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Termitic Diversity of the Dalhia Fleurs Partial Natural Reserve (Bingerville, Côte d'Ivoire)

Akpa Alexandre Moïse Akpesse [a*], Diabaté Dohouonan [b], Coulibaly Tenon [c], Yavo Olivier Kouadja [a], Kouakou Herve Koua [a] and Kouassi Philippe Kouassi [a]

[a] Laboratory of Natural Environments and Biodiversity Conservation, UFR-Biosciences, Université Félix Houphouët-Boigny, 22 P.O. Box 582, Abidjan 22, Côte d'Ivoire.
[b] Department of Agronomy and Forestry, UFR Agronomic Forestry and Environmental Engineering, University of Man, BP 20 Man, Côte d'Ivoire.
[c] Department of Animal Biology, University Péléforo Gon Coulibaly of Korhogo, UFR Sciences Biologiques, BP 1328, Korhogo, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Termites play an important ecological role. The objective of this work is to evaluate the diversity of termites in two different ecosystems (primary forest and horticultural forest) of the Partial Dalhia Fleurs Natural Reserve (DFNR) In each ecosystem, three transects were carried out using the standardized rapid termite assessment method. A total of 20 species of termites were sampled. In the primary forest, 18 species were sampled and 16 species in the horticultural forest. These species belong to two families which are the Termitidae with 17 species and the Rhinotermitinae. These termites were *Macrotermes subhyalinus*, *Macrotermes bellicosus*, *Acanthotermes sp*, *Odontotermes sp*, *Ancistrotermes guineensis*, *Microtermes* sp, *Microtermes* sp2, *Procubitermes* sp, *Protermes* sp, *Pericapritermes* sp, *Microcerotermes parvus*, *Amphidotermes sp*, *Cubitermes fungifaber*, *Noditermes* sp, *Apilitermes* sp, *Amitermes guineensis* and *Trinervitermes sp*. The second family was that of *Rhinotermitidae* with 3 species namely *Coptotermes*

**Corresponding author: E-mail: alexakpesse@gmail.com;*

intermedius, Coptotermes sjöstedti and *Schedorhinotermes lamanianus*. Thus, the Dalhia Fleur Nature Reserve abounds in a significant wealth of termitic fauna. It is therefore important to protect it further.

Keywords: Biodiversity; horticultural forest; nature conservation; termites; primary forest.

1. INTRODUCTION

Termites play an important role in the functioning of tropical ecosystems. They participate in many ecosystem services, in particular the decomposition of organic matter and the evolution of the physico-chemical structure of soils [1,2]. In Africa, termites represent more than 70% of all identified animal species [3]. They represent about 65% of the soil fauna biomass. In addition, their diversity of insects, in particular termites, is linked to their ecosystem. They can also serve as biological indicators to estimate the state of degradation of ecosystems.

Indeed, the Dalhia Fleurs Natural Reserve (DFNR)presents a great floristic diversity, a vertical stratification, an abundance of lianas and epiphytes. It is rich in 446 species divided into 274 genera for 90 families with a dominance of *Tabernaemontana crassa, Pycnanthus angolensis and Ceiba pentandra* [4]. The most important family is that of Fabaceae, it is followed by that of Moraceae, Apocinaceae, Rubiaceae and Malvaceae. It provides several ecosystem services, in particular support services. These include soil, hydrological and ecological functions. The reserve now plays a role of carbon storage, protection of the groundwater table for the supply of drinking water to the city of Abidjan. Carbon sequestration by trees is an ecosystem service that regulates the climate. To this end, studies conducted by Monssou et al. [4] have shown that it stores 194.3 tons of carbon. In addition, ethnobotanical studies carried out around the RNPDF have identified 7 plant species, 4 of which are mainly used by humans in ornamentation, pharmacopoeia and food [4]. It is now the subject of several scientific researches and considered as a center of environmental education. Faced with the threat (fragmentation of habitat and urbanization) that prevails on biodiversity, protected areas are today the subject of sustained attention because they are considered to be the last bastions of biodiversity conservation. Biodiversity is now conserved in the networks of national parks and nature reserves created by the State, with a view to safeguarding its biological heritage. Since then, many studies have followed one another and have made it possible to assess the state of conservation of natural and transformed ecosystems. The first studies on termites in Côte d'Ivoire were carried out by Bodot [5] in lower Côte d'Ivoire, in the Lamto savannah. These also made it possible to know species of termites. However, few studies have been carried out on the diversity of termites subservient to the Dalhia Fleurs Natural Reserve. Thus, this work is part of the conservation of the biodiversity of the genera of termites present in the Dalhia Fleurs Natural Reserve (DFNR).

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in the primary forest (91 ha) and in the horticultural forest (57 ha) of the Dalhia Fleurs Natural Reserve (DFNR). The primary forest is rich in plant species with an average density of 531.1 stems/ha [4]. The horticultural forest has been more anthropized due to horticulture. This Natural Reserve is a tropical rainforest located in the south of Côte d'Ivoire, in the district of Abidjan, east of the municipality of Bingerville (longitude 3°54’25” and 3°55’24” West and latitude 5°21’57” and 5°22’23” North) (Fig. 1). It was devoted to horticulture for several years and even in the 1960s by the late Italian Barbetta. It was set up as a biodiversity and ecotourism reserve, and its management was entrusted to the OIPR (Ivorian Office of Parks and Reserves) by decree number 00895/MINEEF/ of October 17, 2007, with the new name the "Partial Natural Reserve of Dalhia Fleur". The climate is of the subequatorial type with four seasons. Two dry seasons from December to March and from August to September, and two rainy seasons from March to July, and from October to November. Despite its relatively small area, the Reserve has a forest micro-climate. The climate of the reserve is characterized by high rainfall reaching 350 mm in the month. The average annual rainfall is 1475 mm. The average monthly daytime temperatures vary between 25 and 30°C. The soil is essentially ferralitic, with a well-marked humus horizon and a poorly developed gravelly horizon [4].

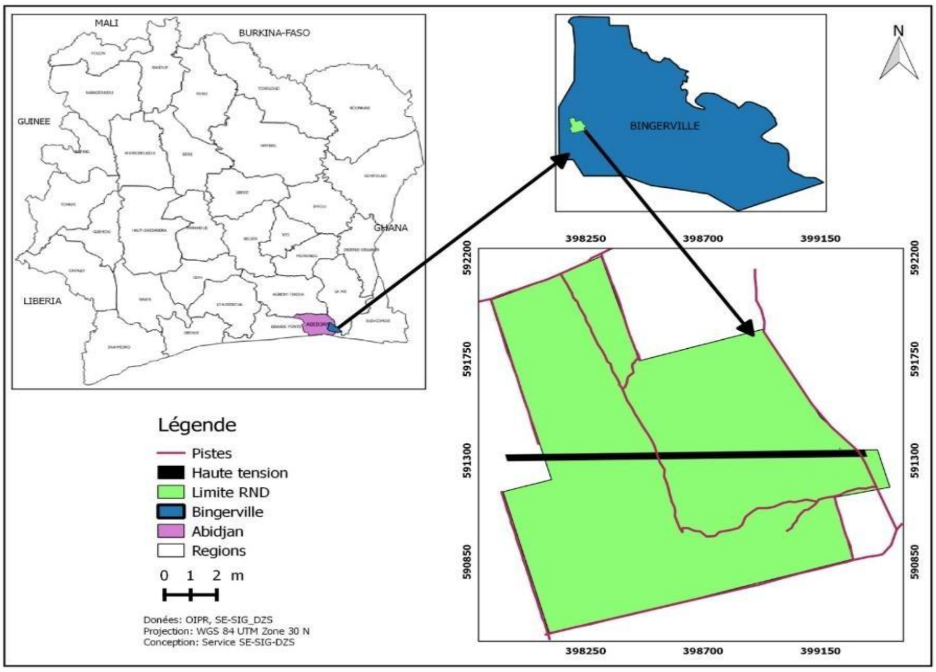

Fig. 1. Location of the Nature Reserve

2.2 Sampling and Conservation of Termites in Forests

Sampling of termites was carried out in three transects of 100 meters long and 2 meters wide in each type of vegetation. Each transect is divided into 20 sections of 10 m² (5m x 2m). Then, the excavation of the 20 sections was done successively by sections along the transects for the collection of termites (Fig. 2).

The first step was to rummage through the litter. For this purpose, the debris of leaves and tree branches strewn on the ground are lifted, broken and carefully examined. Also, aboveground nests present on the ground are chipped and placed in sorting trays (Figs. 3 and 4).

The second step consisted in collecting the termites present on the trunks of trees up to 1.5 m in height. Thus, the over ground nests stuck to the trees are also chipped and placed in sorting trays.

Termites are sampled using entomological forceps. The samples from each section are kept in a pillbox filled three-quarters of its volume with 70% alcohol. The last step consisted in taking two monoliths per transect in order to know the subterranean termites (Fig. 5). All the termites harvested in a section are kept in the same pill box containing alcohol at 70° and labeled.

2.3 Termites' Identification

The identification of the termites was made in the laboratory using a binocular magnifying glass according to the morphometric parameters of the termites based on the morphology of the soldiers. Several parameters have been used by many different authors to perform termite observations and measurements [6].

Four qualitative characters and eight quantitative characters were observed and measured. The qualitative characters are the color and shape of the head, the shape of the pronotum and the presence of mandibular teeth. The quantitative characters are the number of antennal segments, the length of the head (from the posterior edge of the head to the external base of the mandibles), the median width of the head, the length of the left mandible (from the point of insertion from the mandible to the top of the mandible), the length of the head with mandibles (from the posterior edge of the head to the top of the mandible), the length of the gula, the median width of the gula, the length of the left posterior tibia [7]. The genus and species of each lot were determined using the identification keys [8-10]. After this determination, the individuals are counted before being put back into the pillboxes.

Fig. 2. Transect in horticultural forest

Fig. 3. Sampling on horticultural tree trunk

Fig. 4. Sampling in fungus-growers nest

Fig. 5. Monolith

2.4 Calculation of Ecological Indices

Several indices were used to describe the populations of termites present on the sites.

2.4.1 Frequency of occurrence (F)

The frequency of occurrence expressed as a percentage [11] is the ratio of the number of records containing the species studied (Pi) to the total number of records (P). The general formula was:

$$F\ (\%) = \frac{\mathrm{Pi\ x\ 100}}{\mathrm{P}}$$

with: F < 5%: rare species, 5% ≤ F < 25%: accessory species, 25% ≤ F < 50%: frequent species and 50% ≤ F < 100%: constant species; F = 100%: ubiquitous species.

2.4.2 Biological diversity

Specific richness (S):

Species richness (S) corresponds to the total number of termite species sampled in a given environment [12].

Shannon index:

The specific diversity can be evaluated by a diversity index that takes into account both the specific richness and the abundance of the different species. The Shannon index (H') takes into account the number of taxa encountered on a plot. It neglects the rare species present in the environment. It is zero when there is only one taxon and its value is maximum when all the taxa have the same abundance. This index was calculated using the following formula:

$$H' = -\Sigma\ pi * \log2\ (pi)$$

pi = probability of encounter of species i, pi= ni /N with ni = number of individuals of species i, N = total number of individuals.

Equity index:

Also called evenness index, equitability (E) measures the equitable distribution of species. It makes it possible to compare stands comprising different numbers of taxa [13]. Its objective is to observe the balance of the populations present.

$$E = \frac{\mathrm{H'}}{\log 2\ (S)}$$

Simpson's index:

Simpson's index (D) [12] (Morin and Findlay 2001) evaluates the probability that two individuals, randomly drawn from an infinite population of N individuals, belong to the same species. It is calculated according to the following formula:

$$D = \sum_{i=1}^{s} Pi^2$$

D = Simpson's index. The index "derived" from the Simpson index (IS = 1-D) was used. This index varies between 0 and 1. The diversity is minimum for an index equal to = 1 and maximum for an index equal to 0.

Jaccard's index:

The similarity index (Jaccard) or diversity β is a measure of biodiversity that makes it possible to compare the diversity of species between ecosystems. This implies comparing the number of taxa that are unique to each of the ecosystems. It was calculated according to the following formula:

$$Sj = \frac{\mathrm{a}}{(\mathrm{a} + \mathrm{b} + \mathrm{c})}$$

a = number of species common to both plots b = number of species observed only on plot A; c = number of species observed only on plot B. This index varies from 0 (absence of similarity) to 1 (identical environments) [13].

2.5 Statistical Processing

Species richness and biological diversity indices were calculated with Estimate software version 9.11, 2013.

3. RESULTS

3.1 Species Diversity of Primary and Horticultural Forest Species

The sampling of termites in the primary and horticultural forest made it possible to collect 20 species. These belong to two families: the Rhinotermitidae family comprising two subfamilies (Coptotermitinae and Rhinotermitinae) and the Termitidae family divided into 5 subfamilies (Amitermitinae, Macrotermitinae, Nasutermitinae, Cubitermitinae and Termitinae). The species common to both environments (Primary and Horticultural Forest) are 14 in number, which are: *Coptotermes intermedius, Coptotermes sjöstedti, Macrotermes subhyalinus, Macrotermes bellicosus, Odontotermes sp, Ancistrotermes guineensis, Microtermes sp, Procubitermes sp, Protermes sp, Pericapritermes sp, Microcerotermes parvus, Amphidotermes sp, Cubitermes fungifaber* and *Amitermes guineensis* (Table 1).

3.2 Generic Species Diversity in Primary and Horticultural Forest

Generic diversity is expressed by the number of genera present in a given medium. The identification of the harvested termites made it possible to identify 17 genera across the two forests. These genera were *Coptotermes, Schedorhinotermes, Macrotermes, Odontotermes, Acanthotermes, Ancistrotermes, Microtermes, Procubitermes, Protermes, Pericapritermes, Microcerotermes, Amphidotermes, Cubitermes, Amitermes, Noditermes, Apilitermes* and *Trinervitermes*. Among these different genres, 6 are not common to the two environments. These were *Acanthotermes, Microcerotermes, Apilitermes, Noditermes* and *Schedorhinotermes* (Fig. 6).

3.3 Termite Diversity Index

Several biological indices in occurrence, the Shannon, Equitability, Simpson and Jaccard indices allowed us to appreciate the diversity of species in the two forests (Table 2).

The analysis of the index values reveals that the Shannon diversity index was substantially identical in the Primary Forest and that of the Horticultural Forest with respective values of 3.871 and 3.786.

The Evenness Index (E) of the termites of the Primary Forest and that of the Horticultural Forest have a highest values and also substantially identical with respectively 0.928 and 0.946 as values. These values reflect the balance of termite populations present in the two environments (E > 0.80).

The Simpson's index (SI) did not vary and is substantially equal from one forest to another. This index is 0.923 for the Primary Forest and 0.920 for the Horticultural Forest.

The Jaccard similarity index is relatively high with a value of 0.7 greater than 0.5 and tending towards 1. This value indicates that the biological diversity of the two environments is substantially equal.

Table 1. Termite species encountered in primary and horticultural forests

Families	Sub- families	Genrera/species	Trophic groups	Primary forest	Horticultural forest
Rhinotemitidae	Coptotermitinae	*Coptotermes intermedius*	X	*	*
		Coptotermes sjöstedti	X	*	*
	Rhinotermitinae	*Schedorhinotermes lamanianus*	X		*
Termitidae	Macrotermitinae	*Macrotermes subhyalinus*	C	*	*
		Macrotermes bellicosus	C	*	*
		Acanthotermes sp	C	*	
		Odontotermes sp	C	*	*
		Ancistrotermes guineensis	C	*	*
		Microtermes sp	C	*	*
		Microtermes sp2	C	*	
		Procubitermes sp	H	*	*
		Protermes sp	C	*	*
	Termitinae	*Pericapritermes* sp	H	*	*
		Microcerotermes parvus	X	*	*
		Amphidotermes sp	X	*	*
	Cubitermitinae	*Cubitermes fungifaber*	H	*	*
		Noditermes sp	H		*
		Apilitermes sp	H	*	
	Amitermitinae	*Amitermes guineensis*	X	*	*
	Nasutermitinae	*Trinervitermes* sp	F	*	
Total	-	-	-	18	16

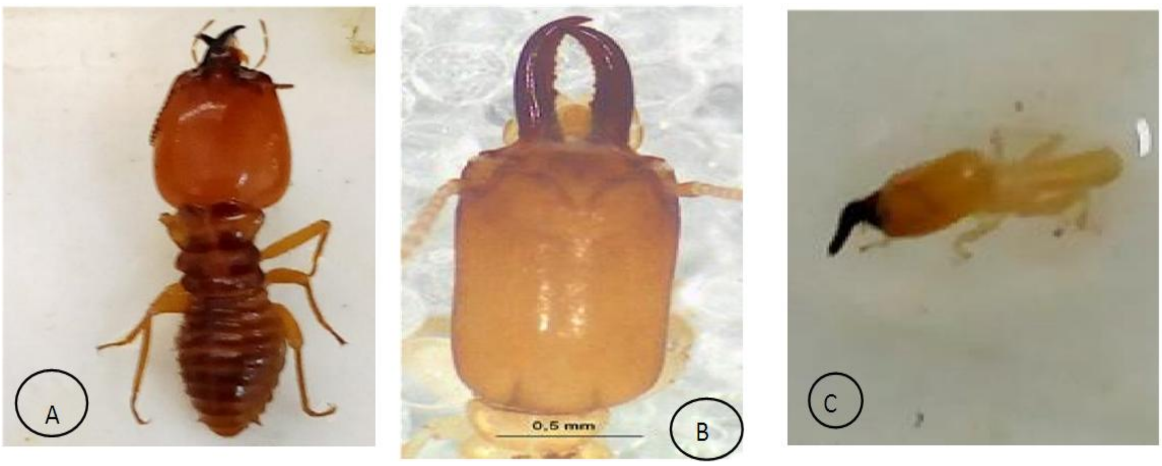

Fig. 6. Some species of termites collected in the forest (A = *Macrotermes bellicosus*, B = *Microcerotermes parvus*, C = *Pericapritermes* sp)

Table 2. Termite biological diversity indices

Clues	Primary forest	Horticultural forest
Specific richness	18	16
Shannon (H')	3,871	3,786
fairness (E)	0,928	0,946
Simpson (Is)	0,923	0,92
Jaccard (Sj)	0,7	-

3.4 Frequency of Occurrence

The analysis of the frequencies of occurrence of termites from the Primary forest showed a dominance of the group of fungus-growers with an overall occurrence of around 189.97%. In this group, the frequent species are: *Microtermes* and *Ancistrotermes*. Other fungus-growers were considered incidental species. The overall frequency of occurrence of wood-feeeders comes second after fungus-growers with 99.98% presence. Common species are: *Amitermes* and *Coptotermes*. The other of wood-feeeders were considered accessory species. In third position were soil-feeders, with an overall frequency of occurrence of 74.98%. This group was dominated by the presence of the only common species, *Cubitermes*. The other soil-feeders are accessory species (Table 3).

At the level of the Horticultural Forest, the frequencies of occurrence of termites showed a dominance of the group of fungus-growers with an overall occurrence of 115.31%. The frequent species is *Microtermes sp*, the other fungus-growers were considered as accessory species. The overall occurrence frequency of wood-feeeders has a presence value of 93.32%. In view of the occurrences, all species are considered incidental. In third position were soil-feeders, with an overall frequency of occurrence of 54.99%. In this group all the species were accessory (Table 4).

3.5 Trophic Group

With regard to the trophic groups, the Primary forest is composed of 4 trophic groups whose fungus-growers were represented with a rate of 43% followed by soil-feeders (31%), wood-feeeders (24%) and grass-feeders (2%) (Fig. 7).

The Horticultural Forest is made up of 3 trophic groups dominated by wood-feeeders (36%), followed by fungus-growers (34%) and soil-feeders (30%) (Fig. 8).

Table 3. Frequency of occurrence of termites in the primary forest

Group trophics	Species	Occurrence frequency (%)	Total (%)
Wood-feeeders	*Microcerotermes parvus*	16.66	
	Amphidotermes sp	16.66	
	Amitermes guineensis	30	99.98
	Coptotermes intermedius	20	
	Coptotermes sjöstedti	16.66	
Fungus-growers	*Microtermes sp*	43.33	
	Microtermes sp2	25	
	Acanthotermes sp	16.66	
	Odontotermes sp	16.66	
	Protermessp	16.66	189.97
	Ancistrotermes guineensis	30	
	Macrotermes bellicosus	18.33	
	Macrotermes subhyalinius	23.33	
Soil-feeders	*Cubitermes fungifaber*	26.66	
	Procubitermes sp	15	
	Pericapritermes sp	16.66	74.98
	Apilitermes sp	16.66	
Grass-feeders	*Trinervitermes sp*	18.66	18.66

Table 4. Frequency of occurrence of termites in the horticultural forest

Trophic groups	Species	Occurrence frequency (%)	Total (%)
Wood-feeeders	*Microcerotermes parvus*	18,33	
	Amphidotermes sp	15	
	Amitermes guineensis	20	93,32
	Schedorhinotermes lamanianus	6,66	
	Coptotermes intermedius	18,33	
	Coptotermes sjôstedti	15	
Fungus-growers	*Microtermes sp*	38,33	
	Odontotermes sp	6,66	
	Protermes sp	12	115,31
	Ancistrotermes guineensis	21,66	
	Macrotermes bellicosus	16,66	
	Macrotermes subhyalinus	20	
Soil-feeders	*Cubitermes fungifaber*	16,66	
	Procubitermes sp	13,33	54,99
	Pericapritermes sp	15	
	Noditermes sp	10	

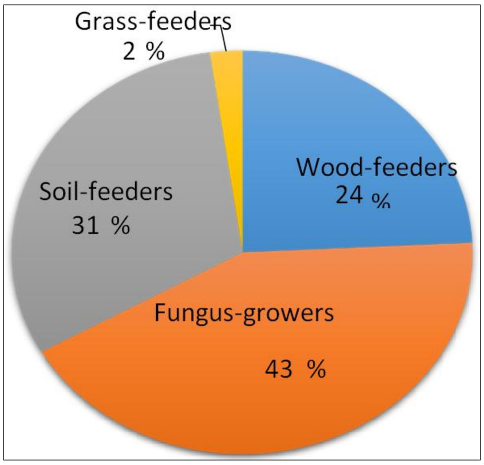

Fig. 7. Distribution of termites from the Primary Forest according to trophic groups

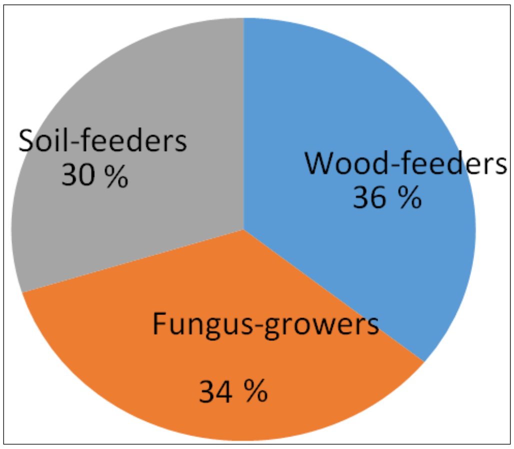

Fig. 8. Distribution of termites from the Horticultural Forest according to trophic groups

4. DISCUSION

4.1 Specific Diversity

The transect method recommended by Jones and Eggleton [14] and used between September and November 2020 made it possible to collect 20 species of termites in the Dalhia Fleurs Natural Reserve (DFNR). The termites collected in the two habitats (primary and horticultural forest) are classified into two families, namely the Termitidae family and the Rhinotermitidae family. The most important is that of the Termitidae which includes 5 subfamilies (*Macrotermitinae, Termitinae, Cubitermitinae, Amitermitinae, Nasutitermitinae*). The second family as for it gathers two Sub-families; Rhinotermitinae and Coptotermitinae. The ecological indices (H'= 3.871 for the primary forest and H'= 3.786) are substantially identical; which shows that these two biotopes have common traits in terms of termite species richness. With the exception of *Acanthotermes sp* and *Microtermes sp* found in the primary forest and *Schedorhinotermes lamaninus* in the horticultural forest, the species are common. Indeed, the specific diversity of termites is often conditioned by factors such as vegetation, climate and more particularly edaphic factors. However, this specificity can be explained at two levels: on the one hand to the heterogeneity of the primary forest not favoring the observation of all the micro-habitats and on the other hand because the horticultural forest has been strongly anthropized at due to horticulture and agriculture, which could negatively impact the specific.

4.2 Richness of this Ecosystem

The frequencies of occurrences observed at the level of the different denotes that, this forest, compared to the sampling area and its overall area is rich in termite species. These results are close to those of Konaté et al. [15], who working in the high Dodo Forest and at Cavally in Côte d'Ivoire obtained 21 and 24 species of termites respectively. This slight difference would be linked on the one hand to the surface sampled, the methods used and the sampling period and on the other hand to similar habitats. On the other hand, the work of Tra-Bi et al. [16] carried out in the Center-West of Côte d'Ivoire, in Oumé, made it possible to identify 34 species belonging to 3 families. This significant difference would be related to the extent of harvesting with 51 transects carried out. These studies were in a climatic zone (Subtropical climate) different from that of the southern region because, according to some authors, the diversity and specific abundance of termite fauna are linked to the plant species present in the ecosystem. In addition, the specific richness of one biotope to another varies according to edaphic and climatic factors.

4.3 Trophic Diversity

In the primary and horticultural forest, the harvested termites mainly belong to the trophic group of fungus-growers with respectively 44 and 41% of the species. This finding is consistent with the ecological traits of fungus-growers species, particularly *Odontotermes sp, Microtermes sp* and *sp2, Ancistrotermes guineensis, Macrotermes bellicosus*, which have an ability to adapt to various environments and varied food preferences. According to dietary habits, after the fungus-growers, follow the wood-feeeders; with 28% in primary forest and 35% horticultural forest, then soil-feeders with 22 and 24% and finally the furriers identified in the primary forest represent 6% of the species harvested. Our results are in agreement with those of Tra-bi et al. [16], who working in the forests of Taï and in agrosystems were able to show that the abundance of termites decreases from fungus-growers to wood-feeeders to grass-feeders. This richness can be explained by the fact that the superficial horizon is rich in organic matter, which would favor the abundance of fungus-growers. In addition, the harvests carried out in the short rainy season allow a good harvest of the termite fauna, in particular the fungus-growers. This idea corroborates with that of Sarr [17], for whom the densities of termites are greater at the beginning and at the end of the rainy seasons. for whom the densities of termites are greater at the beginning and at the end of the rainy seasons [18,19].

5. CONCLUSION

The analysis of the two parameters, namely the termitic diversity and the trophic diversity in the two clothes, made it possible to identify 20 species of termites divided into 16 genera: *Amitermes, Amphidotermes, Acanthotermes, Ancistrotermes, Aplitermes, Coptotermes, Cubitermes, Macrotermes, Nasutitermes,* *Noditermes, Odontotermes, Pericapritermes, Procubitermes, Protermes, Schedorhinotermes* and *Trinervitermes. Among these species, except Acanthotermes, Schedorhinotermes* and *Trinervitermes*, all other species are common. The different results obtained show that the sampled forests are very close in terms of termite faunal richness. At the trophic level, the analysis of the results reveals the fungus-growers are the most numerous overall. These are followed by wood-feeders, soil-feeders and grass-feeders with a very small proportion. In view of all the above, the Dalhia Fleurs Natural Reserve (DFNR), despite its small area and the area sampled, testifies to a wealth of termite fauna. It is therefore important to safeguard them to consider their multiple functions in natural systems and even if possible to regulate their evolution in agronomic systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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