The Effects of Hunting on a Forest Animal Community in Gabon

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Executive Summary

Gabon holds some of the world's richest, most species-diverse tropical rainforest. Over 80% of the country's landcover is forest and up to 20% of its plant and animal species are endemic. However, as the country seeks to increase its economic development through practices such as logging, the resulting creation of new roads and settlements in formerly remote areas increases the risk of bushmeat hunting and poaching. Species such as the African forest elephant have already experienced dramatic declines from hunting, which poses potential ecological consequences such as reduced seed dispersion. This study examined the effects of hunting on an animal community in a northeastern area of Gabon by measuring three types of hunting pressure: roads, waterways, and human populations.

I focused on 9 animal species (Crowned Guenon, Grey-cheeked Mangabey, Mustached Monkey, White-nosed Guenon, Blue Duiker, Yellow-backed Duiker, African Forest Elephant, Chimpanzee and Gorilla) because of their specific targeting by bushmeat hunters or poachers and because they had adequate data to estimate population abundance. The study area, a 5,800 km^2 region in the Ogouué Ivindo province of northeastern Gabon, reflected a gradient of human activities and hunting pressure. The study consisted of direct (animals seen or heard) and indirect (dung piles or nests) observations along 24 transects, which were walked at least once per month from January to December 2014. I used these observations to calculate species abundances and compared these to past estimates. In addition, I analyzed abundance correlations with the three forms of hunting pressure.

Overall, 8 of the 9 species analyzed in this study have declined in abundance since their previous estimates. Blue Duikers have suffered the most drastic decline, followed by Chimpanzees and White-nosed Guenons. Distances to the nearest small village and nearest main road were the overall strongest and most commonly significant indicators of hunting pressure. Results suggest that most of the study area's species decline has been caused by excessive bushmeat hunting. On the whole, the entire wildlife community is declining in abundance and these trends are likely to continue unless measures are taken to reduce rates of hunting and poaching.

Introduction

Gabon holds some of the world's richest, most species-diverse tropical rainforest (Laurance et al., 2006a). Over 80% of the country's landcover is forest and up to 20% of its plant and animal species are endemic (Russo, 2014). In addition, Gabon's forests are home to the largest remaining intact population of African forest elephants and together with the Republic of the Congo, 80% of all western lowland gorillas (Harcourt, 1996; Russo, 2014). Gabon is a relatively politically stable country in the region, which has helped enable the conservation of these natural resources (Laurance et al., 2006a). However, as the country seeks to increase its economic development, practices such as industrial logging and agriculture may pose a threat to wildlife by increasing access to forests and demand for animal products.

Over 75% of Gabon's forests have been divided into logging concessions (Collomb et al., 2000). Increased logging means a greater number of roads and settlements in formerly remote forest areas, which increases the threat of hunting to wildlife by providing better access to hunters and by reducing hunters' costs of moving wildlife to the market for sale (Wilkie et al., 2000). In general, logging in Gabon is frequently inadequately regulated, and even without hunting, excessive disturbances to the forest can reduce the abundance of sensitive species such as the Chimpanzee (Laurance et al., 2006a).

There are two main types of hunting practiced in Gabon- bushmeat hunting and poaching. Bushmeat hunting, conducted primarily on a local scale and for subsistence, provides 80% of the protein and fat for rural communities in Central African, with around 2.2 billion pounds consumed each year (Biello, 2008). A large proportion of the rural Gabonese population practices bushmeat hunting, which commonly targets animals such as duikers and monkeys (Fa et al., 2005; van Vliet and Nasi, 2008b, Poulsen et al., 2009). In addition to supplying food for rural communities, bushmeat is also a source of revenue (Wilkie et al., 2000; Abernethy et al., 2013). Bushmeat is often sold to urban areas, where it is sought for its taste or as a symbol of elite status (Schenck et al., 2006).

Poaching takes place at a broader scale, is strictly illegal, and is practiced primarily for monetary gain. It is a problem that particularly affects species such as the Forest Elephant, which is targeted for its ivory. Between 2002 and 2013, over 65% of Central Africa's forest elephant population was killed, and this trend is not slowing down (Russo, 2014). Elephant poaching has largely been fueled by an increased demand for ivory in China, along with a surge in black market ivory prices, and the increased involvement of international crime syndicates in wildlife trafficking (ANPN, 2013; UNEP et al., 2013; Underwood et al., 2013; Gao and Clark, 2014). In addition, poachers face relatively light penalties if caught and prosecuted: first time offenders might face a maximum of six months in jail (ANPN, 2013).

Changes in the species composition of the animal community as a result of hunting can have repercussions for the forest ecosystem, affecting both plant and animal species, by modifying the strengths of processes like herbivory, predation, and seed dispersal. For example, hunting of animals

could leave the 75% of African rainforest plant species that rely on animal-mediated dispersal without dispersal services, reducing their recruitment (Nasi et al., 2008; Vanthomme et al., 2010; Poulsen et al., 2013). In addition, hunting can severely threaten species with low reproductive rates, such as the forest elephant, gorilla and chimpanzee. On average, 40% of rainforest species are hunted at rates greater than reproductive replacement (Nasi et al., 2008).

The goal of this study was to determine how hunting has affected Gabon's wildlife population. To do this, I estimated current animal population sizes in and around the Ivindo National Park, evaluating the effect of several indices of hunting pressure on animal populations, and comparing current estimates to previous estimates from the same area. I focus on nine species for that are commonly targeted for bushmeat, as well as three endangered species, including: the Crowned Guenon, the Grey-cheeked Mangabey, the Mustached Monkey, the White-nosed Guenon, the Blue Duiker, the Yellow-backed Duiker, the African Forest Elephant, the Chimpanzee and the Gorilla.

Methods

Study Area

My study area was a 5,800 km^2 region in the Ogouué Ivindo province of northeastern Gabon, located around the city of Makokou (Figure 1). The climate there consists of four seasons, two of which are dry (from December to March and from June to September), and two of which are rainy (from September to December and from March to June, Mavoungou et al., 2013a). The area receives around 1700mm of rainfall per year (Mavoungou et al., 2013b) and its mean temperature is 75º F (Sassen and Wan, 2006). The area is located between two national parks, the Ivindo National Park and the Minkebe National Park, and includes the regional capital of Makokou, as well as numerous small villages located along main roads, and two active logging concessions. I chose this area because it provides a gradient of human activities and hunting pressure, so that I could evaluate the effects of these activities (hunting, logging and population) on different wildlife species.

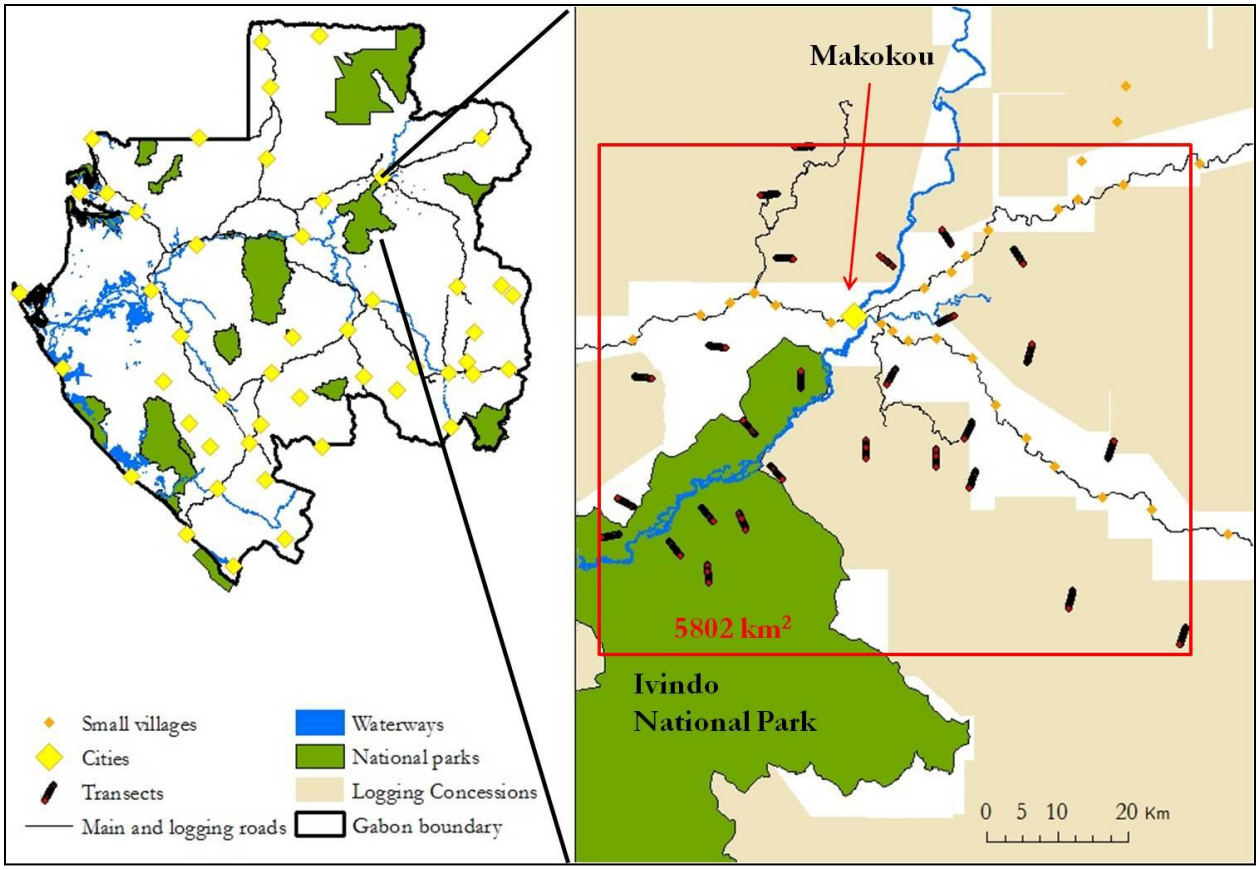

Figure 1. A map of the study area in northeastern Gabon, Africa. The 5802 km^2 study area consisted of 24 transects located around the regional capital of Makokou.

Data

The study consisted of 24 straight-line transects, each 2500m long, which were walked repeatedly by small teams of field assistants and guides, at least once per month, from October 2013 to December 2014. Field assistants walked slowly and quietly along the transects, at a pace of approximately 1 km per hour, in the early morning. They stopped every 50 to 100 m to listen for wildlife and every 200 m for 5 minutes to conduct point counts to survey large birds. Field assistants noted direct animal observations (animals seen or heard) and made efforts not to record individual animals or groups more than once. They recorded apes and monkeys as groups and counted group size, noting their confidence of the group size estimate. Monkey and bird groups were considered to be separate if they occurred more than 50 m apart. Indirect animal observations (dung or nest counts) were marked with individual numbers so that teams could note recurring observations versus new ones. In addition, assistants recorded the age of the dung and nests along with the nest type. Nests found in trees were identified as Chimpanzee nests, while nests found on the ground were identified as Gorilla nests Researchers measured the perpendicular or radial distances from the center of each direct and indirect observation to the center of the transect line.

Analysis

For the purposes of this analysis, I used data collected from January to December 2014. From the field data, I first calculated the total number of direct and indirect observations for each species for the overall area and for each transect. I then used Esri's ArcMap (v. 10.2) to map the number of species occurrences to visualize their spatial distribution. Next, I researched the available peer-reviewed literature on the nine species to determine their abundance, distribution, habitat preferences, threats, and previous densities in the study area. I then used the program Distance (version 6.2) to estimate animal densities from direct observations of monkey groups (Crowned Guenon, Grey-cheeked Mangabey, Mustached Monkey, and White-nosed Guenon), indirect observations of ape nests (Chimpanzee), or indirect observations of Forest Elephant or Blue Duiker dung piles. For the chimpanzee density calculation, I used a nest creation rate of 1 nest per day and a nest decay rate of 91.5 days (Morgan et al., 2006). To calculate the density of elephants, I employed three different dung production and decay rates: 19 days and 90 days, 18.07 days and 45.5 days, and 18.07 days and 55.6 days. For the Gorilla and Yellow-backed Duiker, there were insufficient data to estimate population densities; and therefore, I calculated relative abundance as the number of observations divided by the number of kilometers surveyed. For both the relative abundance and density calculations, only newly discovered dung piles and nests were used for the analyses to avoid double-counting samples.

I then used Esri's ArcMap 10.2 Near tool to measure five different indicators of hunting pressure: distance to the nearest village, distance to Makokou, distance to the nearest major road (km), distance to the nearest main or logging road (km), distance to all roads (km), and distance to the nearest waterway (km). The distance were estimated as the distance from the midpoint of each transect to the feature. These factors were used as indications of hunting pressure, because of the proximity of people or provision of access to the transect areas. Lastly, I used the program R to calculate correlations between these abundances and distance for each transect.

Results and Discussion

Between January and December 2014, I recorded approximately 7,500 total animal observations in 615 km of transects. White-nosed Guenons had the highest number of direct observations, while Yellow-backed Duikers had the lowest. Elephants had the greatest number of indirect observations, whereas Gorillas had the least (Table 1).

Table 1: The number and type of direct and indirect observations, average group sizes, and relative abundances for each species

Species	Direct	Direct type	Relative abundance (individuals/km)	Average group size (# of individuals)	Indirect	Indirect type
Blue Duiker	45	individuals	0.07	NA	212	dung pile
Chimpanzee	34	groups	0.06	NA	70	nest groups
	101	individuals	0.16		161	individual nests
Elephant	37	individuals	0.06	NA	496	dung pile
Gorilla	9	groups	0.01	NA	15	nest groups
	22	individuals	0.04		51	individual nests
White-nosed Guenon	314	groups	0.51	3	NA	NA
	667	individuals	1.08		NA	NA
Grey-cheeked Mangabey	114	groups	0.19	3	NA	NA
	330	individuals	0.54		NA	NA
Mustached Monkey	93	groups	0.15	4	NA	NA
	291	individuals	0.47		NA	NA
Crowned Guenon	82	groups	0.13	6	NA	NA
	404	individuals	0.66		NA	NA
Yellow-backed Duiker	7	individuals	0.01	NA	37	dung pile

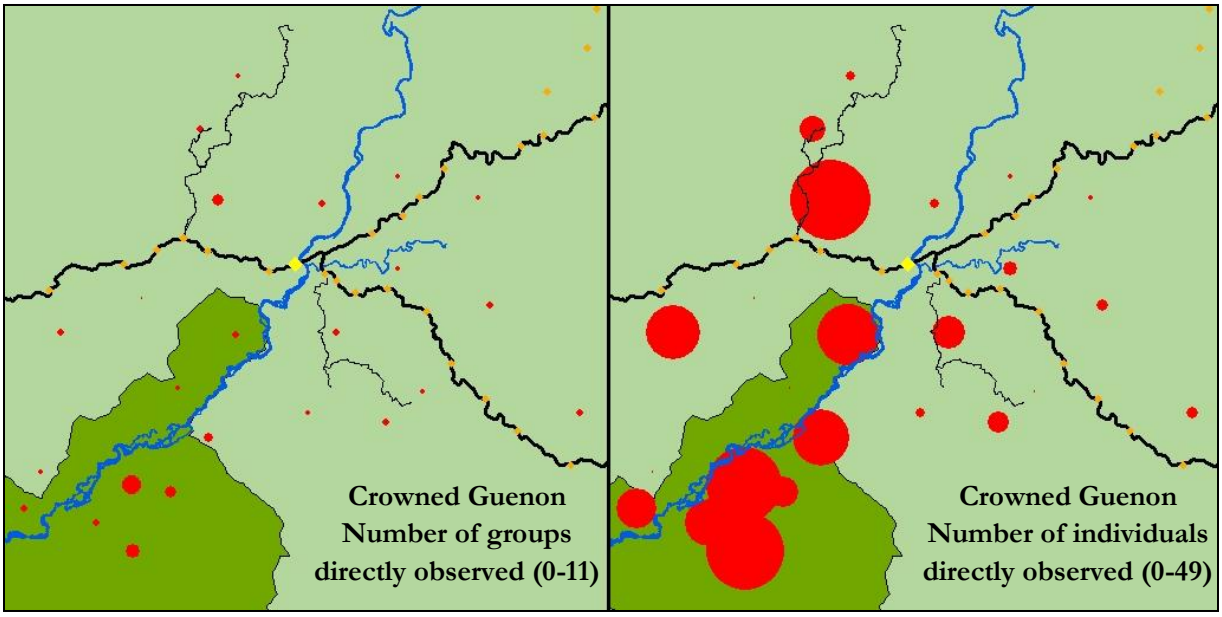

Figure 2: Map of direct (seen or heard) observations of the Crowned Guenon per transect. Red circles are proportionally symbolized to make maps comparable. There were 0-11 groups and 0-49 individuals observed per transect.

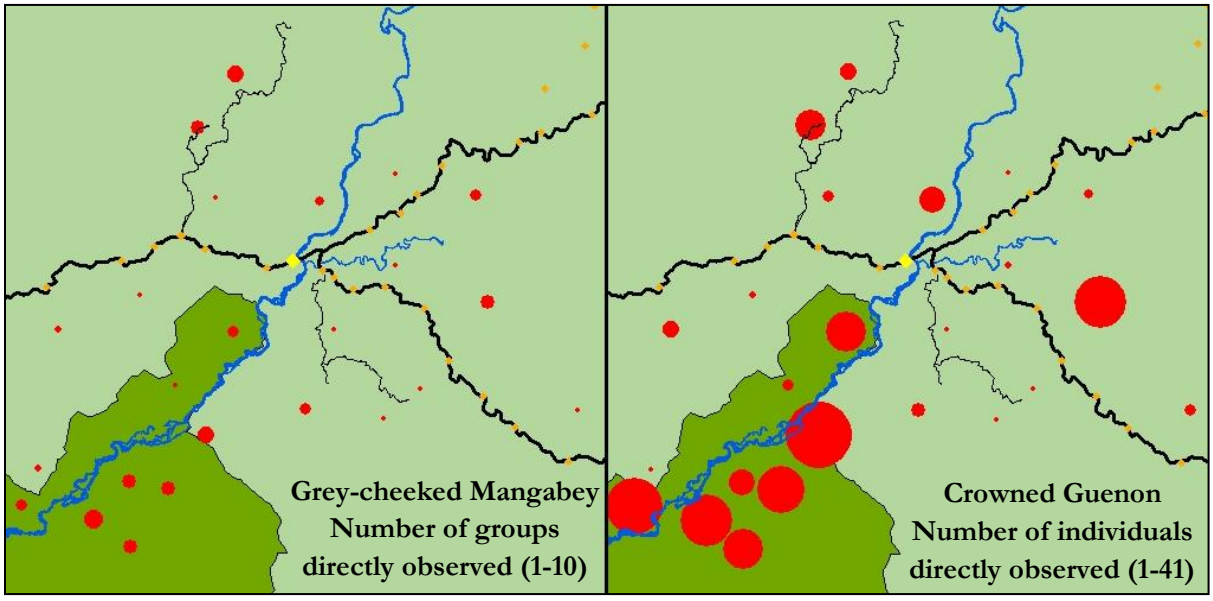

Figure 3: Map of direct (seen or heard) observations of the Grey-cheeked Mangabey per transect. Red circles are proportionally symbolized to make maps comparable. There were 1-10 groups and 1-41 individuals observed per transect.

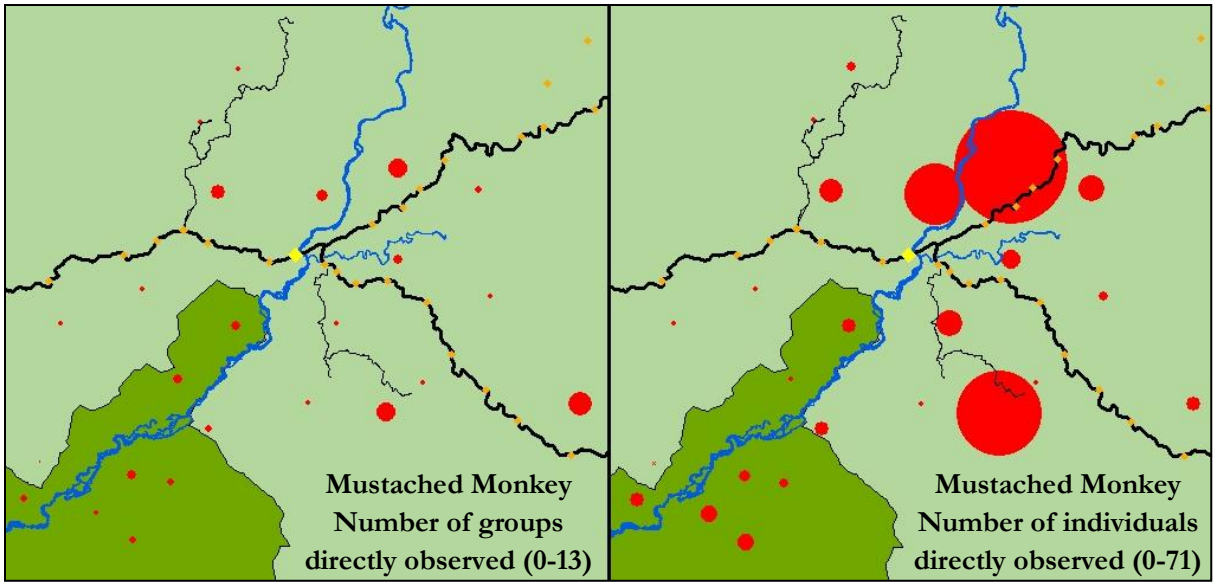

Figure 4: Map of direct (seen or heard) observations of the Mustached Monkey per transect. Red circles are proportionally symbolized to make maps comparable. There were 0-13 groups and 0-71 individuals observed per transect.

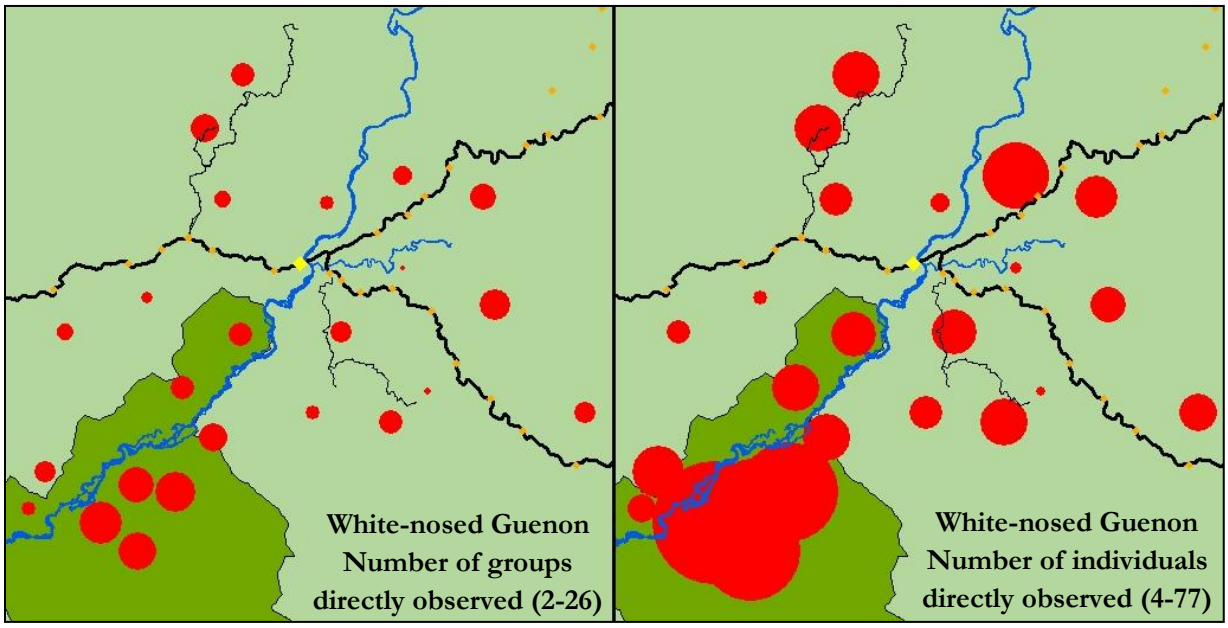

Figure 5: Map of direct (seen or heard) observations of the White-nosed Guenon per transect. Red circles are proportionally symbolized to make maps comparable. There were 2-26 groups and 4-77 individuals observed per transect.

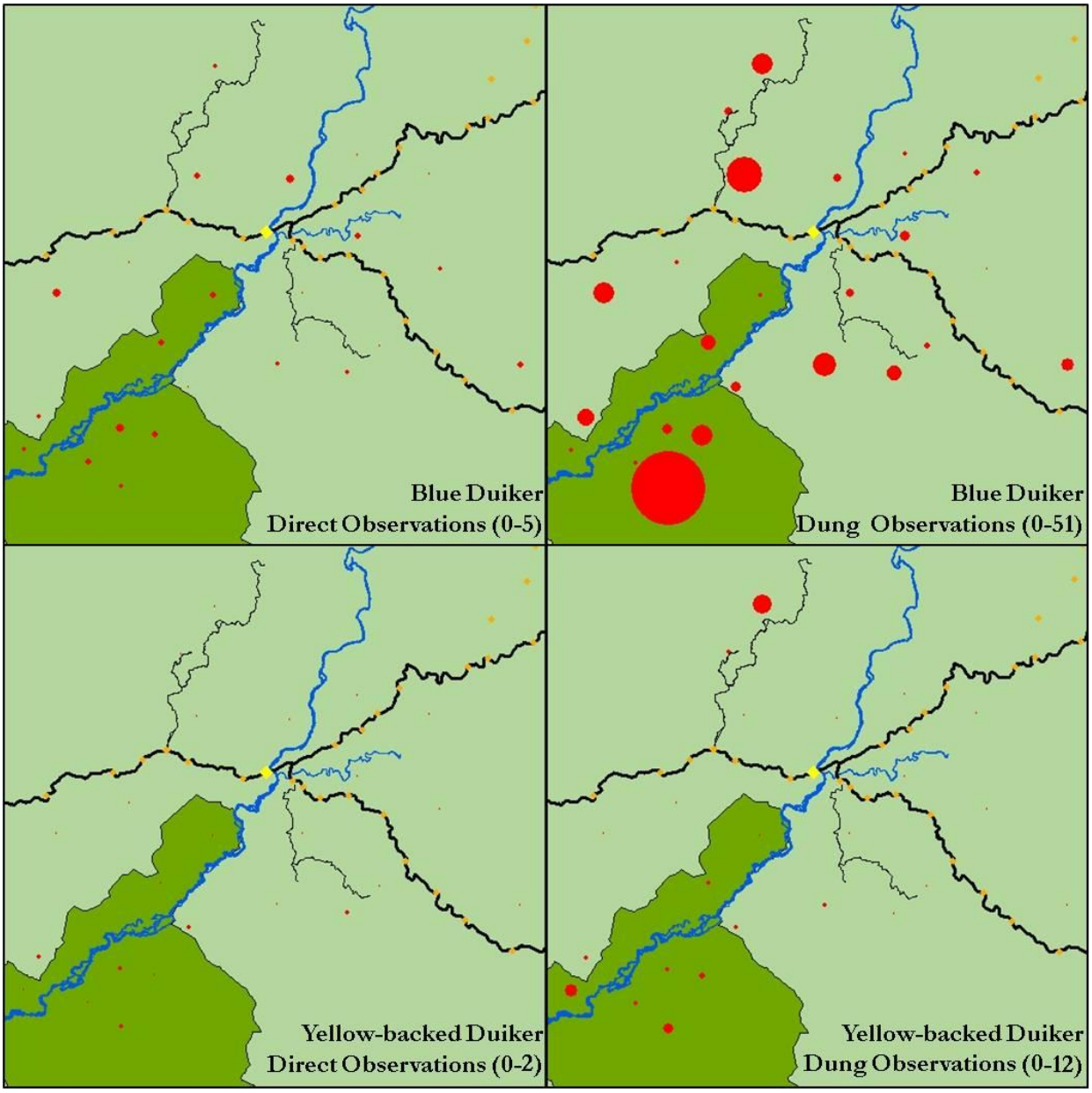

Figure 6: Map of direct (seen and heard) and indirect (dung) Blue Duiker and Yellow-backed Duiker observations per transect. Red circles are proportionally symbolized to make maps comparable. There were 0-5 direct and 0-51 dung observations of Blue Duikers per transect. There were 0-2 direct and 0-12 dung observations of Yellow-backed Duikers per transect.

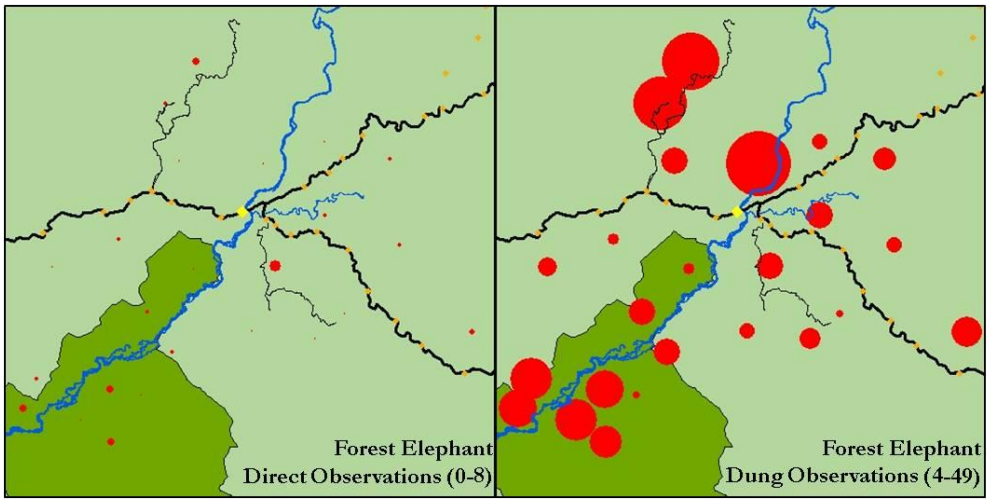

Figure 7: Map of direct (seen and heard) and indirect (dung) Forest Elephant observations. Red circles are proportionally symbolized to make maps comparable. There were 0-8 direct observations of elephants and 4-49 dung observations per transect.

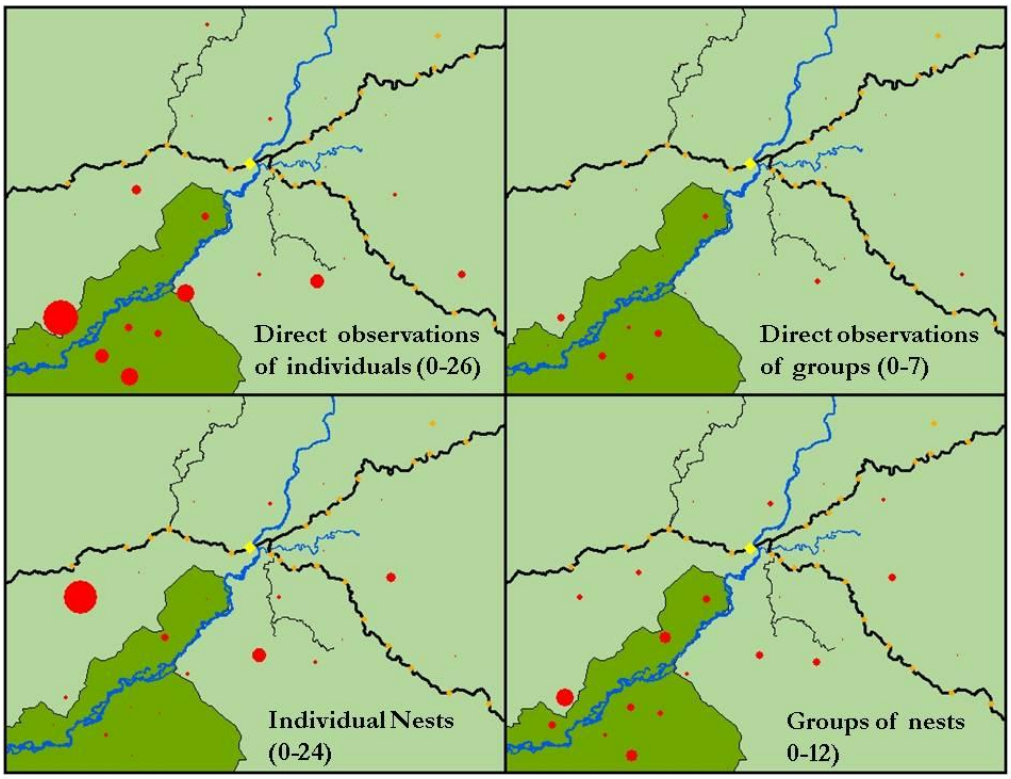

Figure 8: Map of direct (seen and heard) and indirect (nest) Chimpanzee observations. Red circles are proportionally symbolized to make maps comparable. There were 0-26 direct observations of individual Chimpanzees, 0-7 direct observations of Chimpanzee groups, 0-24 observations of individuals Chimpanzee nests, and 0-12 observations of groups of nests (occurring closer than 50 m) per transect.

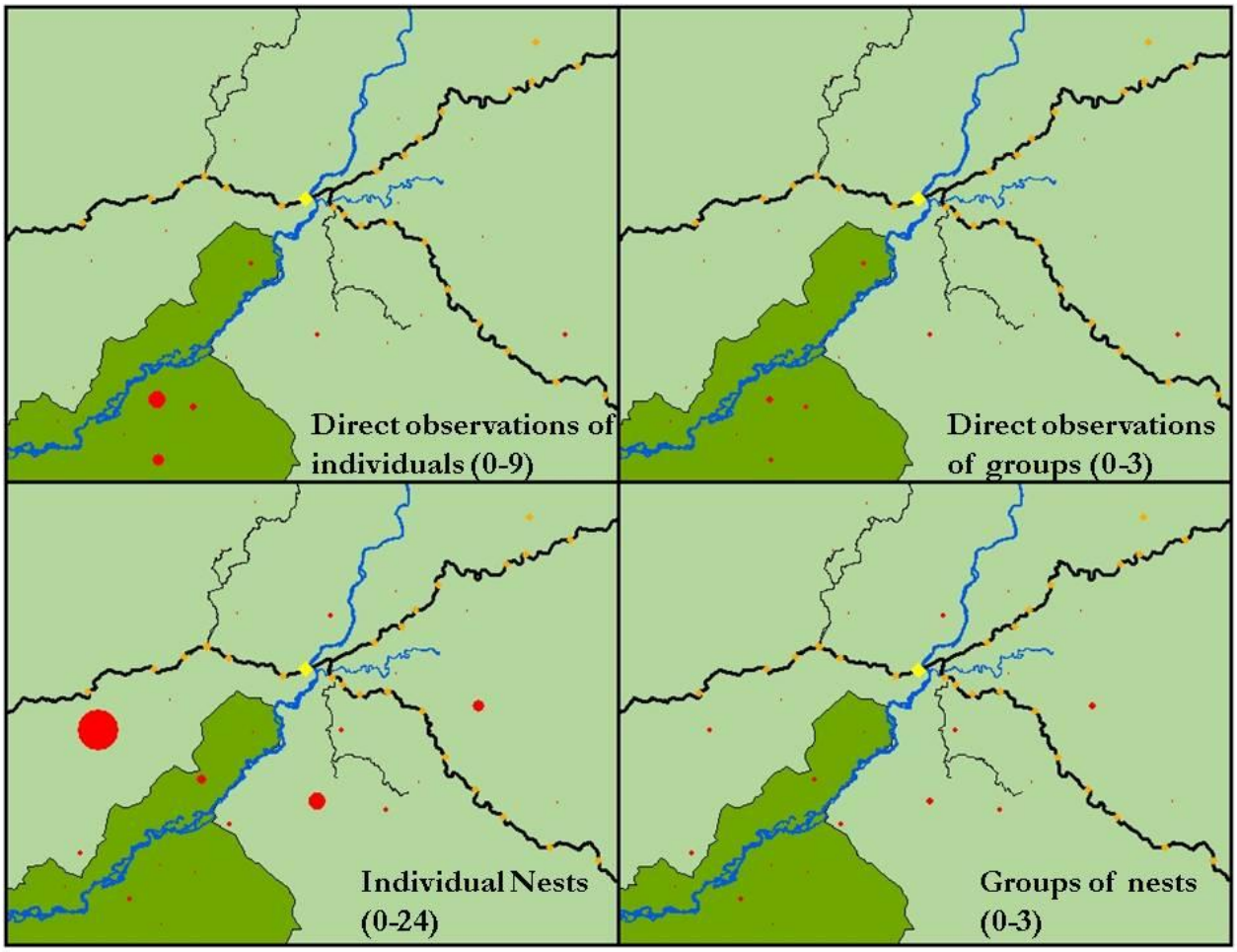

Figure 9: Map of direct (seen and heard) and indirect (nest) Gorilla observations per transect. Red circles are proportionally symbolized to make maps comparable. There were 0-9 direct observations of individual Gorillas, 0-3 direct observations of groups of Gorillas (occurring closer than 50 m), 0-24 individual nest observations, and 0-3 observations of groups of Gorilla nests (occurring closer than 50 m) per transect.

The White-nosed Guenon had the highest density of individuals and the Chimpanzee had the lowest (Table 2). There were too few observations to calculate densities for the Gorilla or Yellow-backed Duiker, so I calculated relative abundances instead (Table 2).

Table 2. The density of wildlife species in the Ivindo landscape in Gabon, including the density, 95% confidence intervals, coefficient of variation, and total abundance of each species in the area. Note that there are three estimates of elephant density representing differing dung defecation or decay rates in the literature. Species are ordered in the table from the most dense to least dense.

Species	*Density Measure*	*Density*[1]	*(CI)*	*df*	*CV (%)*	*Effort (km)*	*Width (m)*	*Local Population Estimate*
White-nosed Guenon *Cercopithecus nictitans*	density of individuals	13.65	(3.36-5.39)	77.7	11.8	615	175	79,207
Crowned Guenon *Cercopithecus pogonias*	density of individuals	11.13	(1.01-2.44)	138.3	22.5	592	145	64,585
Grey-cheeked Mangabey *Lophocebus albigena*	density of individuals	5.00	(3.51-7.14)	74.6	18.0	615	145	29,014
Blue Duiker *Philantomba monticola*	density of dung	3.71	(2.12-6.51)	51.9	28.6	587	4	21,528
Mustached Monkey *Cercopithecus cephus*	density of groups	1.99	(1.33-2.98)	59.1	20.4	587	107	51,877
Elephant *Loxodonta Africana*	density of dung	0.15[a]	(0.11-0.21)	63.2	15.9	615	4	870
		0.32[b]	(0.23-0.44)	63.2	15.9	615	4	1,857
		0.26[c]	(0.19-0.36)	63.2	15.9	615	4	1,509
Chimpanzee *Pan troglodytes*	density of groups	0.12	(0.08-0.16)	25.2	16.8	409	37	696
Gorilla *Gorilla gorilla*	relative abundance	0.02[2]	NA	NA	NA	NA	NA	NA
Yellow-backed Duiker	relative abundance	0.06[2]	NA	NA	NA	NA	NA	NA

[1] Density is number of animals/sq km.
[2] Relative abundance is number of individuals/km.
[a] Using a dung production rate of 19 days and defecation rate of 90 days; [b] dung production rate of 18.07 days and defecation rate of 45.5 days; [c] dung production rate of 18.07 days and defecation rate of 55.6 days.

Table 3: The correlation coefficients for each species with the five measures of hunting pressure. The significant correlations ($p<0.05$) are in bold.

Species	Villages	Makokou	Main Roads	+Logging Roads	+Small Roads	Waterway
Crowned Guenon	**0.57**	0.33	**0.57**	**0.61**	**0.44**	-0.14
Grey-cheeked Mangabey	**0.76**	0.40	**0.77**	**0.62**	**0.42**	-0.20
Mustached Monkey	-0.26	-0.07	-0.27	-0.24	-0.26	0.33
White-nosed Guenon	**0.72**	**0.48**	**0.74**	**0.71**	**0.52**	-0.06
Blue Duiker	**0.42**	0.23	**0.43**	0.32	0.16	0.10
Yellow-backed Duiker	**0.62**	0.39	**0.62**	0.31	0.12	0.03
Forest Elephant	0.28	0.10	0.27	0.24	-0.05	0.03
Chimpanzee	**0.59**	**0.44**	**0.50**	**0.54**	**0.50**	-0.32
Gorilla	-0.07	-0.10	-0.07	-0.17	0.00	-0.05

I found no significant correlations for any species with distance to the nearest waterway, suggesting that local rivers are not used as a source of access for hunters. Distance to the nearest small village and the nearest major road were highly correlated, thus all species that had a significant correlation with distance to small villages had similarly significant correlations with distance to nearest major road. This correlation was not surprising because the villages are located mostly along the main roads, so they would reflect similar overall hunting pressure, especially for bushmeat hunting. While distance to small villages and major roads were the most commonly significant hunting pressures, logging roads and small roads also presented a risk for four of the species; Crowned Guenon, Grey-cheeked Mangabey, White-nosed Guenon and Chimpanzee. Mustached Monkeys, Forest elephant and Gorillas had no significant correlations with any measure of hunting pressure.

Crowned Guenon

The Crowned Guenon (also known as the Crowned Monkey or Mona Monkey; *Cercopithecus mona pogonias*) is a relatively common species and is considered an IUCN species of "Least Concern". It is targeted for bushmeat and in 2002, had a local area density of 7.07 individuals/km^2 (Okouyi et al., 2002). Jeffrey et al. (2010) found that this species prefers open-canopy Marantaceae forest. The Crowned Guenon had the fewest number of groups observed among the monkey species, but the second highest group sizes (Table 1). In addition, it was the only species analyzed whose density actually increased (to 11.13 individuals/km^2; Table 2) since the earlier study (7.07). Crowned guenon abundances were correlated with distance to small villages and major roads, likely reflecting the effect of hunting on its population size (Table 3). The largest number of groups and group sizes were located within Ivindo National Park, with the exception of one large group found near logging roads (Figure 2).

Grey-cheeked Mangabey

The Grey-cheeked Mangabey (*Lophocebus albigena*) is a widespread, common species listed by the IUCN as of "Least Concern". It prefers undisturbed habitats, (Matthews and Matthews, 2002) and is sensitive to human presence (Matthews and Matthews, 2002). The local density of this species was estimated at between 10-20 individuals/km^2 (IUCN, 2014). The Grey-cheeked Mangabey's 2014 density of 5.00/km^2 (Table 2) was lower than its estimated density throughout its distribution (IUCN, 2014). Grey-cheeked mangabey densities were correlated with the distance to nearest the small village and major road (Table 3), likely reflecting hunting pressure. The largest groups of Grey-cheeked Mangabeys were found within Ivindo National Park, likely reflecting its sensitivity to humans and preference for undisturbed habitat. It did, however, have one large population large group on a transect near a main road and villages (Figure 3), so there may be environmental variables there influencing its preferences.

Mustached Monkey

The Mustached Monkey (also known as the Mustached Guenon; *Cercopithecus cephus*) is a common and widespread species, considered of "Least Concern" by the IUCN (IUCN, 2014). It prefers closed-canopy primary forest (Bermejo, 1999), but can succeed in secondary forest as well. It is targeted for bushmeat hunting and its most recent local density was 19.08 individuals/km^2 in 2002 (Okouyi et al., 2002). The density of Mustached Monkeys decreased by approximately 50% between 2002 and 2014, to 8.94 individuals/km^2 (Table 2). However, the relative abundance of this species was not significantly correlated with any measures of hunting pressure.

White-nosed Guenon

The White-nosed Guenon (also known as the Greater Spot-nosed Guenon, Greater White-nosed Monkey, Putty-nosed Monkey, or Spot-nosed Guenon; *Cercopithecus nictitans*) is the largest of the Central African guenons (Jeffery et al., 2010) and is considered a species of "Least Concern" by the IUCN (IUCN, 2014). It is the most common species found in the region (Lahm et al., 1998) and

is the most commonly killed monkey for bushmeat (Lahm, 1993). Its density has been found to increase with increasing distance from roads (Lahm et al., 1998) and it seems to prefer closed-canopy primary forest. In 2002, its local density was estimated to be 56.43 individuals/km^2 (Okouyi et al., 2002). The White-nosed Guenon's density decreased from 2002 to 2014, but it was still the most abundant species found in the region (Table 2). The relative abundance of the White-nosed Guenon was significantly correlated with distance to the nearest major road, followed by distance to the nearest small village (Table 3), indicating that hunting likely reduces the species' population. In addition, the largest number of groups and largest group sizes both occurred inside Ivindo National Park (Figure 5). This all suggests that the species has been affected by the bushmeat trade. Although the population of this species is decreasing, its high population density puts it at less risk than other species.

Blue Duiker

The blue duiker (*Philantomba monticola*) is a common, widespread species in Central Africa and is the most commonly hunted bushmeat species in Gabon (Carpaneto et al., 2007; van Liet et al., 2008a). It is a small duiker, weighing 3-6 kg (Newing, 2006), with a 2008 density of 70 individuals/km^2 (Van Liet et al., 2008a). The Blue Duiker's local density in 2014 drastically decreased from its 2008 estimate to 3.71 in 2014 (Table 2). This represents a 95% loss in a period of 6 years, which is likely a result of overhunting in the bushmeat trade. The highest densities of this species were found inside Ivindo National Park (Figure 6), where hunting pressure is lower.

Yellow-backed Duiker

The yellow-backed duiker (*Cephalophus silvicultor*) is a solitary species (Nakashima et al., 2013) that is present in all forest types, but is especially common in secondary forest (Newing, 2006). The Yellow-backed Duiker has its highest abundance at least 10km away from main roads and 1km from waterways (van Vliet et al. 2008b). It is the largest duiker species, weighing 70kg (Newing, 2006). Yellow-backed Duikers were the least observed species in the area (Table 1, Figure 6), with too few observations for us to estimate a population density. There was no past available density data for the species in the study region, suggesting that it may have had low populations for some time. I found a significant correlation between the relative abundance of the Yellow-backed duiker and its distance to small villages and main roads (Table 3), perhaps reflecting hunting pressure on this species.

Forest Elephant

The Forest Elephant (*Loxodonta Africana*) is considered a "Vulnerable" species by the IUCN (IUCN, 2014). The Forest Elephant's population declined by over 60% from 2002-2011, primarily because of illegal poaching for its ivory (Maisels et al., 2013). The species seems to prefer denser forest areas for its habitat (van Vliet and Nasi, 2008b), but its habits regarding roads are unclear. Some studies have found that forest elephants tend to avoid roads (Blake et al., 2007; Yackulic et al., 2011; Vanthomme et al., 2013), while others have specified that they may use secondary roads for browsing or movement corridors (Laurance et al., 2006b; Clark et al., 2009; Vanthomme et al., 2013). The most highly abundant transects were two located near logging roads northwest of

Makokou and one north of Makokou near the Ivindo River (Figure 7). The density of the African Forest Elephant decreased over 50% from its 2002 estimate at 0.58 individuals/km^2 (Okouyi et al., 2002), reflecting the poaching crisis. The relative abundance of elephants were not significantly with any measure of hunting pressure, perhaps indicating that the poaching pressure does not emanate from the local human population.

Chimpanzee

The central African Chimpanzee (*Pan troglodytes troglodytes*) is the most abundant ape species, but is still considered Endangered by the IUCN because of its likely irreversible decline. It is primarily threatened by disease and hunting, although it is not a primary bushmeat species (Walsh et al., 2003; IUCN, 2014). The chimpanzee likes to establish its nests in primary or swamp forests (Furuichi et al., 1997; Poulsen and Clark, 2004) and may stay away from main roads but not smaller roads (Vanthomme et al., 2013) or logging areas (van Vliet and Nasi, 2008b). The greatest number of direct individual Chimpanzees and observations of groups of Chimpanzee nests occurred on a transect close to Ivindo National Park (Figure 8). The greatest number of individual nests was found on a transect close to a small village and main road (Figure 8). The Chimpanzee's most recent recorded density was 0.78 individuals/km^2 (Furuichi et al., 1997), which fell over 80% to 0.12 in 2014. The relative abundance of the Chimpanzee was significantly correlated with all hunting measures, with the highest being small villages. The Chimpanzee's dramatic decrease in density and its significant correlations could reflect disease transmission from human populations or the Chimpanzee's avoidance of human activity or noise.

Gorilla

The Western Gorilla (*Gorilla gorilla*) is an IUCN Critically Endangered species that has suffered from high levels of poaching and disease, resulting in a decline of over 60% during the last 20-25 years, with dire forecasts for recovery because of its very low reproduction rates (IUCN, 2014). It prefers to nest in secondary forest (Furuichi et al., 1997) or swamp forest areas (Poulsen and Clark, 2004) and had a density of 0.75 individuals/km^2 in 2002 (Okouyi et al., 2002). The largest number of direct individual Gorilla observations was on a transect located deep within Ivindo National Park (Figure 9). The greatest number of individual Gorilla nests discovered was on a transect located close to a main road and small village (Figure 9). This was the same transect where the greatest number of individual Chimpanzee nests was also found (Figure 8). I was unable to calculate a density for the Gorilla, because of its low number of observations. This is worrisome, because it signifies a very low population, which may be because the species is still recovering from past Ebola outbreaks (with slow recovery given its low reproductive rates). Alternatively, the low Gorilla presence may be a result of incorrect identification of Chimpanzee nests, as the two are often hard to distinguish (Poulsen and Clark, 2004). This possibility is lent support by the greatest number of Chimpanzee and Gorilla nests occurring on the same transect. Overall, the general lack of correlations between Gorilla abundance and any hunting pressure is likely due to the lack of observations.

Conclusion

Overall, 8 of the 9 species analyzed in this study declined in abundance since their previous estimates. Blue Duikers suffered the most drastic decline, followed by the Chimpanzee and the White-nosed Guenon. It is possible that differing methods, study areas, or observer differences between this study and some of the previous studies could have introduced some error to density comparisons. However, the overall magnitude of decline in animal abundances seen in the comparisons strongly suggests that is has been driven by hunting.

Distance to the nearest small village or nearest main road was the overall strongest and most commonly significant hunting indicator. Based on bushmeat preferences and indicators of hunting pressure, it appears that most of the decline has been caused by excessive bushmeat hunting. One exception is the Forest Elephant, which has been regionally impacted by organized poaching networks (ANPN, 2013). Another exception is apes, which likely suffered population declines in the recent past due to diseases such as Ebola haemorrhagic fever, and are likely still recovering (Walsh et al., 2003). On the whole, the entire wildlife community seems to be declining in abundance.

These trends are likely to continue unless measures are taken to reduce the pace of hunting and poaching. Otherwise, continued declines in abundance could disrupt trophic cascades, decrease seed dispersal, and alter the species composition of the plant community (Petre et al., 2013). In addition, species may become isolated in protected park areas, where they could still face hunting and poaching threats due to the lack of effective law enforcement (Laurance et al., 2006b). Thus, I recommend that the region needs stricter hunting regulations and hunting/poaching monitoring and enforcement. In addition, because of their vulnerability to human disease and slow-to-recover populations, Chimpanzees and Gorillas require more careful habitat protection and separation from humans (Walsh et al., 2003). Such measures will make it more probable that Gabon will be able to balance conservation with economic development and protect its natural resource wealth for generations to come.

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