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Effects of Human Disturbance on the Endangered Preuss's Monkey (*Allochrocebus preussi*) in the Ebo Forest, Cameroon: Implications for Conservation

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Abstract

Background and Aim: Knowledge of population size is crucial for efficient conservation planning. Limited population survey data exist for the Endangered Preuss's monkey in Cameroon's Ebo forest, a stronghold for this species and several other IUCN RedList species. In this study, we assessed the population size of Preuss's monkey in the Ebo forest. **Methods:** Ecological data on Preuss's monkey and evidence of anthropogenic disturbances were collected based on recce surveys. Encounter Rate was used to assess abundance and distribution, and for comparing relative abundance among four survey sites. We employed ANOVA to test for significant differences in encounters with Preuss's monkey across sites in the Ebo forest. We used regression analysis to identify possible relationships between encounters with Preuss's monkey and anthropogenic activities recorded. **Results:** Based on direct sightings, we observed 66 individuals residing in 11 groups. This resulted in an encounter rate of 0.15_individuals/km, a sighting frequency of 0.024_groups/km, and an encounter frequency of 0.062_groups/km of Preuss's monkeys. On average, an encounter rate of 2.4_signs of anthropogenic activities/km was documented. Our results revealed a negative and significant correlation between encounters of Preuss's monkey and human activities such as hunting signs, logging signs, evidence of planted crops, collection of Non-Timber Forest Products, and fishing activity. **Conclusion:** Our investigation indicates that the population of Preuss's monkey in the Ebo forest totals approximately 481 individuals, which is consistent with their Endangered status. **Implications for Conservation:** We recommend continued monitoring and research on this population to better determine the specific drivers of their population decline. We also advocate a community conservation approach to incentivize local communities to take a more active role in preserving the forest and protecting Preuss's monkey. Equally important, are programs of conservation education and awareness, in an attempt to inspire local people to become involved in this species conservation.

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Keywords
Preuss's monkey, status, anthropogenic disturbances, conservation, Ebo forest

Introduction

Cameroon is among the top 15 countries worldwide with the highest diversity of primate species (Colin et al., 2006; Cowlishaw & Dunbar, 2000), and is 4th in Africa in terms of primate biodiversity after the Democratic Republic of Congo, Tanzania, and Madagascar (Chuo & Angwafo, 2017; UNDP, 2001). Primates support ecological functions, processes, and services such as seed dissemination, pollination, carbon sequestration, and predator-prey relationships, sustaining healthy ecosystems that benefit human and nonhuman communities (Andresen et al., 2018; Brodie et al., 2021; Estrada et al., 2017; McConkey, 2018; Wich & Marshall, 2016). Unfortunately, at present 69% of primates' species are threatened with extinction and listed as Vulnerable, Endangered or Critically Endangered, while 94%, for which data are available, have declining population trends (IUCN, 2024). The causes of primate population decline are linked to human population growth, and associated increases in human activities such as deforestation, habitat conversion and fragmentation, urbanization, global warming, zoonosis, logging, mining, fossil fuel extraction, human-primate conflict, the dispossession of Indigenous Peoples from their traditional homelands, and the unsustainable exploitation of primates for food, body parts, traditional medicine, and as pets (Boonratana, 2020; Estrada et al., 2017, 2019; Fufa et al., 2020; Garber et al., 2024; IUCN, 2022; Nunn & Gillespie, 2016). Thus, it is urgent to conserve primates, including populations living within and outside protected areas (Tudge et al., 2022).

The Ebo forest lies within the Gulf of Guinea's biodiversity hotspot (Oates et al., 2004), and is part of the threatened Cross-Sanaga-Bioko coastal forest ecoregion (Whytock et al., 2021). This forest harbors 11 species of diurnal primates (Oates, 2011), counting some of the region's most charismatic species including the Endangered Nigeria-Cameroon chimpanzee (*Pan troglodytes ellioti*), an unqualified subspecies of the Western gorilla (*Gorilla gorilla*) and one of only two remaining populations of Preuss's red colobus (*Piliocolobus preussi*) (Morgan et al., 2011). Primate research and monitoring efforts in the Ebo-Makombe-Ndokbou forest complex have principally focused on great apes (Dowsett-Lemaire & Dowsett, 2001; Morgan et al., 2003,2011; Morgan & Abwe, 2006; Abwe, 2018; Abwe et al., 2019, 2020; Mfossa et al., 2022,2023), with significantly fewer studies targeted at monkeys (Morgan et al., 2013; Bowers-Sword, 2020; Nkengbeza et al., 2024; Whytock et al., 2021).

There exists limited survey data on the status of Preuss's monkey in the Ebo forest, a stronghold for this species. Approximately 13% of the range of Preuss's monkey lies in the Ebo forest. Human pressure such as agricultural expansion, logging, and hunting for bushmeat threaten the rich biodiversity of this forest (Mahmoud et al., 2019; Mfossa et al., 2022; Morgan et al., 2013). Therefore, conservation actions are urgently needed (Chapman et al., 2020), including the creation of effective management plans to reforest the area and expanding suitable habitat (Rylands et al., 2008; Estrada et al., 2017). This will require an evidence-based conservation approach (Hayward et al., 2015) that includes accurate knowledge of Preuss's monkey distribution, population size, age structure, and life history. Similarly, understanding the current and future anthropogenic threats to the population is imperative for developing effective long-term monitoring programs.

Preuss's monkey (*Allochrocebus preussi*) also referred to as Preuss's guenon is found in mainland Africa and on Bioko Island. Its mainland populations are restricted to southwestern Cameroon and southeastern Nigeria (Cronin et al., 2019). This species is listed as Endangered on the IUCN Redlist (Cronin et al., 2019) and is protected (Class A) in Cameroon by Wildlife Legislation (MINFOF, 2020). Over half of Preuss's monkey population resides outside of Protected Areas, and despite legislation to protect this species, poaching and habitat destruction continue (Cronin et al., 2019). In addition, the species is disproportionately targeted given its large-bodied size (9-15kg) compared to other cercopithecine monkeys and its semi-terrestrial behavior which makes it highly vulnerable to hunters. Especially when on the ground, this species is susceptible to shotgun hunting, hunting with dogs, and caught in snares set for other species (Dowsett-Lemaire & Dowsett, 2001). On Bioko Island, the species' population has declined in excess of 65% between 1986 and 2016 (Cronin et al., 2019).

Between 1992 and 1994, Beeson et al. (1996) studied a population of Preuss's monkey in the Kilum-Ijim forest in the North-West Region of Cameroon and reported that it was the most common guenon inhabiting afro-montane forest. However, less than 10 years later, Maisels et al. (2001) reported that the population size had dropped since the time Beeson et al.s' (1996) study. Very little is known about the ecology and population size of Preuss's monkey in Cameroon, which may be the species last stronghold. Given that the conservation status of the Ebo forest has not been legally determined, there is a continuing risk that logging and other forms of land conversion will continue. In this study, we investigated the current population size and demography of Preuss's monkey in the Ebo forest, and the effects of anthropogenic land conversion on its remaining areas of suitable habitat.

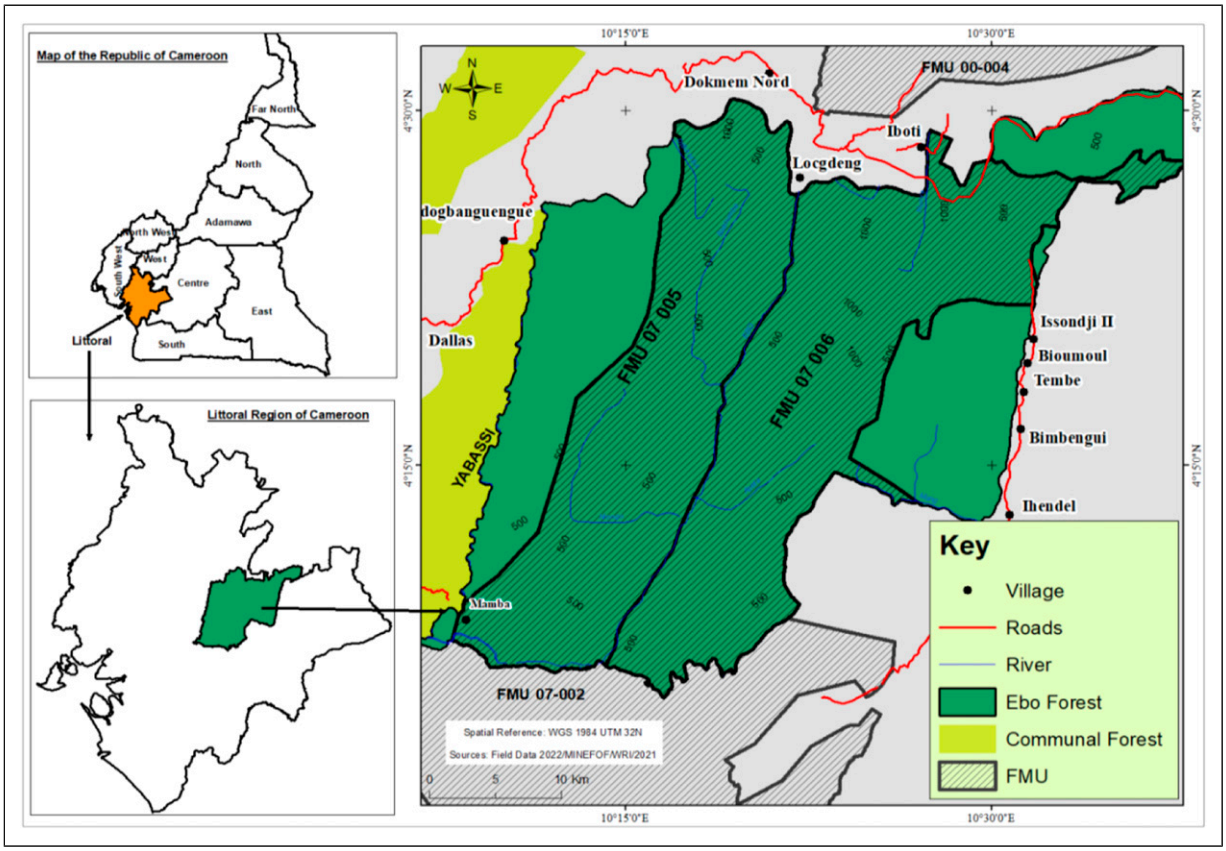

Figure 1. Location of Ebo forest within Cameroon.

Methods

Study Area

The Ebo forest is located in the Littoral administrative region of Cameroon (04°05′09.5″ - 04°31′01.6″ North, and 10°02′59.2″ - 10°38′30.9″ East) (Figure 1), and covers more than 1400 km2 of mixed high-canopy and secondary lowland and sub-montane forest (Abwe et al., 2019; Whytock et al., 2021), north of the lower Sanaga River. The southeastern edge of the forest is less than 50 km from the Cameroon's largest city, Douala. The forest is bisected north to south by the Ebo River (Oates, 2011). Most of the Ebo forest is between an elevation of 300-400m, but some areas may reach up to 1200 m above sea level. The climate is warm and humid tropical with two seasons; a dry season that extends from December to February and a rainy season from March to November. Annual rainfall ranges from 2300 and 3100 mm (Abwe et al., 2019). Average annual temperature in the Ebo forest ranges from 25 – 28°C (Whytock et al., 2021).

Study Design

To conduct population surveys, we divided the Ebo forest into 112 4 km × 4 km quadrats, each assigned a serial number. We further divided the forest into 4 subunits (North West, South West, North East and South East) as designated by their respective geographical positions on a map. We selected these areas (subunits) based on local knowledge of the distribution of Preuss's monkeys (Nkengbeza et al., 2024). In each of the four geographic parts of the forest, we randomly selected three quadrats to survey and to obtain data on the population of Preuss's monkey and signs of human activities. Within each survey site, we conducted forest reconnaissance (recce) surveys within the selected quadrats starting from the center in the four cardinal directions (Figure 2).

A forest recce survey consists of walking throughout the survey area and collecting ecological data by intentionally following paths of least resistance which can deviate to some degree from the initial direction (Bowers-Sword, 2020; Hedges et al., 2012; Mfossa et al., 2022). This survey technique requires less effort and is more cost effective than standard line transects sampling in a difficult terrain like the Ebo forest. Forest recce surveys facilitate quick monitoring of large areas without the need to cut new trails (Fashing and Cords, 2000; Twinomugisha and Chapman, 2007). Moreover, line transects can create new paths and provide easy access for poachers (Buckland et al., 2010).

The survey team consisted of four members: team leader (lead author), one field assistant and two knowledgeable local

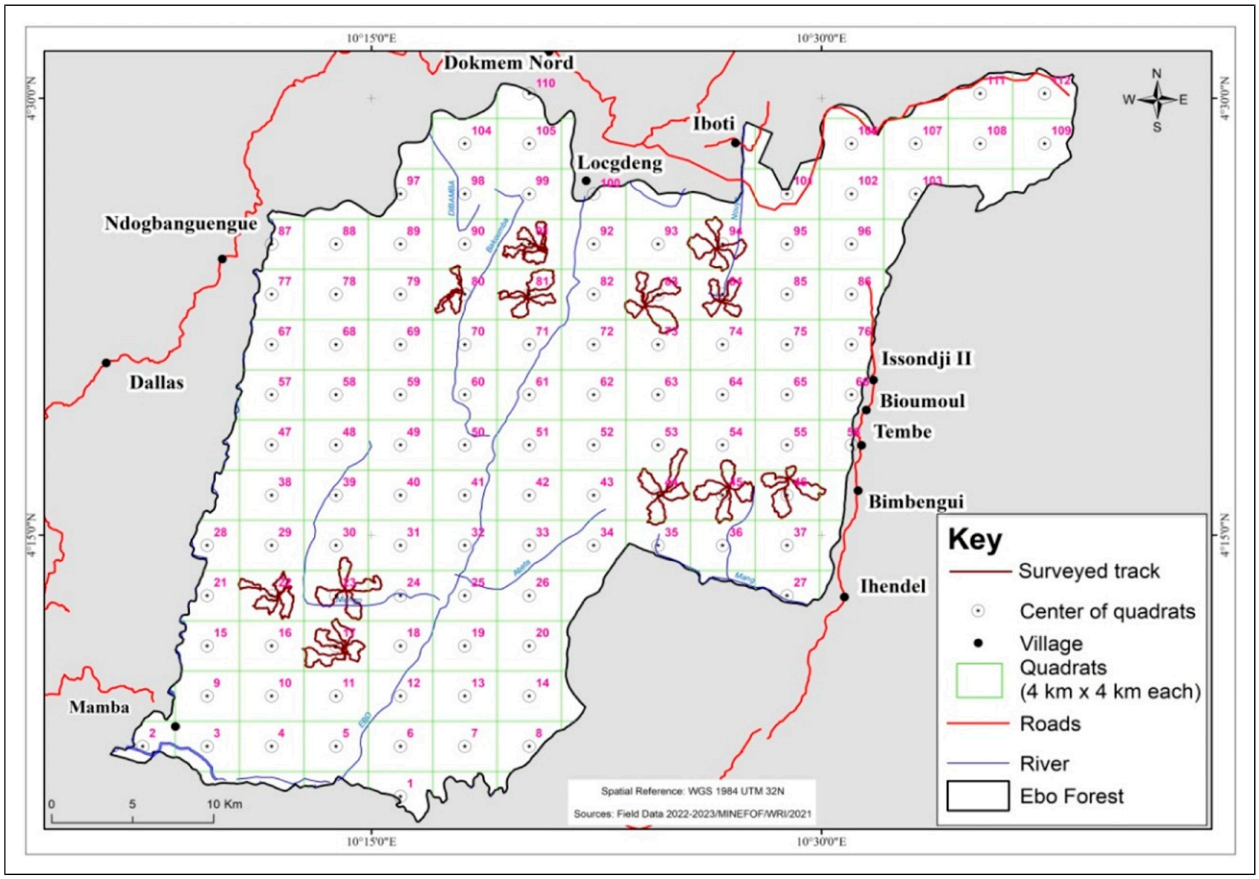

Figure 2. Location and GPS surveyed track of each recce conducted in the 04 survey sites in Ebo forest.

guides (retired hunters) who were familiar with Preuss's monkey vocalizations, and in identifying and counting individuals within a group. The team set a basecamp in each quadrat and conducted recce surveys in approximately each cardinal direction for four days per camp. At the beginning of each survey, the team defined the direction and used a GPS unit and compass to navigate in the forest. The team walked the path irrespective of the vegetation type and only deviated due to natural barriers such as faces of large rock and large rivers. The selected quadrats were surveyed once with a start time that ranged between 06:30 am – 07:00am, an average walking speed of 0.96km/hour, and an average data collection effort of 09.56km daily. The total survey effort was 449.4km (Appendix A). We limited forest surveys to the dry season because seasonal floods during the rainy season make large parts of the Ebo forest inaccessible.

Data Collection

During recce surveys, a GARMIN 64s GPS unit was used to georeference signs of Preuss's monkey such as direct sightings, vocalizations, and evidence of feeding such as fallen fruits with bite marks and fresh stems of *Aframomum* sp. All Preuss's monkey sightings and vocalization times were recorded. When a group of Preuss's monkey was spotted, the survey team followed the group as long as possible and recorded the group size, and composition (adult males, adult females and immature individuals based on body size and vocalizations). Adult males were distinguished by their larger body size and very distinctive call; adult females give distinctive calls and are smaller than adult males. Immatures were recognized by their small body size. Mixed-species associations of Preuss's monkey with other primates' taxa also were recorded. Individuals that were located greater than 20 m apart were considered members of separate groups (Buckland et al., 2010).

Hunting is a widespread activity in the Ebo-Makombe-Ndokbou forest, and primates often react to human presence by becoming cryptic or escaping (Bowers-Sword, 2020). To avoid this, the team walked the quadrats quietly and slowly with frequent stops to carefully screen all forest strata and detect movement or sound. During recces, signs of anthropogenic disturbances such as hunting (individual snare traps, snare lines, hunter's camps, hunter's tracks, hunter encounters, gunshots heard and shotgun shells found on the ground), logging (cut stumps, logging roads, abandoned logs, loading areas and logging camps), collection of Non-Timber Forest Products (NTFPs), evidence of planted crops,

and fishing activities were recorded and georeferenced. Individual snare traps were categorized as active and abandoned. Active snare traps were defined as traps mounted against an animal track. Hunter's camps were grouped into active and abandoned. The team also noted miscellaneous signs of human activity such as cigarette packets, abandoned clothing, abandoned pots, human footprints, machete marks, plastics (biscuits, tissue paper), used batteries, and containers of whisky.

Data Analysis

All data were processed and analyzed with R software version 4.2.1(R Core Team, 2022), with a 95% confidence interval set for all statistical tests. Encounter Rate (ER) also referred as the Kilometric Abundance Index was computed and used to assess abundance and distribution, and for comparing relative abundance among survey sites (Preatoni et al., 2012; Salmona et al., 2014). The ER is a commonly used measurement of how easy it is to find a species, signs of its presence/activity, or signs of human activity at a given site. It is obtained using the formula Encounter Rate (signs/km) = Total number of signs observed/ Total distance travelled (km) (Kondasso et al., 2023). According to Fonkwo et al. (2011), ER ranges from weak ($0.0 \leq ER < 0.5$) to high ($ER > 0.5$). An ER = 0 implies no observation. To estimate the mean group size, we averaged the number of individuals detected during encounters (Maurice et al., 2019).

All Preuss's monkey data were converted into direct sighting frequencies and overall encounter frequencies (direct sightings, vocalizations, and feeding remains). These frequencies were used to calculate the number of direct sightings or encounters recorded per kilometer walked (Cronin et al., 2016; Marshall et al., 2008). Sighting frequencies provide a measurement of the relative density of individuals (Linder and Oates, 2011; Thomas et al., 2010; Cronin et al., 2016).

The Shapiro-Wilk test for normality indicated that our data of encounters with Preuss's monkeys had a normal distribution (P-value > 0.05). We employed a one-way analysis of variance (ANOVA) to test for significant difference in encounters of Preuss's monkey among the four survey sites. The normality test indicated a non-normal distribution (p-value < 0.05) for data on hunting signs, logging, and all categories of human activities that were compared among survey sites. The non-parametric Kruskal-Wallis X^2 test was then performed to test for significant differences among the four sites. We also tested for significant differences in evidence of gun-hunting signs (exclusively shotgun shells and gunshots heard) among the four sites using a Kruskal-Wallis X^2 test. Regression analyses were carried out to test for a relationship between the encounter rates of Preuss's monkey and anthropogenic activities recorded. Encounter rates of these two variables were exported to R software to produce a fitted regression line. We employed ArcGis software version 10.5 to extract the spatial distribution of Preuss's monkey in relation to anthropogenic disturbances.

Results

Assessment of Preuss's Monkey Population in the Ebo Forest

Population Estimates and Sighting Frequency (groups/km). The survey covered a distance of 449.4 km across four geographic sites (Northwest, Southwest, Northeast and Southeast) of the Ebo forest, covering an area of 192 km2. Preuss's monkeys were found to range across altitudes of 87 – 945 m. Based on 11 direct sightings, the team recorded 66 individuals in 11 groups (group size ranged from three to twelve individuals). This resulted in an ER of 0.15_Preuss's monkeys/km and a sighting frequency of 0.024_groups/km. The northeast site of the Ebo forest had the highest ER (0.273_individuals/km) and sighting frequency (0.038_groups/km) of Preuss's monkeys (Table 1).

Encounter Frequency (groups/km). In addition to 11 direct encounters, we heard Preuss's monkey vocalization on 10 occasions, and identified seven locations where these monkeys fed. The total encounter frequency in the Ebo forest was 0.062_groups/km. When we compared Preuss's monkey total encounters among the four survey sites, there were no significant differences [F (3, 8) = 0.8889; P-value=0.4872],

Table 1. Distribution/Encounter patterns of Preuss's monkey in Ebo forest.

	Survey sites			
Survey parameters	North West	South West	North East	South East
Surveyed distance (km)	109.7	120.8	102.6	116.3
Number of individuals sighted	08	09	28	21
Mean group size per site	04	4.5	07	07
ER of Preuss's monkey per site (individuals/km)	0.073	0.074	0.273	0.180
Number of sightings	02	02	04	03
Frequency of sightings (groups/km)	0.018	0.016	0.038	0.025
Number of encounters	10	05	06	07
Frequency of encounters (groups/km)	0.091	0.041	0.058	0.060

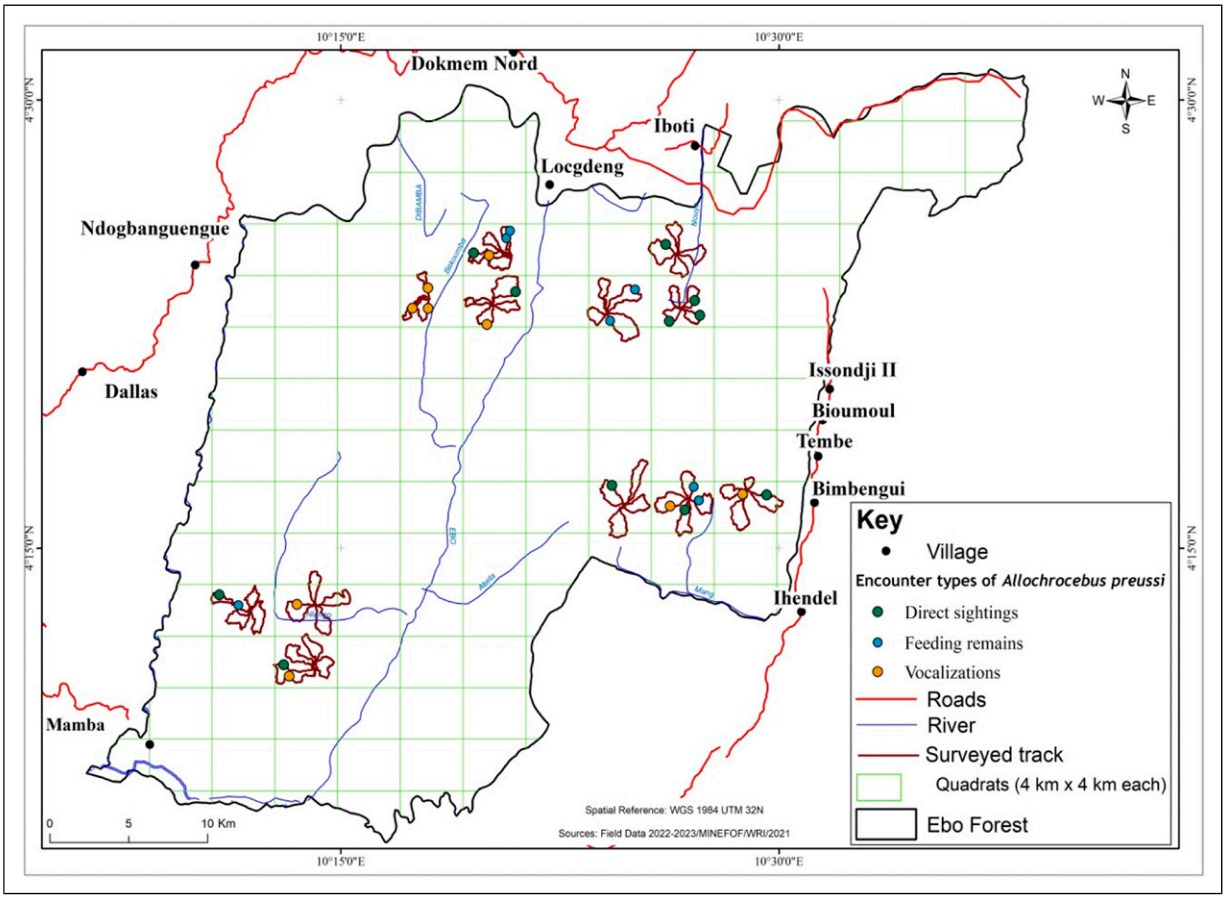

Figure 3. Distribution of different encounter types of Preuss's monkey in Ebo forest.

Table 2. Group structure and composition of Preuss's monkey in Ebo forest.

Total number of sightings	Total number of individuals sighted	Group size range	Adult males	Adult females	Immature individuals	Sex ratio (adult males/ adult females)	Immature /adults ratio
11	66	3 – 12ind.	13 (19.7%)	33 (50%)	20 (30.3%)	0.4	0.4

despite the Northwest site having the highest values (Table 1). We also found that the encounter rates of direct sightings (ER= 0.024_signs/km), vocalizations (ER= 0.022_signs/km) and feeding location encounters (ER= 0.015_signs/km) did not differ. Figure 3 illustrates the distribution of encounter types that were recorded for Preuss's monkey in the Ebo forest.

Mixed-Species Association of Preuss's Monkey With Other Primates in the Ebo Forest. Throughout the survey, we observed three mixed-species associations that involved Preuss's monkey. We found Preuss's monkey in association with the Putty-nosed guenon (*Cercopithecus nictitans*) and the crowned guenon (*C. pogonias*); with the Putty-nosed guenon and the red-eared guenon (*C. erythrotis*), and with the Putty-nosed guenon, the red-eared guenon and the crowned guenon. We defined a mixed-species association when two or more species were in the same location at the same time for a minimum of 10_minutes or travelled together for a distance of at least 50 meters. We note that Preuss's monkey had the smallest group size within these mixed species associations.

Population Structure of Preuss's Monkey in the Ebo Forest. We found that the surveyed Preuss's monkey population was composed of 13 adult males, 33 adult females and 20 pre-adult's individuals. The average group size was 6 ± 2.56 individuals, with a range of 3 to 12. The team documented two groups of three, one group of four, three groups of five, one group of six, two groups of seven, one

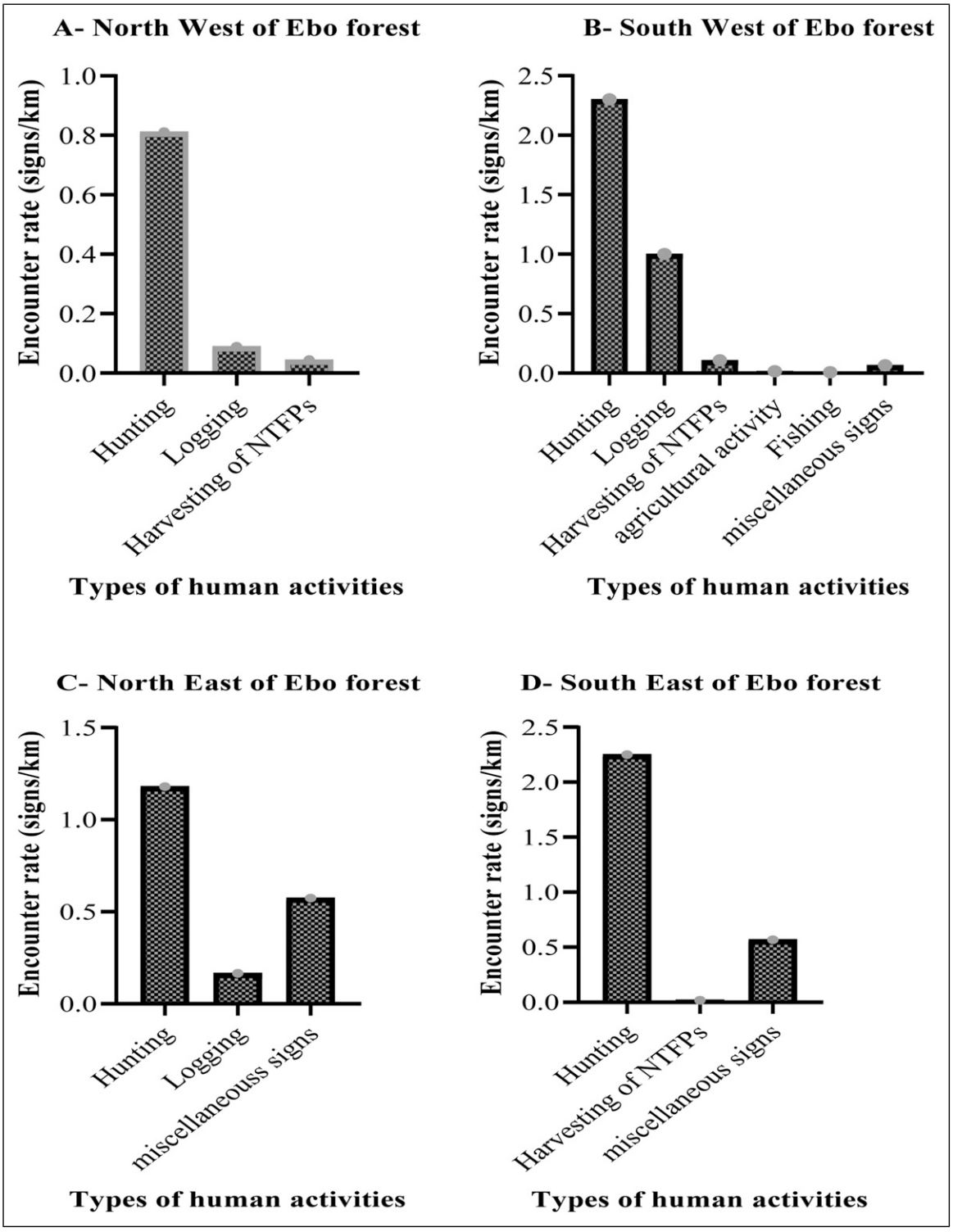

Figure 4. Encounter rates of human activities signs of each human sign type recorded in the 04 survey sites of Ebo forest.

group of nine and one group of twelve individuals. Group structure and composition of Preuss's monkey are indicated in Table 2. Overall, based on the surveyed area, we estimated a population size of 481 individuals of Preuss's monkey in the Ebo forest.

Assessment of Different Categories of Anthropogenic Activities Recorded in the Ebo Forest

The team encountered a total of 1079 indications of human activities, resulting in an ER of 2.4_signs/km (Appendix B). A

Table 3. Encounter rates of signs of human activities per survey sites in Ebo forest.

Survey sites				
	North West	South West	North East	South East
Survey distance (km)	109.7	120.8	102.6	116.3
Frequency of signs of human activities	104	448	197	330
Encounter rates	0.948	3.708	1.92	2.837

Table 4. Encounter rates of hunting signs (signs/km) per survey site in Ebo forest.

Survey sites				
	North West	South West	North East	South East
Survey distance (km)	109.7	120.8	102.6	116.3
Frequency of hunting signs encounters	89	302	121	262
Encounter rates	0.81	2.5	1.18	2.25

comparison of human activities in our four survey sites indicated no significant differences (Kruskal-Wallis X^2 = 2.2437, df = 3, p-value = 0.5234). However, the southwest site had the highest number of signs of human activities (Figure 4B), whereas the northwest site had the lowest number of signs of human activity (Table 3). Hunting signs were encountered at a significantly greater rate among other signs of human activity in the four survey sites (Figure 4).

Assessment of Hunting Activities in the Ebo Forest

The team encountered a total of 774 hunting signs (ER = 1.72_signs/km).Of the 343 individual snare traps sighted, 206 (60 %) were active and 137 (40%) were abandoned. We recorded 19 hunter's camps, including 14 (73.68%) that were active and 5 (26.32%) that were abandoned. There was no significant differences in encounter rates of hunting signs recorded among the four survey sites (Kruskal-Wallis X^2 = 1.4139, df = 3, p-value = 0.7023). However, the southwest site had the highest rate of hunting signs and the northwest site had the lowest (Table 4). Figure 5 shows encounter rates (signs/km) of the different hunting signs recorded in the four survey sites. Among these signs, individual snare traps, hunter's tracks, and shotgun shells were the most common (Figure 6)**.** Finally, we compared encounters rates with different signs of gun hunting signs. These included encounter rates of shotgun shells and gunshots heard in the four survey sites. The results showed no significant differences among these sites (Kruskal-Wallis X^2 = 0.66667, df = 3, p-value = 0.881). However, the southeast site had the highest ER of both shotgun shells and gunshots heard.

Assessment of Logging Activities in the Ebo Forest

The team encountered a total of 149 indications of logging activities (ER = 0.331_signs/km).We found a significant difference among the four survey sites in the encounter rates of logging (Kruskal-Wallis X^2 = 9.4445, df = 3, p-value = 0.02393). The southwest site had the highest ER of logging signs, while no evidence of logging was encountered in the southeast site (Table 5). Cut stumps were encountered at a significantly greater rate compared to other signs of logging suggesting that these are good indicators of logging activities.

Effect of Human Activities on the Distribution of Preuss's Monkey in the Ebo Forest

We found a weakly negative but significant correlation (R^2 = 0.0327; r = - 0.2; P < 0.0001) between encounters of Preuss's monkeys and total signs of anthropogenic activities. The scatter diagram of the fitted regression line (Figure 7) indicates that the more human disturbances were present in the area, the lower likelihoods of encountering Preuss's monkeys. Overall, we had more Preuss's monkey encounters in areas of low human presence (Figure 8).

Discussion

This study offers an assessment of the population demography and size of the Endangered Preuss's monkey in the Ebo forest, Cameroon. The Ebo forest accounts for over 13% of the remaining range of this species. Based on our study, we estimate the remaining population of Preuss's monkey in the Ebo forest is 481individuals.

In our study, we had few sightings of Preuss's monkey. It was sighted 11 times across 47 survey days and 449.4km of field surveys (an area of 192km2). The frequency of sightings was 0.024_groups/km which is comparable to that reported

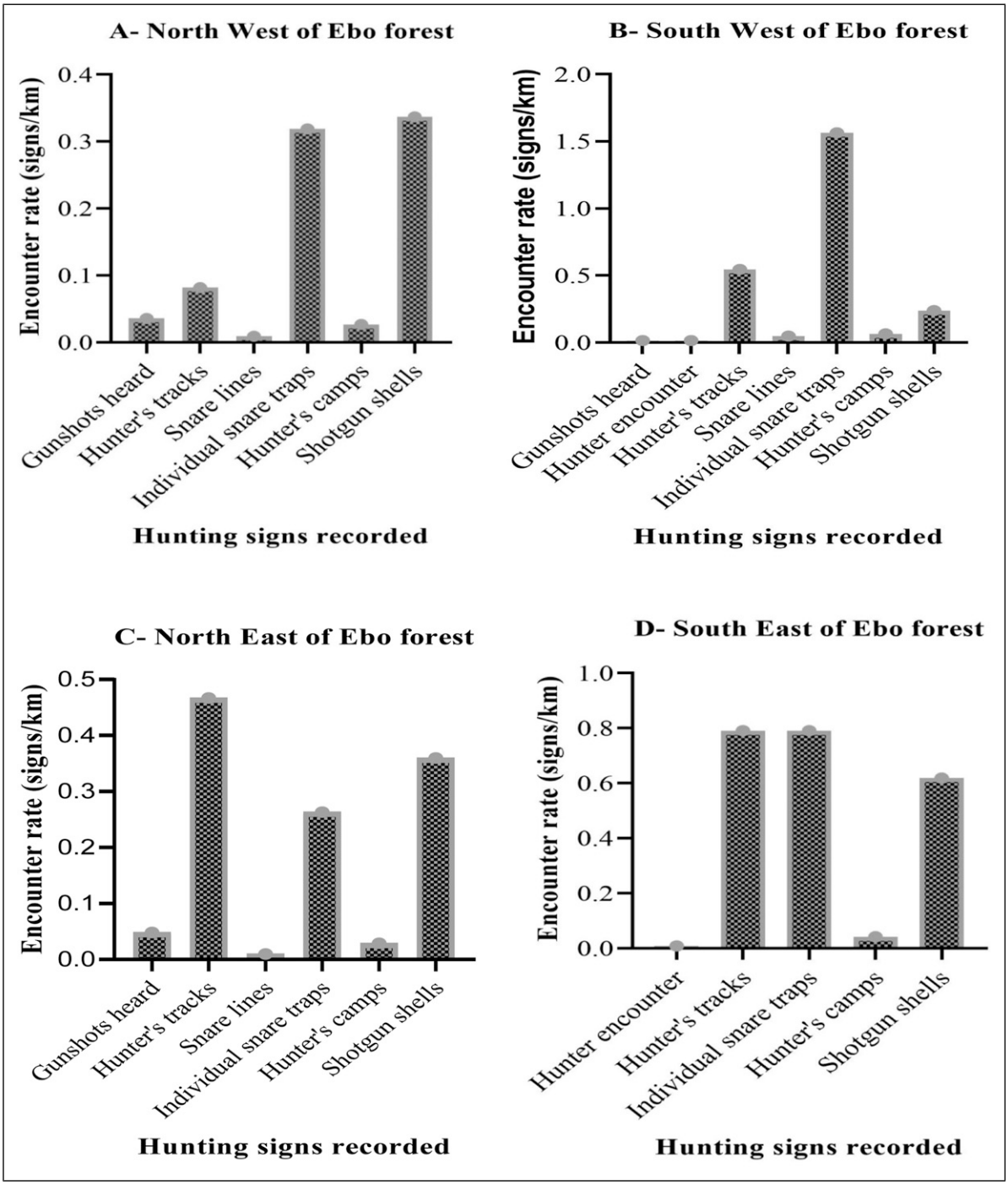

Figure 5. Encounter rates of hunting sign types recorded in each of the 04 survey sites of Ebo forest.

by Bowers-Sword (2020) in the nearby Dokbou forest of Cameroon (0.02_groups/km), and Cronin et al. (2016) survey on Bioko Island in Equatorial Guinea (0.04_groups/km). The group size of Preuss's monkey in the Ebo forest ranged from 3-12 individuals (mean=6). This is smaller than Beeson et al.'s (1996) study at Mount Oku in the western highlands of Cameroon. Group size at the site averaged 10 and ranged from 2-19 individuals. Overall, we found an adult sex ratio of 1 adult female to 0.4 adult males and a ratio of 1.4 adults to 1 preadult.

The number of individuals sighted, the frequency of Preuss's monkey sightings and their encounter rates varied significantly among the four survey sites. Significantly, more individuals of Preuss's monkey were sighted in the north-eastern study site and the overall encounter rate with Preuss's monkeys was significantly higher in the northwestern part.

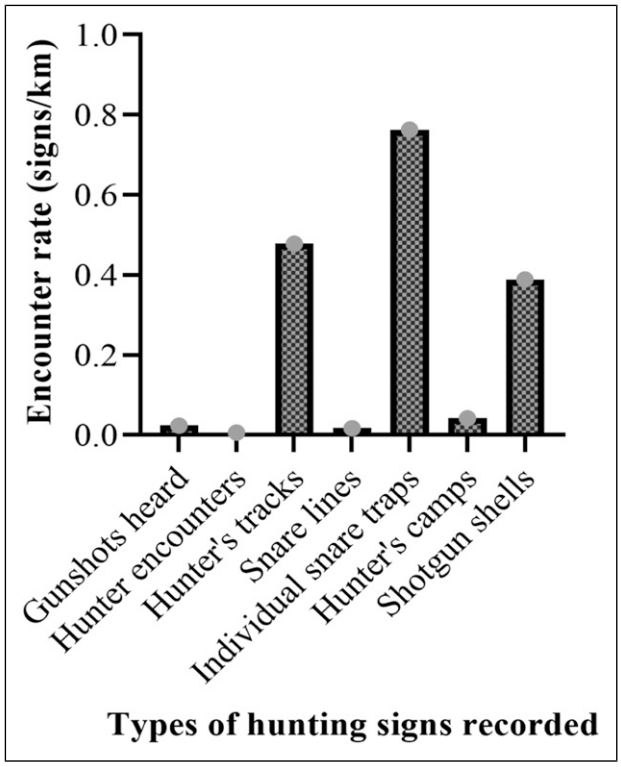

Figure 6. Encounter rates (signs/km) of each hunting sign type recorded in Ebo forest.

This may reflect differences in these four survey areas. For example, we found significantly fewer indicators of anthropogenic disturbance in the northern part of the forest compared to the southern sites. According to Maurice et al. (2019), anthropogenic disturbances such as hunting and logging activities negatively affect primate distribution and survivorship. Despite differences in the number of Preuss's monkeys sighted across our four study areas, there was no significant difference in the frequency of hunting signs. However, the southern parts of the Ebo forest had the highest encounter frequencies of hunting signs, which may result from their close proximity (< 50km) to the cities of Douala and Edea, both of which have high bushmeat demand. Hunting is a prevalent activity in the Ebo forest (Fuashi et al. 2019), and most people living in the southern part of the forest sell bushmeat in Douala to earn more money (Bowers-Sword, 2020). The close proximity of the Ebo forest to the capital city of Douala creates a high demand for forest products, wildlife, and bushmeat trade (Morgan et al., 2011; Whytock & Morgan, 2010; Abwe, 2018; Bowers-Sword, 2020). The transport vehicles leave from the Ebo forest to Douala and Edea with loads of smoked and fresh bushmeat in their cargo. The meat supplies markets and restaurants in these cities (per. obs.). Primates accounted for approximately 37% of the total biomass in these bushmeat markets (Fuashi et al., 2019). In the study by Fuashi et al. (2019), guenons constituted over 68.2% of the primate species hunted, and

Table 5. Encounter rates of logging signs (signs/km) per survey site in Ebo forest.

Survey sites				
	North West	South West	North East	South East
Survey distance (km)	109.7	120.8	102.6	116.3
Frequency of logging signs encounters	10	122	17	0
Encounter rates	0.091	1.009	0.165	0

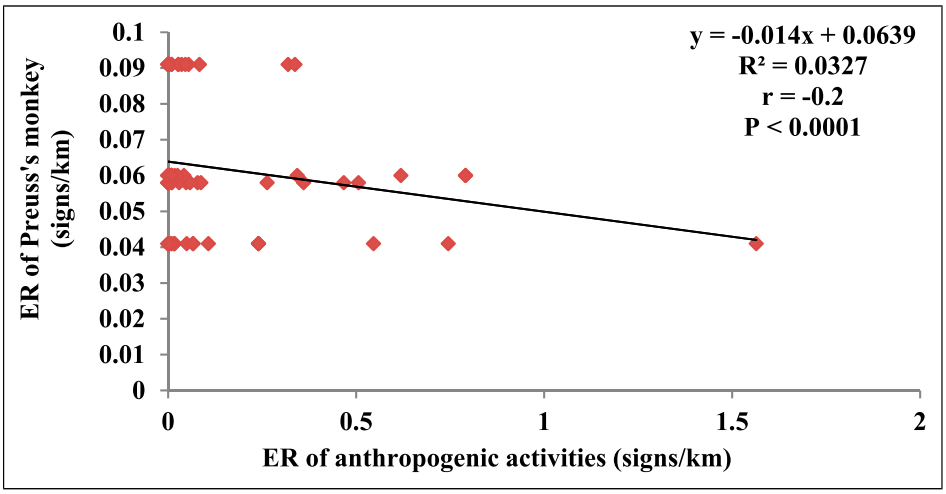

Figure 7. Fitted regression line for the encounter rates of Preuss's monkey and anthropogenic activities in Ebo forest.

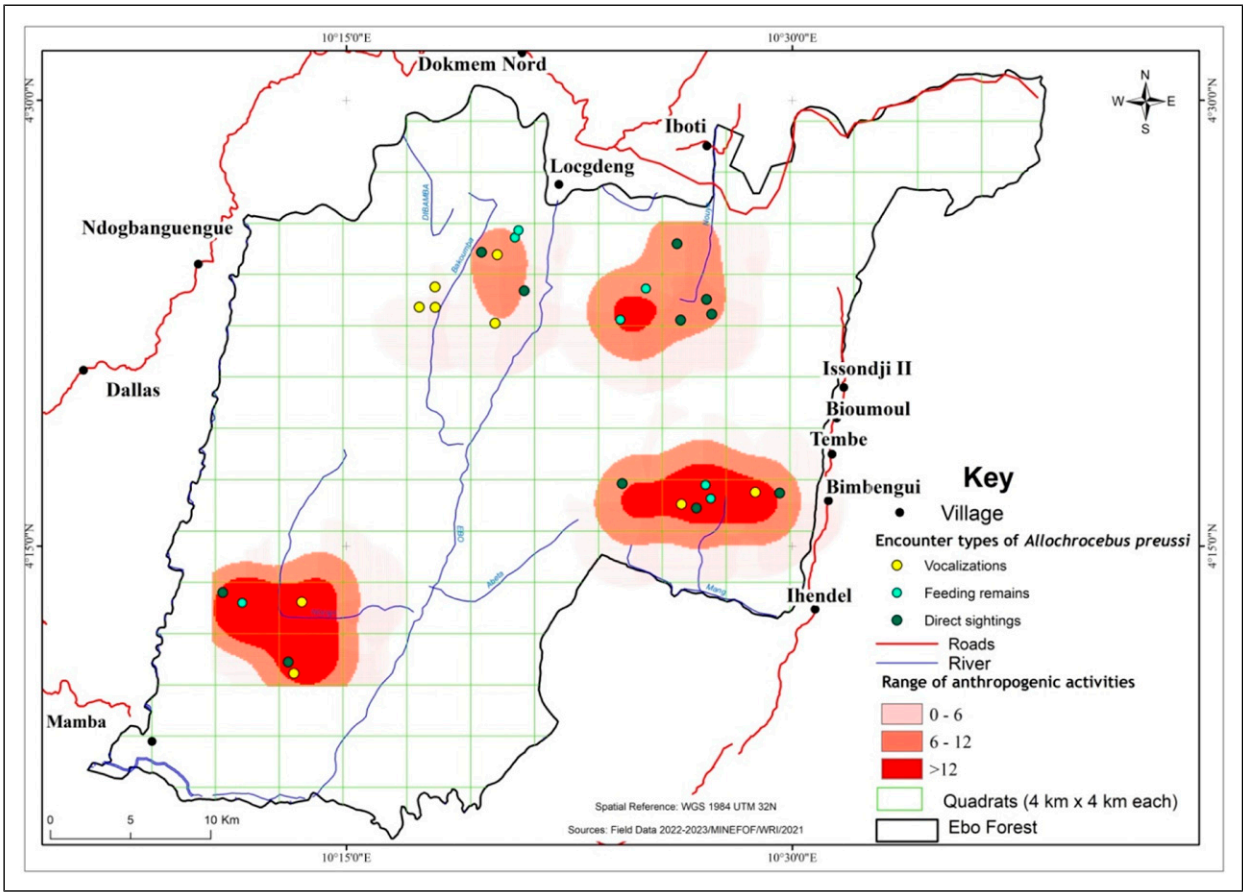

Figure 8. Distribution of Preuss's monkey encounters in relation to anthropogenic disturbances in Ebo forest.

primate species listed by the IUCN Red List as Endangered represented 31.7% of the primate harvested for bushmeat.

We found that hunters' tracks, individual wire snare traps and shotgun shells were the most frequent hunting signs in our survey. This is similar with the results of a study by Mfossa et al. (2022) in the Ebo forest. These authors report that wire snare traps accounted for 20% of hunting signs. In the nearby Dokbou forest, Bowers-Sword (2020) found that wire snare traps accounted for 64% of all hunting signs recorded. Previous studies in the Ebo forest indicated that guns and wire snare traps were the most commonly used hunting methods (Fuashi et al., 2019; Mfossa et al., 2022).

Hunting signs had the highest frequency of anthropogenic activities recorded in the Ebo forest. These results coincide with those of Mfossa et al. (2022) where evidence of hunting activities was highest compared to other anthropogenic disturbances. These findings are also similar with those of Kondasso et al. (2023) in Bouba-Ndjida National Park in northern Cameroon. Apart from small-scale cocoa and other small-scale farming, fishing, and collection of Non-Timber Forest Products (NTFPs) by local people around the Ebo forest, hunting is a key activity because it constitutes an important source of income and animal protein for the local communities (Whytock & Morgan, 2010; Whytock et al., 2016; Fuashi et al., 2019). In the areas of the Ebo forest where there is no electricity and limited access to livestock products due to a poor road networks, local people tend to rely more on bushmeat as their most common source of animal protein (per.obs.). Bushmeat supplies 30-80% of protein to rural people in Cameroon (Lescuyer & Nasi, 2016).

We found most signs of logging occurred in the southwestern site of the forest. The forest on the western part of the Ebo forest suffered from selective logging in the 1970s, while the forest east of the Ebo River is peppered with the remains of abandoned villages (Oates, 2011; Abwe et al., 2019). Logging is a prevalent activity in the Ebo forest (Nana et al., 2021).

There was no significant difference in encounter rates of different anthropogenic activities (hunting signs, logging, evidence of planted crops, collection of NTFPs, and fishing) recorded across the four sites surveyed. However, the southern parts of the forest had the highest frequency of anthropogenic activities. This appears to be attributed to the fact that the southern area has a higher human population density compared to the other study sites (per.obs.), which may result in increased extraction of forest products. A study by Top et al. (2009) in Kampong Thom Province, Cambodia, reported that areas of high forest disturbance coincided with areas of higher human population density. Overall, human

population growth is a contributing factor to forest disturbances (Lugazo, 2017; Legese & Diriba, 2021).

The results revealed a negative correlation between encounters of Preuss's monkey and signs of anthropogenic activities (hunting signs, logging, evidence of planted crops, collection of NTFPs, and fishing). The more common these anthropogenic activities were present in the area, the lower the chances of encountering Preuss's monkeys. Hunting has contributed to the decline in Preuss's monkey population across its range, particularly on Bioko Island (Cronin et al., 2017). A study by Nkengbeza et al. (2024) reported hunting as major threat to Preuss's monkey in the Ebo forest. Studies in the western Amazonian by Rosin and Swamy (2013) found primates populations to occur at lower density in heavily hunted forest areas. Also, studies on impact of gun-hunting on primates on Bioko Islands, Equatorial Guinea, have reported few primate encounters in areas of high hunting activities (Cronin et al., 2016).

Primates are highly affected by poaching (Ripple et al., 2016), and sensitive to deforestation which usually results in the fragmentation of continuous habitat in smaller forest patches (Estrada et al., 2017; Eppley et al., 2020). Primates are often the first mammalian group whose populations decrease in areas of high hunting intensity (Nasi et al., 2011). In addition, primates are highly vulnerable to forest disturbance because of most species are arboreal, and forest-dependent (De Almeida-Rocha et al., 2017).

Knowledge generated in this survey is pivotal to inform conservation actions for Preuss's monkey in Cameroon and particularly in the Ebo forest, which is a stronghold for this species. However, despite efforts led by the Ebo Forest Research Project (EFRP) to gazette the Ebo forest as a Protected Area since 2006, two logging concessions were announced by the government of Cameroon in 2020 to replace the proposed national park (Morgan & Whytock, 2020). The government's decision was met with vehement protests by multiple stakeholders including grassroots' communities, civil society organizations and international NGOs such as Green Peace. This protest campaign initially led to suspending the decision granting logging concessions on August 06th 2020. Three years later, two Prime Ministerial Decrees (No 2023/01630/PM and 2023/01631/PM of 27 April 2023) classified the Ebo forest into 02 Forest Management Units (FMU 07005 and FMU 07006) for logging. These FMUs are the same that were classified in 2020 and subsequently withdrawn due to protests in 2020. Yet the evidence that led to the withdrawal of the FMUs classification of Ebo forest in 2020 is still the same. The Ebo forest contains an estimated 35 million tonnes of sequestered carbon that will contribute to climate change if these logging concessions are not stopped (Global Forest Watch, 2020).

Implications for Conservation

This study provides current information on the population of the Endangered Preuss's monkey in the Ebo forest, a stronghold for this species in Cameroon. Continued monitoring of this population is essential for determining changes in current and future population trends and their drivers. Our findings revealed a high frequency of anthropogenic activities, with hunting as a major threat to Preuss's monkey in the Ebo forest. If care is not taken, hunting for bushmeat to meet the demands of an increasing human population will result in the syndrome of an "empty forest". It is therefore essential to seek adequate conservation measures to sustain wildlife and human communities adjacent to the Ebo forest. This requires community engagement and support, and programs that incentivize local communities around the forest to take a more active role in preserving the forest and protecting Preuss's monkey. Conservation education and outreach activities that target people of all age groups have long been identified as key actions for effective primate conservation in Africa (Oates, 1986; Linder et al., 2021). Also, conservation education and awareness-raising constitute key assets for effective and long-term protection of threatened species and ecosystems (Ardoin et al., 2020; Linder et al., 2024). It is therefore essential to invest in conservation awareness of Preuss's monkey and its habitat, inform local people on the National Wildlife Legislation, and raise awareness that bushmeat hunting in the Ebo forest is unsustainable. By doing this, we can improve support for conservation and inspire local people to become participants in Preuss's monkey conservation in the Ebo forest.

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Author's Contribution

Conceptualization and methodology: SNN, EBF, EDN, EEA. Investigation (field work): SNN, ETN. Data processing and analysis: SNN, NLM. Writing of the first draft: SNN. GIS work: SNN, RNM. Reviewed and performed the final write-up of the manuscript: SNN, NLM, ETN, RNM, JdR, PFT, EEA, EDN, EBF. Supervision: EBF

Declaration of Conflicting Interests

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Data Availability Statement

Data used for the study is available from the corresponding authors upon request.

Supplemental Material

Supplemental material for this article is available online.

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