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Decline in hunter offtake of blue duikers in Bioko Island, Equatorial Guinea

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Running head: Decline in a blue duiker population

Abstract

The blue duiker (*Philantomba monticola*) is an abundant and widely distributed ungulate in continental sub-Saharan Africa. High hunting pressure throughout its range may be particularly threatening to the persistence of island populations of the species. In this paper, we assessed offtake of blue duikers in Pico Basilé, Bioko Island, Equatorial Guinea. We recorded the number of animals shot or snared by 46 commercial hunters over a 33-month period, and the location (elevation) of each animal hunted. From this, we estimated catch per hunter (C_H), catch per hunting day (C_D), and catch per unit effort (*CPUE*). The number of duikers shot or snared across the study period, significantly declined within the mid-altitude range (901-1500 m). There were no significant drops in C_H or *CPUE* at low or high altitudes for snared animals. The ratio of immature to adult animals hunted increased significantly over time within the mid-altitude range. We suggest that these trends in offtake, especially in the more heavily hunted mid-altitudes of the study area, indicate a decline in the population within this range. If this situation is widespread throughout the island, it is likely that unregulated bushmeat hunting will have devastating consequences to the biodiversity of Bioko Island, particularly for heavily hunted species that are naturally less abundant.

Introduction

In West and Central Africa, as many as 84 mammal species are now considered threatened by the commercial bushmeat trade (Van Vliet & Nasi, 2007). Overhunting for profit is known to cause immediate reductions in density of targeted animals (Abernethy *et al*., 2013). In extreme cases overhunting may precipitate the disappearance of local populations and eventually result in the complete extirpation of a species (Fa & Peres, 2001; Fa & Brown 2009; Abernethy *et al*., 2013). Defaunation through overhunting can also affect the functioning of forest ecosystems because of the loss of seed dispersers (Nuñez-Iturri & Howe, 2007; Effiom *et al*., 2013).

Hunted rodents and small duikers, such as the blue duiker (*Philantomba monticola*), are relatively fast breeders and, in theory, can be hunted at relatively high levels. The blue duiker is the most economically important wild ungulate where it occurs (Wilson, 2001) and the species most frequently reported in bushmeat surveys across the continent (Muchaal & Ngandjui, 1999; Wilkie & Carpenter, 1999; Fa, 2000; Lwanga, 2006; Bifarin *et al*., 2008; Fa & Brown, 2009; Kümpel *et al*. 2010). Blue duikers are widespread within their nearly contiguous range across central Africa, and also occur in southern and eastern Africa (Hart & Kingdon, 2013). They are found in a wide variety of forest and woodland habitats (thriving even in heavily human-modified habitats) and can attain much higher densities than the larger sympatric *Cephalophus* species (Newing, 2001; Wilson, 2001; Lannoy *et al*. 2003).

Disappearance of any hunted species is unlikely if connectivity in the landscape permits enough dispersal and immigration, and hunting offtake is not too high (Hart, 2000). However, intensive hunting can cause dramatic population declines, as seen in the case of the Ogilbyi's duiker (*C. ogilbyi*) in the Oban Hills Region, Nigeria (Jimoh *et al*., 2012), or disappearance as reported for the Bay duiker (*C. dorsalis*) in the Ipassa Reserve, Northeast Gabon (van Vliet *et al*. 2007). There is also some evidence that hunting can reduce numbers of blue duikers (Hart, 2000; Jimoh *et al*., 2012), but complete extirpation has not been reported.

Animal populations restricted to islands are often at a greater risk of extinction from hunting because of their small geographic ranges and usually low population numbers. Island forms of the blue duiker, such as those found on habitat islands e.g. Afromontane forests, (Lawes *et al*., 2000), and coastal Cape forests (Seydack *et al.*, 1998) in South Africa or on continental islands e.g. Zanzibar, Mafia and Pemba in Tanzania (Pakenham, 1984; Kock & Stanley, 2009), Bioko Island in Equatorial Guinea (Butynski, Schaaf & Hearn, 2001), may be especially vulnerable to extinction. The Bioko Island subspecies of blue duiker (*P. m. melanorheus*) contributes the largest proportion of the traded bushmeat on the island (Reid *et al*., 2005). Large numbers of blue duikers are sold daily at the main consumer market in the country's capital, Malabo, with no evidence that the supply of this species has fallen, unlike other more vulnerable taxa e.g. primates (Fa *et al.*, 2000; Hearn *et al*., 2001; Cronin *et al*., 2010; Cronin, 2013a, 2015).

Currently, there are no direct data on the population status of the blue duiker on Bioko. The species is assumed to be abundant throughout the island (Butynski, Schaaf & Hearn, 2001), possibly attaining ecological densities significantly higher than in equivalent continental regions (e.g. Mount Cameroon) as a result of ecological release due to the absence of large megaherbivores on the island (Fa & Brown, 2009).

Extirpation of sub-populations of the species may have occurred in some parts of the island (Butynski, Schaaf & Hearn, 2001), however, available data (e.g. Malabo market records) cannot be used to confirm this.

Depletion effects from hunting can be verified from information directly gathered from the number of animals extracted by hunters in a specific locality. This type of information can then be used to determine trends in the number of animals hunted relative to hunter effort and provide information on the status of the harvested population (Stamatopoulos, 2002). Here, we employ three different measures of hunter offtake (catch per hunter, per hunting day and catch per unit effort), over a period of almost 3 years, to determine whether there was any indication of overexploitation of the blue duiker in our study area.

Materials and methods

Study area

Our study took place in the village of Basilé Fang (8.75ºN, 3.58ºE), Bioko Norte Province, Bioko Island, Equatorial Guinea (Fig. 1). Basilé Fang is situated 15 km from Malabo, the country's capital (145,000 inhabitants, CIA World Factbook 2014), at the base of Pico Basilé. The village has a population of approximately 150-200 inhabitants. Most villagers are ethnic Fang from Rio Muni (the continental region of Equatorial Guinea) who moved to Bioko in 2005 to hunt commercially and sell bushmeat for the Malabo market at lucrative prices (Grande Vega *et al*., 2013).

Approximately 330 km^2 of Pico Basilé, encompassing all land >800 m was declared a National Park in the late 1980's. Patches of lowland rainforest occur around

800 m., montane forests range between 800 and 1400 m, mossy forest are found between 1500 and 2500 m and shrub formations and sub-alpine meadows appear above 2500 m (Navarro Cerrillo *et al*., 2012). A surfaced road (<20 km) exists from Basilé Fang to the summit of the Pico, hereafter referred to as the Pico road. By motor vehicle, travel time from the village to the summit is less than one hour.

Military personnel posted at the base of the Pico road protect against unauthorized entry to the telecommunications station at the summit, control the entrance of vehicles and people. Nonetheless, hunters from Basilé Fang (and other villages) are allowed into the national park where uncontrolled shotgun hunting and snaring takes place within the boundaries of the protected area. Hunting of protected species (e.g. primates) within the national park is officially prohibited (Law No. 4/2000) but there is no law enforcement.

Hunting activity

Basilé Fang hunters hunt along the Malabo-Riaba road, but primarily along the northeastern slope of the Pico Basilé. Hunter interviews and hunter follows (N = 22, unpublished data) indicate that all hunters use the Pico road to penetrate the heavily forested slopes on either side (<500m). Hunters are able to walk (or drive) along this road and enter their hunting areas at chosen distances (and therefore altitudes). Hunting locations pre-agreed with other hunters in the village.

Most hunters employed cable snares to hunt terrestrial prey, although a number owned or rented shotguns. Nylon cord snares are either small or large leg traps. Snares differ in the number of cable strands used in the construction of the noose, and in the size of the bent-over sapling or pole used as the trigger mechanism, depending on the target animal. Neck snares, which are less commonly used, are placed either on the ground or above ground on fallen trees, often require a small frame to hold the open noose vertical above ground.

Bushmeat offtake data collection

We familiarized ourselves with the study village and its inhabitants, and in particular M.G.-V., by spending periods of time before the start of data collection interacting and getting to know the hunters and other members of the community. Initial contact was with the village major, who then officially introduced the research team to villagers, to whom the aims of our study were explained. When an adequate level of rapport was established, and permission granted by the hunters to record their catches, we employed a local assistant (A.O.) to document all animals killed by Basilé Fang hunters and brought to the village. From August 2010 until September 2013, we documented the identity of the hunter (name, household), hunting trip duration (number of hours or days, area or camp), and for each animal caught, the species, age class (mature, or young), sex, weight (where possible), method of capture, and whether the carcass was brought to the village whole or not. We also asked hunters at which point (in kilometres) along the Pico road animals were hunted; the position along the road was used to establish the altitude at which the hunt took place. No monetary or other gifts were provided to the hunters and only the assistant was paid. The research assistant was trained and visited regularly by M.G.-V. to ensure the quality of the records.

Estimates of hunting yield

We calculated the hunting yield per month as the number of animals hunted per hunter, per hunting day, as well as the catch per unit effort:

Catch per hunter (C_H), the mean monthly number of animals killed (*MNBD*) per hunter (*NH*):

$$C_H = \frac{MNBD}{NH} \quad (1)$$

Catch per hunting day (C_D), the mean monthly number of animals killed (*MNBD*) per hunting day (*ND*):

$$C_D = \frac{MNBD}{ND} \quad (2)$$

Catch per unit effort (*CPUE*) is derived from the mean monthly number of animals killed (*MNBD*) per unit effort (*UE*):

$$CPUE = \frac{MNBD}{UE} \quad (3)$$

where *UE* is obtained by multiplying *ND* by *NH*.

Altitudinal and temporal changes in hunting yields

We considered three elevational belts roughly corresponding to lowland rainforest (low: 300-900 m), montane forest (mid: 901-1500 m) and mossy forest (high: 1500-2500 m) to determine differences in hunting yields by altitude. We also separated yields from firearms and snares to determine whether changes in capture methods also varied by altitude during the study period.

Changes in population composition

Blue duiker carcasses were classified as adults or juveniles according to their body mass, size and physical characteristics as described in Wilson (2001). From counts of all animals observed each month, we calculated a monthly immature-to-adult (*IAR*) and immature-to-adult female ratios (*IFR*). These ratios have been used to indicate replacement rates, and to assess changes in, and viabilities of nonhuman primate populations (Zucker & Clarke, 2003); they have also been used to assess changes in hunted Bioko animals (Hearn *et al*., 2001). In this study we determined *IAR*s and *IFR*s for the entire study period, as well as by altitudinal bands. We also calculated the monthly sex ratio by dividing the number of adult males by the number of adult females observed each month.

Statistical analyses

We performed all analyses (alpha level set at 0.05) using the statistical software SPSS 22.0 (IBM Corp., 2010). To investigate the relationship between extraction, hunting yields across time and changes in age-ratios we used linear regressions on mean values of predictor variables for each month. χ^2 tests were used to check for altitudinal differences in extractions, hunting yields, and capture method.

Results

General

The blue duiker was one of 18 animal species (12 mammal taxa) hunted in our study (Table S1). A total of 6147 blue duiker carcasses were documented out of 7297 animal carcasses (84.2%) recorded during the study. The proportion of the total number of blue duikers snared (49.9%) or shot (50.1%) was similar.

Numbers, hunting methods and altitudinal distribution of offtake

All monitored hunting trips (N = 819) took place along the Pico road, though 656 of these (80%) were concentrated at mid- and high-elevations; only 20% were at low-elevation.

The number of blue duikers hunted and the hunting method used varied by elevation (Fig. 2). The number of individuals hunted in the mid-elevation range (55.3% of total carcasses) was significantly higher than in the low or high ranges (χ^2 = 2,259.8, df = 6, P < 0.001). In addition, the number of hunting trips that took place in the mid-elevation range (50% of all trips) was significantly more than in the other ranges (χ^2 = 224.19, df = 6, P < 0.001). Almost three-quarters (73.6%) of all animals shot were hunted at mid-elevations, while 37.5% were trapped there. However, at high-elevations more animals (20.7%) were snared (χ^2 = 338.8, df = 6, P < 0.001) than shot (3.3%) (χ^2 = 3.342, df = 6, P < 0.001).

Temporal changes in hunting yields

Overall, the monthly number of blue duikers snared or shot declined significantly throughout the study period (shot: R^2 = 0.292, $F_{1,31}$= 12.400, P < 0.01; snared: R^2 =

0.371, $F_{1,31}$ = 17.661, P < 0.001). During the study period we detected a significant drop of almost half in C_H (R^2 = 0.323, $F_{1,31}$ = 14.765, P < 0.01, Fig. 3A), more than 60% in C_D (R^2 = 0.537, $F_{1,31}$ = 35.995, P < 0.001, Fig. 3B), and about 40% in *CPUE* (R^2 = 0.449, $F_{1,31}$ = 25.243, P < 0.001, Fig. 3C).

C_H varied by elevation and was significantly larger at higher altitudes (χ^2 = 68.2, df = 6, P < 0.001). For snared animals, C_H was larger than expected at high-elevations (χ^2 = 53.1, df = 6, P < 0.001). C_H for shot animals was significantly higher at mid-elevations, and lower at high-elevations, than expected, (χ^2 = 63.0, df = 6, P < 0.001).

Overall, C_H, C_D, and *CPUE* declined at low, mid- and high- elevations, although slopes varied (Table 1, Fig. S1). By hunting method, declines in hunting yields for snares and firearm were significant throughout the study period, with the sharpest declines occurring for snares (Table 1). By altitude and capture method, hunting yield metrics declined in all cases, though not for *CPUE* for firearms and snares at high-elevation (Table 1).

Changes in population composition over time

Throughout the study period, the monthly *IAR* was always less than 1.0 indicating that more adult animals had been hunted compared to immature. This ratio increased significantly over time, from 0.04 at the start of the study to 0.19 by the end (R^2 = 0.186, $F_{1,31}$= 7.084, P < 0.05). Similarly, *IFR* rose significantly over the study period from 0.10 to 0.65 (R^2 = 0.178, $F_{1,31}$= 6.728, P< 0.05). The monthly male/female ratio, which was always >1.0 was not significantly different from 1:1 throughout the study period (χ

$^{2} = 46.1$, df = 32, n.s.). By elevation, monthly *IAR* was only significant at mid-elevation ($R^2 = 0.172$, $F_{1,31} = 6.433$, $P < 0.05$).

Discussion

Bushmeat hunting is still an important activity, practiced by many in Western and central Africa, to obtain meat for food and income (Fa *et al*., 2003, 2006; Willcox & Nambu, 2007). Animals in the bushmeat trade are dominated by ungulates, of which duikers are the most heavily hunted species (Lwanga, 2006; Fa & Brown, 2009; Mockrin, 2009; Kümpel *et al*., 2010). Based on a recent review of studies performed within 36 sites in seven different countries, the blue duiker was the most important prey species, in terms of both the number and biomass of mammals hunted (Fa *et al*., 2005). In our study, the blue duiker contributed 84.2% of all recorded animal carcasses. Compared to other sympatric ungulates, it is likely that the importance of blue duikers in the bushmeat trade reflects their relatively high abundance in tropical forests.

Overhunting is considered the main reason for the reported declines in population densities of tropical forest mammals (Robinson & Bennett, 2000). On Bioko Island, the number of individuals being sold has declined in many species in the Malabo market, especially of the larger and more vulnerable species such as primates and the larger duiker species. This decline has been linked to intensive hunting on the island (Fa *et al*., 2000; Hearn *et al*., 2001; Albrechtsen *et al*., 2007; Cronin *et al.*, 2010, 2013a,b, 2015). Our study agrees with these previous observations but clearly demonstrates, for the first time, the sharp decline in hunting yields of a species otherwise presumed abundant, the blue duiker. Competing explanations for the drop in hunter offtake in our study, other than the sheer pressure from hunters, are unlikely. However, studies that examine the impact of environmental or ecological variables on the population dynamics of duiker populations are still needed. In the case of Bioko, because blue duiker predators such as leopards and golden cats (Hart, 2000), are absent on the island, human hunting is the only significant source of additive mortality.

We determined the area hunted in our study by following a sample of hunters. Subsequent interviews with hunters in the village, and other data gathered by our team on hunting ranges along the Pico road, shows that most extraction occurs on either side of the road. These hunting zones are chosen by hunters because of ease of access from the road, and because the terrain where the road has been built has gentler slopes than areas to the North and South.

The size of the catch from an animal population typically increases when either population density or hunting effort increases (Seber, 1992), thus *CPUE* figures can indicate whether a prey population is overexploited (Quinn, 2003) Rist *et al*., 2010). In our study we used the *CPUE*, catch per hunter, and catch per hunting day to demonstrate that different hunting areas, defined by elevation, have distinctive offtake trends. We showed that the number of animals shot or snared dropped significantly throughout the study at mid-elevations. However, there were significant declines in catches per hunter and *CPUE* at low and high altitudes. Thus, mid-elevations, which are seemingly the most productive and are the most hunted areas, may be suffering depletion since C_H, C_D and *CPUE* fell significantly during the study period. Moreover, the immature to adult ratio, an indicator of population declines, was only significant at mid-altitude.

There was no downward trend for animals hunted with firearms (though not for snares) at low- and high-elevations. A possible explanation is that blue duiker densities are lower in these zones, and thus the opportunities for hunters to shoot animals are less frequent. Similarly, the number of animals snared at these two elevations was comparatively less than at mid-elevation. The reason duiker densities were relatively low at low and high-elevations may be different. For example, at low-elevations, blue duikers (and other species) may be less common because these areas have been hunted out due to their closeness to human habitation. At high elevations, habitat and climatic factors may be more important here in explaining duiker abundance. Research on how habitat characteristics and habitat quality interact with hunting pressure is required to better understand the reasons for the observed trends in our study.

There is currently little control of bushmeat hunting in Pico Basilé. We show that hunting may be pushing species, such as the blue duiker, towards depletion. However, hunting sustainability in this part of the island could be improved by reducing overall hunting pressure, by setting limits to the geographic locations and number of hunting areas used by hunters, regulating the use of shotguns (since these are used to target more vulnerable species, e.g. primates) and allowing hunting in well delimited areas (Rist *et al*. 2010). Such a system requires the provision of incentives for resident hunters to participate in self-monitoring schemes that can allow quicker management decisions. However, such a scheme must be complemented by developing alternative livelihoods for young men in the village, as well as applying better hunting practices, such as minimizing wastage from individual traps (by encouraging regular checking) and implementing rotational hunting. Ideally, these last two measures should be set, enforced, and monitored at the community level, aided by appropriate technical assistance and political oversight, to ensure local responsibility and buy-in.

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Table 1. Trends in hunting yields according to altitude and hunting method.

Hunting Yield/Capture Method/Altitude	N	R^2	B	Const.	*F*	*P*
a) Catch per Hunter (C_H)						
Shot						
Low	28	0.08	-0.207	13.019	2.158	n.s.
Mid	31	0.333	-0.395	20.323	14.484	<0.01
High	22	0.011	-0.047	6.565	0.221	n.s.
Snared						
Low	26	0.114	-0.187	11.541	3.093	n.s.
Mid	28	0.456	-0.568	22.693	21.834	<0.01
High	31	0.114	-0.184	13.911	3.721	n.s.
b) Catch per Hunting Day (C_D)						
Shot						
Low	28	0.092	-0.065	6.164	2.628	n.s.
Mid	31	0.265	-0.043	4.687	10.43	<0.01
High	21	0.001	-0.002	0.869	0.019	n.s.
Snared						
Low	27	0.346	-0.124	6.054	13.205	<0.01
Mid	28	0.156	-0.041	4.251	4.795	<0.05
High	30	0.289	-0.024	1.721	11.397	<0.01
c) Catch per Unit Effort (*CPUE*)						
Shot						
Low	28	0.092	-0.065	6.105	2.643	n.s.
Mid	31	0.107	-0.026	4.086	3.468	n.s.
High	21	0.003	0.003	0.756	0.054	n.s.
Snared						
Low	27	0.27	-0.092	5.315	9.234	<0.01
Mid	28	0.197	-0.046	4.136	6.377	<0.05
High	31	0.103	-0.011	1.378	3.327	n.s.

FIGURE LEGENDS

FIG. 1. Distribution of human settlements, main roads and protected areas in Bioko Island, Equatorial Guinea. Our study site (Basilé Fang) is also indicated.

FIG. 2. Altitudinal differences in the extraction of blue duikers according to hunting methods.

FIG. 3. Temporal variation in average monthly values for the three hunting yield metrics used in the study: (A) Catch per hunter (C_H); (B) Catch per hunting day (C_D); (C) Catch per unit effort (*CPUE*). Vertical lines represent standard error (SE).

Fig. 1

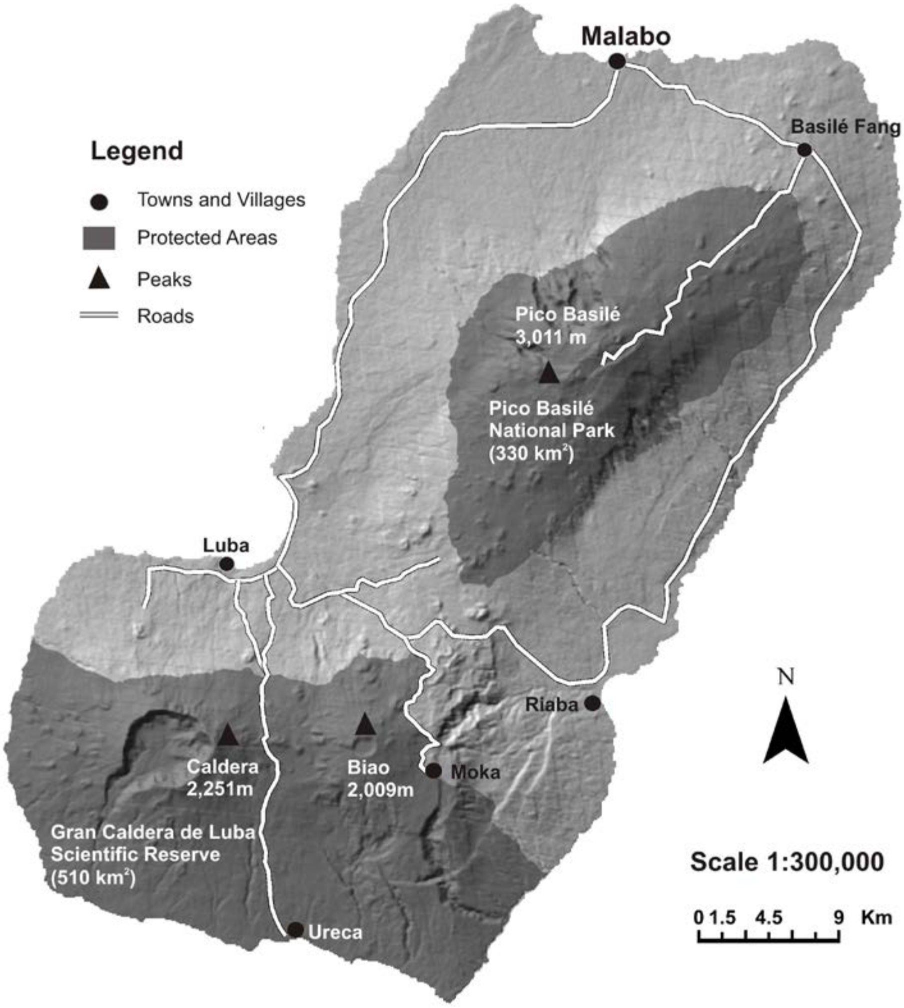
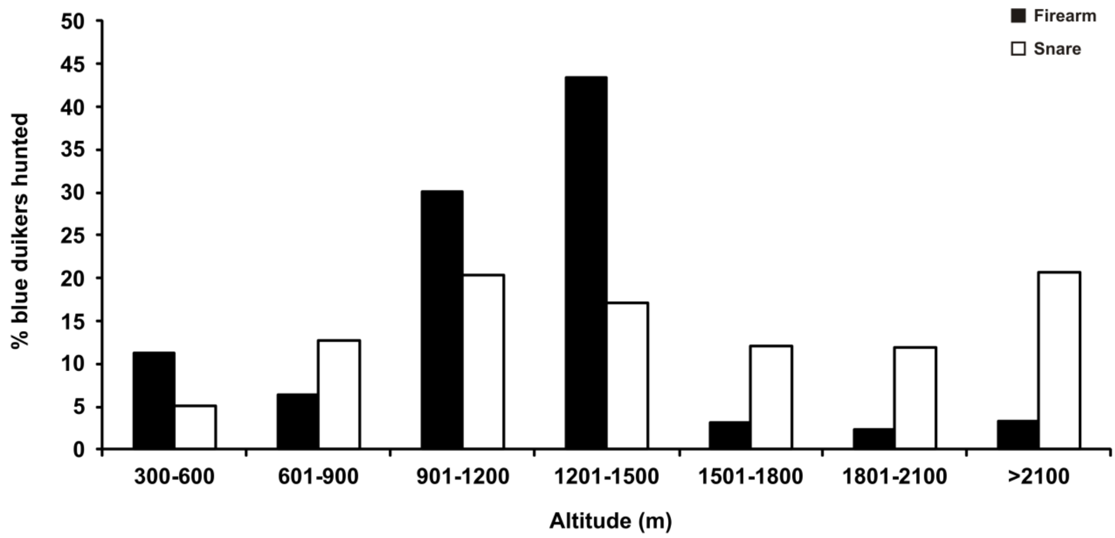
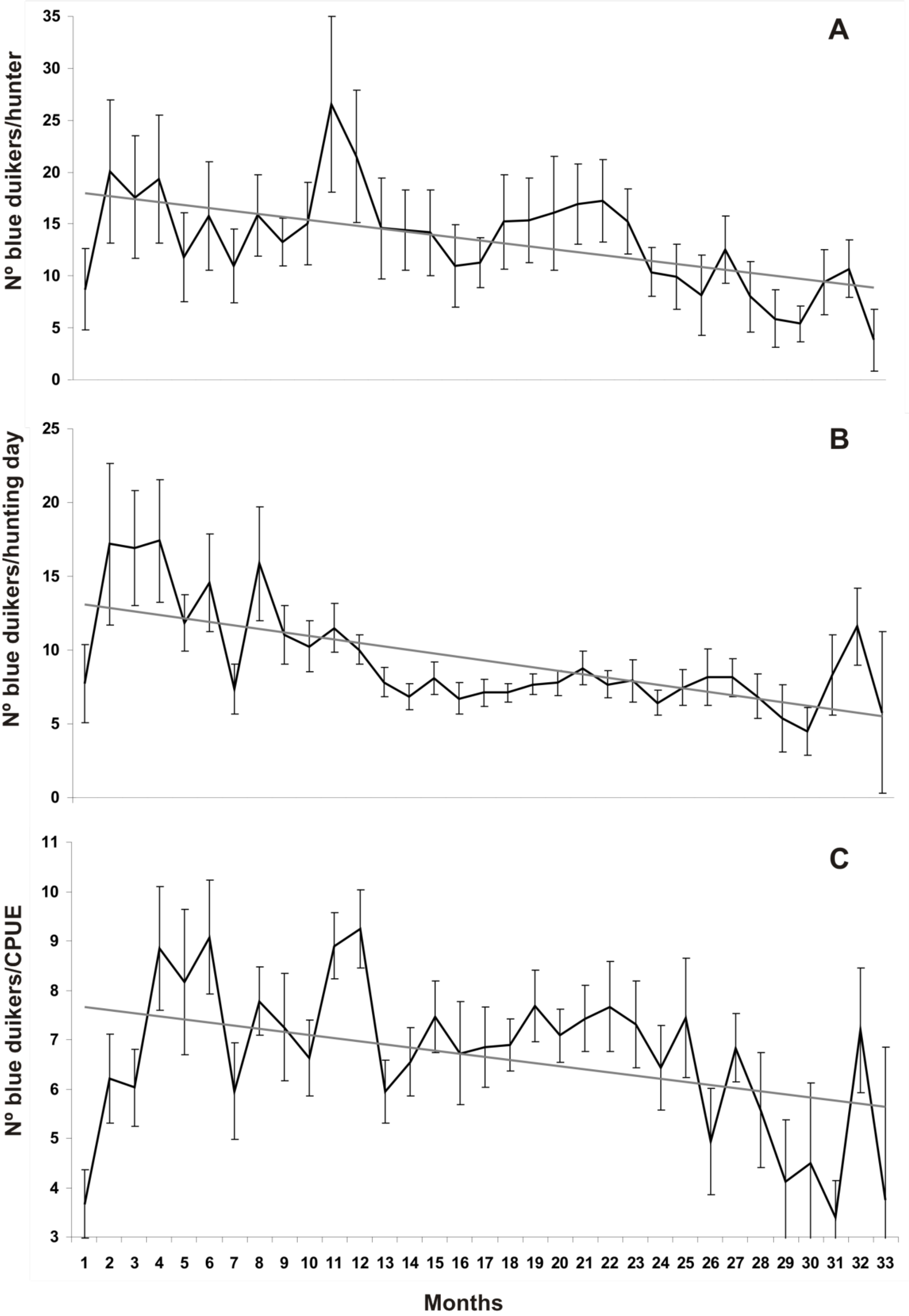

Malabo
Basilé Fang
Legend
Towns and Villages
Protected Areas
Peaks
Roads
Pico Basilé
3,011 m
Pico Basilé
National Park
(330 km²)
Luba
N
Riaba
Caldera
2,251m
Biao
2,009m
Moka
Gran Caldera de Luba
Scientific Reserve
(510 km²)
Scale 1:300,000
0 1.5 4.5 9 Km
Ureca

Fig.2.



Firearm
Snare
% blue duikers hunted
50
45
40
35
30
25
20
15
10
5
0
300-600
601-900
901-1200
1201-1500
1501-1800
1801-2100
>2100
Altitude (m)

Fig. 3.



A
B
C
Nº blue duikers/hunter
Nº blue duikers/hunting day
Nº blue duikers/CPUE
35
30
25
20
15
10
5
0
11
10
9
8
7
6
5
4
3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Months

Supplementary Information

Decline in hunter offtake of blue duikers in Bioko Island, Equatorial Guinea

María Grande-Vega, Miguel Ángel Farfán, Ambrosio Ondo, and John E. Fa

Table S1: List of hunted species and number of carcasses recorded in our study.

Group/Common Name	Scientific Name	Number of Carcasses	%
Birds			
Blue Plantain Eater	*(Corythaeola cristata)*	78	1.07
Palm Nut Vulture	*(Gypohierax angolensise)*	1	0.01
Reptiles			
Unidentified snakes	*Colubridae*	3	0.04
Rock python	*(Python sebae)*	4	0.05
Cobra	*(Naja melanoleuca)*	2	0.03
Rhinoceros viper	*(Bitis nasicornis)*	1	0.01
Hyrax			
Tree hyrax	*(Dendrohyrax dorsalis)*	16	0.22
Pangolin			
African white-bellied pangolin	*(Phataginus tricuspis)*	5	0.07
Primates			
Preuss's guenon	*(Allochrocebus preussi)*	3	0.04
Russet-eared guenon	*(Cercopithecus erythrotis)*	74	1.01
Black colobus	*(Colobus satanas)*	27	0.37
Bioko Allen's galago	*(Sciurocheirus alleni)*	1	0.01
Unidentified guenons	*(Cercopithecus spp.)*	6	0.08
Rodents			
Brush-tailed porcupine	*(Atherurus africanus)*	224	3.07
Forest giant pouched rat	*(Cricetomys emini)*	299	4.10
Unidentified squirrels	*(Scuiridae)*	197	2.70
Ungulates			
Ogilby's duiker	*(Cephalophus ogilbyi)*	209	2.86
Blue duiker	*(Philantomba monticola)*	6147	**84.24**
		7297	

FIGURE S1 Temporal variation in: A) hunting yields per hunter according to capture methods, B) hunting yields per hunting day according to capture methods, and C) catch per unit effort according to capture methods. Vertical lines represent standard error (SE).