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Original Article

Environmental and Social Parameters Effects on Olive Colobus Monkey's (*Procolobus verus*) Unit Calls in Taï National Park, Côte d'Ivoire

Jean-Claude Koffi BENE[1,2] and Eloi Anderson BITTY[2,3]

[1]Unité de Formation et de Recherche d'Environnement, Université Jean Lorougnon Guédé; Daloa BP 150 Daloa

[2]Centre Suisse de Recherches Scientifiques en Côte d'Ivoire ; 01 BP 1303 Abidjan 01.

[3]Laboratoire de Zoologie et Biologie Animale, Université Félix Houphouët Boigny d'Abidjan-Cocody; 22 BP 582 Abidjan 22

ABSTRACT

There is no society without communication system. Animal communication is primarily an information exchange between living organisms belonging to the animal kingdom, able to modify their activities and behavior. This communication can take place between animals of the same species (intra-specific communication) or between animals of different species (inter-specific communication). It creates connections, synchronizes behaviors, regulates interactions, adapts to the social environment and involves an individual caller and an individual receiver. In general, animals that live in closed environments such as dense rainforests like Taï National Park (TNP) communicate more often through vocalization. Focal animal studies and Ad Libitum conducted in three groups of Olive Colobus monkey in Taï National Park indicate that this monkey possess a vocal repertoire consisted of unit calls and combination calls. The study also showed that some environmental and social parameters significantly affect the emission of different unit calls of this monkey species.

Key words: *Olive Colobus, vocalization, unit calls, inter-group communication, intra-group communication.*

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INTRODUCTION

The non-human primates transmit information between individuals of the same species and / or different species using vocal and non-vocal signals [1]. The study of vocal communication among non-human primates' populations in their natural environment has grown in recent years [2] - [8]. However, the majority of these investigations have been made on species living in open habitats such as savanna, though visibility in tropical forests is often extremely low and significantly affects the behavior of these animals. Vocalization becomes, in this case, the most efficient way to transmit social and ecological information between individuals [9]. Studies on animal communication show that each type of predator sparks emission of specific alarm calls by some Monkeys [10] - [13]. And even, the members of neighboring groups of monkey that hear these calls perceive its meanings. [14] From these studies, we know that there are also calls involved in the control of spatial proximity of group members and give information about recurring events in their environment [15].

The Olive Colobus (*Procolobus verus*), the subject of our work has been studied in its natural habitat on Tiwai Island (Sierra Leone) and in the Taï National Park (Côte d'Ivoire), but it vocal behavior had never been systematically described [16]. However, these studies have shown that individuals form associations almost permanent with a particular group of Diana guenon (*Cercopithecus diana*), even in habitats where predation pressure is relatively low [17], [18]. In addition, although on average, the size of groups that form the Olive Colobus is very small, adults male and female were observed changing group [19].

The study of Olive Colobus' vocal repertoire conducted in the Taï National Park, showed that the

monkey has a vocal repertoire consisted of eight types of unitary calls [7], but individuals were able to combine three of these unit calls in more complex sequences characteristic of different social contexts [20], as this was recently reported in Campbell's guenon (*Cercopithecus campbelli*). In addition, there is a sex differences in the use of the same unit call types [8]. The purpose of this study is to see the influence of some environmental and social parameters on the emission of the different unit calls of Olive Colobus in TNP.

MATERIAL AND METHODS

Study site

Rainforest of TNP provided the framework for our study. The TNP is located at the south-western Côte d'Ivoire between 5'08 and 6'07 latitudes north and 0'47 and 7'25 longitudes west. The rainfall pattern is bimodal with two rainy seasons and two dry seasons or less rainfall. The park is characterized by evergreen rainforest. This forest is home to about 140 mammals' species including 12 primates, 15 species of ungulates, 13 species of carnivores, 3 species of pangolins, the Forest Elephant (*Loxodonta africana cyclotis*) and 2 species of Felines (Leopard *Panthera pardus*, and the golden Cat *Felis aurata*)...

Sampling

The observations were made on three groups of Olive Colobus with a total of three adult males, nine adult females, two juveniles and six infants. Adults are individuals whose secondary sexual characters are developed and clearly visible. Juveniles are those whose secondary sexual characters are not visible and infants are individuals that continue to suck.

Focal animal observation: all individuals of the three groups are clearly identified and known. Each individual is followed for a period of 15 min, and several times alternately. Observations generally begin at 07:00 AM to 5: 30 PM. The first individual is chosen at random, then, we observe a break of 15 minutes before selecting another individual. The choice of that other individual is in such a way not to follow the same monkey twice. Then we collect information about the behavior of the focal individual and environmental parameters according to table 1.

Ad libitum observation: During the 15-minutes break between to two focal samples, all calls emitted by Olive Colobus are recorded using the same variables in table 1. This allowed us, in addition to the calls recorded during the focal observations, to identify all the calls emitted by the group during the day.

Table 1: Description of environmental and social parameters considered in the study

Variables	Modalities	Description
Individual	Adult male	Male sexually mature
	Adult Female	Female sexually mature
	Juvenile	Young that has not reached sexual maturity
Calls	Unit call	Call type emitted alone
General illumination	Dark	No shadow on the ground, sky heavily overcast
	Medium	No shadows on ground, sky moderately overcast
	Lighted	Direct sunlight
Vegetation density	Dense	Thick undergrowth, upper canopy not visible
	Medium	Moderate or little undergrowth
	Open	Some tree crowns visible
Location in home range	Border	Outer most or overlapping grid cells
	Centre	Inner grid cells not bordering on or visited by a neighboring group
Neighboring groups	Mixed	Groups are together
	Close	Separate groups of approximately 50m
	Distant	Separate groups of at least 100m
Poly-specific associations	Mixed	Groups are together
	Close	Separate groups of approximately 50m
	Distant	Separate groups of at least 100m
Key behaviors	Locomotion	Move action, locomotion
	Game	Action to play alone or with others
	Foraging	Action to feed
	Sitting	To be sited
	Grooming	Action to scratch, scratch or be scratched
	Sleep	Action to sleep

Data analysis: In this paper, mainly frequencies were calculated and XLSTAT software is used to the Chi-square test to compare these frequencies.

RESULTS

Environmental parameters

Period of day and unit calls: We have analyzed the emission of unit calls by Olive Colobus depending on the period of the day. There is a clear difference between the emission frequency of these calls with $N_{morning}$ = 426 and $N_{afternoon}$ = 307, with a percentage of 58.12% and 41.88%. At each type of call, we have: A-call N_{total} = 112, B-call N_{total} = 477, C-call N_{total} = 26, D-call N_{total} = 8, E-call N_{total}= 87, F-call N_{total} = 9, G-call N_{total} = 12, H-call N_{total} = 2 (see table 2 for frequencies). These observed differences in frequencies of unit calls according of the period of the day were highly significant (Chi^2 = 30,905, df = 8, p <0.001).

Illumination and unit calls: The illumination affects significantly the emission of unit calls. We can observe that more than half of the calls are emitted in lighted moment with 53.07% ($N_{lighted}$ = 389), then in moderate illumination 35.47% (N_{medium} = 260) and finally when there is no illumination 11.46% (N_{dark} = 84). This same difference is also observed for each type of unit call according to illumination (table 2). Within the same illumination type, differences between the emission of the unit call types are significant (Chi^2 = 48,206 df = 24, p = 0.002).

Vegetation density and unit calls: The vegetation was divided into three categories: dense vegetation, medium and open vegetation. With the analyzes we note that vegetation aspect affects significantly the emission frequency of the different unit call types of Olive Colobus with more screams, when vegetation is dense with N_{dense} = 525 or 71.63% of calls, against N_{medium} = 186 or 25.38% in moderate vegetation and finally N_{open} = 22, or 3.01% for open vegetation (Table 2). In addition, when considering a type of vegetation there is a very significant difference in the emission of the unit calls with a different a Chi^2 = 84,396 df = 16, p <0.001.

Location in home range and unit calls: The unit calls of Olive Colobus do not show a major different according to their position in the group's home range. When the group of monkeys is at the centre of its home range or the edge of this area, the frequency of the calls emission is respectively 49.39% and 50.61% with (N_{border} = 362 and N_{centre} = 371). According to the Chi-square test of Pearson this difference is not significant (Chi^2 = 15,741, df = 8, p = 0.046) (Table 2).

Position in the strata and unit calls: The stratum2 with N_{strat2} = 484 (66.03%) and the stratum1 with N_{strat1} = 156 (21.29%) have recorded the maximum unit calls during the study compared to the stratum3 (N_{strat3} =71 with 9.69%), the stratum4 (N_{strat4} = 17 with 2.32 %), the stratum0 (N_{strat0} = 5 with 0.69%) and the stratum5 with N_{strat5} = 0 (table 2). As before, B-call dominates in each stratum with a highly significant difference (Chi^2= 381912 df = 40, p <0.001).

Table 2. Emission frequency of unit calls according to some environmental parameters

		Unit calls							
Variables *(N=733 calls)*	Modalities	A-call	B-call	C-call	D-call	E-call	F-call	G-call	H-call
Period	Morning	66.07	55.13	50.00	50.00	63.21	77.77	66.66	100
	Afternoon	39.93	44.87	50.00	50.00	36.79	22.23	33.34	0.00
Illumination	Lighted	50.00	53.03	65.38	62.50	48.27	55.55	75.00	100
	Moderate	37.50	33.54	34.62	37.50	47.12	44.45	8.33	0.00
	dark	12.50	13.42	0.00	0.00	4.60	0.0	16.67	0.00
Vegetation	Dense	49.10	78.19	73.07	37.50	67.81	77.77	66.66	50.00
	Medium	45.54	20.12	15.39	50.00	32.19	22.23	0.00	50.00
	Open	5.35	1.68	11.54	12.25	0.00	0.00	33.34	0.00
Position	Border	40.17	51.78	69.23	50.00	47.12	33.33	33.33	0.00
	Centre	59.83	48.22	30.77	50.00	52.88	66.64	66.67	100
Strata	Stratum0	0.00	0.20	0.00	37.50	0.00	0.00	8.33	0.00
	Stratum 1	23.21	20.96	38.46	0.00	12.64	11.11	50.00	100
	Stratum 2	71.43	66.04	57.70	50.00	67.82	66.67	41.67	0.00
	Stratum 3	5.36	10.48	3.84	12.50	12.64	22.20	0.00	0.00
	Stratum 4	0.00	2.30	0.00	0.00	6.89	0.00	0.00	0.00
	Stratum 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Stratum 0: 0m ground level
Stratum 1: 0 to 5m

Stratum 2: 5 to 15m
Stratum 3: 15 to 25m
Stratum 4: 25 to 40m
Stratum 5: Beyond 40m

Social parameters

Sex of the individual and unit calls: We note that the male of Olive Colobus of Taï National Park emit more unit calls than females respectively with N_{male} = 401 or 54.70% and N_{female} = 215 or 29.33% and individuals of sex unknown with N = 117 or 15.96% (table 3). According to the Chi-square test of Pearson these observed differences in the unit calls emission based on gender are highly significant (Chi ^{2} = 1361,774, df = 16, p <0.001).

Group activity and unit calls: The different unit call types were issued during three major activity types (sitting, foraging, and locomotion). In these activities, we note a clear difference between sitting and the others: sitting with N_{sited} = 516 or 70.40% recorded the highest unit calls, then foraging $N_{foraging}$ = 113 or 15.42% and locomotion $N_{locomotion}$ = 103 in the last position with 15.06% (table 3). Here also, the difference observed between the activities of Olive Colobus issuing unit calls was highly significant (Chi ^{2} = 206962 df = 40, p <0.001).

Group dispersion and unit calls: Here, we note that more than 90% of calls are emitted when individuals of Olive Colobus are together (table 3). However, the difference between the emission frequency of the unit calls in every type of dispersion shows no significant difference ($N_{together}$ = 706, $N_{dispersed}$ = 27 and Chi ^{2} = 4051, df = 8, p = 0852).

Age class and unit call: Adults gather the females and males of Olive Colobus and they emit the maximum unit calls with N_{adult} = 622 or 84.46% of the calls against only $N_{juvenile}$ = 77 (10.51%) for juveniles and N_{infant} = 34 or 4.64% for infants (table 3). We observe a highly significant difference between the emission of unit call types based on age class (Chi^2 = 6500,333 df = 16, p <0.001).

Presence of neighbors and unit calls: Except when Olive Colobus has only one neighbor, we see that the number of unit calls decreases with the increasing of the number of neighbors in all cases with a predominance of B-call (table 3). The influence of the number of neighbors in the emission frequency of unit call types in Olive Colobus shows a highly significant difference with Chi^2 = 561611, df = 56 and p <0.001.

Table 3. Emission frequency of unit calls according to some social parameters

		Unit calls							
Variables *(N=733 calls)*	Modalities	A-call	B-call	C-call	D-call	E-call	F-call	G-call	H-call
Activity	Sited s	75.00	69.39	61.54	37.50	79.31	0.00	91.66	100
	Fourrage	10.71	18.24	30.77	12.50	1.15	44.44	0.00	0.00
	Locomotion	14.29	12.37	7.69	50.00	18.39	55.56	8.34	0.00
	Non seen	0.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00
Dispersion	Dispersed	2.68	4.62	0.00	0.00	2.30	0.00	0.00	0.00
	Together	97.32	95.38	100	100	97.70	100	100	100
Age	Juvenile	16.04	0.62	0.00	37.50	60.91	0.00	0.00	0.00
	Infant	0.00	0.00	0.00	0.00	39.09	0.00	0.00	0.00
	Adult	83.93	99.38	100	62.50	0.00	100	100	100
Neighbor	V0	13.40	31.65	34.61	25.00	12.64	11.11	8.33	0.00
	V1	35.71	16.77	30.77	0.00	41.38	11.11	50.00	50.00
	V2	29.46	26.83	3.84	37.50	19.54	0.00	0.00	0.00
	V3	17.85	18.66	19.23	0.00	18.39	55.56	25.00	50.00
	V4	0.00	2.30	7.69	0.00	0.00	11.11	8.33	0.00
	V5	0.89	1.04	0.00	0.00	0.00	11.11	0.00	0.00
	V6	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	Vns	2.67	2.51	3.84	37.50	8.04	0.00	8.33	0.00

V0 to V6 = number of neighbors (0 to 6)
Vns = number of neighbors unknown

Presence of other monkey species and unit calls: Two general observations can be made from the analysis of unit calls emission based on association of Olive Colobus with other monkey species. The first is that we recorded the maximum unit calls in the presence of Red Colobus, then in the presence of Campbell's guenon and the white-nosed monkey. But very little unit calls are recorded in the

presence of Diana guenon, the mangabey and Black-and-White Colobus. The second observation is that except Diana guenon and de facto neighbor Olive Colobus with which calls are emitted when they are close, the other unit calls were heard when the different species were mixed (table 4).

Table 4. Emission frequency of unit calls according to polyspecific associations

Species	Association	Unit calls *(N=733)*							
		A-call	B-call	C-call	D-call	E-call	F-call	G-call	H-call
Aty	Absent	78,58	78,61	76,92	37,50	87,56	66,67	91,67	50
	Mixed	15,17	12,58	19,23	62,50	8,04	22,22	8,33	50
	Close	6,25	8,60	3,85	0	5,00	11,11	0	0
Bad	Absent	52,68	32,91	53,84	50	41,38	33,33	25	0
	Mixed	43,75	57,86	42,30	37,50	55,17	66,67	41,67	100
	Close	3,57	9,22	3,85	12,50	3,45	0	33,33	0
Cam	Absent	54,46	40,46	7,69	37,50	41,38	33,33	58,33	0
	Mixed	43,75	55,55	92,31	62,50	43,68	66,67	41,67	100
	Close	1,78	3,99	0	0	14,94	0	0	0
Dia	Absent	95,53	94,97	92,31	100	88,50	88,89	100	50
	Mixed	1,78	0,63	0	0	0	0	0	0
	Close	2,68	4,40	7,69	0	11,49	11,11	0	50
Pet	Absent	54,46	39,41	30,77	37,50	45,98	33,33	83,33	50
	Mixed	44,64	57,86	61,54	62,50	54,02	66,67	16,67	50
	Close	0,90	2,73	7,69	0	0	0	0	0
Pol	Absent	81,25	80,92	65,38	87,50	60,92	77,78	58,33	100
	Mixed	17,85	17,40	34,42	12,50	28,73	22,22	41,67	0
	Close	0,90	1,68	0	0	10,34	0	0	0
Ver	Absent	95,53	94,97	92,31	100	88,50	88,89	100	50
	Mixed	1,78	0,63	0	0	0	0	0	0
	Close	2,68	4,40	7,69	0	11,49	11,11	0	50

Aty = *Cercocebus atys* Bad = *Piliocolobus badius*
Cam = *Cercopithecus campbelli* Dia = *Cercopithecus diana*
Pan = *Pan troglodytes verus* Pet = *Cercopithecus petaurista*
Ver = *Procolobus verus* Pol = *Colobus polykomos*

DISCUSSION

The vocal communication occurs mainly in animals living in the forest where gestures and postures are difficult because of the foliage. In dense forests as Taï National Park, this type of communication becomes the surest way to recognize its congener and to get some information about the events of the environment. Indeed, vocalizations indicate age, sex, social status of the caller. They also serve to assembly the troops, keep away intruders, indicate the presence of predator etc. [21], [22]. The unit calls of Olive Colobus in TNP are emitted to characterize various social contexts [7], [8], [20]. This study presents evidence that these calls are also influenced by some environmental and social parameters. This monkey emits more unit calls in the morning compared to the afternoon. In addition, the illumination of the environment, vegetation density and group activity etc… have a significant influence on the emission frequency of these unit calls.

Location in home range shows no remarkable effect on the emission frequency of Olive Colobus unit calls. The monkey visits all this area, which is also the territory of its associated Diana guenon, almost identically. In addition, previous studies have shown that the monkey did not emit unit call functioning as spacing-call that may be issued by the groups to mark its territories. Only some combined calls seem to play such a role [20]. Most primates in forest produce these call types for long distance communication [23]. Traditionally, researchers have hypothesized that these long-range vocalizations transmit information relating to intergroup spacing or territorial behavior [24]. Indeed, different groups of the same species can live in the same area with different territories. Intergroup encounters can therefore occur. During these events, Vervet monkeys for example, can emit a vocalization called "*wrr*" when they discovered another group of Vervet. The function of this call is to inform members of the group and to deter individuals from neighboring group [25]. For the howler monkey, these calls are issued in a number of contexts: at daybreak or before daybreak, when they are harassed by the people and dogs, having seen or heard another con-specific group close or far-away [26].

We also notice a clear difference between the calls emitted when monkeys are spread. In general, the number of unit calls decreases when the number of neighbors increases and dominant calls are B-call, A-call, C-calls and E-call. Except A-call, all others occur in the context of stability and are issued in large numbers. According to [15], these calls are contact calls and maintain social cohesion. They help the monkey in this context to feel in direct relationship with the individual of the same group that is not seen because of the dense vegetation of TNP. It is therefore evident that the emission frequency of these calls types decreases when visual communication is used with individuals very close to each other within five meters. In contrast to the male of Diana guenon, male Olive Colobus involves very often in the issuance of these contact calls. In addition, the ability to recognize individual must have some influence on individual or group, on the structure and social organization of species. Indeed, the identity of the caller can influence the decision of the recipient to approach, avoid or ignore [28], [29]. Behavioral responses to playback experiments conducted in the forest also suggest that subject individuals can distinguish different types of transmitter [30], [31]. Comparing available data in primates and other mammal species, we also realize that animals are able to recognize their congeners only through their vocalizations or when these vocalizations are combined with other sensory information [32] - [34].

The maximum of unit calls are emitted by adult males and females except for E-call, exclusive to juveniles and infants. In addition, adults comprise the largest number of individuals in the study groups. These two reasons seem sufficient to explain the dominance of this age class in the emission of unit calls in contrast with the assertions of [1] and [27]. The work of these authors conducted on captive Campbell guenon rose that juveniles represent the age class that make the most calls. Furthermore, Olive Colobus emits the maximum of its calls at the stratum 2. This stratum is supposed to be the place where this monkey hides itself to escape from predators eyes. The other way to fight against predation is poly-specific association [35]. According to these authors, the other species and especially Red Colobus initiate the association with Diana guenon, and therefore with the Olive Colobus, as these two species are mixed up all the time in the TNP. During these associations we can note the issuance of more unit call in the presence of Red Colobus, the Campbell guenon and White-nosed monkey. Moreover, we find that the unit calls emitted in the presence of other groups of Olive Colobus, have been much more when the different groups were close (50-100 meters). These unit calls are mostly contact calls and maintaining social cohesion [7], [15].

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