Acta Tropica 112 (2009) 308–315

Contents lists available at ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

Influence of habitat and seasonal variation on wild mammal diversity and distribution with special reference to the *Trypanosoma brucei gambiense* host-reservoir in Bipindi (Cameroon)

Jacques Anselme Massussi[a,*], Champlain Djieto-Lordon[b], Flobert Njiokou[c], Claude Laveissière[d], Jan Douwe van der Ploeg[e]

[a] *Institute of Agricultural Research for Development, P.O. Box 167, Meyomessala, Cameroon*
[b] *Yaoundé I University, Zoology Laboratory, Room 154, P.O. Box 812, Yaoundé, Cameroon*
[c] *Yaoundé I University, Laboratory of General Biology, Room 131, P.O. Box 812, Yaoundé, Cameroon*
[d] *IRD Campus International de Baillarguet, 34398 Montpellier Cedex 5, France*
[e] *Wageningen University and Research Centre, Department of Social Science, P.O. Box 8130, NL-6700, EW, Wageningen, The Netherlands*

ARTICLE INFO

Article history:
Received 30 July 2009
Accepted 11 August 2009
Available online 2 September 2009

Keywords:
Human African trypanosomiasis
Wild mammals
Animal density
Trypanosoma brucei gambiense
Glossina palpalis palpalis
Habitat types

ABSTRACT

To evaluate the role of wildlife in the resurgence and perenisation of human African trypanosomiasis (HAT), we investigated the influence of habitat and seasonal variations on the diversity and spatial distribution of wild mammals, with special reference to those recognised as potential host-reservoirs of *Trypanosoma brucei gambiense* in Bipindi (southwestern Cameroon). To achieve this, we carried out transect surveys in four habitat types over two years. A total of 31 mammal species were recorded, of which 14 occurred in the undisturbed forest, 9 in cocoa plantations, 11 in farmlands and 11 in village-adjacent gallery forests. Among them, six species (*Cephalophus monticola*, *Cephalophus dorsalis*, *Atherurus africanus*, *Cricetomys emini*, *Nandinia binotata* and *Cercopithecus nictitans*), known as reservoir hosts of *T. b. gambiense*, occurred in all kinds of habitats suitable or unsuited to *Glossina palpalis palpalis* and in all seasons. These species are the most involved in the transmission cycle (human being/tsetse flies/wild animals). *Cercopithecus cephus*, *Miopithecus talapoin* and *Heliosciurus rufobrachium* host *Trypanosoma brucei* spp.; however, only *C. cephus* does not occur permanently in the suitable habitat of *G. palpalis palpalis*. In general, some species (*C. monticola*, *Tragelaphus spekei* and *C. emini*) showed a slight density increase from the long dry to the heavy rainy season within the undisturbed and farmland habitats, and a slight decrease within cocoa plantations and village-adjacent forests in the same period. The density of *A. africanus* increased greatly from the long dry season to the heavy rainy season in the undisturbed forest while, the density of primates in this habitat decreased slightly from the long dry season to the heavy rainy season. These variations indicate a permanent movement of wild mammal reservoir or feeding hosts from one biotope to another over the seasons. *Thryonomys swinderianus* needs to be investigated because it occurs permanently in the suitable habitat of *G. palpalis palpalis* and *Potamochoerus porcus* for its genetic similarities to domestic pigs, favourable feeding hosts of *G. palpalis palpalis*.

1. Introduction

In central Africa, a resurgence of sleeping sickness has been observed in old foci since the early 1970s, and in the 1990s the prevalence was comparable to that of 1930 (OMS, 1996). Until the early 1990s, *Trypanosoma brucei gambiense* (the parasite responsible for the human African trypanosomiasis) was considered to be transmitted by a fly of the genus Glossina only from man to man (Asonganyi and Ade, 1994). It was thus believed that the residual reservoir of infection responsible for the resurgence was in human populations, despite the fact that *Glossina palpalis palpalis* feeds not only on humans, but also on domestic and wild animals (Mehlitz, 1986). For instance, experimental infestations carried out in several countries have revealed the potential role of some domestic and wild mammals as reservoirs for trypanosomes (Mehlitz et al., 1982; Zillmann et al., 1984). Moreover, various field studies highlighted the reservoir potentialities of some livestock (pigs, dogs, sheep, goats and cattle) and wild mammal species (African brush-tailed porcupine, blue duikers and giant rats) (Gibson et al., 1978; Scott et al., 1983; Tai et al., 1984; Mehlitz, 1986; Paindavoine et al., 1986; Noireau et al., 1986). These results were confirmed by those obtained with molecular techniques (Truc et al., 1997; Herder et al., 2002; Njiokou et al., 2006).

* Corresponding author. Tel.: +237 22 28 86 38; fax: +237 22 23 35 38.
E-mail address: massuja@gmail.com (J.A. Massussi).

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doi:10.1016/j.actatropica.2009.08.027

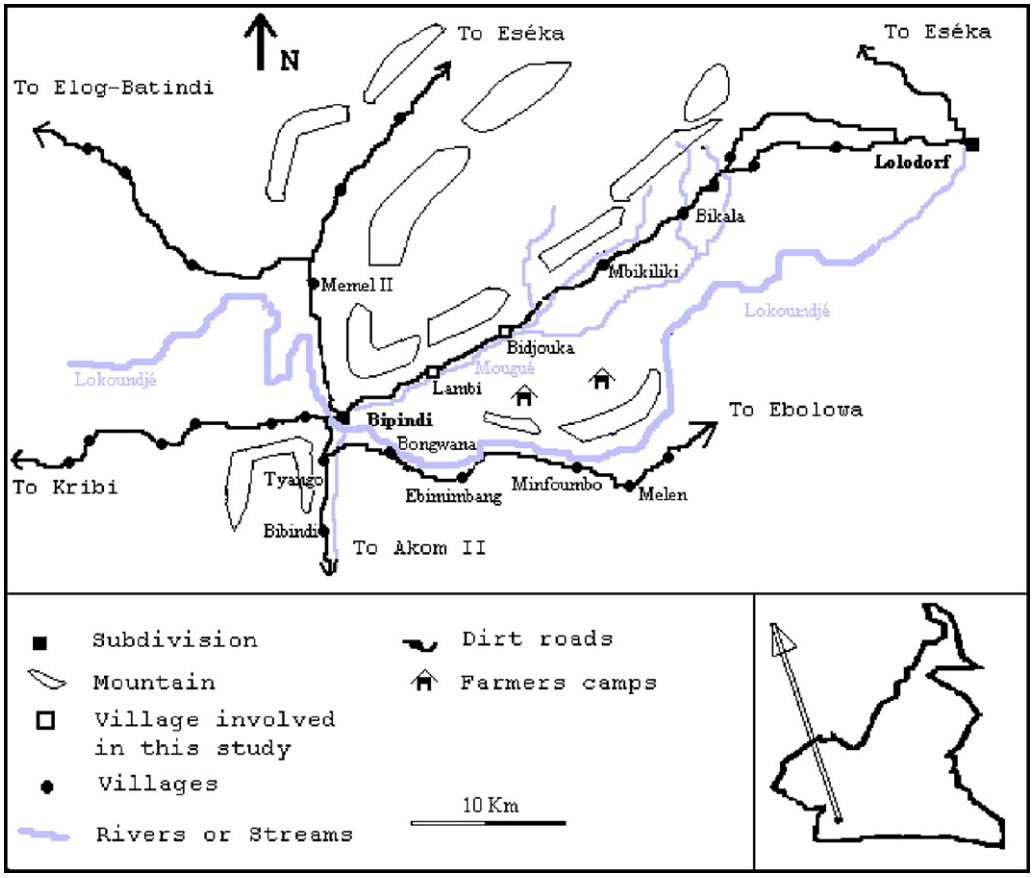

Fig. 1. Map of Cameroon and location of the Bipindi area modified from Grébaut et al. (2001).

In Cameroon, parasitological methods used until the early 1990s failed to reveal the role of domestic and/or wild animals as reservoir hosts of *T. b. gambiense* (Asonganyi et al., 1986, 1990; Dukes et al., 1990; Berl et al., 1992). Since 1994, studies using molecular techniques revealed the reservoir role (8 species) and feeding role (18 species) of wild mammals (including primates, rodents, ungulates, small carnivores) (Herder et al., 2002; Njiokou et al., 2004) and consequently their implication in the resurgence of HAT.

This discovery indicated the existence of a triangular transmission scheme of *T. b. gambiense* involving the vector (tsetse flies), the terminal host (human), and the reservoir hosts (livestock and wild animals). However, the importance of wild animals in this scheme remained unknown. Therefore, a multidisciplinary project aimed at collecting data for a better understanding of HAT resurgence in Bipindi was implemented. In this framework, the objective of the present work was to study the spatial distribution of wild mammals, hosts of *G. palpalis palpalis* in the Bipindi area with particular reference to habitat preference and seasonal cycles.

2. Methodology

2.1. Study site

The study was carried out in Bipindi (3°06′–3°68′N, 10°70′–11°E) (Fig. 1) located in the main active focus of HAT in Cameroon (Grébaut et al., 2001). The climate is equatorial with four seasons: a heavy rainy season from September to mid-November, a small rainy season from mid-March to mid-June, a long dry season (mid-November to mid-March) and a short dry season from July to August. The annual average rainfall is about 2000 mm (Van Dijk, 1999) and the mean annual temperature is about 25 ± 3 °C.

The study area belongs to the Atlantic Biafran district of the humid evergreen forest. Because of human pressure (extensive logging and agriculture) the local vegetation can be subdivided into village-adjacent forest, farmlands and fallows (rich in *Macaranga-Chromolaena*), cocoa plantations and the undisturbed forest. The area is surrounded by hills and several streams run along vegetation types and villages.

The population density is low, about 7 inhabitants/km^2 (Van Dijk, 1999), consisting of a majority of Bantu groups (Ngumba, Bassa, Fang and Bulu tribes) and a pygmy minority (Bagyeli). Most of the Bagyeli people live in small settlements in the forest at about 7–10 km from roads and Bantu villages, but also in some permanent project settlements where medical care and schooling are available. The main activities are hunting–gathering (mostly by pygmies), shifting cultivation and cocoa cropping (mainly by the Bantu).

2.2. Data collection

Seven line transects were established in two villages, of which two (1 km each) were installed in the undisturbed forest (about 7 km from the village), two (1 km each) in the farmlands and fallows, two (0.5 km each) in cocoa plantations and one (0.5 km) in the village-adjacent forest.

Four surveys (2 diurnal and 2 nocturnal) were completed on each transect line per season by a team of four persons (two researchers and two local specialised hunters) in 2003. In 2004 only diurnal surveys were completed on the same transect per season. Therefore, twenty-four surveys were completed in two

Table 1
Species richness in each biotope in the Bipindi area. Count data were obtained from 14 surveys conducted in four seasons over two years.

Biotopes	Und. Forest[a]				Cocoa Pl.[b]				Farm/Fall.[c]				Vil-Adj Fo[d]			
Seasons	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs
Primata	3	3	3	2	0	4	1	0	0	0	O	1	1	1	0	0
Rodentia	2	3	3	3	3	4	3	4	2	4	4	4	2	4	2	3
Carnivora	1	3	3	3	1	2	2	2	1	3	2	2	0	3	1	1
Artiodactyla	3	4	4	5	1	3	2	2	0	3	5	2	0	3	2	3
T. Nb. of species	9	13	13	11	5	13	8	8	3	6	11	9	3	11	5	7

SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season; T. Nb. of species: total number of species.
[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.

years (2003–2004). Standardised sheets were used to record direct observations and indirect evidence (dung, tracks, vocalisation, feeding signs and animal carcasses). For each direct observation, the data recorded included (1) the species observed, (2) its location along the transect, (3) the perpendicular distance from the animal to the transect, (4) the activity of the animal, (6) the estimated number of animals seen in case of groups. Daily surveys started between 06h30 and 08h00 AM and night surveys between 07h00 and 08h00 PM. Daily survey on each transect lasted about 3–3h30 and night surveys 1h30–2 h. Surveys were conducted by walking along the transect at a speed of 0.3–0.4 km/h. Small breaks of 5–15 min were taken each 100 m to hear the vocalisations of animals.

2.3. Data analysis

Data recorded were pooled according to the seasons and the biotopes and the animal densities computed for each biotope per season. All sightings (live animal observed, tracks, dung, feeding signs) were pooled for the determination of animal densities (White and Edwards, 2001). Therefore, the density of species i (1,...,16) in biotope j (1,...,4) during the season t (1,...,4) and seasonal survey occasion k (1,...,4) is given by the formula:

$$\mathbf{D}_{ijtk} = \frac{\mathbf{N}_{ijtk}}{2w_{jtk}\mathbf{L}_j\mathbf{P}}$$

where **N** is the total number of sightings for species i in biotope j and seasonal survey occasion k, **w** the effective strip width obtained on each side of the transect in biotope j at season t and at seasonal survey occasion k, **L** the transect length in biotope j at season t and at seasonal survey occasion k. **P** (0.607) is the probability of detection (White and Edwards, 2001).

To test the spatio-temporal patterns of the distribution of each animal species, estimated densities were analysed. At each level (biotope), ANOVA was used with time (seasonal occasion) (Mayaka Bileng, 2002). Finally, the Student–Newman–Keuls procedure was used to separate significantly different means (Steel and Torries, 1981). All these analyses were carried out on SPSS 12.0.

3. Results

3.1. Species richness of the Bipindi area and diversity of species potential host-reservoirs of T. b. gambiense

A total of 31 mammal species belonging to six orders namely Artiodactyla, Rodentia, Carnivora, Primata, Pholidota and Hyraxes (Table 1) were recorded. In the statistical analysis, the species considered as rare or less common in the area, or not observed or seen during the survey but known to exist and captured by hunters were excluded. These species consisted of the Royal antelope (*Neotragus pygmaeus*), the Ogilby's duikers (*Cephalophus ogilbyi*), Peter's duiker (*Cephalophus callipygus*), Red-backed flying squirrel (*Anomalurus erythronotus*), Large-spotted Genet *(Genetta tigrina)* and the small-spotted genet (*Genetta servalina*), the Golden potto (*Arctocebus calabarensis*), the galago (*Perodicticus potto*), the gorilla (*Gorilla gorilla*), the chimpanzees (*Pan troglodytes*), the mandrills (*Mandrillus sphinx*), the Pholidota (*Manis gigantea*, *M. tricuspis* and *M. tetradactyla*), and Tree dassie (*Dendrohyrax arboreus*).

Among the species considered in the analysis, 14 occurred in the undisturbed forest, 10 in cocoa plantations, 10 in fallows/farmlands and 10 in village-adjacent forests (Fig. 2). Six of these species have been recognised as reservoir hosts of *T. b. gambiense* and ten host *T. brucei* spp. Reservoir host species consisted of ungulates (*Cephalophus monticola* and *Cephalophus dorsalis*), rodents (*Cricetomys emini* and *Atherurus africanus*), small carnivores (*Nandinia binotata*) and primates (*Cercopithecus nictitans*) (Table 2). Ungulates

Table 2
Diversity of mammal species hosting *T. b. gambiense* and *T. brucei* spp. in the Bipindi area.

Species	Biotopes			
	Und. Forest[a]	Cocoa Pl.[b]	Farmland Pl[c].	Vil-Adj Fo[d]
Ungulates				
Cephalophus monticola	A	A	A	A
Cephalophus dorsalis	A	A	A	A
Cephalophus silvicultor	E	E	E	E
Tragelaphus spekei	B	B	B	B
Potamochoerus porcus	C	D	D	D
Rodentia				
Cricetomys emini	A	A	A	A
Heliosciurus rufobrachium	B	B	B	B
Atherurus africanus	A	A	A	A
Thryonomys swinderianus	D	C	C	C
Carnivora				
Nandinia binotata	A	A	A	A
Viverra civetta	E	E	E	E
Crossarchus obscurus	B	B	B	B
Primates				
Miopithecus talapoin	D	B	B	B
Cercopithecus cephus	B	B	D	D
Cercopithecus mona	B	D	D	D
Cercopithecus nictitans	A	A	D	D

A: reservoir host of *T. b. gambiense*; B: reservoir host of *T. brucei* spp.; C: not investigated for *T. b. gambiense* and *T.brucei* spp.; D: not occurring; E: not reservoir host of *T. brucei* spp.
[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.

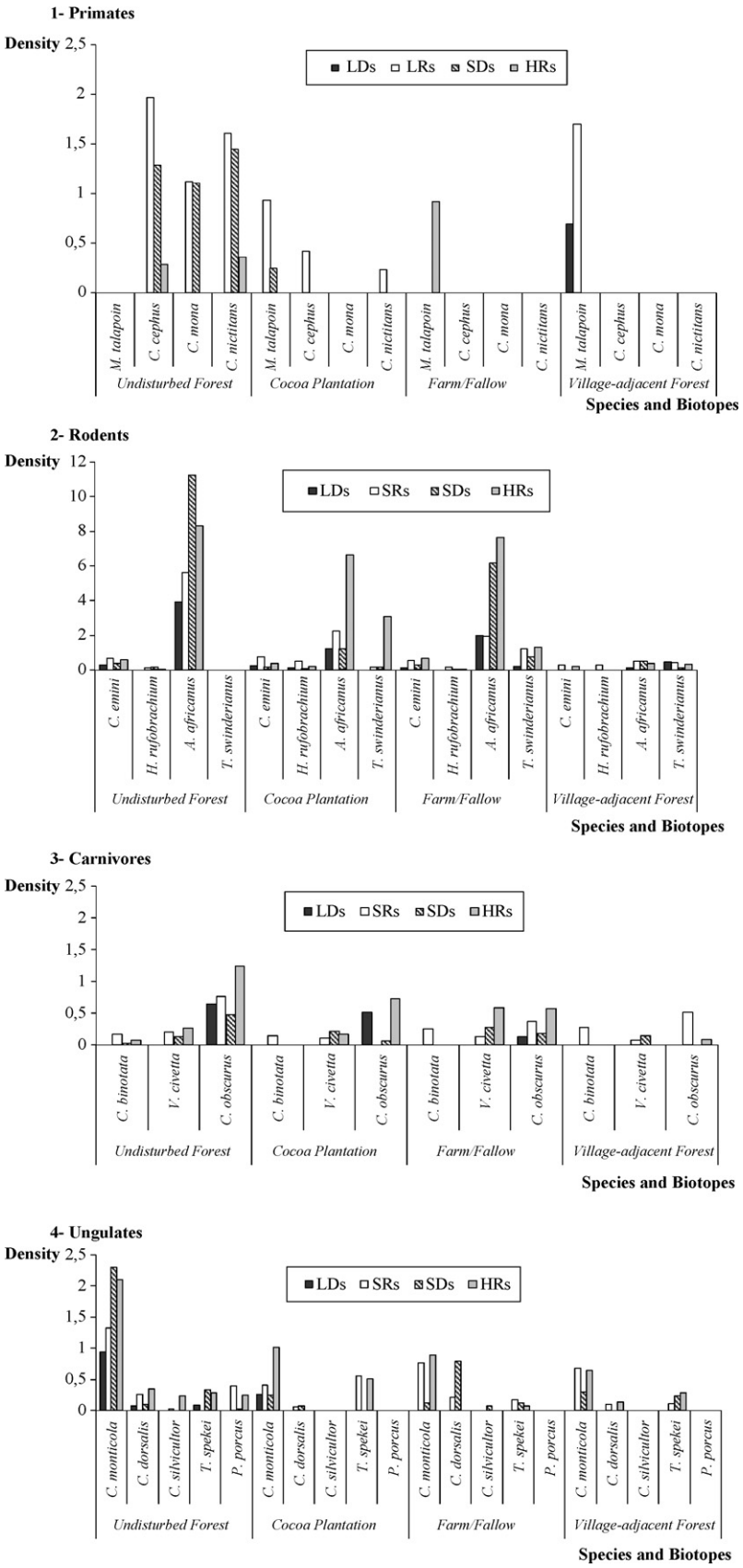

Fig. 2. Seasonal variation of mammal species density in four biotope types. LDs: long dry season, SRs: small rainy season, SDs: short dry season, HRs: heavy rainy season.

Table 3
Mean density per square kilometre (and standard errors in parentheses) of most frequent mammal species found in Bipindi. Data obtained from 14 surveys conducted in four seasons (2003–2004) over two years. SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season.

Species	Biotopes				
	Und. Forest[a]	Cocoa Pl.[b]	Food Pl.[c]	Vil-Adj Fo[d]	All
Ungulates					
Cephalophus monticola	1.77(0.34)	0.47(0.16)	0.49(0.18)	0.46(0.18)	0.82(0.13)
Cephalophus dorsalis	0.2(0.05)	0.05(0.03)	0.33(0.22)	0.07(0.04)	0.17(0.06)
Cephalophus silvicultor	0.06(0.03)	0	0	0	0.02(0.1)
Tragelaphus spekei	0.18(0.03)	0.3(0.15)	0.12(0.05)	0.18(0.1)	0.19(0.05)
Potamochoerus porcus	0.19(0.09)	0	0	0	0.06(0.02)
Rodentia					
Cricetomys emini	0.51(0.08)	0.41(0.13)	0.44(0.09)	0.15(0.07)	0.39(0.05)
Heliosciurus rufobrachium	0.14(0.05)	0.26(0.12)	0.08(0.04)	0.09(0.06)	0.15(0.04)
Atherurus africanus	7.91(2.39)	2.77(0.99)	4.62(1.65)	0.41(0.12)	4.13(0.86)
Thryonomys swinderianus	0	0.79(0.46)	0.9(0.25)	0.31(0.11)	0.53(0.14)
Carnivora					
Nandinia binotata	0.09(0.03)	0	0.08(0.03)	0	0.07(0.02)
Viverra civetta	0.18(0.05)	0.15(0.08)	0.27(0.12)	0.07(0.04)	0.17(0.04)
Crossarchus obscurus	0.77(0.11)	0.25(0.11)	0.33(0.09)	0.18(0.1)	0.09(0.06)
Primates					
Miopithecus talapoin	0	0.39(0.31)	0	0.59(0.31)	0.29(0.12)
Cercopithecus cephus	1.15(0.32)	0	0	0	0.34(0.1)
Cercopithecus mona	0.74(0.25)	0	0	0	0.23(0.08)
Cercopithecus nictitans	1.1(0.3)	0	0	0	0.31(0.09)

[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.

and rodents occurred in all kinds of habitat types and in all seasons but their densities varied. Accordingly, *N. binotata*, the only carnivore reservoir host of *T. b. gambiense* recorded occurred only in the undisturbed forest and farmland. Finally, in the primate group, *C. nictitans* was sighted in the undisturbed forest and farmland habitat.

3.2. Densities and distribution in different habitat types of mammal species according to seasons

The mean animal densities of each species were computed according to seasons and biotopes. The results are given in Tables 3, 4, 5 and 6.

Among ungulates (Table 4), only the Blue duiker (*C. monticola*), the Black striped duiker (*C. dorsalis*) and the Sitatunga (*Tragelaphus spekei*) occurred in all kind of habitats. *C. monticola* was significantly abundant in the undisturbed forest and its density increased gradually from the long dry season to the heavy rainy season. During the long dry season, no ungulate species was sighted in the farmland habitat and the village-adjacent forest. Furthermore, the densities of *C. monticola* showed very highly significant biotope effect ($p \leq 0.001$) but no significant season variation ($p \geq 0.05$). The yellow-backed duiker (*Cephalophus silvicultor*), rare in all kinds of habitats, was recorded only in the undisturbed forest and the farmland habitats. The densities of this species were very low and showed no significant biotope and seasonal differences ($p \geq 0.05$). The Bush pig (*P. porcus*) was encountered only in the undisturbed forest during the small rainy season, the short dry season and the heavy rainy season.

Rodents were relatively common in all habitats but their densities varied according to biotopes and seasons (Table 5). In fact, the Cane rat (*Thryonomys swinderianus*) occurred only in cocoa plantations, the farmland habitats and the village-adjacent forest with densities varying significantly ($p \leq 0.05$) according to biotopes and seasons. The African brush-tailed porcupine (*A. africanus*), the most abundant species of this group occurred in all biotopes. However, its density showed a significant biotope effect ($p \leq 0.05$) but no significant seasonal variation ($p \geq 0.05$). The Giant rat (*C. emini*) occurred also in all kinds of habitats but no significant difference ($p \geq 0.05$) of its densities was observed among biotopes; however, a significant density variation was recorded according to seasons ($p \leq 0.05$). The Sun squirrel (*H. rufobrachium*) occurred in all kind of habitat types; its densities showed no significant biotope and seasonal effects ($p \geq 0.05$).

Small carnivores were encountered in all four habitat types (Table 6). The Dark mangoose (*Crossarchus obscurus*) occurred in the undisturbed forest and the farmland habitats in all seasons. In the village-adjacent forest, this species was sighted only during the rainy seasons; while in cocoa plantations, they occurred all the year except in the small rainy season. The densities of mangoose showed highly significant biotope effects ($p \leq 0.01$) and significant seasonal variation ($p \leq 0.05$). In fact, this species moves in large groups from one biotope to another feeding by scratching the ground for eggs, insects, worms and lizards. The African civet (*Viverra civetta*) and the palm civet (*N. binotata*) were sighted in all biotopes during the small rainy season and were not observed in the long dry season. However, no significant biotope and season effects ($p \geq 0.05$) of *V. civetta* densities were recorded; while *N. binotata* showed highly significant season effects ($p \leq 0.01$) but no significant biotope effects ($p \geq 0.05$).

Primates in general occurred mainly in the undisturbed forest and cocoa plantation (Fig. 2) where the food and hiding habitats were available. However, one species, *Miopithecus talapoin* was observed only along Mougue River in the village-adjacent forest. In cocoa plantations and fallows/farmlands, *M. talapoin* moved all the day from place to place looking for food. The primate densities are given in Table 4. In general, they decreased from the small rainy season to the long dry season. During this last season, only *M. talapoin* was sighted in the village-adjacent forest. *Cercopithecus cephus*, *Cercopithecus mona* and *C. nictitans* showed highly significant variation of densities among biotopes ($p \leq 0.001$) (see Table 7) and no significant variation between seasons ($p \geq 0.05$).

Table 4
Mean density per square kilometre of ungulates found in Bipindi area. Data obtained from 14 surveys conducted in four seasons (2003–2004) over two years.

Species	Biotope																	
	Und. Forest[a]				Cocoa Pl.[b]				Farm/Fall.[c]				Vil-Adj Fo[d]				Probab.	
	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	F_a	F_b
C. monticola	0.94	1.33	2.29	2.11	0.26	0.41	0.24	1.01	0	0.77	0.11	0.89	0	0.68	0.29	0.64	***	ns
C. dorsalis	0.08	0.26	0.09	0.35	0	0.06	0.07	0	0	0.21	0.78	0	0	0.1	0	0.14	ns	ns
C. silvicultor	0	0.03	0	0.23	0	0	0	0	0	0	0.07	0	0	0	0	0	ns	ns
T. spekei	0.09	0	0.32	0.28	0	0.56	0	0.51	0	0.17	0.12	0.08	0	0.11	0.23	0.29	ns	ns
P. porcus	0	0.39	0.02	0.25	0	0	0	0	0	0	0	0	0	0	0	0	*	ns

SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season. *Fa*: *F*-test according to biotopes; *Fb*: *F*-test according to seasons; Probab.: probability; ns: not significant.
[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.
* $p \leq 0.05$.
*** $p \leq 0.001$.

Table 5
Mean density per square kilometre of rodents found in the Bipindi area. Data obtained from 14 surveys conducted in four seasons (2003–2004) over two years.

Species	Biotope																	
	Und. Forest[a]				Cocoa Pl.[b]				Farm/Fall.[c]				Vil-Adj Fo[d]				Probab.	
	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	F_a	F_b
C. emini	0.31	0.67	0.33	0.61	0.27	0.75	0.13	0.39	0.14	0.53	0.28	0.69	0	0.30	0	0.21	ns	*
H. rufobrachium	0	0.12	0.14	0.05	0.11	0.52	0.06	0.23	0	0.18	0.02	0.06	0	0.31	0	0	ns	ns
A. africanus	3.95	5.62	11.23	8.34	1.22	2.25	1.20	6.65	2.00	1.95	6.15	7.64	0.11	0.50	0.48	0.39	*	ns
T. swinderianus	0	0	0	0	0	0.19	0.15	3.07	0.21	1.23	0.73	1.31	0.45	0.42	0.09	0.33	*	*

SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season. *Fa*: *F*-test according to biotopes; *Fb*: *F*-test according to seasons; Probab.: probability; ns: not significant.
[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.
* $p \leq 0.05$.

4. Discussion

4.1. Dispersal and potential migration of potential host-reservoir of T. b. gambiense

Some of the species sighted in the present study are known to host *T. brucei* spp., namely the blue duiker, the black striped duiker, sitatunga (ungulates), the giant rat, the sun squirrel, the African bush-tailed porcupine (rodents), the palm civet (carnivore), the dwarf guenon, the moustached monkey and the greater white-nosed monkey (primates) (Herder et al., 2002). In general, the distribution of these species depended on their habitat requirements including food, water, resting and hiding places and their adaptability to environmental variations.

Many streams and rivers run through the study area, and around the village, making the water available. In the vicinity of farmland habitats and cocoa plantation, some streams dried up during the long dry season so that water holes were mainly localised in the undisturbed forest. During the long dry seasons, animal densities decreased in the village-adjacent forest, the farmland habitats and cocoa plantations and increased in the undisturbed forest during the same period. These water holes are also suitable habitats for tsetse flies because the offer favourable reproductive and resting conditions (Laveissière et al., 2000).

Table 6
Mean density per square kilometre of carnivores found in Bipindi. Data obtained from 14 surveys conducted in four seasons over two years.

Species	Biotope																	
	Und. Forest[a]				Cocoa Pl.[b]				Farm/Fall.[c]				Vil-Adj Fo[d]				Probab.	
	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	F_a	F_b
N. binotata	0	0.17	0.03	0.07	0	0.15	0	0	0	0.25	0	0	0	0.28	0	0	ns	**
V. civetta	0	0.21	0.14	0.27	0	0.11	0.22	0.17	0	0.13	0.28	0.59	0	0.08	0.15	0	ns	ns
C. obscurus	0.65	0.77	0.49	1.24	0.51	0	0.07	0.73	0.13	0.37	0.19	0.57	0	0.52	0	0.09	**	*

SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season. *Fa*: *F*-test according to biotopes, *Fb*: *F*-test according to seasons; Probab.: probability; ns: not significant.
[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.
* $p \leq 0.05$.
** $p \leq 0.01$.

Table 7
Mean density per square kilometre of primates found in Bipindi area. Data obtained from 14 surveys conducted in four seasons over two years.

Species	Biotope																	
	Und. Forest[a]				Cocoa Pl.[b]				Farm/Fall.[c]				Vil-Adj Fo[d]				Probab.	
	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	SRs	SDs	HRs	LDs	F_a	F_b
M. talapoin	0	0	0	0	0	0.93	0.25	0	0	0	0	0.92	0.69	1.70	0	0	ns	ns
C. cephus	0	1.97	1.29	0.29	0	0.42	0	0	0	0	0	0	0	0	0	0	***	ns
C. mona	0	1.12	1.11	0	0	0	0	0	0	0	0	0	0	0	0	0	***	ns
C. nictitans	0	1.61	1.45	0.36	0	0.23	0	0	0	0	0	0	0	0	0	0	***	ns

SRs: small rainy season; SDs: short dry season; HRs: heavy rainy season; LDs: long dry season. *Fa*: *F*-test according to biotopes, *Fb*: *F*-test according to seasons; Probab.: probability; ns: not significant.

[a] Undisturbed forest.
[b] Cocoa plantation.
[c] Food plantation.
[d] Village-adjacent forest.
*** $p \leq 0.001$.

The densities of wildlife hosts of *T. b. gambiense* differed with habitat type, being higher generally in the undisturbed forest than in other biotopes, but also with seasons. The densities of these mammals were low in the dry season than in wet season. This variation was due to the availability of food and water randomly distributed during the wet season whereas in the dry seasons, the distribution was clumped around water holes and remaining forage areas. Therefore, during the dry season, the water holes constitute favourable contact zones between the vectors and hosts.

Within the group of ungulates the density of the blue duiker which was high in all biotopes during the heavy rainy season, declined significantly in the long dry season. The density of the black striped duiker declined in the undisturbed forest from the small rainy season to the short dry season, and slightly increased during the same period in the farmland habitats. Sitatunga is very well adapted to swampy areas; however, the highest densities of this species observed in cocoa plantations during the wet seasons due to the high availability of food (stems, flowers and fresh herbs) in this biotope. During these wet seasons, ungulates also fed on fruits of various plants such as *Scyphocephalum mannii*, *Staudtia kamerunensis*, *Elaeis guineensis*, *Ricinodendron heudelotti*, *Antrocaryon klaineanum*, *Klainedoxa microphylla* identified in the undisturbed forest. *C. monticola* and *C. dorsalis*, sedentary species (Kingdon, 1997) are particularly diurnal and nocturnal, resting under tree trunks, rocks or in thickets, the suitable resting places for *G. palpalis palpalis* because of its low humidity, darkness and coolness (Laveissière et al., 2000).

Rodents are common in all biotopes except for *T. swinderianus* not occurring in the undisturbed forest. Most of them are nocturnal; they moved therefore at night between their hideouts (rocks along rivers and streams) and feeding places. In general, their highest densities were obtained in the undisturbed forest in all seasons. Moreover, animal densities increased from the short rainy season to the short dry season with a slight decrease during the heavy rainy season and a slight increase in the long dry season. These variations of densities among biotopes according to seasons are due to the availability of food such as grains, fruits and roots of numerous plant species recorded in farmland habitats (*E. guineensis*, *Zea mays*, *Arachis hypogaea*, *Manihot esculenta* and *Cucumis sativus*,), cocoa plantations and the undisturbed forest (*E. guineensis*, *Coula edulis*, *Poga oleosa*, *Trichoscypha arborea*, *Thricoscypha acuminata* and *Baillonella toxisperma*).

Palm civets were also common in all biotopes. This species can be arboreal or terrestrial, feeding on fruits, eggs, young birds and chicks. They are nocturnal or diurnal. According to hunters, suitable biotopes for this species are those providing food. In cocoa plantations, farmland and village-adjacent forests, this species was observed only during the small rainy season. In the undisturbed forest, the palm civet occurred all year round except in the long dry season.

In the group of primates hosting *T. brucei* spp., only dwarf guenons were observed in farmlands and village-adjacent gallery forest. This species was encountered in the canopy and on the ground moving between the vicinity of village (farmlands) and undisturbed forest (Massussi, 2002). They fed on *Musa paradisiaca*, *Musa sapientum*, *Carica papaya* and other foodstuff from human plantations. The greater white-nosed monkey and the moustached monkey were encountered in the undisturbed forest and cocoa plantations where they feed on different fruits such as *Irvingia gabonensis*, *Musanga cecropioides*, *P. oleosa*, *S. kamerunensis*, *Klainedoxa gabonensis*, *Thricoscypha arborea*, *Uapaca guineensis*, *B. toxisperma*, *T. acuminata*, and *Pycnanthus angolensis*. These species did not occur in farmland and village-adjacent forest because of hunting pressure. They were diurnally active and rested in trees.

The permanent movements of wild mammals from one biotope to another according to seasons increase the contacts between the hosts and the vectors occurring in all biotopes (Mbida Mbida, 2005), and whose distribution among biotopes is mostly dependent on feeding host availability (Laveissière et al., 2000).

4.2. Potential role of wild mammals in the resurgence and maintenance of sleeping sickness

The transmission, resurgence and perpetuation of sleeping sickness depend on many factors, some of the most important being host–vector contact, host susceptibility and trypanosome distribution in the vector population (Allsopp, 1972). Many species of wild mammals found in the Bipindi area host *T. brucei* spp. (Herder et al., 2002). According to Allsopp (1972), wild animals are able to support the infection. The period that a parasite could survive in a host is significant and the long-lasting infections observed during laboratory experiments may not exist in nature (Allsopp, 1972). During the infection time, wild animals constitute a reservoir of trypanosomes. The link is established between different host-reservoirs by the vectors (*G. palpalis palpalis*) occurring from the village-adjacent forest to the undisturbed forest (Mbida Mbida, 2005). Some species such as the giant rats, the African brush-tailed porcupine, the sun squirrel, the blue duiker, sitatunga, the black striped duiker, the two-spotted palm civet, the dwarf guenon occur permanently in the suitable habitats of *G. palpalis palpalis*. This permanent presence of wild mammals in the *G. palpalis palpalis* habitat increases the contact between wild animals and the population of tsetse flies (Njiokou et al., 2004) causing repeated infestation of wild animals, and therefore resulting in the maintenance of the disease.

The contact between the flies and hosts depends on various factors such as the diurnal activity behaviour of the animal species, the activity of the flies influenced by the temperature and humidity, the luminosity, the wind and rainfall. Therefore, species like the greater white-nosed monkey and the moustached monkey, occurring periodically in the suitable habitat of *G. palpalis palpalis*, could host the parasite for a period of time and favour the infestation of other mammals.

The fundamental objective of this study was to survey wild mammal species, hosts of *T. b. gambiense* and to investigate their probable role in the resurgence of sleeping sickness. Sixteen most frequently encountered species of wild mammals were surveyed in the region of Bipindi. Among them, 43.75% were reservoir hosts of *T. b. gambiense* while 31.25% of these species host *T. brucei* spp.; 12.5% were not investigated so far, while 12.5% did not host *T. brucei* spp. Therefore, wild animal species occurring in Bipindi can be classified in four groups:

(1) Wild animals (giant rats, African brush-tailed porcupine, sun squirrel, cane rats, blue duiker, sitatunga, black striped duiker, two-spotted palm civet, dark mangoose and dwarf guenon) that occur permanently in the suitable habitat of *G. palpalis palpalis* (the village-adjacent forest, farmland habitats and cocoa plantations). They insure frequent contact with the tsetse fly population and therefore the perenisation of sleeping sickness.
(2) Wild animals (greater white-nosed monkey, mona monkey and moustached monkey) that occur periodically in the suitable habitat of *G. palpalis palpalis*, moving from the unsuited to suitable habitats of flies and which ensure the spread of trypanosomes among wild animals.
(3) The third group includes wild animals that occur permanently in the suitable habitat (cane rats and bush pigs) of *G. palpalis palpalis* but not yet investigated. This group is more important due to the high reproduction rate of cane rats and the genetic similarities between bush pigs and domestic pigs, the preferential host of *G. palpalis palpalis*.
(4) The last group consists of wild animals (*C. silvicultor*, *V. civetta*) not hosting *T. brucei* spp.

This study shows that some animals come very close to human settlements to look for food and shelter. These animals interfere in the domestic transmission cycle of trypanosomiasis (human/tsetse flies/domestic mammals).

Acknowledgements

We thank the General Secretariat of OCEAC for permission to conduct this research within OCEAC study sites and to use OCEAC technicians and offices; especially Dr. Bilongo Manene (the formal secretary general of OCEAC). We thank the Research Institute for Development (IRD) that provided direct funding and indirect funding through "Jeune Equipe Associée" to support the fieldwork and a research allowance to Massussi J.A. for the rest of the material. We finally thank the population of Bipindi for their participation, contribution to this study and their hospitality.

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