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Diversity and abundance of terrestrial mammals in the northern periphery of Tanoe-Ehy forest in rainy season (South-eastern of Côte d'Ivoire)

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Abstract

The Tanoé-Ehy Marsh Forest (TEMF), an unprotected forest that is about to be turn into a voluntary nature reserve is a forest block in south-eastern Côte d'Ivoire known as being of great importance for the conservation of biodiversity. But in the rainy season, that forest is largely over flooded and terrestrial mammals are likely to move to the periphery and make them vulnerable to anthropogenic threats. Our objectives are to determine the diversity, the relative abundance of terrestrial mammals and their spatial distribution in the northern periphery of the TEMF during the rainy season. We collected data by conducting recce surveys after interviews with local people. In total, we obtained 33 species among which ten primates' species were identified. According to the recce survey, the African Civet (*Civettictis civetta*) and the Bushbuck (*Tragelaphus scriptus*) are the most common and abundant species in the study area with 12.7% and 12.0% of relative abundance respectively. In addition, six of the listed species are on the IUCN Red List, including *Piliocolobus waldronae*, a critically endangered species, *Cercocebus lunulatus* and *Cercopithecus roloway* endangered species, *Colobus vellerosus*, *Phataginus tetradactyla* and *Phataginus tricuspis*, three vulnerable species. Thus, the consideration of the periphery for the sustainable management of the TEMF is proving to be an imperative.

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Introduction

For decades, and all over the world, the decline of forests, particularly wetlands, has continued, both in terms of area and quality (Gardner *et al.*, 2015). Several authors had reported that deforestation is associated with the loss of local animal biodiversity (Brash, 1987; Turner *et al.*, 1994). In Côte d'Ivoire, western Africa, since 1960 about 67% loss of the original forest cover has been recorded (Koné, 2016). Tanoe-Ehy Marsh Forest (TEMF) covers 12,000 ha in south-eastern Côte d'Ivoire. It represents a refuge zone for the original mammals of the region and where the stakes of conservation are immense (Oates *et al.*, 2000; Béné *et al.*, 2012), It is recognized as a priority site for the biodiversity conservation (Zadou *et al.*, 2011; Ahon *et al.*, 2012). However, this forest massif has undergone several threats over the past decades, the main ones being poaching, logging and agricultural clearing. To mitigate the threats, several actions have been initiated and have resulted in the willingness of local communities to conserve the forest and turn it into a Voluntary Nature Reserve. Nevertheless, the pressures are not weakening. For instance, logging and agricultural activities are growing in terms of area covered. However, forests with marshy character, where access remains difficult, seem to be spared such as the TEMF. In the rainy season, the rare emerging lands within this swamp forest are completely flooded. As a result, many mammal species of the forest could migrate to more suitable areas including the periphery where land is still accessible. Due to the marshy character of the TEMF and the difficulties for accessing it in the rainy season, few attempts have been made to investigate the diversity and abundance of terrestrial mammals that occur there during that wet season. However, knowing mammals' species that occur at the periphery of the forest during the rainy season is important to provide insight to animal's seasonal movement pattern and guiding conservation decision-making.

The objectives of this work are to determine the diversity, the relative abundance of terrestrial mammals as well as their spatial distribution throughout the periphery of TEMF.

Materials and methods

Study area

The TEMF is located in the extreme south-east of Côte d'Ivoire (Fig. 1). The average temperature is 26° C with an average annual rainfall ranging between 1400 and 1600 mm (Brou *et al.*, 2005). Data were collected during the rainy season in May 2018 and the material used for this study includes:

- a field guide as described by Kingdon in 2004 was used for mammals' identification;

- a GARMIN 62ST GPS for recording the geographical coordinates of the observations of animals and their signs (droppings, footprints, trails, vocalizations);

- a pair of BUSHNELL AS00366 (8x42) binoculars to facilitate distant observations;

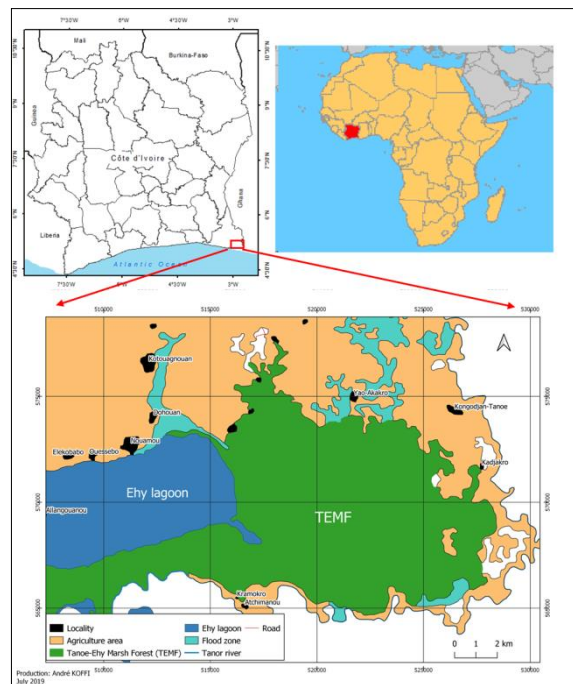- a compass for orientation in the forest;

Fig. 1. Location of Tanoe-Ehy Marsh Forest.

Experimental procedure

Two methods were used for data collection: interviews and recce surveys.

Interview

To choose interviewee, we focused mainly on hunters and farmers whose have their agricultural plantations near the forest through guided interviews in each of

four nearest villages neighboring the north periphery of TEMF: Nouamou, Dohouan, Kotouagnuan and Yao-Akakro (Fig. 1). The survey questionnaire used for the interview consisted of collecting information on the mammal species observations made in the month preceding the survey, the location and the type of observations. Applicants are also asked to compile an exhaustive list of terrestrial mammals existing on the study site, and their relative abundance. The Jonathan Kingdon's guide of African mammals is submitted to the respondent to identify the species mentioned.

Recce survey

The recce consisted of walking through farms at the forest periphery and in the forest within a 500-meter strip on both sides of the forest boundary. The survey team of two persons walked slowly and silently so as to observe the terrestrial mammals or their presence indices (cries, footprint, food remains, burrow, track, dung) (Oates *et al.*, 2000). On each survey route in the forest, 15 minutes of listening and observations points distant consecutively by 500 meters were performed in addition to the reconnaissance walk. With the help of a local field guide, all the presence indices from any mammal species identified without doubt and their number were recorded as well as their geographical coordinates. Some survey routes took place in open areas such as wind throw or agricultural plantations at the edge of the forest while others in closed areas like forest with closed canopy.

We used recce survey because it may be one of the best methods for collecting terrestrial mammal data in the study area. This method favors visual contact with any species likely to be present in the study area (N'Gaba, 2015). It has been used in similar studies in TEMF, (Béné and Akpatou, 2007).

Analysis of Results/Data

The relative abundance of mammal species or their encounter frequency calculation follows the Lougbegnon formula (Lougbegnon *et al.*, 2012) concerning interviews data:

F = number of times species (i) is cited/sum of the number of times all species were cited.

The relative abundance of mammal species calculation with recce data was carried out according to the N'Gaba formula (N'Gaba, 2015):

F = number of observations of a species i / total number of observed indices.

Data from recce were also used to have biodiversity richness of terrestrial mammals that was obtained by calculating the Shannon's diversity index and equitability index of Pielou:

- Shannon: $H' = -\Sigma$ pi x log2 (pi), for the specific richness (Magurran, 2004), (pi = relative abundance of species i);

- Pielou: E = H'/ log2 (g), to compare stands with different numbers of taxa (Dajoz, 1982), (g = specific richness).

With the use of Excel (2013) software, the geographical coordinates of the observations were organized and recorded for each order of terrestrial mammals under text file. This was used, through the QGIS 2.2.0 software to produce the terrestrial mammal order distribution map. The international conservation status of the terrestrial mammal species was determined by reference to the IUCN Red List (IUCN, 2019).

Results

Species richness, relative abundance and conservation status of terrestrial mammals

According to the interviews, a total of 33 mammal species were identified and are grouped into 29 genera, 16 families and six orders (Table 1). The most abundant terrestrial mammal species are the bushbuck representing 6.9% of the species mentioned, the African civet 6.2%, the Slender-tailed squirrel and the greater cane rat with 5.2% each. In contrast, the least abundant species are the Pel's flying squirrel, the long-tailed pangolin, the Miss Waldron's red colobus each with a relative abundance of 1%. The white-bellied pangolin has the lowest relative abundance (0.5%). At the international level, among the 33 mammal species mentioned, some are listed on the IUCN red list of endangered species:

• one species listed as critically endangered (CR) is Miss Waldron's red colobus;

• two endangered species (EN), the white-naped mangabey and the Roloway monkey;

• three vulnerable species (VU), the Geoffroy's colobus, the long-tailed pangolin and the white-bellied pangolin;

• three Near Threatened Species (NT), the olive colobus, the African Clawless Otter and the Spotted-necked Otter.

The recce survey recorded 276 observations belonging to 22 species 20 genera, 11 families and five orders. The family of Cercopithecidae, with six species is the most diversified family. The Shannon diversity index (H') of 2.78 and the Pielou equitability index of 0.90 indicate that the biodiversity richness of the site is quite important, and that the species have almost the same dominance. However, some species (African civet, bushbuck, Gambian pouched rat, slender-tailed squirrel) emerge from the lot somewhat. The African civet and the bushbuck with 12.7% and 12.0% encounter rates respectively are the most frequent in the site (Table 1). The less abundant species are the Roloway monkey, the olive colobus and the Long-tailed pangolin with each 0.4% of the collected indices. Regarding families, Bovidae have the highest relative abundance with 17.8% of the indices collected, followed by Sciuridae with 15.6%. The lowest indices were recorded in the Nandiniidae and Manidae families.

Table 1. Species richness, abundance and international conservation status of mammal species.

| Family | Common Name | Scientific Name | Interview | | recce | | IUCN statuts (2019) |
			Number of time species cited	Relative abundance (%)	Observation number	Relative abundance (%)	
Carnivora							
Herpestidae	Common kusimanse	*Crossarchus obscurus*	13	3,2	21	7,6	LC
	Common slender mongoose	*Herpestes sanguineus*	10	2,5	6	2,2	LC
	Marsh mongoose	*Atilax paludinosus*	5	1,2	9	3,3	LC
Mustelidae	African clawless Otter	*Aonyx capensis*	15	3,7			NT
	Spotted-necked Otter	*Lutra maculicollis*	15	3,7			NT
Nandiniidae	African palm civet	*Nandinia binotata*	5	1,2	4	1,4	LC
Viverridae	Cape genet	*Genetta tigrina*	5	1,2			LC
	African civet	*Civettictis civetta*	25	6,2	35	12,7	LC
Cetartiodactyla							
Bovidae	Maxwell's duiker	*Philantomba maxwellii*	11	2,7	6	2,2	LC
	Royal Antelope	*Neotragus pygmaeus*	13	3,2	10	3,6	LC
	Bushbuck	*Tragelaphus scriptus*	28	6,9	33	12	LC
Suidae	Red River Hog	*Potamochoerus porcus*	10	2,5	10	3,6	LC
Hyracoïdea							
Procaviidae	Southern tree hyrax	*Dendrohyrax arboreus*	10	2,5			LC
Pholidota							
Manidae	Long tailed pangolin	*Phataginus tetradactyla*	4	1	1	0,4	VU
	White-bellied pangolin	*Phataginus tricuspis*	2	0,5			VU
Primates							
	Olive colobus	*Procolobus verus*	7	1,7	1	0,4	NT
	Geoffroy's colobus	*Colobus vellerosus*	9	2,2	2	0,7	VU
Cercopithecidae	Miss Waldron's red colobus	*Piliocolobus waldronae*	4	1			CR
	White-naped mangabey	*Cercocebus lunulatus*	14	3,5	8	2,9	EN
	Roloway monkey	*Cercopithecus roloway*	7	1,7	1	0,4	EN
	Lowe's monkey	*Cercopithecus lowei*	18	4,4	11	4	LC
	Spot-nosed monkey	*Cercopithecus petaurista*	16	4	18	6,5	LC
Galagidae	Thomas's Dwarf galago	*Galagoides thomasi*	10	2,5			LC
	Demidoff's Dwarf galago	*Galagoides demidoff*	11	2,7			LC
Lorisidae	West African potto	*Perodicticus potto*	7	1,7			LC
Rodentia							
Anomaluridae	Pel's flying squirrel	*Anomalurus pelii*	4	1			LC
Hystricidae	African brush-tailed porcupine	*Atherurus africanus*	19	4,7	19	6,9	LC
Cricetidae	Gambian pouched rat	*Cricetomys gambianus*	17	4,2	25	9,1	LC
Sciuridae	Slender-tailed squirrel	*Protoxerus aubinnii*	21	5,2	25	9,1	DD
	Western palm squirrel	*Epixerus ebii*	16	4	10	3,6	LC
	Forest giant squirrel	*Protoxerus stangeri*	17	4,2	8	2,9	LC
	Green bush squirrel	*Paraxerus poensis*	16	4			LC

| Family | Common Name | Scientific Name | Interview | | recce | | IUCN statuts (2019) |
			Number of time species cited	Relative abundance (%)	Observation number	Relative abundance (%)	
Thryonomyidae	Greater cane rat	*Thryonomys swinderianus*	21	5,2	13	4,7	LC
Total			405	100	276	100	

DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered

Spatial distribution of mammals

In the rainy season, terrestrial mammals can be found as well in open habitats (53%) as in closed environments (47%). However, encounters in open environments are slightly larger. These open areas generally consist of agricultural areas, logging sites or windfalls. Spatial distribution of mammals according to taxonomic orders, at the northern periphery of the forest during rainy season is highlighted (Fig. 2). Cetartiodactyla, Rodentia and Carnivora follow almost identical distribution all along the periphery. Pholidota is represented by a single species (*Phataginus tetradactyla*) recorded in the northwest of the study area.
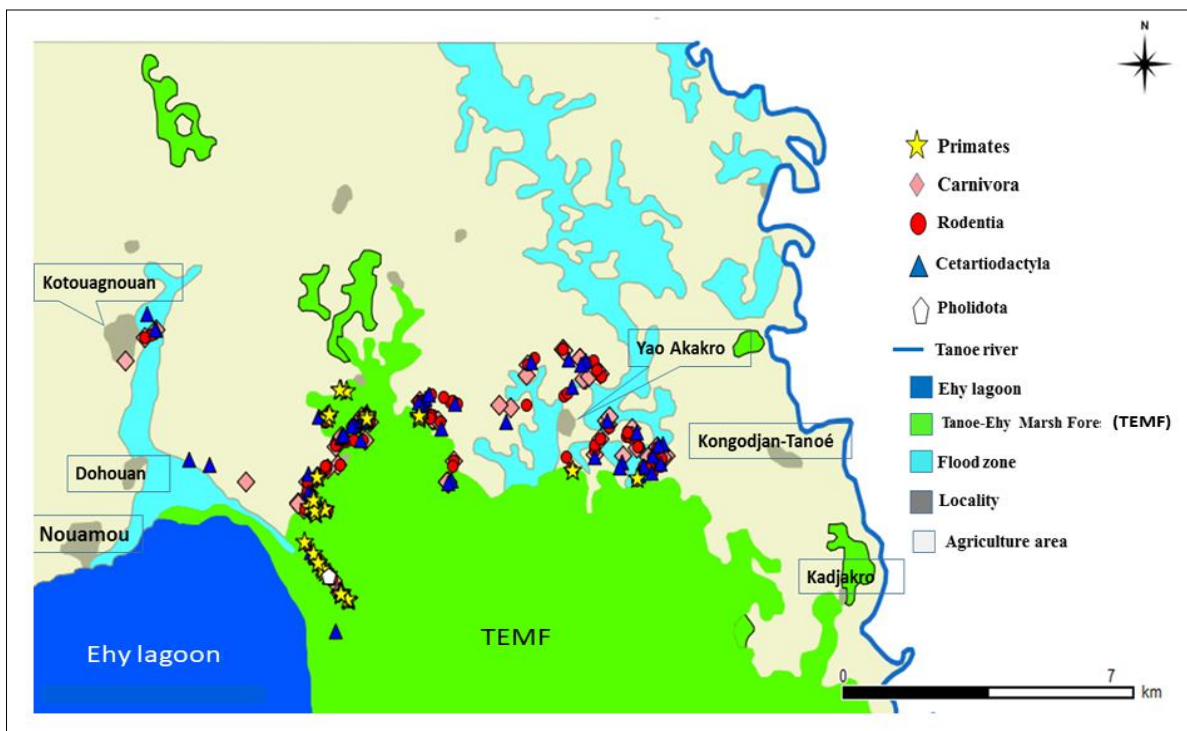

Fig. 2. Spatial distribution of taxonomic orders of terrestrial mammals.

Discussion

The survey of local populations identified 33 mammal species, while reconnaissance walks method (recce) identified 22 species. Most species not confirmed by this second method are nocturnal species such as representatives of Viveridae or aquatic species like those of Mustelidae or very rare species like Miss Waldron's red colobus. These are discrete species, hardly detectable from the recce method. However, a survey of mammals conducted in the forest by researchers in 2007 using the same method of recce revealed a lower mammal species richness (16 species) (Béné and Akpatou, 2007). The difference with the present study could be explained by the difference of the seasons (dry season in their case during which animals are dispersed throughout the forest and its periphery). Alternatively, the difference of the sampling sites could explain the contrasting results. Indeed, the work of these researchers took place inside this swampy forest where animals for the most part are hardly observable as well as their tracks. However, several species encountered by them were also observed by our team.

The relative abundance calculated for each species reveals that for both methods, the African civet, the bushbuck and the slender-tailed squirrel are the most frequently observed. The least abundant species are white-bellied pangolin, long tailed pangolin, Miss Waldron's red colobus, Pel's flying squirrel according to interviews whereas, the recce survey mentions long tailed pangolin, olive colobus, Roloway monkey, Geoffroy's colobus as the least observed. In addition to Miss Waldron's red colobus which is a critically endangered species and declared extinct by some authors (Oates *et al.*, 2000), there are other species with special status. Roloway monkey and White-naped mangabey are two endangered species while Geoffroy's colobus is vulnerable and Olive colobus near threatened. These species with special status make TEMF a "hotspot" for conserving biodiversity for mammal species (Gonedelé, 2008). Also, the Shannon diversity index (H' = 2.78) indicates that the mammals' richness of the study area is important compared to indices recorded in the Marahoué National Park (H' = 1.83) in the central Côte d'Ivoire and Boumba-Bek National Park (H' = 2.18) in Cameroon (N'Gaba, 2015; Kadjo *et al.*, 2014). The mammals' biodiversity richness could be explained by the fact that this forest is the only large forest still best preserved in the region. Because of its swampy nature and therefore hardly practicable, many hunters would not venture there. As a result, it has become a refuge for local wildlife. But other largely documented factors that explain the species richness of animals in different habitats include environmental heterogeneity, increasing available space in ecological niches, isolation possibilities and divergent adaptation, coexistence, persistence and diversification of species (Tews *et al.*, 2004; Stein *et al.*, 2014).

At the periphery of the forest, animals can be found in both closed and open environments, but a little more in an open environment (53%). Open forest environments, also known as clearings, are focal points for wildlife. These clearings are nuptial arenas, places of grazing, places of rest, etc. (Noupa and Nkongmeneck, 2008). In the present study, the open areas consist mainly of cassava, maize, oil palm and cocoa fields, most of which are in production in the rainy season. There is therefore an important availability of food resources for rodents and Cetarcodactyla, hence their massive presence along the entire periphery of the forest. The presence of these taxa on the periphery would also attract the carnivores who are their predators. Thus, one could explain the important presence of carnivores also on the periphery of the forest in the same places as rodents and cetartiodactyls. This reveals an interdependence of trophic relationships between different animal species (Loreau, 1996; Thébault and Loreau, 2005).

Conclusions

At the end of this work, 33 terrestrial mammal species were identified by interview and 22 confirmed by field sampling, including six species on the IUCN Red List. The African civet, the bushbuck and the slender-tailed squirrel have the highest relative abundance. The order distribution map shows that the species are abundant and distributed along the northern periphery of the TEMF during the rainy season. However, because of the many human activities recorded in the site, the animals could be threatened. Therefore, the sustainable management of fauna of the TEMF will have to go through a better management of its periphery. We plan to survey in the dry season inside the forest to compare the results that will be obtained with those of this study.

Contribution of authors

Research concept- Dr. Djaha André Koffi

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Supervision- Dr. Jean-Claude Koffi Béné

Data collection- Mr N'draman Jean Jacques Donatien Kassi

Data analysis and interpretation- Dr. Djaha André Koffi, Mr N'draman Jean Jacques Donatien Kassi

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Writing articles- Dr. Djaha André Koffi, Mr N'draman Jean Jacques Donatien Kassi

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Article editing- Dr. Djaha André Koffi

Final approval- Dr. Jean-Claude Koffi Béné

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