Camera trap is low-cost for mammal surveys in long-term: comparison with diurnal and nocturnal surveys

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Key words: Camera traps, Conservation, diurnal surveys, monitoring, nocturnal surveys

Publication date 31/10/2020, http://m.elewa.org/Journals/about-japs/

1 ABSTRACT

Sustainable wildlife management requires dedicated efforts and heavy financial resources. To count wild mammals, various follow-up techniques in wildlife are often used without a clear understanding of the long-term costs. Cost is a monetary expenditure made to satisfy a given service. Understanding long-term costs associated with different mammal surveys methods is the key needed by ecologists to making good management decisions. This paper aims to suggest a suitable method for estimating the abundance of large and medium-sized mammals, based on the cost analysis in the long-term. We compare three methods: camera traps, nocturnal survey, and diurnal survey. The comparison focuses on the relative abundance of animals recorded, sampling effort, and cumulative cost in the long-term. Our review indicates that camera traps are suitable for inventorying species that are difficult to detect by nocturnal and diurnal surveys. Nocturnal survey, therefore, was more efficient for collecting the abundance data with high sighting frequency of animals. Here the efficiency is defined as the ability of each method to detect more animals during a given period of time. Considering the cost analysis, camera traps were low-cost in the long-term than nocturnal and diurnal survey methods. Despite the high initial costs, it is suggested that camera traps may be an efficient survey method in the long-term regarding cost. A camera is an ideal tool for mammals monitoring.

2 INTRODUCTION

The knowledge necessary for wildlife conservation may require dedicated efforts and heavy financial resources. Activities involving fauna monitoring are usually limited by the lack of resources; therefore, the choice of a proper and efficient methodology is fundamental to maximize the cost-benefit ratio (Lyra-Jorge *et al*., 2008). Frequently the true costs of monitoring are not recognized and are, therefore, underestimated (Caughlan and Oakley, 2001). We need to monitor wildlife populations to determine whether management goals are achieved and to improve future decisions (Barea-Azcón *et al*., 2007; Mansson *et al*., 2011). To detect mammal species, often multiple labor-intensive survey techniques are required (Welbourne *et al*., 2015) such as diurnal surveys (Bowler *et al*., 2017; Galetti *et al*., 2017) and nocturnal surveys (e.g. Romero *et al*., 2016; Jost Robinson *et al*., 2017; Kamgaing *et al*., 2018). Camera trapping is a new method widely used to assess animal distribution, density and behavior, with large numbers of studies relying on capture rates or presence/absence information

(Kolowski and Forrester, 2017). In addition, Camera-trap is the most effective method to count primates, great apes and terrestrial species, in particular, in given area (Romero *et al.*, 2016). Recent studies have reported that nocturnal surveys may be necessary to estimate abundance of duikers (Kamgaing *et al.*, 2018). In this study, three methods were used, notably: camera traps, diurnal surveys, and nocturnal surveys. The choice of an appropriate survey method requires clear research objectives and the awareness of the method efficiency and limitations towards the desired objectives (Lyra-Jorge *et al.*, 2008). Camera traps surveys have been often compared, in terms of cost and efficiency (Welbourne *et al.*, 2005; Gaidet-Drapier *et al.*, 2006), with line transect methods, and evaluated on the basis of their performance (Viquerat *et al.*, 2012). In wildlife management systems, where a variety of monitoring methods are used, the overall performance generally improves with monitoring expenditure, but very few studies explicitly account for expenditure (Mansson *et al.*, 2011). In addition, the costs of a sampling method are commonly a limiting factor for surveying large areas (Silveira *et al.*, 2003). The comparison of costs between studies is difficult because these costs depend on the economic situation of the country and vary from year to year (Gaidet-Drapier *et al.*, 2006). Moving into the implementation phase without careful evaluation of costs and benefits is risky because if costs are later found to exceed benefits, the program will fail (Caughlan and Oakley, 2001). Thus, understanding the long-term cost and efficiency of a method will allow managers to make a good management planning in protected areas. But little attention has been paid to their cost in the long-term (Silveira *et al.*, 2003). In this light, the present paper aims to suggest a suitable method for estimating the abundance of large and medium-sized mammals, based on the cost analysis in the long-term. Cost is a monetary expenditure made to satisfy a given service. This study is the first in Central Africa to use camera traps and direct observations to investigate on cost in long-term.

3 MATERIAL AND METHODS

3.1 Study area : The study was conducted in Southeastern Cameroon in the Boumba Bek National Park (BBNP) and its surrounding areas. The geographic position of the survey area is Northern latitudes (2°09'-2°20'N) and Eastern longitudes (15°35'-15°50'E). Figure 1 shows the study area in the eastern region of Cameroon, covers about 2, 382 km². Basically, BBNP is part of the Tri-national Dja-Odzala-Minkebe landscape, also called TRIDOM, a cross-border complex comprised of Dja Fauna Reserve, Mengame Gorilla Sanctuary, Nki, and BBNP (Cameroon), Odzala-Koukoua National Park (Congo), Minkebe, Ivindo and Mwagma National Park (Gabon). The region has an equatorial climate with about 1600 mm of rainfall per annum. There are two wet seasons and two dry seasons. The average monthly temperature is 25°C or 26°C and fluctuates lightly (Ekobo, 1998). The vegetation of the region is a mosaic of semi-deciduous, evergreen, and swamp forest types (Letouzey, 1985).

3.2 Period and design of the survey : Censuses were carried out from February 2016 to May, 15th 2016 during diurnal and nocturnal surveys. Camera traps were deployed on February 1, 2016, and recovered March 31, 2016. The survey period overlaps between the major dry season (December to mind-March) and minor rainy season (mid-March to June). The wildlife censuses were conducted in three sites, inside the BBNP , Gribe and Gounepoun area (Figure. 1). In each site, six-2km line transects were set and every line transect was linked by a perpendicular recce of about 2 km so to cover all habitat types. A total of 108 km walked for each sampling such as nocturnal and diurnal surveys. Diurnal and nocturnal surveys were performed in three seven-day series per site. There were 14 days in between series to avoid double counting.

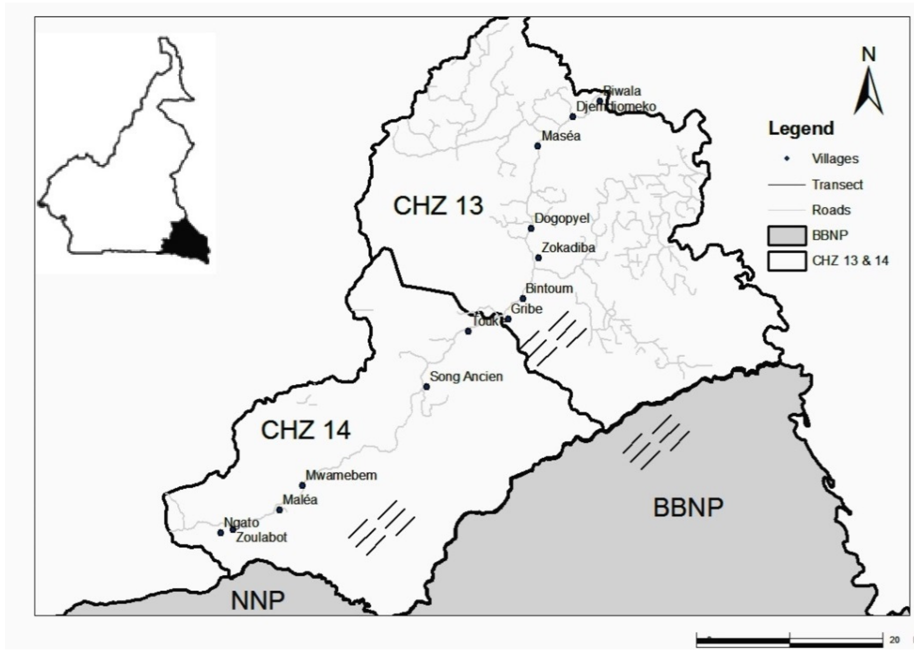

Fig. 1. Map showing the study area and the transect placement

3.3 Camera traps : Thirty cameras Bushnell Trophy Cam model were used to obtain 1,800 trap-days. We established two camera traps stations on each transect (Figure. 1). Camera traps were positioned ≈ 45 cm above the ground and usually attached to a tree. The position of the tree was chosen beside the animal track, in order to maximize encounters with animals by placing cameras at locations of high use by animals (Rovero *et al.*, 2010; Jansen, 2014). Two camera traps were set-up systematically along each line transect, both spaced by 1 km. Camera traps were set to operate continuously at the highest sensitivity. The detector records at the same time the movement of the animal, the date, time and year of this event, on an effective distance of 15 to 30 m (Silveira *et al.*, 2003; Collen *et al.*, 2008). Cameras were programmed to provide a 10 sec interval between two successive pictures in order to avoid unnecessary duplication of the remaining animal portrait on the location. 1.5V Panasonic type batteries were used. A plastic sheet was set above the camera for protection against rain. The tapes were used to seal the edges of each camera, to avoid any rain falling on the sides of the camera and any moisture.

3.4 Diurnal surveys : Censuses of direct observation were taken in the morning between 8:00 am and 12:00 pm. The survey was performed by three people; a recorder and two observers. Animals were counted with the naked eye. When an individual animal or a group of the animal was observed, the horizontal distances along line transect and the perpendicular distance from transect to the animal(s) were measured using a measuring tape (Kamgaing *et al.*, 2018). Each transect was walked every day. The effective start and end of the time of each transect census were recorded.

3.5 Nocturnal surveys: The survey was carried out from 7:00 pm-7:30 pm to 9:45 pm – 10:00 pm. The survey was carried out by three people using headlamp on both side of the line transect. Animals have been identified by their peeling color and eyes reflex. The same data as those taken for the diurnal survey were recorded (Viquerat *et al.*, 2012; Kamgaing *et al.*, 2018).

3.6 Monetary value : The economic evaluation of costs was estimated from fixed and variable expenses. The fixed expenses are the total amount of goods and services used to operate all methods, and are represented by monetary value (i.e. CFA Francs). These consist of global positioning system set, the value of the vehicle used and cost of the set-up of line transects (Lyra-Jorge *et al.*, 2008). The total amount of asset acquisition was valued at 664,750 FCA francs. As the fixed costs were the same for all methods used in the survey, they were kept out of the calculations (Lyra-Jorge *et al.*, 2008). Variable expenses refer to the total amount of goods and services that vary by methods. In this study, variable expenses include remote daily allowance for the research personnel's and other costs of operating each method. For cameras traps, renewal costs were not taken into account in the present study.

3.7 Data analysis

3.7.1 Relative abundance: Encounter rate for direct observations and photographic rate (taken with camera traps) of each species were calculated, based on different methods. Encounter rate was calculated by dividing sightings of animals by the number of kilometers walked (Kamgaing *et al.*, 2018). Photographic rate refers to the number of species-appareances per camera trap days (O'Brien *et al.*, 2010; Blake *et al.*, 2017), often referred to as a relative abundance index (Kolowski and Forrester, 2017). Instances, where the same species were captured by the same camera more than once within one hour, were excluded from photographic rate calculation (Bowkett *et al.*, 2007), in order to avoid scoring the same individual for multiple times. STATISTICA 8.0 software is used to compare differences in the number of species detected by different methods by using one-way ANOVA.

3.7.2 Sampling effort

3.7.2.1 Observation time : Observation time is the total effective labor time to count animal for each of the observation methods. The mean observation time per transect was computed from records of the time spent in the field. The difference in detection time between transects was used to calculate a variance (expressed as % CV) as described by Gaidet-Drapier *et al.* (2006). The time needed to reach the starting point was excluded, because the census actually starts along line transects.

3.7.2.2 Sighting frequency : The average number of sighting frequency was computed for each of the diurnal and nocturnal survey. This value is calculated from the total number of detected animal divided by the total effective labor time for each of the observation methods. The values allow comparison of the on the efficiency for collecting animal observation datas (e.g. Gaidet-Drapier *et al.*, 2006).

3.7.2.3 Camera effort: The Trap-days were calculated as the number of cameras deployed multiplied by the number of a period (days) when the cameras were functioning (Rovero *et al.*, 2010; Bowler *et al.*, 2017; Blake *et al.*, 2017). In this study, only images photographed between 8:00 am to 12:00 am and 7:00 pm to 10:00 pm have been taken into account in order the comparison should be made for equal length of survey.

3.7.3 Cumulative cost: The research on which this study is based started in 2016. The R 3.4.1 Software was used to build the curve of accumulative cost in a long time (25 years). Cumulative curve were obtained from remote area allowance (RAA) for the personnel's and purchase costs of renewing the equipment for each method for 25 years from 2016 to 2040. Tape measuring will be renewed once in five years for diurnal and nocturnal surveys. Regarding nocturnal count, headlamp and batteries will be renewed every five years and annually, respectively. Batteries for trap cameras should be changed annually, and plastic sheets renewed once in five years. The x-axis represents the years and y-axis represents cumulative costs.

4 RESULTS

4.1 Relative abundance : The camera traps survey covered a total of 1,800 trap-days, and a total of 764 animals (capture rate = 0.424 animals/day) belonging to 28 species were recorded. Regarding direct observations, 323 (encounter rate = 2.991animals/km) sightings of 14 species were recorded for the nocturnal survey, and 190 sightings (encounter rate =

1.759 animals/km) of 17 species for diurnal survey. The species identified range in size from brush-tailed porcupines (*Artherurus africanus*) to forest elephants (see Table 1). For all the methods, ungulates represented most of the observations, with blue duikers (*Philantomba monticola*) and red duikers (*Cephalophus spp*) being the most frequently observed species. From the comparison of average sighting per each method, it appears that there are no significant differences among the three methods (ANOVA: $F_{2\ 60}$ = 1, 3193; p = 0, 27496) (Figure. 2).

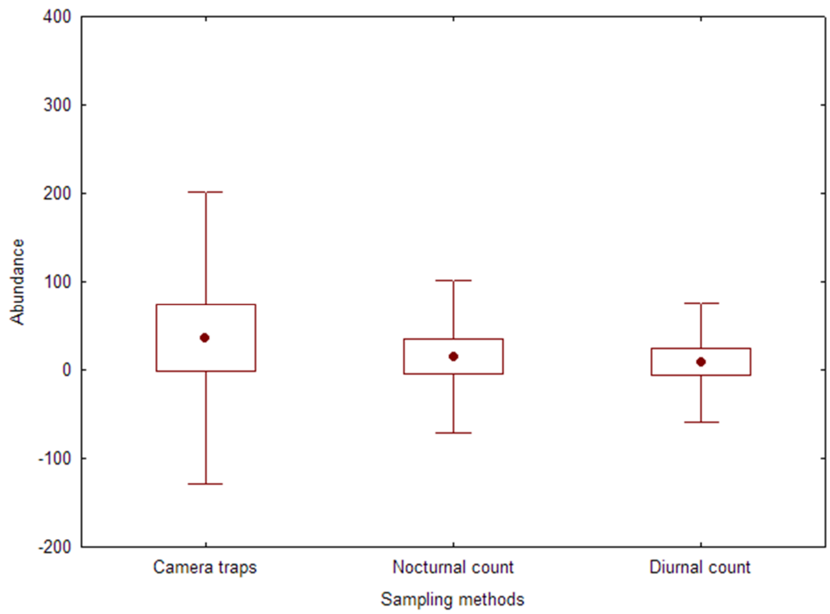

Fig. 2. Means (black points), standard errors (boxes) and standard deviations (whiskers) of relative abundance for camera traps, nocturnal and diurnal surveys

Five rare or threatened species belonging to Class A according to Cameroonian law[1] were only detected with the camera traps (see Table 1). The number of species recorded was clearly high for camera traps. Thus, camera traps appear as the most effective surveying method to detect different species in comparison to nocturnal and diurnal surveys in given area.

[1] *The Government of Cameroon grouped animals into three classes such as, A, B and C, according to Law No. 94/01 of 20 January 1994 to lay down Forestry, Wildlife and Fisheries Regulations; Decree No. 95/466/PM of 20 July 1995 to lay down the conditions for the implementation of Wildlife Regulations and Order No. 0648/MINFOF of 18 December 2006 to set the list of animals of classes A, B and C.*
Class A comprises rare species or species threatened with extinction. As such, they are totally protected and it is forbidden to kill them. In class A, species in Appendix I of CITES classification with regards to the classification of UICN.
Class B comprises species that benefit from partial protection, and which can only be hunted, captured or killed by obtaining a wildlife exploitation title or license. In class B, species of Appendix II to the exception of those already admitted into class A at the national level of CITES classification and those of groups quasi threatened to minor preoccupations of the categories of UICN;
Class C comprises mammals, reptiles and batrachians other than those of class A and B and birds of the annexes III of the CITES. In class C, species of Appendix III at the national level of CITES classification or belonging to groups of minor preoccupation according to UICN

Table 1. The total number of species recorded by camera traps, nocturnal survey, diurnal survey and the quotation of UICN red list regarding to the status and population trend.

Species	Camera data		Nocturnal surveys		Diurnal surveys		quotation of UICN Red List	
	N*	D*	n	ER	n	ER	Status[c]	Pop trend
Bate's pygmy antelope (*Neotragus batesi*)	NR	1	NR		NR		LC	Unknown
Brush-tailed porcupine (*Artherurus africanus*)	24	10	15	0,139	2	0,019	LC	Unknown
Bongo (*Tragelaphus euryceros*)	NR	8	NR		6	0,056	NT	Decreasing
Buffalo (*Syncerus cafer nanus*)	2	NR	NR		NR		LC	Decreasing
Yellow-backed duiker (*Cephalophus silviculto*r)	30	6	NR		NR		NT	Decreasing
Blue duiker (*Philantomba monticola*)	265	101	195	1,806	9	0,083	LC	Decreasing
Red duiker (*Cephalophus* spp)[a]	76	44	24	0,222	10	0,093		
African golden cat (*Profelis aurata*)	3	NR	NR		NR		VU	Decreasing
Water chevrotain (*Hyemoschus acquaticus*)	2	NR	NR		NR		LC	Decreasing
Chimpanzee (*Pan troglodytes*)	8	6	1	0,009	1	0,009	EN	Decreasing
African civet (*Civettictis civetta*)	6	3	50	0,463	NR		LC	Unknown
Tree hyrax (Dandrohyrax arboreus)	1	NR	4	0,037	NR		LC	Decreasing
Elephant (*Loxodonta africana cyclotis*)	6	2	2	0,019	NR		VU	Decreasing
Gorilla (*Gorilla g gorilla*)	7	8	NR		1	0,009	CR	Decreasing
Aardvark (*Orycteropus afer)*	5	2	NR		NR		LC	Unknown
White-bellied pangolin (*phatoginus tricuspis*)	5	2	19	0,176	3	0,028	VU	Decreasing
Geant pangolin (*Smutsia gigantea*)	3	NR	1	0,009	NR		VU	Decreasing
Small monkeys[b]	12	96	NR		156	1,444		
Bosman's potto (*Perodicticus potto*)	NR	NR	6	0,056	NR		LC	Stable
Red river Hog (*Potamochoerus porcus*)	7	13	6	0,056	2	0,019	LC	Decreasing
Total	462	302	323	2,991	190	1,759		

[a] Red duikers include Peter's Duiker [(*Cephalophus callipygus*); LC/Decreasing], Bay Duiker [(*C dorsalis*); NT Decreasing], White-bellied duiker [(*C leucogaster*); NT/Decreasing], Black-fronted duiker [(*C nigrifons*); LC/Decreasing]

[b] Small monkeys include Black and White colobus [(*Colobus guereza*), LC/unknown]; Agile Mangabey [(*Cercocebus agilis*); LC/stable], Crowned Monkey [(*Cercopithecus pogonias*); VU/decreasing], White-nosed Guenon [(*C nictitans*); LC/Decreasing], Moustached Monkey [(*C cephus*); LC/unknown], Grey-cheeked Mangabe [(*Lophocebus albigena*); LC/Decreasing]

[c] *International Union for Conservation of Nature and Natural Resources Red List status (LC = Least Concern, VN = Vulnerable, NT = Near Threatened, EN = Endangered CR = Critically Endangered) and IUCN population trend are also listed (IUCN Red List of Threatened Species Version 2017-3 <wwwiucnredlistorg> Downloaded on 29 December 2017)*

The n refers to the number of species recorded. N* refers to the night record carry out by the camera trap and D* refers to the images taken by the camera during the day. The ER refers to the number of sightings of animals per km walked and NR means Not Registered.

4.2 Sampling effort : We accumulated a total of 12,600 hours of photograph recordings using camera traps. Day record totaled 7,200 hours, and while night record was 5,400 hours. With regard to sampling on linear transect, 2,205 hours were totaled for nocturnal survey and 279 hours during the diurnal survey (see Table 2). The mean detection time per transect differs greatly between survey methods. The camera traps were operating day and night to record any related movements of animals. The average time deployed per transect was 2.45 h (CV = 21.36%), and 3.10 h (CV = 15.8%) for nocturnal and diurnal surveys, respectively. During diurnal survey, wildlife is particularly sensitive to the human presence, and therefore, we tried to walk slowly to avoid making noise during our trips on line transects. The average number of sightings for each method was: 0.10 (CV = 23.86%) sighting per hour using camera traps, while 1.46 (CV= 21.46%) sighting and 0.68 (CV= 32.21%) were obtained for the nocturnal and diurnal surveys, respectively. Camera traps survey, therefore, is not efficient due to the lowest sighting frequency of collecting animal observations than other methods. To conclude, a nocturnal survey with high rate of sighting per hour is more efficient. The summary of sampling efforts is shown in Table 2.

Table 2. Details of sampling effort during the three field surveys.

Methods	Total recording and observation time (hour)		Trap-days	N of species	Detection time per transect (hour)		Sighting frequency (sighting/h)	
					Mean	CV(%)	Mean	CV(%)
Camera traps	Night record	5,400	1,800	28			0.08	25.07
	Day record	7,200					0.04	22.65
Nocturnal surveys		2,205		14	2.45	21.36	1.46	21.46
Diurnal surveys		279		17	3.1	15.8	0.68	32.21

4.3 Monetary value: Costs are expressed in local currency (CFA francs) [2]. Results on sampling costs show a large difference between methods (see Table 3). The costs of camera traps, which had an estimated yearly expenditure of 3, 977, 700 CFA francs in 2016, were three times more costly than the day or night survey. Camera traps were more expensive due to the high purchase costs (≈ 87% of total expenses), than night (≈ 3% of total expense) and day surveys (≈ 0.3%). Camera trap data requires much more effort to handle.

[2] Value in CFA francs, average exchange rate of February/2016: (1 € ≈ 655,957 CFA francs)

Table 3. Comparison of the estimated cost of different items of camera traps, nocturnal and diurnal methods during the first year design.

Variable expenses (CFA francs)				
Methods	**Items**	**Quantity**	**Unit value**	**Total**
Camera traps	Camera traps	30	100,000	3, 000,000
	Memory card (SD card)	144	2,000	288,000
	Batteries	288	450	129,6000
	Plastic sheet	6	2,850	17,100
	Identification picture fees	2	2,500	5,000
	Researcher's day allowance	7 days	1 x 40,000	280,000
	Field assistant's day allowance	18 days	1 x 6,500	78,000
	Field worker's day allowance	18 days	2 x 5,000	180,000
Total				**3, 977,700**
Nocturnal survey	Headlamp	5	1,500	7,500
	Batteries	54	450	24,300
	Tape measure	1	4,000	4,000
	Researcher's day allowance	7 days	1 x 40,000	280,000
	Field assistant's day allowance	63 days	1 x 6,500	409,500
	Field worker's day allowance	63 days	2 x 5,000	630,000
Total				**1, 335,300**
Diurnal survey	Tape measure	1	4	4000
	Researcher's day allowance	7 days	1 x 40,000	280,000
	Field assistant's day allowance	63 days	1 x 6,500	409,500
	Field worker's day allowance	63 days	2 x 5,000	630,000
Total				**1, 323,500**
Fixed expenses (CFA francs)				
	Compass	1	46,000	46,000
Camera trap, nocturnal and diurnal surveys	Taxi rent	30	4,625	138,750
	Field worker's day allowance	8 day * 3	4*5,000	480,000
Total				**664,750**

Value in CFA francs, average exchange rate of February/2016: (1 € ≈ 655,957 CFA francs)

The handling costs of data are included in the identification picture fees, researcher's day allowance, field assistant's day allowance, field worker's day allowance. However, despite the high spending in the initial year, the accumulated costs after the fifth year of camera traps appear less costly than the cumulative costs of night and day count surveys. The Figure 3 shows 25-year cumulative costs projection, comparing three methods of wildlife surveys. Camera trap method thus seems to be the low-cost survey in the long-term for detecting species richness and relative abundance in protected areas. However, there are a few limitations to this method. The renewal costs of trap cameras had not been taken account and the methods were not replicated over many years.

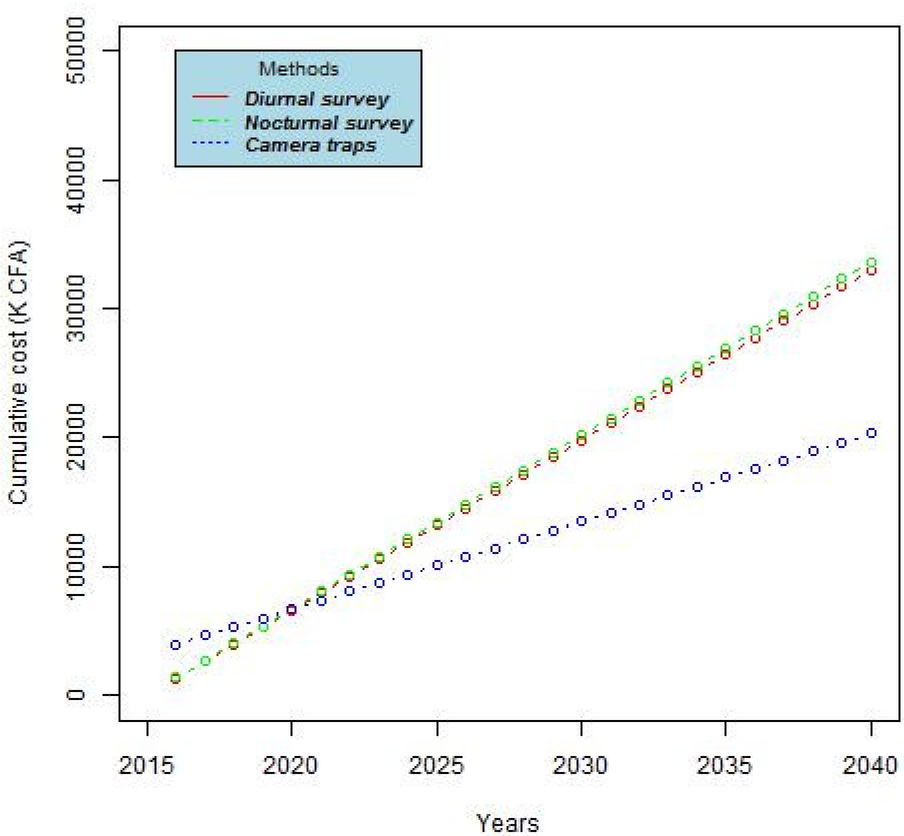

Fig. 3. Accumulated cost in long-term of diurnal, nocturnal and camera traps surveys by year

5 DISCUSSION

5.1 Species richness : The present study confirmed the presence of 28 medium and large-sized mammal species, or groups of species, in the study area. Our results actually confirmed the presence of all these species as described by Ekobo (1998) in the same research site. Previous studies have reported the presence of some medium-sized mammals such as Marsh cane rat (*Thryonomys swinderianus*) and Hedgehog (*Atelerix albiventris*), as well as the large felids, Leopard (*Panthera pardus*), in the study area (Ekobo, 1998). These species have been recorded by using the indirect observations such as tracks, footprints, and dung. Sometimes, indirect observations may be necessary to identify the presence of some species particularly sensitive to human presence or disturbance.

5.2 Camera traps : The number of mammal species recorded by camera traps was higher than those obtained from other studies carried out in Central Africa (n = 25; Gessner *et al*., 2014). In this study, camera traps were employed for a period of two months and successfully recorded various mammal species. The mammal species detected with camera traps were twice as many as those of the night counts and four times as many as the day counts. Results confirm that camera traps are an effective method for making species inventories as it has been shown in other studies on medium and large-sized mammals (Gessner *et al*., 2014; Howe *et al*., 2017). Our camera traps recorded species that are extremely difficult to detect by direct observations, such as *Neotragus batesi, Cephalophus silvicultor, Profelis aurata, Hyemoschus acquaticus, Orycteropus afer*. These species are listed as belonging to class A, protected animals. Results have demonstrated that camera traps can be used to detect rare species or threatened ones (Srbek-Araujo and Chiarello 2005; Bowler *et al*., 2017). The cameras were also particularly effective for registering nocturnal species and other cryptic species that were often escape from direct observations (Rowcliffe *et al*., 2014; Bowler *et al*., 2017). The recorded image makes it easy to identify an animal or group of animals from different families that share the same habitat. The use of cameras is gradually reducing human effort (Bowler *et al*., 2017) and considerably reduces ecological disturbances to the vegetation, unlike direct observations that require the work to cut the linear transects as described by Ekobo (1998). Cameras were just set and at several points and the data were retrieved, thus reducing the human activities in this study. As reported by Hossain *et al*. (2016), the cameras also capture the human activities in protected areas, hunting, in particular, is one of the serious threats to the survival of wildlife. The use of cameras can help wildlife managers to constantly monitor wildlife as well as to monitor hunting activities. However, the conservation effort should take into consideration the local population living around the protected areas and their use of forest resources, such as foraging the resources for medicinal, self-consumption, aesthetic, cultural and other purposes. Integrating local people into conservation program is essential to ensuring sustainable management carried out jointly with the wildlife conservation service. Such an approach will make it possible to reconcile man and fauna; therefore, it could improve the performance of management.

5.3 Line Transect Surveys (LTS) vs. Camera traps: Most of the inventoried species recorded by diurnal counting consist of arboreal primates, with approximately 83% of the recorded animals. The putty-nosed guenons (*Cercopithecus nictitans*) were more abundant than other species. Our results confirm the results reported by Ekobo (1998), where the same species was most represented in the same research site. Our results advocate diurnal survey as a suitable method to count arboreal monkeys in the tropical rainforest. These results confirm the study conducted by Romero *et al*. (2016) who showed that diurnal survey is a suitable method to inventory monkey species in a given area. This study reveals that encounter rate of blue duikers was higher in the night than in the daytime, and encounter rate for red duikers also seemed higher in the night compared with the day survey. For the line-transect sampling, the nocturnal survey appears more effective than the diurnal survey to count duikers. Others authors reported that nocturnal survey is the most accurate method for surveying duikers (Larrubia and Arnhem, 2009; Kamgaing *et al*., 2018). In general, however, diurnal survey is not an efficient method to detect medium-sized mammals (Hoffmann *et al*., 2010). In comparison with direct observational studies, camera traps performed well regarding rare and nocturnal species (Bowkett *et al*., 2007; Gessner *et al*., 2014). In this study, cameras trap successfully recorded many duikers compared to diurnal and nocturnal surveys. Camera traps provide more accurate records of the presence of mammals, including duiker species. Our results encourage a more widespread use of camera traps to count *Cephalophus* spp. populations in central Africa. Out of the 28 large and medium-sized mammal's species recorded in the study area, only nine species were common to three methods. The numbers of encountered mammal species were higher in the survey with camera traps than the other methods, except for white-bellied pangolins, which were more frequently observed at night, probably because of their arboreal habit. Our results confirm that camera traps appear the most effective surveying method to detect different species in given area (Srbek-Araujo and Chiarello, 2005; Tobler *et al*., 2015; Bowler *et al*., 2017). Species recorded in the night survey consisted mostly of African civet (*Civettictis civetta*), Bosman's potto (*Perodicticus potto*), White-bellied pangolin (*phatoginus tricuspis*) and *Cephalophus* spp. In fact, all these species actually have nocturnal activities. In this study, the Bosman's potto (*Perodicticus potto*) species were not detected with the camera traps nor in the diurnal survey, but they were detected relatively well in nocturnal surveys. The Bosman's potto is arboreal and nocturnal species (Nekaris *et al*., 2010).

5.4 Sampling effort : The observation time during the investigations differ greatly from one method to another. The camera traps covered an estimated detection time of 5,400 hours during the night record and 7,200 hours from day record, while 2,205 hours and 279 hours were covered by the nocturnal and diurnal surveys, respectively. The recording time of camera traps is more important because the camera remained active every day and all day long for a period of 60 days. The total recording time varies according to the operating time and the number of cameras traps fixed on a given area. Many researchers have found different values of camera traps operating time. For example, Gessner *et al*. (2014) used 47 camera traps; all operating well for a period of 15,282 h which covered a total of 697 trap-days. Silveira *et al*. (2003) accumulated a total of 24,840 h of operating time, 30,600 h of track census and 28,050 h of line transect, while Welbourne et al. (2015) recorded an operating time of about 1,820 h, with an effort of 1008 trap-days and 1,488 detection events of mammals. Little information is available on sighting frequency attached to wildlife censuses. Detection time per transect in day count (mean = 3.1 hours and CV = 32.21 %) was slightly longer than the night (mean = 2.45 and CV = 21.36%) due to a reduced visibility during the night census. Regarding sighting frequency, our results advocated nocturnal survey with high rate of sighting per hour is more efficient than diurnal and camera traps. On the other hand, Gaidet-Drapier *et al*. (2006) have shown water point counts are potentially efficient than car count, foot count, and bicycle count in a drier area.

5.5 Monetary value : The actual cumulative costs of camera traps survey for the first-year period was 3, 977,700 CFA francs, compared with only 1, 335,300 CFA francs for nocturnal survey and 1, 323,500 CFA francs for diurnal survey. Despite the cost of camera trapping being high at first sight due to camera purchase cost, this method produces a longer term record and the cameras can be re-used in other projects (Lyra-Jorge *et al*., 2008). Camera traps equipment was 30 times more expensive than other, more labor-intensive methods. In order to assess the high cost of long-term methods, the cumulative cost curve has been established over a period of 25 years. The cumulative cost of camera traps was greater than other methods in the first 5 years. This cost became less than those for night and day counts after that period and remained so during the rest of the period. Our results demonstrate that camera traps are low-cost in the longer-term than line-transects (diurnal and nocturnal) methods. This result supports existing research (Welbourne *et al*., 2015; Silveira *et al*., 2003). There is no huge gap between the cumulative cost of diurnal and nocturnal surveys in both the first year of investment and the rest of the period. However, after the eleventh year, a very slight difference of about 2.2% (24,300 CFA francs) seems to be created between the nocturnal and diurnal surveys. The diurnal survey will become slightly more expensive than the night count after an eleventh year or any year after. Increasingly, recent studies have developed methods for identifying individual animals using the infra-red sensor (e.g. Villette *et al*., 2017; Howe *et al*., 2017), wildlife monitoring (e.g. Gessner *et al*., 2014; Bowler *et al*., 2017) and quantifying levels of animal activity (Rowcliffe *et al*., 2014; Suraci *et al*., 2017). Camera traps provide more accurate records of photographed mammals. This technology may well replace human efforts and greatly reduces damage to vegetation.

6 CONCLUSION

We have demonstrated that: (1) camera traps are a low-cost survey in the long-term to count and monitor mammals, (2) camera traps appear most effective surveying method for evaluating species richness in a given area, (3) nocturnal survey, therefore, was more efficient in term of sighting frequency. In other words, camera traps have effectively challenged human eyes in terms of detectability, because the sum of direct observations (diurnal and nocturnal) was lower than those detected by the cameras in the same transects. Consequently, this information is very important for wildlife managers and conservationists to use as a basis for planning their management program. However, because of the issues related to the technical malfunctions of camera traps (Fagart *et al*., 2016); we need a more detailed research about the cost per unit area per detected animals.

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