BUSHMEAT HUNTING IN SOUTHEASTERN CAMEROON: MAGNITUDE AND IMPACT ON DUIKERS (*CEPHALOPHUS* SPP.)

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ABSTRACT Information regarding the hunting activities of local residents is essential for solving sustainability problems in afro-tropical forests. We studied bushmeat hunting in two Community Hunting Zones (CHZs 13 and 14) located in the northern periphery of Boumba-Bek National Park in southeastern Cameroon. We monitored 899.14 hunter-days in nine neighboring villages, over a period of 12 months. Animals were hunted in national parks and in logging and agroforestry zones. We recorded 587 carcasses of 38 species, for a total fresh biomass of 3.46 tons. Ungulates and primates were the most heavily hunted; however, the latter were primarily represented in CHZ 13, the zone with the most intensive hunting pressure. Reptiles and birds were fairly represented among offtakes (4.36%). Harvests varied considerably by species and CHZ. The blue duiker (41%) and the putty-nosed monkey (15%) were the most frequently captured. In contrast with the latter, the blue duiker was harvested at similar rates in all the villages, indicating its importance for local people. Hunters consumed 26.7% of their total catch with their families and sold 67.8%. The bushmeat trade, defined in terms of the proportion of animals sold, was positively correlated with the number of households. In both CHZs hunting was largely unsustainable for blue duikers. However, in CHZ 14 offtakes of red duikers were probably under sustainable harvest limit. Our analysis have implications for the development of adaptive wildlife management plans that could enhance sustainability in the region. Overhunting will not be solved, unless the bushmeat trade is tackled effectively.

Key Words: Bushmeat; Cameroon; Duiker; Harvest rate; Sustainability.

INTRODUCTION

Bushmeat has always been an important cultural and medicinal item, and it is the main source of protein for thousands of rural families in African rainforests (Abernethy et al., 2013). It contributes between 30 and 80% of the protein consumed in rural households in central Africa (Auzel, 2007). However, over the last three decades, numerous factors have combined to create significant pressure on wildlife species. Bushmeat hunting, population growth, increasing urban demand for meat, economic crisis, and poverty have made hunting a major threat to wildlife in most tropical forests (Rist et al., 2008). Logging (Davies, 2002; Yasuoka, 2006) and other extraction industries (CITES, 2000) are largely responsible for the increasing demand for wildlife products and the creation of hunting, transport, and commercial facilities.

Today, commercial hunting constitutes the most serious threat to large vertebrates (Wilkie et al., 2011), jeopardizing their ecological roles and hence the general livelihoods of forest dwellers (Nasi et al., 2011). In the Congo basin, overharvesting is threatening the survival of at least 80 species and sub-species of mammals including 17 species of primates and 12 species of duikers (WWF, 2008). Fa et al. (2006) reported that in Nigeria, about 34 kg of bushmeat are extracted per km^2 and an estimated total of 0.74 to 1.12 million tons are harvested in the Congo basin. As a result, many species are increasingly scarce, although some are endowed with a remarkable capacity to recover from hunting and can tolerate relatively high levels of habitat disturbance.

In Africa, duikers (*Cephalophus* spp.) constitute a remarkable group of mammals with respect to their economic, ecological and zoological importance (Dubost, 1980). They are the most frequently encountered mammals. They are also known to be among the most productive species (Newing, 2001; Nasi et al., 2008), and some of them can tolerate high levels of habitat disturbance. However, many populations have been reported to be under serious threat due to unsustainable offtakes (Fa et al., 1995; Fimbel et al., 2000; Fa et al., 2001; van Vliet & Nasi, 2008; Abernethy et al., 2013).

A necessary first step in the management of bushmeat hunting is evaluating the sustainability of current offtake levels. This implies measuring the bushmeat harvest and evaluating its impacts on hunted populations (Milner-Gulland & Akcakaya, 2001). Additionally, assessing the sustainability of hunting requires a sound appraisal of catchment areas and an understanding of spatial and temporal changes in hunting practices (van Vliet & Nasi, 2008). Therefore, practicable and scientifically robust indicators are crucial for measuring sustainability and updating policies pertaining to bushmeat hunting policy in west and central Africa (van Vliet et al., 2010; Taylor et al., 2015).

In this paper, we provide basic information regarding bushmeat hunting patterns (hunters' profiles, species composition, use of bushmeat, hunting tools and hunting territories) within two local communities with substantially different human densities and hunting pressures. We also evaluate the sustainability of hunting and suggest conditions for sustainable wildlife management.

RESEARCH AREA

The Boumba-Bek National Park (BBNP) is situated at the eastern edge of Cameroon, between the latitudes of 2°08' and 2°58' N and longitudes of 14°43' and 15°16' E (Fig. 1). Field research was conducted in nine villages in Community Hunting Zones (CHZ) 13 and 14, an area located at the northern border of Boumba-Bek National Park and bounded to the southwest by Nki National Park. (Fig. 1). These villages are located along a secondary road that passes through the CHZs from the northeast at the village of Biwala 1 to the Southwest at Ngatto

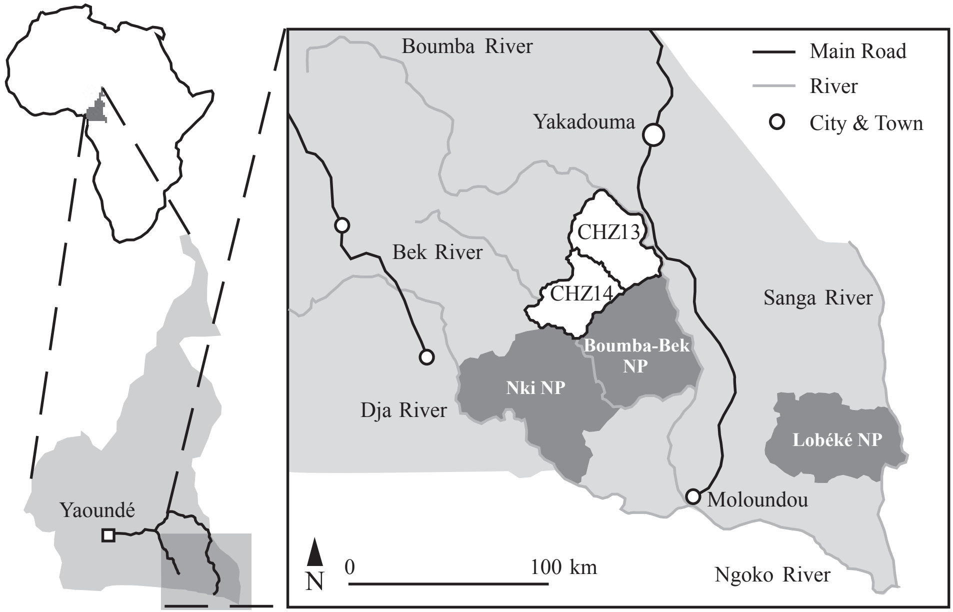


Fig. 1. Location of the study area, Community Hunting Zones (CHZ) 13 and 14, and the neighboring national parks (NP).

Ancien. There are five villages in each of these CHZs. The human population in the villages of CHZ 13 (Biwala 1, Massea, Zoka Diba, Bintom, Gribe) is estimated at 4,500 people. The villages of CHZ 14 (Song Ancien, Gouonepoum Ancien, Zoulabot Ancien, Malea Ancien), comprise approximately 800 people (Halle, 2000; see also Toda, 2014). As CHZs 13 and 14 cover 1,130 and 877 km^2, their population densities are 4.0 and 0.9 people/km^2 respectively.

Forest exploitation has occured in BBNP (MINFOF, 2011). Annual rainfall varies from 1500 to 1700 mm, with two rainy seasons and two dry seasons. The vegetation in the southeast Cameroon region is classified as transitory between evergreen forest and semi-deciduous forest populated by species of Sterculiaceae and Ulmaceae (de Namur, 1990; Letouzey, 1985).

BBNP is endowed with high biological diversity. Botanical studies conducted in the national parks and their peripheries revealed a mixture of primary forests, secondary forests, monodominant forests, swampy forests with *Raphia laurentii* and/or *Phoenix reclinata*, etc. (Letouzey, 1985). Studies also revealed the presence of 764 plant species belonging to 102 botanical families (WCS, 1996). Ekobo (1998) reported the presence of 831 species distributed over 111 botanical families in the Boumba-Bek and Nki project area. More than 44 plant species were of very high commercial value. Animal diversity is also very high. Wildlife censuses revealed the presence of 34 species of large mammals and 121 species of fish. At least 12 species of ungulates, 11 species of primates and four carnivorous species have been identified in BBNP (Ekobo, 1998).

Population, Livelihood and Culture

Two main groups of people are found in the area: the Konabembe Bantu and the Baka hunter-gatherers. The primary hunting tools currently used in the area are wire snares and firearms. Crossbow and hunting nets have almost entirely disappeared. However, a few Baka still use spears.

The seeds, grains and fruits of many species are of crucial importance for the livelihood of local populations. The most heavily exploited species are *Irvingia gabonensis*, *Ricinodendron heudelotii*, *Tetrapleura tetrapleura*, *Gnetum africanum*, *Afromomum dalzeillii*, *Cola* spp., *Baillonella toxisperma* (Ekobo, 1998). Among the 131 ligneous species identified in the area, at least 41 are used in the Baka pharmacopeia (Kenfack & Fimbel, 1995).

METHODS

Data Collection

We monitored offtakes during 899 hunter days from 122 of the 236 active hunters in nine villages in the area. Because we carried out predominantly village-based surveys, our samples excluded the majority of semi-nomadic Baka hunters who essentially leave in forest camps. Hunters were monitored during variable periods within and between villages. In the villages of CHZ 13, we monitored 36 of the 80 active hunters (14 of the 21 gun hunters, 15/40 trappers and 7/19 gun hunters and trappers), for a total of 300 hunter days. Among the 156 active hunters in CHZ 14, we monitored 86 (5/9 gun hunters, 71/122 trappers and 10/25 gun hunters and trappers), totaling 593 hunters days (Table 1). When were not accompany hunters into the forest, we visited them in their households after each hunting expedition to inspect their catches. We recorded the fresh biomass, the weapon used, the expected use (sale, consumption or both) and the selling price for animals that were captured. We adopted nomenclature following Kingdon (1997). To visualize the spatial organization and extent of the hunting territories, we followed hunters into the forest and recorded GPS coordinates along gun hunting paths and snare lines.

Data Analysis

Villages were classified into two groups according to the CHZ in which the settlement was found. Gribe, whose settlement is in the vicinity of both CHZs, was assigned to CHZ 14 because its hunters were more active in that zone (Fig. 6).

Smoked and rotten carcasses were considered as having average biomass of the species. Statistical analysis was completed using Statistica 8.0 software (StatSoft, Inc., 2007). All means are reported with one standard deviation (± SD) and a one-way ANOVA was used to test the significance ($\alpha = 0.05$) of observed differences. Using ArcGIS 10, the GPS coordinates recorded on hunting paths were transposed on a geographical map. We used the convex hull function of Quantum

GIS software (version 1.8.0) to connect the outermost points recorded in each CHZ and delimitate the catchment areas. The numbers of households and hunters per hunting tool were determined by house-by-house counting with the aid of two local assistants in each village.

Annual offtakes were estimated as follows:

Number of carcasses harvested per year = Number of carcasses recorded × (Total number of hunters/number of hunters monitored) × (365/duration of monitoring in days).

To determine the sustainable levels of hunting, we compared actual offtakes with theoretical sustainable harvests, based on the productivity and density of the duiker populations in the area. The most common methods used to calculate sustainability of hunting follow the model of Robinson and Redford (1991). These authors estimate the sustainable harvest rate to be 40% of annual production for "short-lived species" with a life span of 5–10 years (blue and red duikers).

RESULTS

Typology of Hunters, Numbers and Survey Efforts

In November–December 2013, 236 hunters were active in the study area. Among them, 30 (12.7%) were using only shotguns, 162 (68.6%) only cable snares, and 44 (18.7%) were using both (Table 1). Although the number of households was similar in CHZ 13 and 14, there was an important difference in the number of hunters (80 in CHZ 13 vs 156 in CHZ 14). In addition, gun hunting was relatively more prevalent in CHZ 13, where the human population was higher. Hunters using shotguns represented 50% of the total number of hunters in CHZ 13 (40/80) while they constituted only 22% in CHZ 14 (34/156).

Baka Pygmies often used shotguns belonging to the Konabembe to obtain meat, in exchange for other commodities. At least one Baka hunter from Gribe still used spear and dogs. We followed him for two hunting expeditions, the first of which occurred in the daytime with spears and dogs, and the second, by night with shotgun and headlamps. Both were unproductive.

The households had an average of 0.7 ± 0.3 hunters. A household was defined as persons living in one home and using the same cooking materials. Each single or widowed person who was living and preparing food in his or her own house was considered to form a separate household.

Among the 93 hunters interviewed, 64 (68.8%) were between 10 and 40 years old of age (Fig. 2). Most hunters were Konabembe Bantu, though some were Baka pygmies. There were also others Bantu-speaking hunters (two Eton, two Kako, one Nzime, one Yerebe and one from the Central African Republic), representing natives from other areas. Hunters engaged in a diverse set of activities to earn a livelihood, with farming as the principal activity for 58.1%, followed by bike transporting (10.7%), fishing (9.7), and enrollment in studies (7.5). Only

Table 1. Types and numbers of hunters, mean duration of the survey, and number of households per village

	Village	Gun hunters		Trappers		Gun and trap hunters		Total		Number of households	Mean duration of hunter monitoring (days)
		Nm	Nt	Nm	Nt	Nm	Nt	Nm	Nt		
CHZ 13	Masséa	4	11	2	20	2	10	8	41	107	7.67 ± 0.58
	Bintom	6	6	5	5	1	1	12	12	33	9.58 ± 7.12
	Zoka Diba	4	4	8	15	4	8	16	27	67	7.75 ± 6.65
	Total	14	21	15	40	7	19	36	80	207	8.33 ± 1.08
CHZ 14	Gribé	2	4	28	43	8	23	38	70	76	7.29 ± 3.92
	Song Ancien	1	1	10	14	-	0	11	15	18	7.91 ± 3.48
	Gouonepoum Ancien	-	0	6	7	1	1	7	8	6	7.00 ± 4.46
	Zoulabot Ancien	0	1	9	15	-	0	9	16	30	6.67 ± 2.24
	Maléa Ancien	1	1	11	24	-	0	12	25	32	5.42 ± 0.90
	Ngatto Ancien	1	2	7	19	1	1	9	22	28	7.11 ± 0.78
	Total	5	9	71	122	10	25	86	156	190	6.90 ± 0.83
	Grand total	19	30	86	162	17	44	122	236	397	7.37 ± 1.11

Nm: Number of hunters monitored.
Nt: Total number of hunters.

six respondents (6.5%) affirmed that hunting was their main livelihood activity pertaining. Most hunters were married (59; 63.4%), 23 were single (24.7%), and 11 (11.8%) divorced. Although we did not collect information on household size, these observations indicate that most hunters had a family to support, suggesting the importance of the bushmeat trade for its contribution to household revenue.

Diversity and Harvested Bushmeat Volume

During the study period, we recorded 587 animals belonging to 38 species (33 mammals, three birds and two reptiles) for a total fresh biomass of 3,459.55 kg (Table 2). In terms of number of carcasses, mammals accounted for 95.74% of total catches, reptiles 3.41%, and birds 0.85%. In terms of weight, 97.86% of the total harvested biomass consisted of mammals, 2.03% of reptiles and 0.11% of birds.

In terms of number, over 53% of catches were ungulates (313 carcasses, nine species), followed by primates (28%, 162 carcasses, 11 species), rodents (9%, 50 carcasses, three species), pangolins (4%, 24 carcasses, two species), carnivores (1.53%, nine carcasses, six species) and galliformes (0.68%, four carcasses, two species). Hyraxes, insectivores, bucerotiformes and testudinia were fairly represented with only one individual each (0.2%).

In terms of weight, ungulates also constituted also the major proportion (66.47%) of the total offtake, indicating the importance of this animal group for local people. Primates, rodents and carnivores constituted 24.8%, 3.7% and 0.8% respectively of the total biomass extracted.

In villages of CHZ 13, where human density was higher, we recorded 25 species, compared with 33 in CHZ 14. Carnivores were extremely rare in CHZ 13. Of the nine individual animals recorded (five species), only one (the African

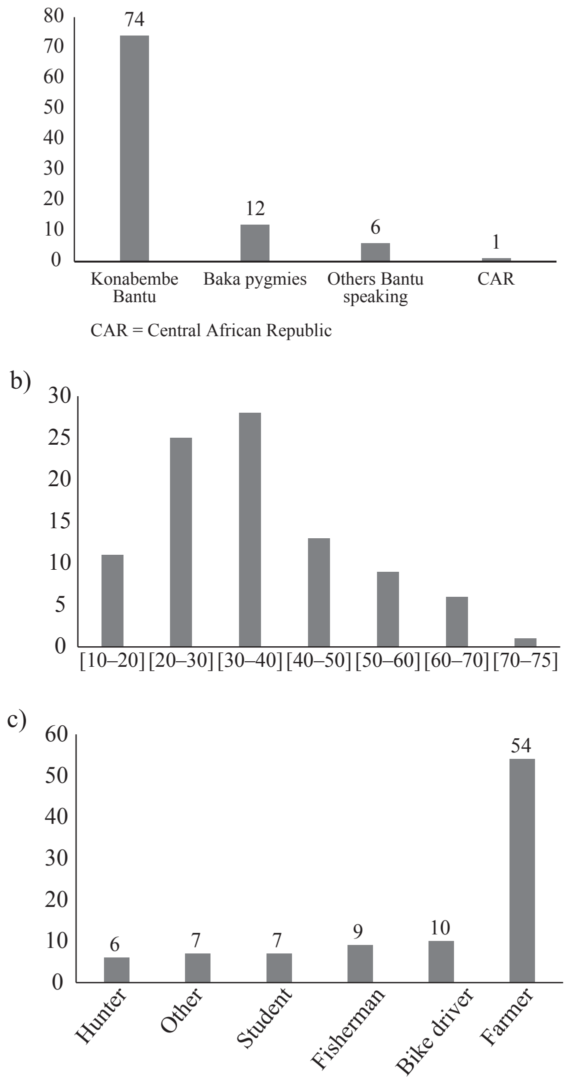


Fig. 2. Distribution of hunters according to (a) origin group (b) age class and (c) principal livelihood activity.

palm civet *Nandinia binotata*) was found in CHZ 13.

Although diverse species were hunted, the blue duiker *Cephalophus monticola*, was by far the most frequently hunted, representing 41.74% of the total catches (30.57% by weight). The second most hunted species was the putty-nosed monkey *Cercopithecus nictitans* (14.65% of catches, 12.31% by weight), followed by the Peter's duiker (4.35%, 12.35%).

There was no significant difference in the mean number of red duikers harvested per hunter per day between the two CHZs (df = 1, n.s.) (Fig. 3). However, the

Table 2. Number of animals and fresh biomass harvested in 9 villages by local hunters

	CHZ 13									
	Mas		Bin		ZD		Total CHZ 13		Gri	
Species	n	m	n	m	n	m	n	m	n	m
Ungulates	36	219.87	64	344.4	47	369.75	147	934.02	56	480.04
Cephalophus callypigus	1	15.33	2	22.9	5	87.27	8	125.5	7	100.27
Cephalophus dorsalis	2	29.33	2	20.33	3	38.33	7	87.99	5	82.1
Cephalophus monticola	32	140.21	59	276.17	36	160.65	127	577.03	41	164.77
Cephalophus nigrifrons									1	12.9
Cephalophus silvicultor			1	25			1	25		
Hyemoschus aquaticus										
Neotragus batesi					2	3.5	2	3.5		
Potamochoerus porcus	1	35			1	80	2	115	1	80
Tragelaphus spekei									1	40
Primates	13	70.78	33	189.94	85	444.97	131	705.69	14	62.5
Cercocebus agilis			4	33.9	14	109.87	18	143.77	2	11.4
Cercopithecus ascanius			1	4	1	4	2	8		
Cercopithecus cephus	4	15.25	1	5.1	3	12.5	8	32.85	2	7
Cercopithecus mona					2	10.5	2	10.5		
Cercopithecus neglectus										
Cercopithecus nictitans	7	33.2	16	85.22	48	239.3	71	357.72	7	32.5
Cercopithecus pogonias			4	13.9	15	51.3	19	65.2	3	11.6
Colobus guereza	1	16.5			1	16.5	2	33		
Colobus satanus			1	12			1	12		
Lophocebus albigena	1	5.83	6	35.82			7	41.65		
Perodicticus potto					1	1	1	1		
Rodentia			6	18.17	5	6.96	11	25.13	21	47.23
Atherurus africanus			4	14.17	1	3	5	17.17	11	37.47
Cricetomys emini			2	4	4	3.96	6	7.96	9	8.86
Protoxerus stangeri									1	0.9
Carnivora			1	3.5			1	3.5	2	7.61
Atilax paludinosus										
Bdeogale nigripes									1	4.11
Crossarchus obscurus										
Felis aurata										
Genetta servalina										
Nandinia binotata			1	3.5			1	3.5	1	3.5
Pholidota			7	16	4	6.5	11	22.5	6	16
Phataginus tricupsis			6	14	4	6.5	10	20.5	6	16
Uromanis tetradactyla			1	2			1	2		
Others*	1	3	6	16.8	6	13.8	13	33.6	9	42.2
Agelastes niger									1	1
Atelerix sp.										
Ceratogymna albotibialis					1	0.8	1	0.8		
Dendrohyrax dorsalis			1	3	1	4	2	7	1	3.5
Francolinus lathami									2	1.1
Kinixys sp.	1	3	4	10.3	4	9	9	22.3	1	2.5
Varanus niloticus			1	3.5			1	3.5	4	34.1
Total	50	293.65	117	588.81	147	841.98	314	1,724.44	108	655.58

*Galliformes, Hyraxes, insectivores, bucerotiformes and testudinia.
n: Number of carcasses, m: Fresh biomass (kg).

CHZ 14												Grand total	
SA		GA		ZA		MA		NA		Total CHZ 14			
n	m	n	m	n	m	n	m	n	m	n	m	n	m
34	234.8	24	201.6	18	190.63	14	137.8	20	120.9	166	1,365.77	313	2,299.79
2	29.3	4	82.6	2	15.6	2	43.6	3	30.4	20	301.77	28	427.27
4	59.7	2	18	3	41.33	2	36.6	2	19	18	256.73	25	344.72
27	110.8	16	69.5	12	49.98	9	32.5	13	53	118	480.55	245	1,057.58
		1	20.7					1	16	3	49.6	3	49.6
1	35					1	25.1			2	60.1	3	85.1
		1	10.8							1	10.8	1	10.8
								1	2.5	1	2.5	3	6
				1	83.72					2	163.72	4	278.72
										1		1	40
1	6	8	40.2			1	7	7	35.5	31	151.2	162	856.89
		2	10					1	12	5	33.4	23	177.17
												2	8
								1	4	3	11	11	43.85
												2	10.5
		1	2							1	2	1	2
1	6	2	8			1	7	4	14.5	15	68	86	425.72
										3	11.6	22	76.8
		1	8							1	8	3	41
		2	12.2							2	12.2	3	24.2
								1	5	1	5	8	46.65
												1	1
3	8.25	5	16.7	3	10.5	3	7	4	11.5	39	101.18	50	126.31
2	7.25	5	16.7	3	10.5	3	7	3	9.5	27	88.42	32	105.59
1	1							1	2	11	11.86	17	19.82
										1	0.9	1	0.9
		3	7	1	3	1	1.5	1	4.3	8	23.41	9	26.91
		1	3							1	3	1	3
										1	4.11	1	4.11
		1	1							1	1	1	1
						1	1.5	1	4.3	2	5.8	2	5.8
		1	3							1	3	1	3
				1	3					2	6.5	3	10
4	13.6	1	2	2	7.5					13	39.1	24	61.6
4	13.6	1	2	2	7.5					13	39.1	23	59.6
												1	2
		2	4	1	1.5			4	6.75	16	54.45	29	88.05
								1	0.75	2	1.75	2	1.75
								1	3.5	1	3.5	1	3.5
												1	0.8
										1	3.5	3	10.5
										2	1.1	2	1.1
		2	4	1	1.5			2	2.5	6	10.5	15	32.8
										4	34.1	5	37.6
42	262.65	43	271.5	25	213.13	19	153.3	36	178.95	273	1,735.11	587	3,459.55

Bin: Bintom, Mas: Masséa, ZD: Zoka Diba, Gri: Gribe, SA: Song Ancien, GA: Gouonepoum Ancien, ZA: Zoulabot Ancien, MA: Maléa Ancien, NA: Ngatto Ancien.

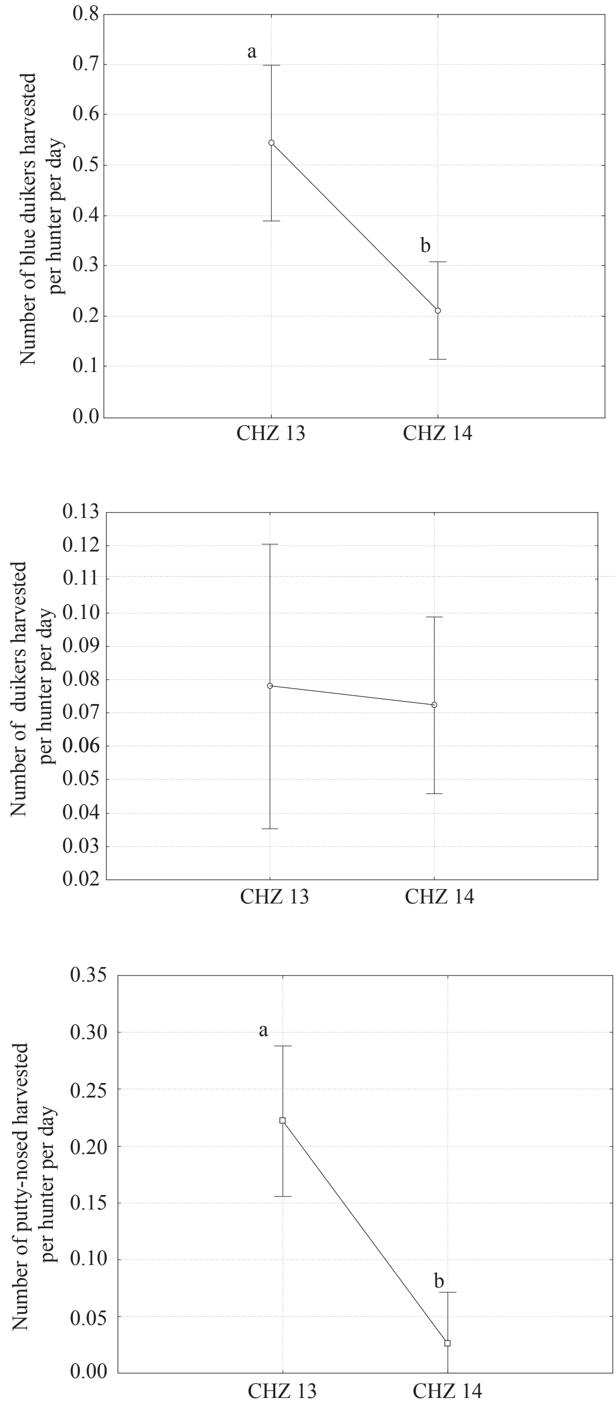


Fig. 3. Mean number of (a) blue duikers, (b) red duikers and (c) putty-nosed monkeys harvested per day by local hunters in CHZ 13 and 14. a and b are significantly different (df = 1, $p < 0.01$).

average number of blue duikers and putty-nosed monkeys harvested per hunter per day was significantly higher for villages in CHZ 13 compared with those for villages in CHZ 14 (df = 1, $p < 0.01$), suggesting a most severe impact of hunting on these species in the more densely populated CHZ 13.

Hunting Tools and Use of Bushmeat

Hunting tools

Shotguns were used to kill 49.8% of all animals (47% of the total fresh biomass), while 46.1% of the animals were caught by traps (50% biomass). As most primates are arboreal, they are primarily hunted with firearms (97%), though two putty-nosed monkeys, two agile mangabeys and one grey-checked mangabey were caught with snare traps (3%). Rodents were most commonly captured with traps (92%). Nile monitors were killed using spears or with the aid of dogs; only tree pangolins (39.1%) and turtles were captured up by hand (Table 3).

In CHZ 13, the more densely human populated of the two zones, guns were the most important hunting weapon providing 79% of the game (80% biomass), whereas snare traps provided only 15% (16% biomass). However, in CHZ 14, where hunting pressure was lower, 82% (84% biomass) of game was caught using cable snares, and only 16% (15%) were killed with shotguns.

Gun hunting occurred as both a diurnal and a nocturnal activity. Guns were used in the daytime to hunt monkeys whereas, night hunting, carried out with the aid of electric torches, was mainly to shoot blue duikers (102 shot by night vs 12 by day), Peter's duiker (three vs four) and the brush-tailed porcupine (three vs one).

Table 3. Number of animals and biomass harvested by local hunters using different weapons

		Shotgun		Trap		Others*		Total	
		n	m	n	m	n	m	n	m
CHZ 13	Ungulates	112	660.76	33	251.26	2	22	147	934.02
	Primates	131	705.69					131	705.69
	Rodentia	3	10.17	8	14.96			11	25.13
	Carnivora	1	3.5					1	3.5
	Pholidota	1	2	2	3.5	8	17	11	22.5
	Others†	1	0.8	3	10	9	22.8	13	33.6
	Total	249	1,382.92	46	279.72	19	61.8	314	1,724.44
CHZ 14	Ungulates	15	101.7	151	1,264.07			166	1,365.77
	Primates	26	130.3	5	20.9			31	151.2
	Rodentia	1	4.2	38	96.98			39	101.18
	Carnivora			8	23.41			8	23.41
	Pholidota			12	36.6	1	2.5	13	39.1
	Others†	2	21.3	11	18.15	3	15	16	54.45
	Total	44	257.5	225	1,460.11	4	17.5	273	1,735.11
	Grand total	293	1,640.42	271	1,739.83	23	79.3	587	3,459.55

†Galliformes, Hyraxes, insectivores, bucerotiformes and testudinia.
*Gathered by hands or caught by dogs.
n: number of carcasses.
m: fresh body mass (kg).

Use of bushmeat

Hunters sold bushmeat from their homes, along the road in the village, or in neighboring villages. Buyers were local people, as well as outsiders. Hunters sold 58.0 ± 36.9% of their captures and earned 1,263 ± 1,658 CFA francs (2.31 ± 3.03 US dollars) per day. Although some meat was consumed by the hunters and their families (26.7%, 157 carcasses), most animals were sold (67.8%, 398 carcasses). Only 18 carcasses (5.9%) were offered to other households, and one blue duiker was exchanged for another commodity. Due to extreme decomposition, six carcasses (1.0%) were abandoned on cable snares. Two putty-nosed monkeys (0.3%) were also abandoned because after they were shot, their bodies remained on high branches, out of reach of the hunter. Neither the proportion of animals sold (R^2 = 0.02; df = 37; ns) nor the proportion consumed (R^2 = 0.01; df = 37; ns) was correlated with the number of animals per of each species that were hunted, suggesting that hunters sold or consumed their meat independently of the number of animals they extracted (Fig. 4).

The number of households per village (Fig. 5) was negatively correlated with the proportion of animals consumed (R^2 = 0.8) and positively correlated with the proportion sold (R^2 = 0.65) suggesting that hunters sold the bushmeat most frequently in larger villages, where the demand was higher. In contrast, no correlation was detected between the number of animals captured in each village (R^2 = 0.16) and the number of households, suggesting that the latter factor did not heavily influence hunting pressure during the study period.

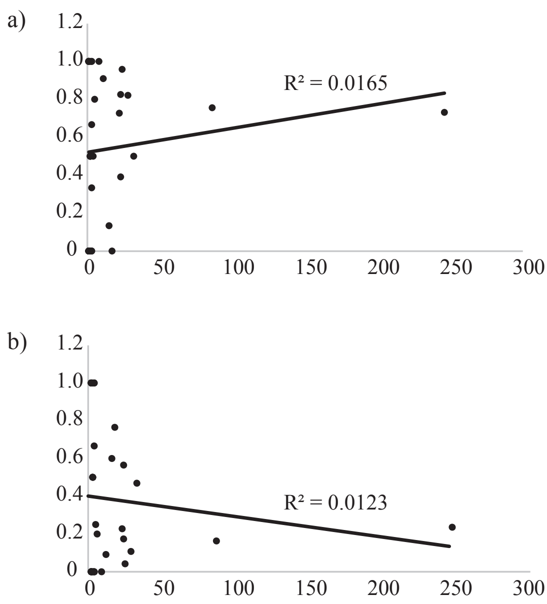
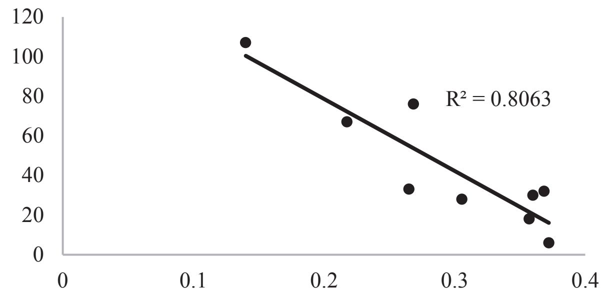
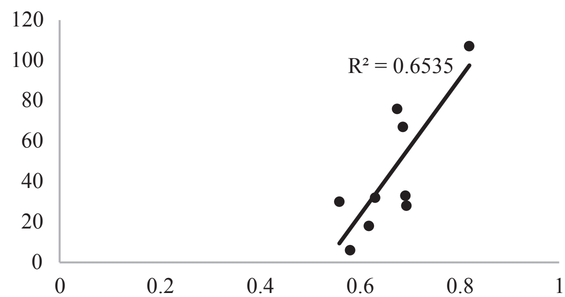


Fig. 4. Correlation between the number of animals killed and (a) the proportion sold and (b) the proportion consumed. Each dot on the graphs represents a species.

a)



b)



c)

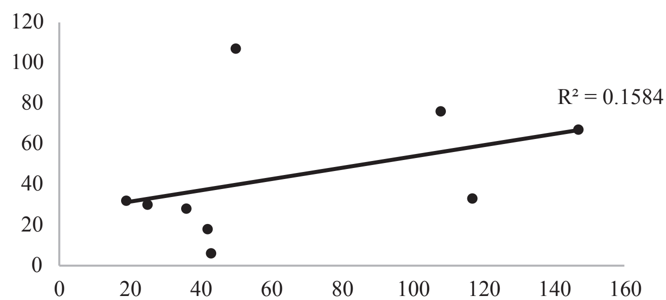


Fig. 5. Correlation between the number of households per village and (a) the proportion of animals consumed, (b) the proportion sold and (c) the total number of animals harvested. Each dot on the graphs represents a village.

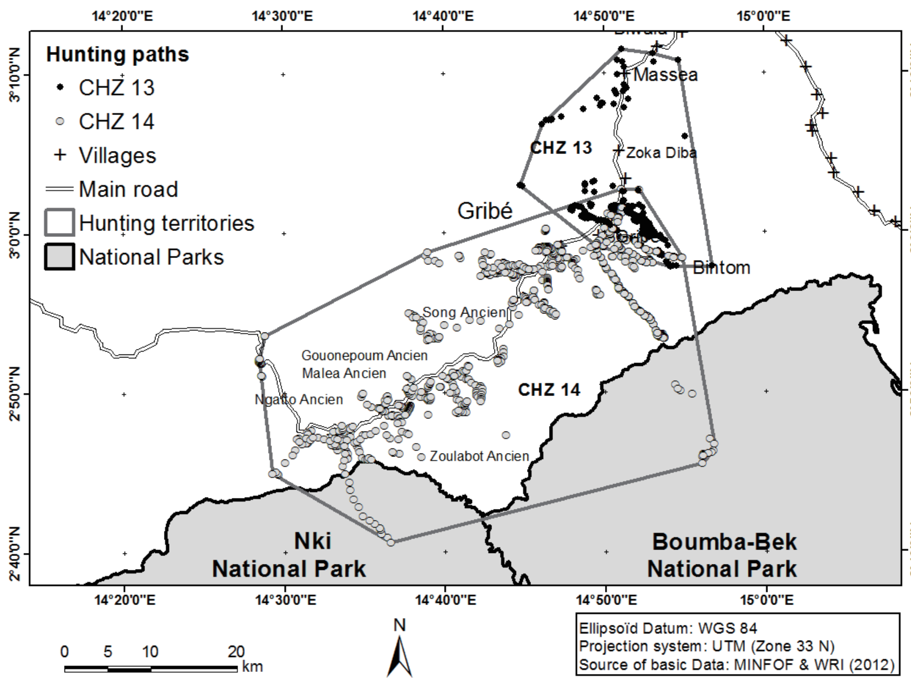


Fig. 6. Spatial extent of catchment areas for the villages in CHZ 13 and in CHZ 14.

Catchment Areas

Hunting was carried out in the agro-forestry zone, in logging concessions (which overlapped with CHZs 13 and 14), and in Boumba-Bek and Nki National Parks (Fig. 6).

Hunting paths were most commonly oriented southward, indicating a preference by local hunters for areas close to national parks. The areas of hunting territories (estimated under ArcGIS 10) were 372 km^2 and 1497 km^2 for CHZ 13 and 14 respectively.

In CHZ 13, the longest distance as the crow flies travelled for hunting was 11 km from the settlement. However, in CHZ 14, where hunting pressure was lower, the highest distance was 30 km.

DISCUSSIONS

The aim of this study was to compare patterns of bushmeat hunting between two sites with considerably different human population densities and hunting pressures in a typical afro-tropical rainforest. In CHZ 13, the human population density was four times higher than in CHZ 14, whereas the density of large and medium-sized mammalian species was higher in CHZ 14 (Bobo et al., 2014). We evaluated annual harvest rates by recording animals killed by local hunters in nine villages, four in CHZ 13 and five in CHZ 14. Numerous prior studies have relied on estimates of harvest rates based on carcass counts in bushmeat markets. Such data have proved to be useful for providing rapid estimates of harvest rates at large geographic scales (Fa et al., 2006). However, as previously noted, significant proportions of the hunting offtake may not reach markets (Lahm, 1996; Fa & García Yuste, 2001; Ling & Milner-Gulland, 2006; Wright & Prinston, 2010), resulting in underestimation of harvest rates when market data alone are considerd. Futhermore, market surveys are unable to detect changes in hunter off-takes (Taylor et al., 2015) and bushmeat use.

We monitored 899.14 hunter-days by observing 122 of the 236 hunters active in nine villages in southeastern Cameroon. To our knowledge, this is the first documented study where offtakes were measured directly in the forest and in households, taking into consideration the number of hunters, individual villages and catchment areas. However, we did not take into account the Baka hunter-gatherers who live primarily in forest camps. The actual numbers of households and active hunters in the area are therefore higher than our statistics suggest because we focused on the households settled along the main road (predominantly the Bantu). As a result, our total harvests rates also represent and underestimation of the actual harvest rate from hunting. In Gribe, semi-nomadic Baka-hunters constitute about 52.7% of the total population (Toda, 2014).

Blue and red duikers are typically the most frequently hunted species in and around protected areas in central Africa (Dounias, 1999; Noss, 2000). Mockrin et al. (2011) found that in the Kabo area (Republic of the Congo), the blue duiker constituted 32.5% of the total number of carcasses and 13.0% of the total fresh biomass extracted by hunters. The Peter's duiker (*Cephalophus callypigus*) constituted 20.7% and 30.4% of the number of carcasses and total fresh biomass harvested respectively. Similar results were reported in the Dja Biosphere Reserve where the blue duiker was the most heavily hunted species both in terms of number of carcasses and biomass harvested (Dethier, 1995; Jeanmart, 1998; Wilkie & Carpenter, 1999). The proportion of small-sized species (rodents) in hunters' catches is highest in the most heavily hunted areas (see Wright & Prinston, 2010).

Ungulates, primates and rodents are the most hunted taxa in the forests of the Congo basin (Table 4). Dounias (1999) found that in Campo Ma'an National Park (in south Cameroon) ungulates, primates, and rodents constituted 77%, 11% and 5% of captures respectively. Infield (1988) found that in Korup National Park, duikers and primates represented 75% and 20% of animals caught. Together, birds and reptiles were the least represented taxa with only 4% of total catches. Because these are harvested in opportunistic ways by women and children as they engaged in other livelihood activities (Taylor et al., 2015), their proportions are generally underestimated in bushmeat studies. During the study period, 159 hunters used only traps, 29 only used shotguns and 44 used both. In the Dja Biosphere Reserve, Takforyan (2001) reported a proportion of 92% trappers among all hunters.

It is known that the composition of prey is influenced by a related history of hunting and can serve as an indicator of the conservation status of local fauna (Cowlishaw et al., 2005; Fa et al., 2015). Taylor et al. (2015) and Yasuoka et al.

Table 4. Percentages of carcasses from ungulates, primates and other taxa reported in the current study and in other hunting sites

Site	Source	Ungulates (%)	Primates (%)	Rodents (%)	Other taxa (%)
Dja	Dethier (1995)	88	3	5	4
Ekom	Ngneugeu & Fotso (1996)	87	1)	6	6
Campo Ma'an	Dounias (1999)	77	11	5	7
Ekim	Delvingt et al. (2001)	85	4	6	5
CHZ 13	This study	47	42	4	4
CHZ 14	This study	61	11	14	6
CHZ 13 & 14	This study	53	28	9	10

(2015) recognized that trends in the species composition of hunter catches may reflect the status of wildlife in the surrounding region, with offtake varying due to changes in hunting effort, weapons, and size of hunting territories.

A comparison of the taxonomic composition of hunters' catches with other hunting sites found in the current studies with those reported at other hunting sites in Cameroon suggests a lower proportion of ungulates relative to primates and rodents, in our area of study. This may be partly due to differences in the importance of hunting technology (guns vs snare traps). It may also result from differences in hunting pressure. In fact, Fa et al. (2015) reported that in Nigeria and Cameroon, the size of the surrounding human populations was negatively correlated with the proportion of ungulates sold at bushmeat markets and positively correlated with the percentage of rodents. The authors also found a higher proportion of carnivores at markets with higher human population densities.

In the present study, shotguns and cable snares, the main hunting tools, provided 49.8% and 46.1% of total catches respectively. In southern Cameroon, Dounias (1999) reported that cable snares were the most important hunting tool, harvesting 42% of the number of carcasses and 44% of the biomass. Their main targets were rodents (88%). Ungulates were hunted with both shotguns (54%) and snares (45%). About 80% of primates were captured with guns.

The use of the shotgun was most important in the more heavily hunted CHZ 13, providing 79% of the total number of carcasses (80% of the total biomass), whereas snare traps captured only 15% (8% biomass). However, in CHZ 14, where human density was four times lower, 82% of the animals were killed with snares and only 16% with guns. It is important to note that similar proportions of hunters using each tool were monitored in the two CHZs. In CHZ 13, we monitored 53% (21/40) of the hunters using guns and 37% (22/59) of those using traps. In CHZ 14, 44% (15/34) of the gun hunters and 55% (81/147) of the trappers were monitored. The difference between areas in regard to in proportion of catches attributed to each hunting tool suggests that with increasing hunting pressure, shotguns are used more heavily, and primates become more predominant in hunter catches. On the other hand, under intensive hunting pressure, both ungulates and primates become scarced while rodents and carnivours are more prevalent as game.

Limited information is currently available regarding bushmeat consumption and consumer choices in West Africa, although changes in consumption demand constitute a key determinant of future hunting levels and are therefore, important to monitor (van Vliet et al., 2010). In the current study, there was a negative correlation between the proportion of animals consumed and the number of households per village. The proportion of animals sold was significantly higher in the villages with large number of households, suggesting that the number of household influenced the magnitude of bushmeat trade. A number of the carcasses (4.5%) were abandoned in the forest, exchanged for another commodity or offered to relatives. Furthermore, a substantial proportion of the proportion sold remained within the village. These observations confirm that many of the animals that are hunted do not reach markets.

The longest distances travelled by hunters (as a crow flies) were observed in CHZ 14, where the human population density was lower. This may be due to the fact that the main hunting technique in CHZ 14 was snaring. In fact, hunters generally exploit larger hunting grounds to set traps, in contrast with gun hunting which can be carried out successfully in nearby forests (Yasuoka et al., 2015). Insufficient data were available to draw any conclusion regarding seasonal variations in area use and resource extraction among the user groups. However, our results suggest that hunters do not exploit a circular area around the center of the settlement, but tend to be more active in the southern sector, near to National Parks. Based on the geographic positions of hunting camps around the village of Sendje, in Equatorial Guinea, Fa & García Yuste (2001) estimated a hunting area of 1,010 km^2. It is important to notice that the catchment area may certainly be underestimated thus, sustainable productions too. On the other hand, we might obviously have missed some carcasses during our investigations, implying that actual harvest rates may be more important. We followed only one hunter from each CHZ inside national parks. Additional hunting expeditions need to be monitored to improve accuracy in the estimation of the spatial extent of village hunting territories.

Determining the actual sustainability of hunting hinges on estimates of the available stock, increasing rate of the population under hunting, and the harvest rates of hunters. We used the Robinson and Redford (1991) model to evaluate the impact of hunting. Maximum annual production P_{max} was estimated as follows:

$$P_{max} = (0.6D \times r_{max}) - 0.6D,$$

where D is the density and r is the maximum finite rate of increase of the species (or the increase of the population from time t to time t ± 1). Values of r_{max} are from Feer (1993) and Fimbel et al. (2000).

Bobo et al. (2014) conducted mammal surveys in Community Hunting Zones 13 and 14 within the same study period as our research and estimated densities of 1.60 individuals/km^2 for blue duiker and 2.30 for red duikers in CHZ 13. In CHZ 14, densities were 4.90 individuals/km^2 for the blue duiker and 7.30 for red duikers. Because duiker density estimates differ according to the CHZ, we analyzed sustainability separately in CHZ 13 (Table 5) and in CHZ 14 (Table 6).

Hunting was not sustainable in both CHZs for the blue duiker. However, in

Table 5. Comparison of sustainable productions and observed harvest rates for duikers in CHZ 13

Species/group of species	Density (ind/km^2)*	r_{max}		Sustainable harvest rate (no. km-2)		Actual harvest rates (ind/year/km^2)
		a	*b*	from *a*	from *b*	
Red duikers**	2.3	1.24	1.65	0.33	0.90	4.19
Blue duiker	1.6	1.63	2.33	0.60	1.28	33.24

*Bobo et al. (2014).
a: Fimbel et al. (2000).
b: Feer, 1993.
** Cephalophus callipygus, Cephalophus nigrifons, Cephalophus leucogaster, Cephalophus dorsalis.

Table 6. Comparison of sustainable and observed harvest rates for duikers in CHZ 14

Species/group of species	Density (ind/km^2)*	r_{max}		Sustainable harvest rate (no. km-2)		Actual harvest rates (ind/year/km^2)
		a	*b*	from *a*	from *b*	
Red duikers**	7.3	1.24	1.65	1.05	2.85	2.76
Blue duiker	4.9	1.63	2.33	1.85	3.91	7.75

*Bobo et al. (2014).
a: Fimbel et al. (2000).
b: Feer (1993).
** Cephalophus callipygus, Cephalophus nigrifons, Cephalophus leucogaster, Cephalophus dorsalis.

CHZ 14, harvest rates of red duikers were sustainable for the higher sustainability estimate (*b*) and above the lower estimate (*a*). Because four different species (of red duikers) were grouped for the density estimate, our conclusion regarding the sustainability of hunting of these animals risks obscuring overexploitation at the level of individual species. Additionnally, given that offtakes from the Baka hunter-gatherers were not included, our estimates underrepresented the actual amount of harvests. If Baka harvests had been included in our data, hunting would likely have been determined to be at larger unsustainable levels. Yasuoka (2006) reported that, during the *molongo* (a foraging expedition carried out every 2–3 years), Baka of Zoulabot Ancien killed 13–24 red duikers and 0.9–9.7 blue duikers per km^2 per year for commercialization. Harvest rates for subsistence hunting were 0.8 and 0.04 for red and blue duikers respectively.

Biological harvest models have been subject to criticism as methods for assessing the sustainability of hunting. Most of them depend upon several parameters including population density, increasing growth rate and harvest levels, whose values are erroneously represented using punctual data; in fact, these variables are subject to significant variation over time and space, and accurate data for them are extremely difficult to obtain in African rainforests (van Vliet & Nasi, 2008). As a result, conclusions regarding the sustainability of hunting should be viewed with caution.

Developing alternative sources of protein and income such as meat from domestic animals, for this region as part of the strategy for reducing reduce human pressure on wildlife resources and improving the livelihood of the local people. However, such initiatives will doubt encounter numerous constraints in southeastern Cameroon, as in most tropical forests, and a substitute for bushmeat will be feasible only if it is at least as productive as bushmeat hunting in terms of economic revenue. On the other hand, it is obvious that the bushmeat crisis in tropical forests extends beyond economic factors. In fact, many households in the area keep domestic animals such as pigs and chicken. Hunters do not use domestic meat for daily subsistence. In general, they reserve domestic animals for occasional ceremonies. Wildlife is hunted for consumption, for commercial purposes, and for socio-cultural reasons, and hunting remains an important element of the cultural identity of most forest dwellers in afro-tropical areas. Hence, the analysis of socio-economic and cultural conditions is an important component of conservation and development projects. In particular, the Pygmy communities are known to be extremely dependent on forest resources, in contrast with the Bantu peoples, and cannot rapidly adopt alternative sources of protein such as domestic meat (Yasuoka, 2006). Given the prevalent socio-economic conditions and the constraints on animal husbandry in remote forest areas, forest residents in southeastern Cameroon are unlikely to shift promptly to domestic sources of protein. This constitutes what is possibly the most serious obstacle to the development of alternative protein sources in most African rainforests.

CONCLUSIONS

The hunting activities observed in the study area were driven by two main objectives: direct consumption and trade. The proportion of animals sold (but not the total number of animals harvested), was positively correlated with the number of households, demonstrating that the magnitude of bushmeat trading was predictable from demographic parameters. Given the high harvest rates, the growing human population and reducing forested areas within the study area, hunting may not be ecologically sustainable over the long term. It is clear that if the current harvest rates are not considerably reduced, hunting will not be able to meet the subsistence and economic needs of local populations.

As a long-term goal, sensitization campaigns must be implemented. They should promote education and be directed primarily at youth. Indigenous people cannot readily shift to alternative sources of protein and income such as livestock or fish. In the short term then, effective surveillance remains then the most efficient measure to be taken to reduce the bushmeat trade. Long-term educational activities, controls along the main roads and antipoaching patrols in and around Boumba-Bek and Nki National Parks are in urgent need of reinforcement.

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