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Vulnerability and morphometric characteristics of hunting game species in the Lama Forest Reserve (Southern Benin republic)

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Abstract
Protected areas play an important role in the sustainable conservation of biodiversity. In southern Benin Republic, the Lama Forest Reserve is a refuge for wildlife. It also generates significant incomes for the local population. However, anthropogenic activities together with uncontrolled hunting are increasingly threatening the sustainability of these resources. The study aims at investigating the hunting activities characteristics and the morphometric traits of hunted species in the Lama Forest Reserve. Snowball method has been used to constitute the sample of field respondents. Descriptive and inference statistics have been carried out to show results and analyze data. The results show that twenty-three species are mainly hunted, more for trade than for subsistence, with a dominance of mammals. It should be noted that hunting activities don't have the same level among hunted games, species and sexes although this is not generally significant statistically.

Keywords: wildlife, bushmeat, morphometric traits, conservation, Semi-deciduous forest

Introduction

Africa's forest ecosystems are among the richest and most important in terms of diversity and abundance of both plant and animal species [1]. In some societies, wildlife is an important source of animal protein [2-5], an essential component of food and income security for rural communities [6-8] and also hunting trophies [9]. The impact of anthropogenic pressures on animal species is well documented in tropical forests [10]. Game hunting is increasingly causing a reduction in wildlife populations [11-16]. The export of bushmeat from rural communities in Africa to Europe makes this market more clandestine and therefore has a negative impact on conservation actions [17]. This is exacerbated by the use of sophisticated modern weapons [15, 18]. In the fields, weapons are used to preserve crops, unlike in the forest [19]. The most commonly used hunting tools are traps and rifles [19]. In this socio-economic context, the challenge of protecting endangered species is to reconcile sustainable conservation while taking into account the realities and needs of populations [20].

In Benin, population growth [21] implies a significant need for meat. Despite its negative impacts, hunting remains an important protein supply activity for communities close to wildlife reserves [22]. In the Pendjari Biosphere Reserve, several clandestine circuits have been developed to illegally circulate bushmeat and hunting trophies [23]. The Pendjari and W Biosphere Reserves in the northern part of Benin and the Lama Forest Reserve in the Southern part are among the ecosystems where hunting activity is really important in the country. In the first two protected areas, there is open hunting season per year and period when hunting is prohibited. But hunting is carried out all the year round by the populations in Lama Forest Reserve. The people around the Lama Rainforest consider all types of bushmeat edible despite government restrictions on hunting [24]. About twenty species are mainly hunted in the Lama Forest Reserve [25]. Hunting and the bushmeat trade are then organised informally, with the development of networks between various actors [26]. Although the practice/phenomenon cannot be completely banned, there is still an urgent need to limit not only the slaughter rate but also characterize the morphometric traits of the hunted species in order to ensure their

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sustainability. A number of aspects related to hunting and bushmeat have been studied in the Lama Forest Reserve, such as those of Codjia and Assogbadjo [2] and Djagoun *et al*. [25], but the literature is still to be documented with regard to morphometric measurements and the weight of hunted species. However, the sustainability of natural resources depends on knowledge of resources, resource conservation and rational use by local populations. Thus, the general objective of the study is to investigate the hunting activities characteristics and the morphometric traits of hunted species in the Lama Forest Reserve. Specifically, it involves (1) identifying the species hunted in the Lama Forest Reserve, (2) highlighting the forms and methods of hunting in the Lama Forest Reserve, (3) Collecting morphometric data of sampled

species and (4) assessing the impact of hunting on wildlife conservation.

2. Materials and Methods
2.1. Study environment
The study area is the Lama Forest Reserve, one of the rare relics of dense semi-deciduous forest still perceptible in the southern part of the country. The Lama Forest Reserve is located in the southern part of Benin (Figure 1), about 70 km from Cotonou. It extends between 6°55' and 7°00' north latitude and between 2°04' and 2°12' east longitude, over an area of 16,250 ha [27]. It straddles the communes of Toffo (9,750 ha) and Zogbodomey (6,500 ha).
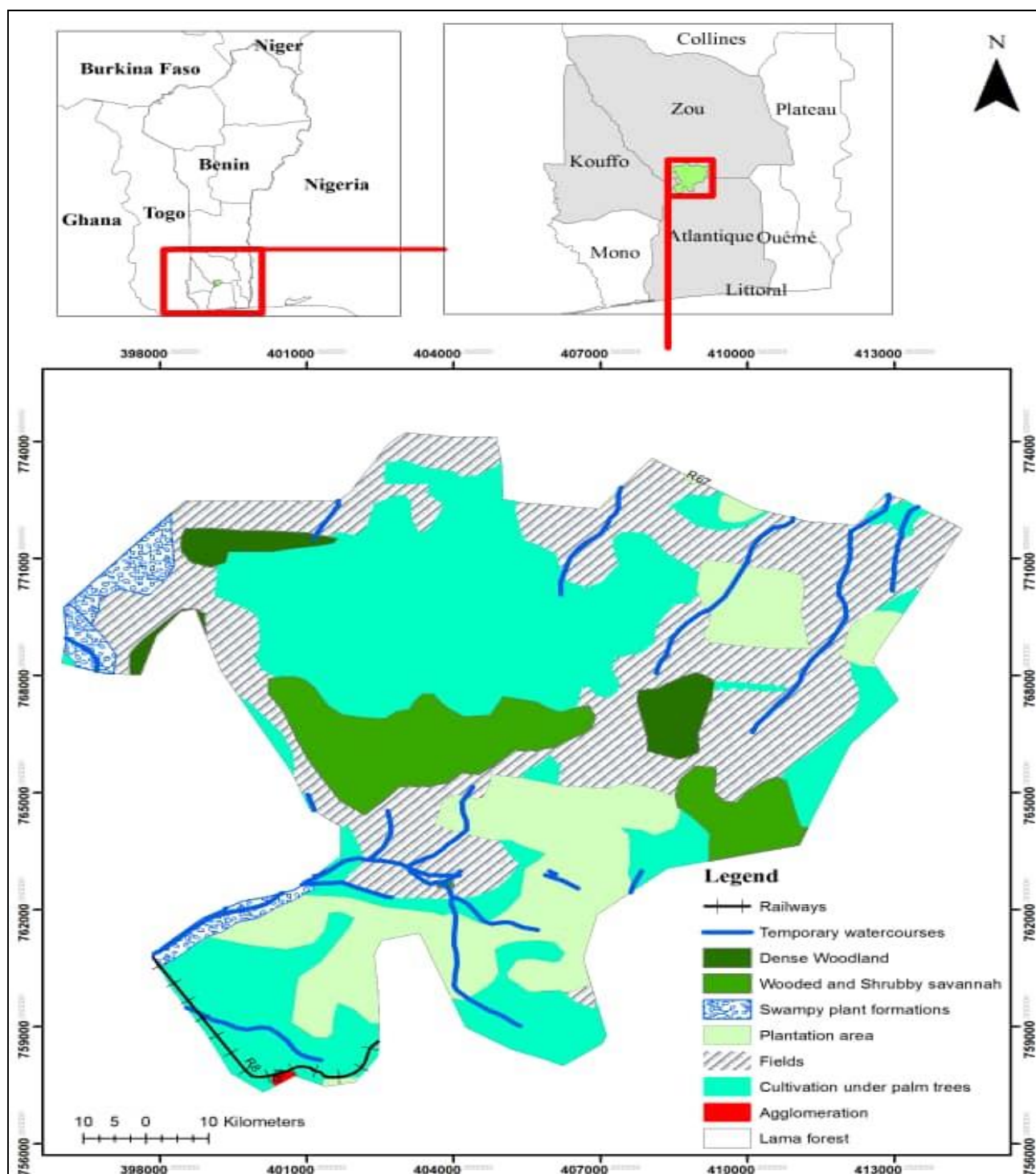
Source: Données IGN, 2009

Fig 1: Lama Forest Reserve in Benin

2.2. Wildlife diversity and human resources

The Lama Forest Reserve is home of mammals, birds, insects, fishes and herps species. According to Emrich *et al.* [28], it is home to 171 species of birds and 142 of which are known from the Central Core of the forest. The inventory by Emrich *et al.* [28] reports a total of 19 reptile specimens and 5 amphibians collected and conserved for the whole of the Central Core of the forest. In the ephemeral pools of the Central Nucleus, the presence of Catfish (*Clarias gariepinus*) and probably endemic Cyprinodontidae [28] is mentionned. With regard to insects, ninety-three (93) species of butterfly have been noted in the Lama Forest Reserve, thirty-eight (38) of which are infested with forest areas, twenty-two (22) with savannahs and 18 are considered ubiquitous. The central core of the Lama Forest Reserve contributes considerably to the specific wealth of termites and lepidoptera in South of Benin.

The population around the Lama Forest Reserve is made up of those of the communes of Toffo and Zogbodomey [27]. It's estimated at 194,520 inhabitants [29, 30] with a growth rate of between 2.24% and 2.76% from 2002 to 2013 [31, 32]. The population size projection estimate estimates is at about 224,571 inhabitants in 2018 [31, 32].

2.3. Data collection

2.3.1. Identification of hunted species, hunting tools and methods in the Lama Forest Reserve

The snowball method [33-35], used by Nago *et al.* [36], was used to constitute the field sample of hunters. A total of thirty-one hunters were sampled. The most hunted species were identified on the basis of the frequency of species citation by hunters. The identification of species by the hunters was done by means of a species recognition form containing the name and photo of the species. The surveys were conducted using semi-structured interviews.

The identification of the hunting methods used and the forms of hunting practised in the Lama Forest Reserve was made on the basis of surveys conducted among thirty guards but also among thirty-one hunters, thanks to semi-structured interviews using the snowball method [33, 34, 35].

2.3.2. Hunting game species measurement and assessment of the impact of hunting on the conservation of wildlife resources

As far as surveying is concerned, the various morphometric measurements [37] according to the species were taken using tape measures and scales. The length of the head, the total length of the body, the length of the tail, the length of the wings of the birds and the height at the withers of the ungulates were among other morphometric measurements taken. These species were individuals killed, wounded or captured during huntings, and observed on the roadside or in local game markets.

The sex of the game was identified in order to assess the vulnerability of the females to the sustainability of the species.

2.4. Data analysis

2.4.1. Identification of hunted species, hunting tools and methods in the Lama Forest Reserve

The data collected was inserted into the Excel spreadsheet, which allowed to produce graphs showing the numbers and frequencies of the data collected. The function "balloonplot" of the package "gplots" of R software [38] made it possible to make the density table of species according to types of uses and types of habitat. It has been calculated using the Chi-squared test to see if the types of use and types of habitat are significant variables. The correspondences analysis was used to see distribution of hunted species according to the types of use and types of habitat.

The Chi-squared test was also applied to see if there is a significant difference between citation frequencies as a function of species (Figure 2). The test was done using the " chisq.test ()" function of R software.

Using the Rstudio tool and the Rcmdr package, the Chi-squared test was used to see if there was a significant difference between the respondents' responses according to the forms of hunting use in the Lama Forest Reserve (Figure 5), and the frequency of citation in relation to the hunting periods (Figure 7). This test was carried out after filling in the contingency table and applying cross sorting to the 'statistics' tab of the R commander.

2.4.2. Hunting game species measurement and assessment of the impact of hunting on the conservation of wildlife resources

Similarly, the Shannon diversity index and the Piélou diversity index as below were calculated to assess the diversity of species hunted in the Lama Forest Reserve.

- Shannon Wienner diversity index H' [39] used by Chabi-Boni *et al.* [22]

$$H' = -\sum \left[\left(\frac{ni}{N}\right) * log_2\left(\frac{ni}{N}\right)\right]$$, where:

ni: number of individuals of a species i; N: total number of individuals of all species;

H': Shannon Diversity Index varies from 1 to 5 bits;

H' is high (H> 3.5): high diversity means that there is a high diversity of species hunted by hunters in the Lama Forest Reserve within the group;

H' is low (H<2.6): low diversity means that there is a low diversity of species hunted by hunters in the Lama Forest Reserve.

- Pielou equitability index E [40] used by Chabi-Boni *et al.* [22]

It's determined by the following formula:

$$E = H'/log_2 S$$

Where S is the species richness of the species killed or captured by hunters during hunting.

E is between 0 and 1. E tends towards 0 when almost all individuals belong to a single species and takes the value 1 when all species have exactly the same overlap.

Concerning assessment of the impact of hunting on the conservation of wildlife resources, the z-test was done to see if there is statistical significance between the proportions of males and females within each species (Figure 9) and within all species combined. It was carried out using the ''prop.test ()'' function.

3. Results

3.1. Identification of the species hunted in the Lama Forest Reserve

The following table 1 presents the different species hunted in the Lama Forest Reserve. Twenty-three species, including mammals, reptiles and birds, are hunted in the Lama Forest Reserve (Table 1).

Table 1: List of hunted species of Lama Forest Reserve in Southern Benin

Local names		Scientific names	Families
Holli	**Fon**		
Ewou	Ho	*Thryonomys swinderianus*	Thryonomyidae
Ôtou	Zoungbô	*Cephalophus monticola*	Bovidae
Ôtou	Zoungbô	*Cephalophus niger*	Bovidae
-	Tè	*Cephalophus maxwelli*	Bovidae
Awawa	Zounvoun	*Dendrohyrax dorsalis*	Procaviidae
Ikoun	Wassagbé	*Xerus erythropus*	Sciuridae
-	Assoklé	*Pternistis bicalcaratus*	Phasianidae
-	-	*Genetta genetta*	Viverridae
Ôgbanyin	Agbanlin	*Tragelaphus scriptus*	Bovidae
Ehoro	Azoui	*Lepus crawshayi*	Leporidae
Wo koukoui	-	*Crossarchus obscurus*	Herpestidae
Ôgbè	-	*Cercopithecus mona*	Cercopithecidae
Iwô	Lihui	*Manis tricuspis*	Manidae
-	Sonou	*Guttera pucherani*	Numididae
Êlèdè	Gbéglouza	*Potamochoerus porcus*	Suidae
-	Dangbé	*Python regius*	Pythonidae
-	Hon	*Python sebae*	Pythonidae
Awassa	Atchou	*Cricetomys gambianus*	Nesomyidae
Eman	Gbédja	*Arvicanthis niloticus*	Muridae
Ôgbè	Zinvè	*Cercopithecus erythrogaster erythrogaster*	Cercopithecidae
Ochiké	Zin-ayiwè	*Chlorocebus aethiops tantalus*	Cercopithecidae
-	Vê	*Varanus niloticus*	Varanidae
-	Djakpata	*Bitis arietans*	Viperidae

The histograms in figure 2 illustrate the hunted species in the Lama Forest Reserve cited by the respondents. Five species of mammals were hunted as a priority, including *Thryonomys swinderianus* (96.77%), followed respectively by *Lepus crawshayi* (90.32%), *Cephalophus maxwelli* (58.06%), *Xerus erythropus* (54.83%) and *Cricetomys gambianus* (54.83%). An inequality was found in the frequency of hunting species in Lama Forest Reserve (X-squared = 147.63, df = 22, p-value < 2.2e-16).
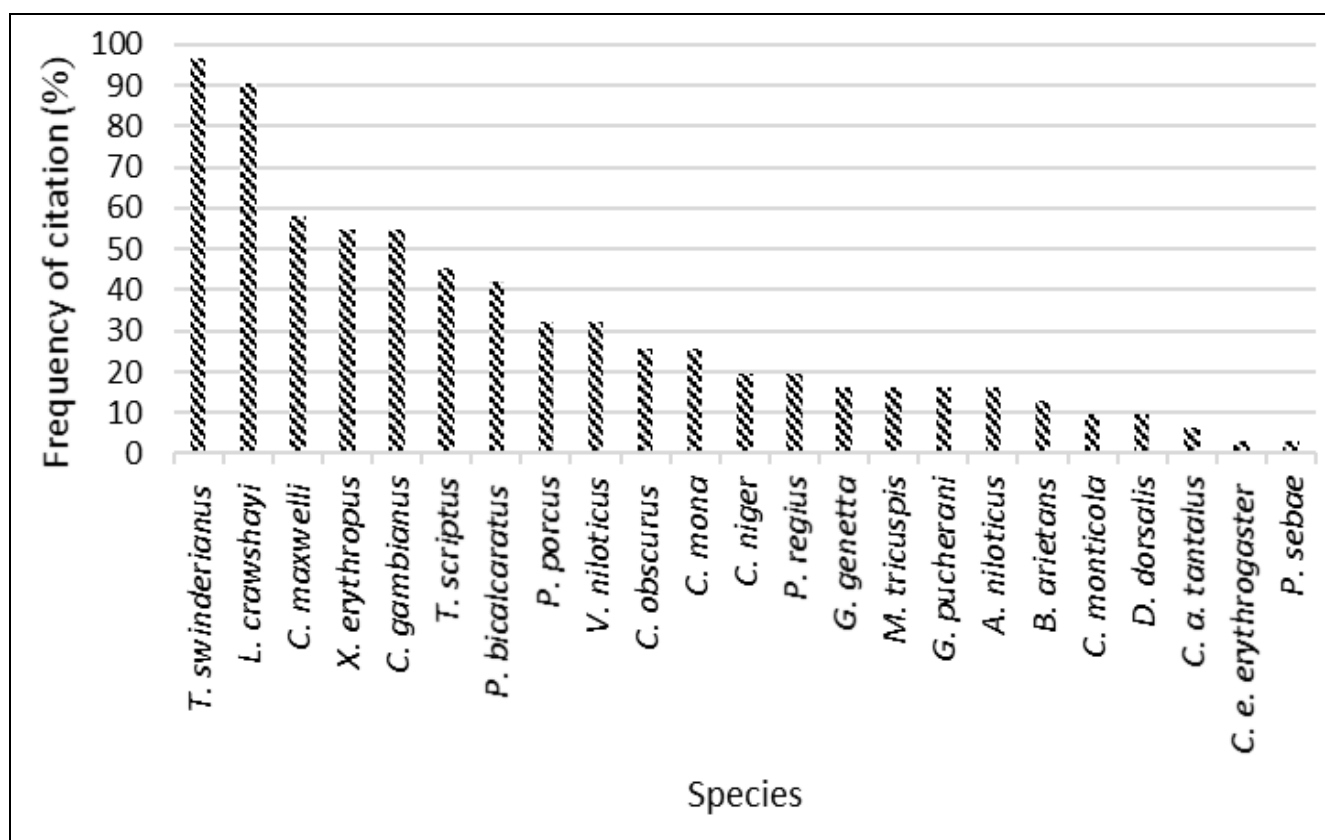

Fig 2: Frequency of citation of the most hunted species according to respondents

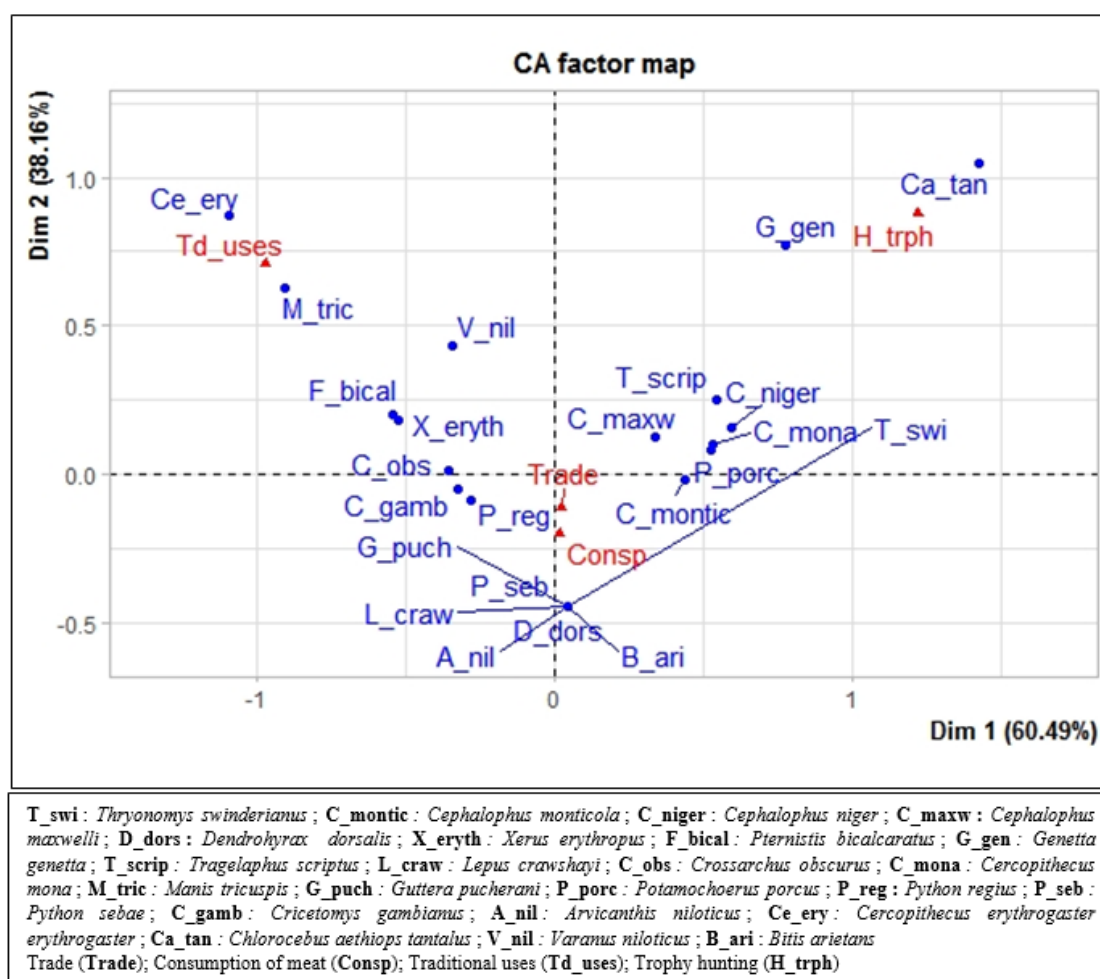Table 2 shows the density of species according to types of uses. The majority of hunted animal species were used for trade (Trade) and meat consumption (Consp), followed by traditional uses (Td_uses) and trophy hunting (H_trph).

Table 2: Density of species according to types of uses

		Consp	Trade	H_trph	Td_uses
1.	*Thryonomys swinderianus*	●	●		
2.	*Cephalophus monticola*	•	•	•	
3.	*Cephalophus niger*	•	•	•	
4.	*Cephalophus maxwelli*	●	●	•	•
5.	*Dendrohyrax dorsalis*	•	•		
6.	*Xerus erythropus*	●	●		●
7.	*Pternistis bicalcaratus*	●	●		●
8.	*Genetta genetta*	•	•	•	•
9.	*Tragelaphus scriptus*	●	●	•	•
10.	*Lepus crawshayi*	●	●		
11.	*Crossarchus obscurus*	•	•		•
12.	*Cercopithecus mona*	•	•		
13.	*Manis tricuspis*	•	•		●
14.	*Guttera pucherani*	•	•		●
15.	*Potamochoerus porcus*	•	•		
16.	*Python regius*	•	•	•	
17.	*Python sebae*	•	•		•
18.	*Cricetomys gambianus*	•	•		
19.	*Arvicanthis niloticus*	●	●		●
20.	*Cercopithecus erythrogaster erythrogaster*	•	•		•
21.	*Chlorocebus aethiops tantalus*	•	•	•	
22.	*Varanus niloticus*	●	•	•	●
23.	*Bitis arietans*	•	●		

The points in the above figure 3 showed the factor map of hunted species according to types of uses (X-squared = 154.33, df = 66, p-value < 0, 0001). The differences were statistically significants. More dependency existed between species and consumption and trade uses (Figure 3). The animals were therefore primarily hunted in the Lama Forest Reserve for consumption and trade.

CA factor map

T_swi : *Thryonomys swinderianus* ; C_montic : *Cephalophus monticola* ; C_niger : *Cephalophus niger* ; C_maxw : *Cephalophus maxwelli* ; D_dors : *Dendrohyrax dorsalis* ; X_eryth : *Xerus erythropus* ; F_bical : *Pternistis bicalcaratus* ; G_gen : *Genetta genetta* ; T_scrip : *Tragelaphus scriptus* ; L_craw : *Lepus crawshayi* ; C_obs : *Crossarchus obscurus* ; C_mona : *Cercopithecus mona* ; M_tric : *Manis tricuspis* ; G_puch : *Guttera pucherani* ; P_porc : *Potamochoerus porcus* ; P_reg : *Python regius* ; P_seb : *Python sebae* ; C_gamb : *Cricetomys gambianus* ; A_nil : *Arvicanthis niloticus* ; Ce_ery : *Cercopithecus erythrogaster erythrogaster* ; Ca_tan : *Chlorocebus aethiops tantalus* ; V_nil : *Varanus niloticus* ; B_ari : *Bitis arietans*
Trade (**Trade**); Consumption of meat (**Consp**); Traditional uses (**Td_uses**); Trophy hunting (**H_trph**)

Fig 3: Factor map of hunted species according to types of uses

In the following table 3, the density of occurrence of hunting species is presented. The majority of hunted animal species were found within the central core of the forest, followed by plantations surrounding the core zone. Therefore, some species such as *Thryonomys swinderianus* and *Lepus crawshayi* were found in large numbers in the fields.

Table 3: Density of species according to types of habitat

	Species	Field	Planting area	Forest
1.	*Thryonomys swinderianus*	●		●
2.	*Cephalophus monticola*		·	·
3.	*Cephalophus niger*		·	·
4.	*Cephalophus maxwelli*		●	●
5.	*Dendrohyrax dorsalis*			·
6.	*Xerus erythropus*			·
7.	*Pternistis bicalcaratus*		·	·
8.	*Genetta genetta*	●	●	·
9.	*Tragelaphus scriptus*	●		●
10.	*Lepus crawshayi*		·	●
11.	*Crossarchus obscurus*	●	●	·
12.	*Cercopithecus mona*		·	·
13.	*Manis tricuspis*		·	·
14.	*Guttera pucherani*	·	·	·
15.	*Potamochoerus porcus*		·	·
16.	*Python regius*	·		
17.	*Python sebae*			●
18.	*Cricetomys gambianus*	·	·	·
19.	*Arvicanthis niloticus*	·		·
20.	*Cercopithecus erythrogaster erythrogaster*	●	·	
		·		
21.	*Chlorocebus aethiops tantalus*	·	·	·
22.	*Varanus niloticus*	·	·	●
23.	*Bitis arietans*	·	·	·

The points in figure 4 showed the factor map of hunted species according to types of habitat (X-squared = 150.55, df = 44, p-value < 0,0001). The differences were statistically significants. More dependency was found between species and central core of the forest and planting areas (Figure 4). This confirmed the impact of habitats in the conservation of biological resources, depending on the degree of conservation.
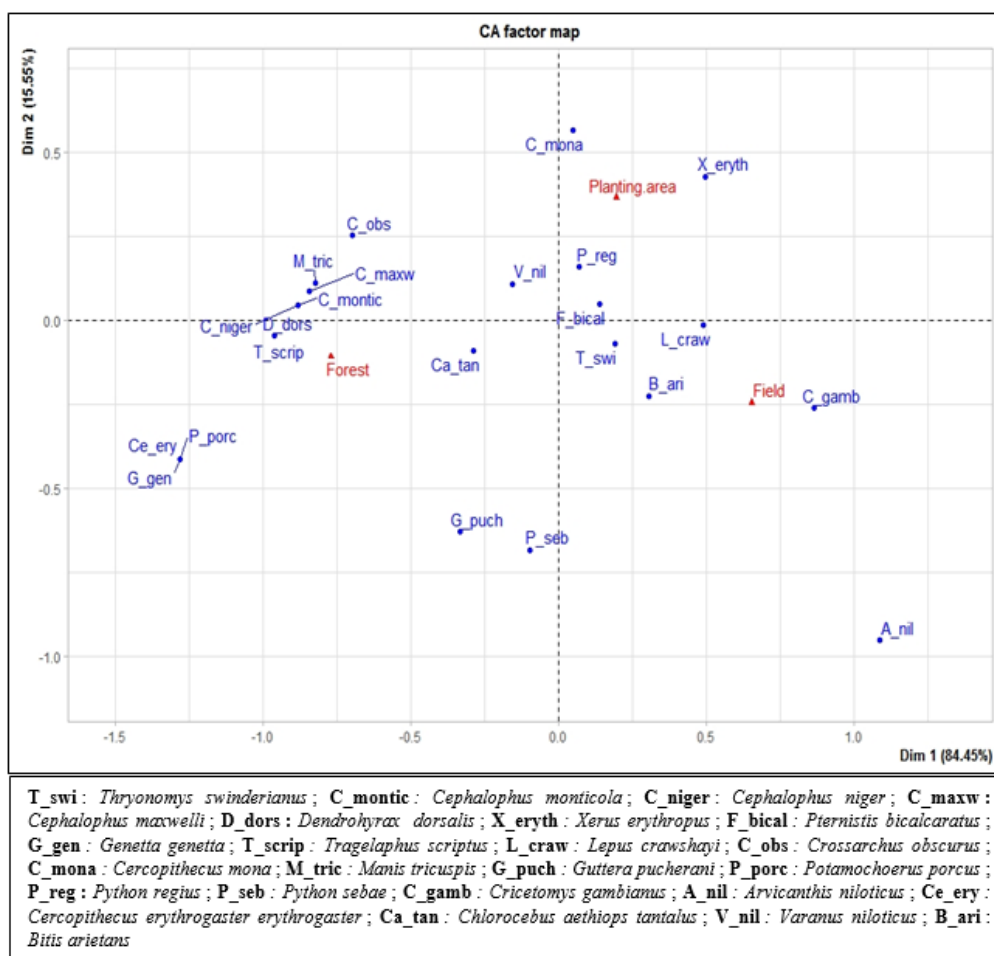

T_swi : *Thryonomys swinderianus* ; C_montic : *Cephalophus monticola* ; C_niger : *Cephalophus niger* ; C_maxw : *Cephalophus maxwelli* ; D_dors : *Dendrohyrax dorsalis* ; X_eryth : *Xerus erythropus* ; F_bical : *Pternistis bicalcaratus* ; G_gen : *Genetta genetta* ; T_scrip : *Tragelaphus scriptus* ; L_craw : *Lepus crawshayi* ; C_obs : *Crossarchus obscurus* ; C_mona : *Cercopithecus mona* ; M_tric : *Manis tricuspis* ; G_puch : *Guttera pucherani* ; P_porc : *Potamochoerus porcus* ; P_reg : *Python regius* ; P_seb : *Python sebae* ; C_gamb : *Cricetomys gambianus* ; A_nil : *Arvicanthis niloticus* ; Ce_ery : *Cercopithecus erythrogaster erythrogaster* ; Ca_tan : *Chlorocebus aethiops tantalus* ; V_nil : *Varanus niloticus* ; B_ari : *Bitis arietans*

Fig 4: Factor map of hunted species according to types of habitat

3.2. Identification of hunting tools and methods in the Lama Forest Reserve

Subsistence hunting and commercial hunting were both forms of hunting in the Lama Forest Reserve (Figure 5). Thus, 100% of the hunters and 83.33% of the rangers surveyed revealed that the most common form of hunting in the Lama Forest Reserve was commercial hunting. No significant difference existed between subsistence and commercial game hunting in the Lama Forest Reserve (X-squared = 0.0065591, df = 1, p-value = 0.9355).
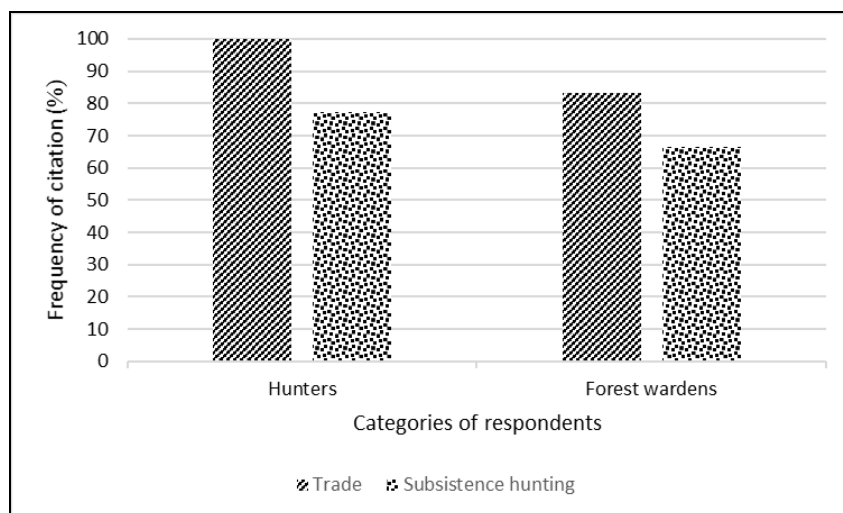

Fig 5: Frequency of citation of forms of hunting by respondents

In order to carry out the hunt, hunters used several means to injure, kill or capture the animals (Figure 6). These means included, among others, metal dog-toothed traps (a), machetes (b), clutch-wire trebuchet (c) and home-made rifles (d).

Fig 6: Hunting tools in Lama Forest Reserve

The histogram of figure 7 below illustrates the hunting periods. In the Lama Forest Reserve, hunting took place both in the dry and rainy seasons. Nevertheless, according to 93.33% of the rangers and 96.77% of the hunters surveyed, the dry season was the period of intense hunting activities in the Lama Forest Reserve but no significant difference was found for game hunting according to hunting periods (X-squared = 0.91017, df = 1, p-value = 0.3401).
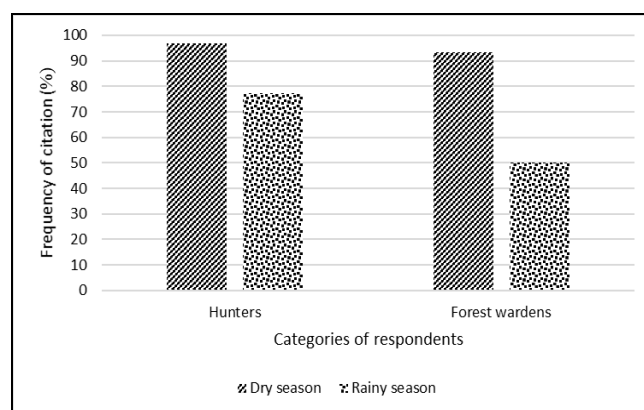

Fig 7: Frequency of citation of hunting periods

Table 4 hereafter presents the hunting methods in the Lama Forest Reserve. According to the investigations, seven hunting methods were distinguished. Several methods were used for game hunting (Table 4). Different methods were used according to the hunting period (dry season and rainy season).

Table 4: Hunting methods in the Lama Forest Reserve according to periods

Hunting methods	Hunting periods
Stalking hunting	Dry season and Rainy season
Night hunting	Dry season and Rainy season
Hound hunting	Dry season
Canvas hunting	Dry season
Trapping	Dry season and Rainy season

3.3. Morphometric characteristics of hunting game species
Figure 8 accounts for the measurements of species in the field. In addition to the frequently hunted species cited by respondents, *Naja nigricollis* and *Cricetomys gambianus* were the two other captured species also observed.

Fig 8: Measurements of hunted game species in Lama Forest Reserve

The measurements of the various parameters considered were recorded in Tables 5, 6 and 7. The parameters measured varied according to the species.

Table 5: Measurement on captured mammals

Species	Total lenght LC (cm)	Head's length LT (cm)	Weight P (g)	Tail's lenght LQ (cm)	Height at withers HG (cm)
T. swinderianus	42.46 ± 8.11	10.23 ± 1.62	2748.23 ± 1096.87	14.99 ± 2	-
L. crawshayi	41.76 ± 2.16	10.40 ± 0.91	1665.05 ± 287.50	6.57 ± 0.84	-
C. gambianus	31.53 ± 3.39	9.26 ± 1.03	504.11 ± 390.41	32.76 ± 2.76	-
X. erythropus	29.03 ± 1.80	8.97 ± 1.20	661.55 ± 133.31	25.03 ± 0.81	-
C. obscurus	34.25 ± 1.76	8.5 ± 1.41	789.2 ± 98.85	17.6 ± 0.84	-
G. genetta	40.5 ± 3.53	9.25 ± 1.06	829.05 ± 133.43	34 ± 2.82	-
M. tricuspis	31	10	503.6	35	-
C. maxwelli	77	21	6.5	-	41

Table 6: Measurement on captured birds

Species	Total lenght LC (cm)	Head's length LT (cm)	Longueur de l'aile LA (cm)	Weight P (g)	Tail's lenght LQ (cm)
P. bicalcaratus	26.04 ± 2.66	6.80 ± 0.53	21.61 ± 4.02	373.15 ± 100.77	6.50 ± 0.80
G. pucherani	42 ± 2	7.67± 0.28	25.67 ± 2.08	1276 ± 195.72	16.17 ± 0.76

Table 7 : Measurement on captured reptiles

Species	Total lenght LC (cm)	Head's length LT (cm)	Weight P (g)	Tail's lenght LQ (cm)
N. nigricollis	150	7	756.6	36
V. niloticus	43.05 ± 6.76	9.1 ± 1.94	1637.75 ±576.22	49.325 ± 15.28

The hunted species diversity index H = 2.67 was low (H < 3.5). A low diversity was found within the species hunted in Lama Forest Reserve. The diversity index E of hunted species E = 0.75 tended towards 1, from which it was able to deduce that most of the species hunted were representative.

3.4. Evaluation of the impact of hunting on the conservation of wildlife resources
The histogram in figure 9 illustrates the proportions of males and females killed according to the species observed. A clear inequality existed in the sex of the species killed. Captured birds observed as well as the ones of *Thryonomys swinderianus* and *Genetta genetta* were female.
According to the z-test, no sex difference was noticed between captured individuals for the species *Genetta genetta* (p-value = 0. 3173), *Crossarchus obscurus* (p-value = 1), *Cephalophus maxwelli* (p-value = 1), *Lepus crawshayi* (p-value = 0.8084), *Cricetomys gambianus* (p-value = 0.4927),

Manis tricuspis (p-value = 1), *Guttera pucherani* (p-value = 1) and *Varanus niloticus* (p-value = 0.4795).

On the contrary, sex differential hunting existed for three species amongst them *Thryonomys swinderianus* (p-value= 0.009322) and *Pternistis bicalcaratus* (p-value= 0.000818), where females were more hunted than males and, *Xerus erythropus* (p-value= 0.03565), where male individuals were more killed than female.
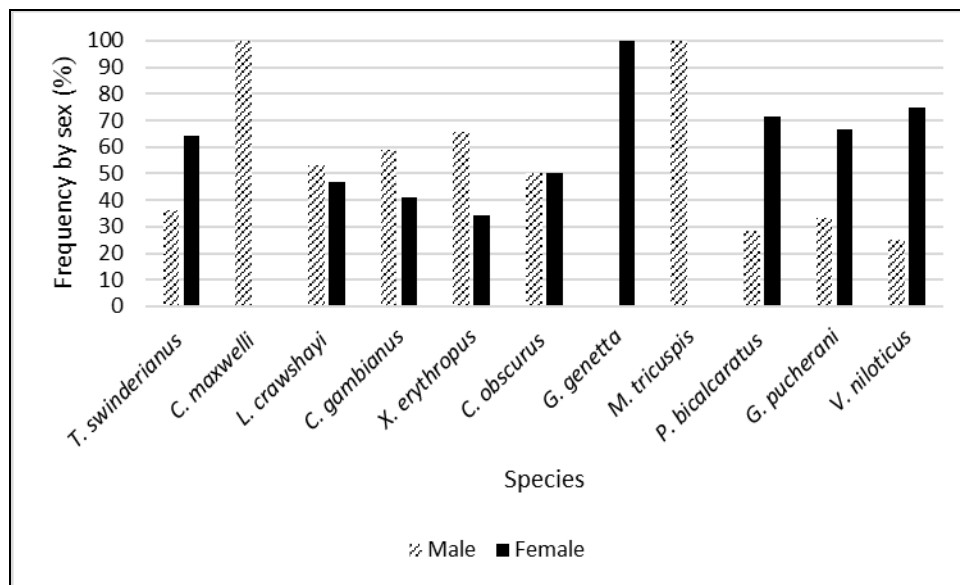

Fig 9: Proportion of species killed by sex

About 55% of the species killed were females *versus* 45% of males and no significant difference existed in the hunting of game species in this reserve according to the sex of the animals (X-squared = 3.2472, df = 1, p-value = 0.07155).

4. Discussion
4.1. Methodology and data
This study is a contribution to the ecological monitoring of wildlife. The methodology used is the snowball survey method [33, 34, 35] used by Nago *et al*. [36]. The investigations are not limited to hunters but also to security guards of the Lama Forest Reserve. This allows for less unquoted information. The statistical analyses have shown that the variables obtained are significants. As far as hunting management is concerned, the method of Robinson and Redford [41] is able to have been tested with the theory of stock recruitment, but requires prior ecological monitoring. The data collected are based not only on surveys but also on observation of the species in the field and their measurements according to the species and the measuring tools.

4.2. Identification of species hunted in the Lama Forest Reserve
The results show that twenty-three species are mainly hunted in the Lama Forest Reserve. Similarly, Djagoun *et al*. [25] showed that around twenty bushmeat species are hunted as a priority. Among these twenty-three species that are hunted, there are five species that are heavily hunted consisting of ungulates and rodents. This confirms the results of Bassett [11], Puit *et al*. [52], Fa and Brown [43], Duonamou *et al*. [44] and Lattine *et al*. [45] who state that the bushmeat trade is dominated by mammals. The results of Djagoun *et al*. [25] revealed the same but to this is added other species such as *Philantomba walteri* and *Atilax paludinosus*. This can suggest the rarity of these species two years after the studies of Djagoun *et al*. [25]. In addition to forests, hunted species are found in plantations and fields. The hunting of species such as *Thryonomys swinderianus*, hares and squirrels is carried out

in all three zones but especially in the fields. These results corroborate those found by Codjia and Assogbadjo [2]. The results of Chabi-Boni *et al*. [22], Djagoun *et al*. [25] and Zangada *et al*. [46] confirmed that some species, despite anthropogenic pressures, show a preference for more or less anthropised habitats. Some respondents revealed that certain species are captured in large numbers in anthropised environments rather than in protected environments, as revealed by the results of Chabi-Boni *et al*. [22]. This may be due to the fact that the core area is protected and hunters have difficulty hunting there because of surveillance patrols. Hunters capture or kill the species mainly for trade and meat, followed by trophy and magical-religious needs.

4.3. Identification of hunting tools and methods in the Lama Forest Reserve
The results show that in the Lama Forest Reserve, hunting is mainly carried out for the bushmeat trade and consumption [47]. Subsistence poaching is mainly of monkey and antelope species [48]. Hunters use metal dog-tooth traps, cable traps, machetes and home-made guns as a means of injuring, capturing or killing animals. Trapping and hunting with guns are the most widely practised, according to Fargeot [19]. In this study, hunting tools are considered for wildlife as a whole. In the work by Puit *et al*. [52], the tools were specified, afterwards, according to order, but only with mammals, not with other orders. Hunting is carried out individually or in groups using various methods at night or during the day, in the rainy or dry season depending on the species. Night hunting is gradually being reinforced by the use of LED lights by increasing the frequency and efficiency of hunting, which is becoming a major threat to wildlife [47]. The results of the surveys stipulate that hunting takes place more in the dry season than in the rainy season. These results confirm those of ONAB [27].

4.4. Morphometric characteristics of hunted animals
Morphometric and body weight measurements such as head

length, total body length and tail length are taken in general on the eleven species hunted by hunters and specifically wing length in birds and height at withers in ungulates. This study can also have focused on eggs, in oviparous birds, which represent the hope of their survival. In terms of measurements, Ettian *et al*. [49] in their work, depending on the objectives, had only taken measurements of *Thryonomys swinderianus* head, tail and hind legs, but also its weight. The parameters measured at the level of the three classes vary according to the species. The average body length of *Xerus erythropus* is 29.03 cm; the average length of the tail is 25.03 cm and the average weight is 661.5 g. On the other hand, the work of De Visser *et al*. [50] showed that the average body and tail length of *Xerus erythropus* were 25.5 cm and 21.9 cm respectively and its average weight was 650 g. The average length of the body and tail of *Cricetomys gambianus* are 31.53 cm and 32.76 cm respectively, while they are 35.2 cm and 36.1 cm respectively [50]. The average body and tail length of *Thryonomys swinderianus* are 42.46 cm and 14.99 cm respectively while Zangada *et al*. [46] found that the average body and tail length of the *Thryonomys swinderianus* are 30 cm and 20 cm respectively. Morphometric and body weight measurements show that hunted animals are younger than those hunted some years ago [46, 50].

4.5. Evaluation of the impact of hunting on the conservation of wildlife resources

In the work of Chabi-Boni *et al*. [23] and Puit *et al*. [52], the orders of animals most affected by hunting are presented, and in that of Djagoun *et al*. [25], the species most affected. This study shows that hunting samples are non-selective with the presence of males and females in the captures. This study goes even further by specifying the vulnerability of species according to gender. The results show that the proportion of female species killed, wounded or captured during hunting is higher than that of male species killed, wounded or captured during hunting. This state of affairs has a negative impact on the reproduction of species as well as on the sustainability and conservation of wildlife resources in the Lama Forest Reserve. The harnessed ibex, duikers, monkeys and bushpigs are all species find mainly in the central core of the forest, but which are economically profitable and therefore more sought-after by hunters. Investigations by ONAB [27] have already shown a decline in the population of many species in the central core area due to poaching. Studies such as those by Coubéou [51] had already reported once that populations of several species formerly present in the central core had been decimated. In oviparous species, it will also be important to consider the eggs.

5. Conclusion

The study shows that hunters hunt species as long as they have a socio-economic interest. Also, no measures restricting the quota or the characteristics of the game to be killed have yet been implemented. It will then be essential to investigate specifically the share of meat consumption in other uses of bushmeat, the protein needs of populations, and then the share of bushmeat in the protein sources of populations in support of the work of Codjia and Assogbadjo [2], with the aim of developing sustainable strategies for species conservation. It will be important for hunters to be officially enlisted and only those species that have already been experimented with will be hunted. Thus, researchers will also carry out experimental *ex-situ* breeding and reproduction work, as in the case of the

grasscutter, which is already quite successful.

7. Conflicts of interest

The authors declare that there are no conflicts of interest regarding this publication.

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