid estimation of termite diversity, along belt transects 100 m long by 2 m wide (Jones and Eggleton, 2000) in order to describe the diversity and taxonomic composition of the local termite assemblage.

Materials and methods

Study area

The studies have been carried out in the region of Abidjan, in the CNF. The CNF is located on the area of Félix Houphouët-Boigny University of Cocody (3°57 N - 5°20 W). The CNF covers 11 hectares. The climate is equatorial, with an average inter-annual rainfall exceeding 1800 mm. The climate is characterized by four seasons, two rainy seasons and two dry seasons. The average temperature ranges from 24 °C to 30 °C, with an average value of 26 °C. The soils are mostly ferralitic desaturated (Perraud, 1971) with low organic matter content (2-3%). The CNF is composed of two parts: a fallow and an arboretum comprised of plant species from different countries. These plants give an appearance of humid forest (Kouakou, 2009).

Sampling method

Three separate blocks of each habitat type were sampled. The sampling of termites was done by using a standardized method designed for rapid estimation of termite biodiversity diversity, along belt transects 100 m long by 2 m wide (Jones and Eggleton, 2000). Each transect was subdivided into 20 contiguous sections (5 m x 2 m) and each section was searched for termites by two experienced collectors for 30 min (i.e. 1 man-hour of sampling per section). In all sections, microhabitats (logs, litter, stumps, twigs, nests, runways sheetings, fallen branches, etc.) were hand-searched up to a height of 2 m above ground level. Twelve samples of surface soil (each about 12 cm x 12 cm by 10 cm deep) were dug out haphazardly in each section and manually dissected. Representative samples of the termites (around 10 individuals of each termite party encountered, including both the soldier and worker castes whenever possible) were sorted and put into ethyl alcohol 70%. Samplings were based on the occurrence (presence-absence) of individual species rather than abundance, with respect to the highly aggregative behavior of termites.

Identification of collected termites

The collected termites were identified at the Biology and Animal Zoology laboratory (Université Félix Houphouët-Boigny, Abidjan) and at the laboratory of Evolutionary Biology and Ecology (Université Libre de Bruxelles, Belgium). Specimens were identified to the level of species using standard determination keys such as: Ahmad (1950), Bouillon and Mathot (1965), Roy-Noël (1966), Sands (1965, 1972, 1998) and Sjöstedt (1926). After identification, each species was classified in one feeding group (i.e., fungus-growers, soil-feeders, wood-feeders, and grass-feeders) by taking into account the food supply, the shape of the mandibles and the intestinal contents of the workers.

Data analysis

Sampling completeness was tested by constructing sample-based species accumulation curves. Using the program EstimateS (version 7.0) (Colwell, 2004), rarefaction curves were constructed after randomizing 500 times the sample order to ensure the statistical representation of the target assemblage (Cao *et al.,* 2002). Following the description of Brose *et al.* (2003) for incidence data, we chose the first order and non-parametric estimator jackknife 1 as estimator of the species richness. The total species richness of termites was obtained by enumerating all species observed over transects. The Shannon index (H'), Simpson index, and the Equitability (E') were calculated for each habitat. As we used presence-absence data, the relative frequency was defined as the number of encounters per transect, where the presence of one species in a section represented one encounter (Magurran, 2004). Analysis of variance (ANOVA) and the Newman-Keuls test ($p < 0.05$) were performed with STATISTICA software (version 7.0) (Ihaka and Gentleman, 1996).

Results

Sampling efficiency

The curves corresponding to the accumulation of species observed and estimated species richness approaching the asymptote for the Campus (Fig. 1). Thus, the observed species richness was considered a good estimate of the estimated richness in this area. The coverage of the sampling was high for both environments (≥ 82.63 %). However, in the CNF, after 60 quadrats, the rarefaction curves continue to increase, indicating that additional sampling would be required to give an accurate representation of species richness in this environment. The lowest number of unique species was collected in campus area (one single species) unlike CNF area (5 unique species) that the rarefaction curve has not reached the asymptote.

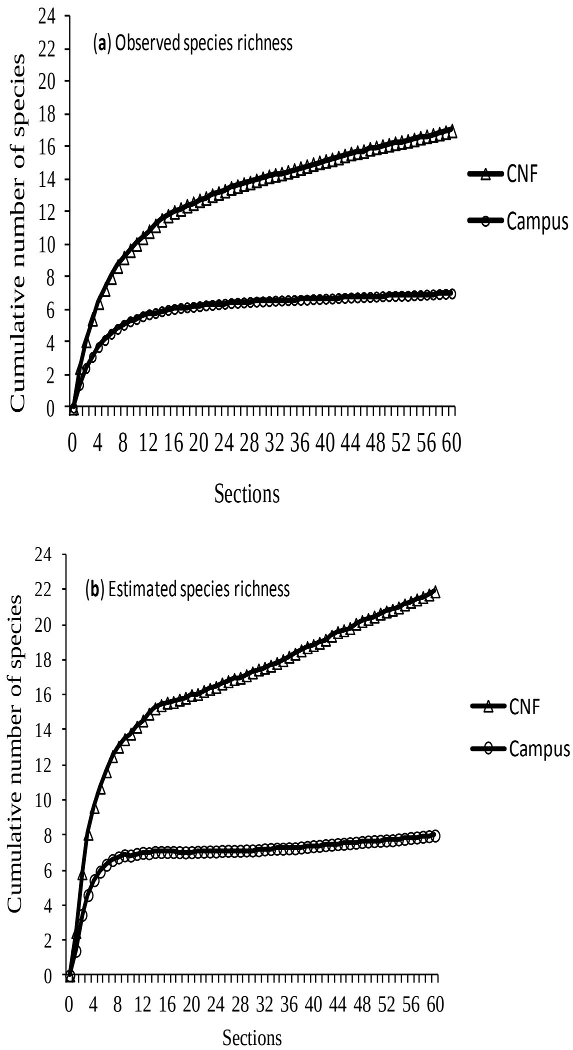

Fig. 1. Sample-based accumulation curves of observed (Sobs) (**a**) and estimated species richness (Jacknife1) (**b**) of termites in the two habitats.

Species richness and species diversity of termites

A total of 18 species were sampled in the two areas combined (Table 1). Two sub-families of the Rhinotermitidae' family, Coptotermitinae and Rhinotermitinae were collected. Five sub-families were represented to the Termitidae' family: Nasutitermitinae, Apicotermitinae, Macrotermitinae, Termitinae and Cubitermitinae. These species belonged to 21 genera. The sub-families of Coptotermitinae, Rhinotermitinae, Nasutitermitinae and Apicotermitinae, with respectively one species each were least represented in these two habitat types. The Macrotermitinae sub-family, with 6 species of termites was most represented.

Based on observed species, the CNF was the richest habitat with 17 species and campus area was the poorest with 7 species (Table 2). On the other hand, while comparing the habitat types on the basis of mean species richness, the richness of the CNF (15.66 ± 1.36) was significantly higher than those found in Campus area (6.33 ± 1.02) (ANOVA, F=71.27; p = 0.001). Shannon and Simpson diversity index recorded in the CNF was higher than those of the Campus area. However, the evenness was low in the campus area but higher in the CNF area. Thus showing that a good distribution of species in the CNF area.

The similarity of the two areas was assessed by the calculation of the similarity index between termite assemblages found in the different habitats. The results showed a very low similarity of the termite species compositions of the two areas (0.38) (Table 2).

The relative abundance of termites varies from one habitat to another. The CNF has the highest abundance of termites with a total abundance of 149 with an average abundance of 2.55 ind./Sections (Table 2). Campus, with a relative abundance of 79, has the lowest abundance of termites is 1.31 ind./Section.

Variation of the feeding groups proportion

The species collected in these two habitats were classified into three feeding groups (fungus-growers, soil-feeders and wood-feeders). In CNF, soil-feeders and fungus-growers', are the most abundant groups with respectively 43% and 41% of total species abundance (Fig. 2). However, on the campus area, the soil-feeders group was very weakly present with 1% of total termite. The proportion of fungus-growers' was higher and they represented 73% of the total abundance of termites (Fig. 2).

Table 1. Taxonomic structure of termites collected in the two habitats.

Subfamily / Species or morphospecies	FG	CNF	Campus
Coptotermitinae Holmgren			
Coptotermes intermedius Silvestri	w	1	0
Rhinotermitinae Froggat			
Shedorhinotermes laminianus (Sjöstedt)	w	6	0
Macrotermitinae Kemner			
Ancistrotermes cavitorax (Sjöstedt)	f	13	17
Ancistrotermes crucifer (Silvestri)	f	1	0
Macrotermes bellicosus (Smeathman)	f	3	6
Macrotermes subhyalinus (Rambur)	f	6	0
Microtermes toumodiensis (Grassé)	f	1	11
Pseudacanthotermes militaris (Hagen)	f	37	28
Apicotermitinae			
Aderitotermes sp	s	22	1
Nasutitermitinae Hare			
Nasutitermes arborum (Smeathman)	w	5	0
Cubitermitinae Weidney	s		
Cubitermes subcrenulatus (Silvestri)	s	14	0
Cubitermes fungifaber (Sjöstedt)	s	9	0
Procubitermes sjöstedti (von Rosen)	s	10	0
Basidentitermes potens (Silvestri)	s	7	0
Termitinae Latreille			
Amitermes evuncifer (Silvestri)	w	0	14
Microcerotermes parvulus (Haviland)	w	1	0
Microcerotermes fuscotibialis (Sjöstedt)	w	10	8
Pericapritermes urgens (Silvestri)	s	1	0

FG: Feeding group; **f**: fungus-growers, **s**: soil-feeders, **w**: wood-feeders, and **g**: grass-feeders

Table 2. Metrics of termite diversity in the different land-use systems.

Habitats	Species richness	Estimated species richness (Jackk 1)	Sample coverage	Mean observed species richness per transect	Shannon's index	Simpson's index	Evenness	Similarity	Uniques	Total relative abundance
CNF	17	21.92	77.55%	15.66±1.36 ^{b}	2.37	0.88	0.83	0.33	5	147
CC	7	7.98	87.71%	6.33±1.02 ^{a}	1.66	0.78	0.76		1	79

Similarity between transects: mean similarity between transects of each site; Uniques: species collected only once in each habitat. Mean species richness with same letters (a, b, c) are not statistically different at p = 0.05 level.

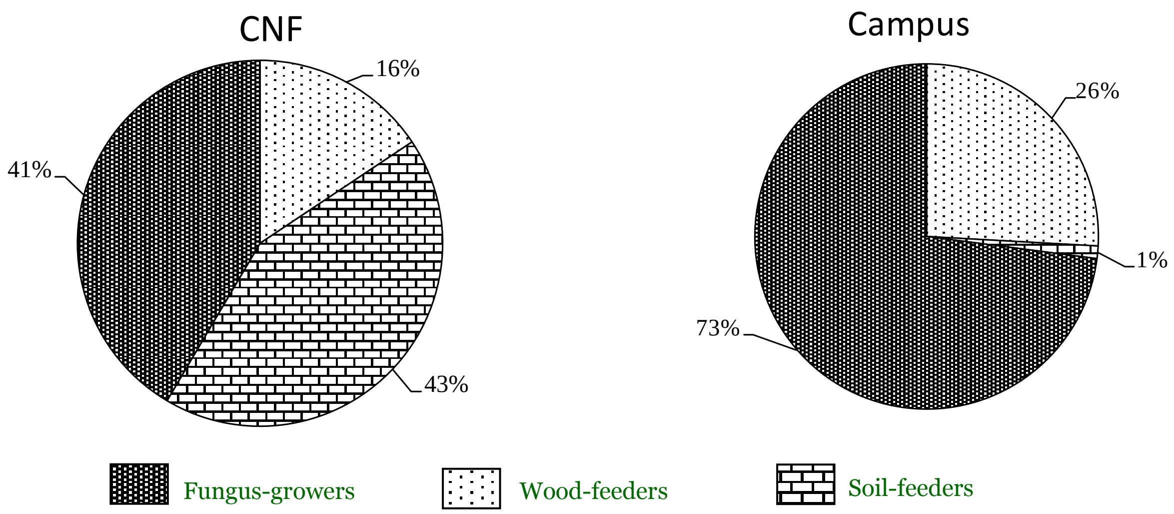

Fig. 2. Proportions of the feeding groups in different habitat types.

Discussion

Sampling efficiency

We evaluated sampling efficacy with sample-based rarefaction curves. The termite species richness was efficiently assessed in the campus area but was not efficiently assessed in the CNF. This fact was illustrated on the one hand by the plateau asymptote attained by the observed rarefaction curves in the campus area. Moreover, our results agreed with Chao *et al.,* 2005 about the link between the rarefaction curves and the number of unique species. According to these authors, the observed species accumulation curves level off when the number of unique species starts decreasing. Such a trend was observed in the present study for the campus area where few unique species (1 unique) were found contrary to the CNF (5 unique species). In this habitat, the trends indicated that additional samplings were required to provide an accurate picture of the pool of local species richness. However, our sampling provided a good picture of termite species composition after running three transects in the two habitats, with 82.63% of the expected termite species sampled. The sampling method was successfully applied, implying that our objective of examining the termite assemblage structure across habitat type could be addressed.

The termite assemblage

The study showed that the termite assemblage considerably shrinked in the campus area compared to the CNF. Termite species richness was high in the CNF however; it was considerably lower in the campus area. This fact could be a consequence of a higher disturbance level in the Campus area, where human pressure on habitats may be unfavorable for natural communities (Brooks *et al.,* 2002). The pressing need of using in the campus area, destruction of the forest for the construction of buildings and roads, passage of lawn mower, and student activities causing a decline in the variety and abundance of suitable nesting and feeding sites, as well as changes in microclimate. Many termite species occupy microhabitats such as rotting tree stumps, dead logs, humus around the base of trees and mounds of other species (Eggleton and Bignell, 1997, Jones *et al.,* 2003). Such microhabitats often disappear from an intensively used area. Many studies suggested that, termite species richness declined due to land use (Eggleton *et al.*, 2002; Jones *et al.,* 2003; Attignon *et al.*, 2005), habitat disturbance (Eggleton *et al.,* 2002) and habitat fragmentation (Davies, 2002).

Significantly more termites were collected in the CNF area than in the Campus area. This result could be explained by the cessation of the human activities in this area. The CNF then function as fallows. The important floral diversity in the CNF could have an effect on the recolonization of this area by termites. After several years, the litter was accumulated in this area and the canopy was developed. Moreover, the presence of dried branches fallen to the ground and the litter layer provide abundant trophic resources for termites, as well as a more humid microclimate more or less similar to a natural environment. The presence of this litter layer and dried branches which fall on the ground also constitute important sources of food for termites. In summary, the relative stability of the CNF, such habitats may provide variable food resources for nourishment and niches for nesting could explain his highest termite species richness and abundance. Our results were in agreement with those of Dosso *et al.*, 2012, who showed that the total species richness (15 species) observed in rural forests are significantly lower than protected forests located within Lamto reserve (25 species).

The fungus-growers' groups are dominant in all areas and they are less affected by the habitat degradation. Their ability to live in disturbed habitats is due to their remarkable adaptation favored by the symbiotic relationship they have with *Termitomyces* fungus. This fungus degrades wood fragments that become digestive for termites (Matoub, 1993; Guedégbé *et al.*, 2008).

The soil feeders group was a group of termites which was the most sensitive to habitat disturbance because the lowest proportion of this group was found (1%) in the campus area. This observation confirms the results obtained by many studies whose found that the abundance of soil feeder's termites was decreased due to habitat degradation (Eggleton *et al.,* 1995, 2002; Davies 2002; Jones and Prasad 2002; Jones *et al.*, 2003).

The presence of termites in the CNF could also accelerate the recovery of other communities in these areas. Many studies suggest that termite could constitute a food resource for a wide range of animals and their mound nests serve as refuge for a wide range of animals (inquilines), from other soil macrofauna (Choosai *et al.,* 2009) to small animals, such as birds, reptiles and mammals during unfavourable times (Dangerfield *et al.*,1988).

Conclusion

The CNF has restored termite species diversity and participated in its conservation.

The data obtained will be an important database in the documentation of CNF. This study could have interest to encourage the leaders of CNF to initiate a research project on knowledge of various aspects of fauna of CNF.

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