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RESEARCH ARTICLE

Abundance of Pangolins in Southern Campo Ma'an National Park, South Region, Cameroon

Ngong K. Kaimo[1], Mvo Denis Chuo[1], Chefor Fotang[2], Theodore B. Mayaka[1]

[1]Research Unit of Applied Biology and Ecology, Faculty of Science, University of Dschang, Cameroon.
[2]Department of Ecology, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany.

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Corresponding Author: Ngong K. Kaimo, Research Unit of Applied Biology and Ecology, Faculty of Science, University of Dschang, Cameroon.

Abstract

Giant pangolin (Smutsia gigantea) and white-bellied pangolin (Phataginus tricuspis) are all classified as "Endangered", while black-bellied pangolin (Phataginus tetradactyla) is classified as "Vulnerable" on the IUCN Red List of threatened species. All their populations are decreasing rampantly due to hunting, habitat degradation and illegal trade of their scales from Africa to Asia. This research was carried out to determine their abundance in Campo Ma'an National Park (CMNP) and to investigate the effect of human activities on their distribution. We used camera trapping techniques to confirm their presence in the study area, then reconnaissance and line transects methods to collect direct and indirect pangolin indices after which the encounter rates (ER) were calculated. We recorded 28 active sleeping burrows of pangolins in the study area. The Relative abundance index was 0.3 pangolins per 100days of camera trapping effort. The ER of sleeping burrows stood at 1.2 signs/km (n=51). Hunting was the only human activity recorded with an ER of 0.8sign/km. The Pearsian correlation test revealed a negative correlation between pangolin and human signs with a coefficient of determination of 0.001 indicating a low anthropogenic influence on pangolin distribution in southern CMNP. The one-way anova test showed no significant difference on the impact of human activities on pangolin distribution between and within forest types. The probability of encountering a pangolin burrow increased with increase in Euclidian distance from park interior to nearest road and village. This study will serve to provide baseline information on pangolins and to boost conservation efforts in CMNP.

Key words: Abundance, Cameroon, Encounter Rate, Local Pangolin Species, Line Transects Technique.

1. Introduction

The four African pangolin species include: Temminck's pangolin (*Smutsia temminckii*), giant pangolin (*Smutsia gigantea*), black-bellied pangolin (*Phataginus tetradactyla*) and white-bellied pangolin (*Phataginus tricuspis*).White-bellied and giant pangolins are classified as "Endangered" (Nixon et al., 2019; Pietersen et al., 2019b), while black-bellied and Temminck's pangolins are classified as "Vulnerable" (Ingram et al., 2019a; Pietersen et al., 2019a). All African pangolin species just like others are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), with a zero annual export quota for wild-caught individuals traded primarily for commercial purposes (CITES, 2017).

African pangolin populations are fast declining due to hunting (Challender and Hywood, 2012), habitat degradation and loss (Challender et al., 2014; WABiCC, 2020), and illegal trade of their scales from Africa to Asia, especially from Central Africa (Challender et al., 2020; Ingram et al., 2019b). West and central Africa have been reported as the main trafficking hubs of pangolin scales to Asia (Emogor et al., 2021; Ingram et al., 2019b; World Health Organization [WHO], 2020). The demand for African pangolins

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has increased steadily since 2008 as result of trade agreements and greater ties between Africa and Asia (Challender and Hywood, 2012; Challender et al., 2016). The continuous decline in Asian pangolins and the insufficient supply to meet demand has resulted to continuous trafficking of the four African species to supply the Asian market. (Challender and Hywood, 2011; Challender and Hywood, 2012). This is due to weaker law enforcement in Africa (Challender and Hywood, 2012; Ingram et al., 2019b; WHO, 2020). An estimated 0.42–2.71 million pangolins were killed annually in Central Africa from 1975–2014 (Ingram et al., 2018). There is a general lack of national and global population estimates (Pietersen *et al*., 2014), thereby constraining conservation efforts worldwide.

Much research in Cameroon has been carried out on local ecological knowledge of pangolins (Kaimo *et al*., 2019; Mouafo *et al*., 2021; Ichu *et al*., 2017), trade on pangolins (Mouafo *et al*., 2022; Ingram *et al*., 2018, 2019a; Harvey-Caroll *et al*., 2022) and relative abundance of pangolins in certain parts (Bruce *et al*., 2018; Ichu *et al*., 2017; Angwafo *et al*., 2020). Anthropogenic pressure continues to increase resulting to large-scale rapid loss of their forest habitat (Mcbeath and Leng, 2006), despite conservation efforts made by the government of Cameroon, probably due to insufficient law enforcement (Boakye *et al*., 2016), unemployment and poverty (Kaimo *et al.*, 2019; Angwafo *et al*., 2020).

CMNP is a biodiversity hotspot, with a wide range of animal species, including several taxonomic endemics (Tchouto *et al*., 2006). It is home to more than 80 species of mammals including more than 350 forest elephants (*Loxodonta Africana cyclotis*), duikers, hippos, bush pigs, pangolins, black colobus, mandrills (*mandrillus sphinx*) and leopards (*Panthera pardus*) (Dongmo *et al*., 2015; Mveng, 1984). A small population of forest buffalo resides in the southern area of the park (Bekhus *et al*., 2008). It harbours population of more 700 critically endangered western lowland gorillas (*Gorilla gorilla*) and 700 endangered central chimpanzees (Mattheus and Mattheus, 2004). The area is considered a priority landscape for conservation of western lowland gorillas and central chimpanzees by the IUCN (Maisels *et al*., 2015), and is the site of an ongoing gorilla habituation project. There are 122 reptile species, 165 fish species and 27 millipede species, the most abundant being *Aporodesmus gabonicus* (Mbenoum *et al*., 2018). There are 28 species of bats among which two are endemic to Cameroon and include *Nycteris major* and *Hipposiderus curtus*. It is also home to 246 fish species representing 46% of the already inventoried fish species in Cameroon. These include 4 known endemic and 8 species limited to the Campo Ma'an area (https://discover-cameroon.com/en/cameroon-national-parks/)

The National Park is surrounded by five forest logging concessions, industrial rubber plantations, industrial oil palm plantations and a buffer zone (Tchouto *et al*., 2006). The labourers in these concessions and the local population relish pangolin meat, resulting in a high demand for more pangolins. There still exists a knowledge gap on the abundance and distribution of local pangolin species, thereby making conservation efforts by park officials very difficult as this knowledge would have helped conservationists to map out those areas and reinforce patrols (Mouafo et al., 2023; Angwafo et al., 2020).

1.1 Study Purpose and Scope

From a broader perspective, very little information has been provided by park authorities and local communities regarding pangolins' status in CMNP. That explains why published information on pangolins in CMNP is still scarce. This study will therefore provide baseline information for further scientific work on the local pangolin species in the CMNP. This is particularly important following their current statuses. It will also provide significant information that can guide similar studies in related fields. More specifically, the study aimed at: (1) determining the abundance of pangolins in the southern part of CMNP which would go a long way to inform park authorities of the current pangolin population trend which will save as baseline data to compare future findings from subsequent and more in-depth research in the entire park and (2) determining the distribution of pangolins in the various parts of the park which would enable park officials on the priority sites to intensify patrol activities. This is very important as the park is very vast thus reduces the effectiveness of conservation endeavours.

2. Material and Methods

2.1 Description of Campo Ma'an National Park

CMNP (2°15'– 2°30' N, 10°00'– 10°15'E; Fig. 1) was created in 2000 by merging Campo Wildlife Reserve, 1,582 km2, and the adjacent Ma'an forest plantation, 990 km2 (Owono, 2001). Average annual rainfall in CMNP ranges from 2800 mm, near the Atlantic coast to 1670 mm, further inland (PNCM, 2014; Tchouto et al., 2006). The mean annual temperature is about 25°C, although some variation occurs between the western and eastern sections of Campo Ma’an. Campo Ma’an and its environs belong to the Atlantic basin drainage system. Two main watersheds are found in the environs of Campo Ma’an: The Ntem and the Lobé watersheds, characterized by rivers which flow in a NE-SW direction (Mbenoun, 2017). The climate of CMNP and its peripheral zone is of the four-season coastal unequal type, including 2 dry seasons and 2 rainy seasons, namely: a long dry season from late November to February, a short rainy season from March to May, a short dry season from from june to mid-August and a long rainy season from mid-august to November. Hydromorphic and ferralitic soils are the dominant soil types with hydromorphic soils found in the valleys and lowlands; while ferralitic soils develop from acidic parent rocks.

The forest is evergreen and has a predominantly closed canopy, and is described as Atlantic Biafran forest with many plant species in the Caesalpiniaceae family (Mbenoum et al., 2018; Tchouto el al., 2009). The forest region containing the Campo Ma’an National Park is believed to have persisted as a tropical rainforest throughout the Pleistocene era, based on the distribution of slowly dispersing plants species and high degrees of endemism (Tchouto et al., 2009). The central part of the study site (Depicar Island; Fig. 1) consists mainly of primary and secondary forests. The primary forest consists of a late serial climax community forest that has never been logged and has developed through natural processes. It is a mixture of both swampy and gallery forests. The secondary forest mostly consists of colonization trees that regenerated after the primary forest has been harvested. Extending far beyond the park boundaries are the Equatorial Guinea to the south, Atlantic Ocean to the West, Vallee-du-Ntem and Mvila to the east. The park is home to more than 80 species of mammals including more than 350 forest elephants (*Loxodonta Africana cyclotis*), duikers, hippos, bush pigs, pangolins, black colobus, mandrills (*mandrillus sphinx*) and leopards (*Panthera pardus*) (Dongmo *et al*., 2015; Mveng, 1984). A small population of forest buffalo resides in the southern area of the park (Bekhus *et al*., 2008). It harbours population of more 700 critically endangered western lowland gorillas (*Gorilla gorilla*) and 700 endangered central chimpanzee (Mattheus and Mattheus, 2004).

The National Park is surrounded by five forest logging concessions, industrial rubber plantations, industrial oil palm plantation and a buffer zone (Tchouto et al., 2006). Selective logging took place in 1994–1995, leaving logging roads through the park (Bekhuis et al., 2008). The park is subject to many threats, mainly due to logging, poaching, agricultural activities and coastal development (WWF Global, 2018). Construction of the Memve’ele hydroelectric dam and the Kribi deep-sea port represent additional threats to the biodiversity of the region (Fiona et al., 2015). Due to the high biodiversity and need for continued and sustainable conservation, Campo Ma’an has been proposed as a pilot ecotourism site (Forje et al., 2021).

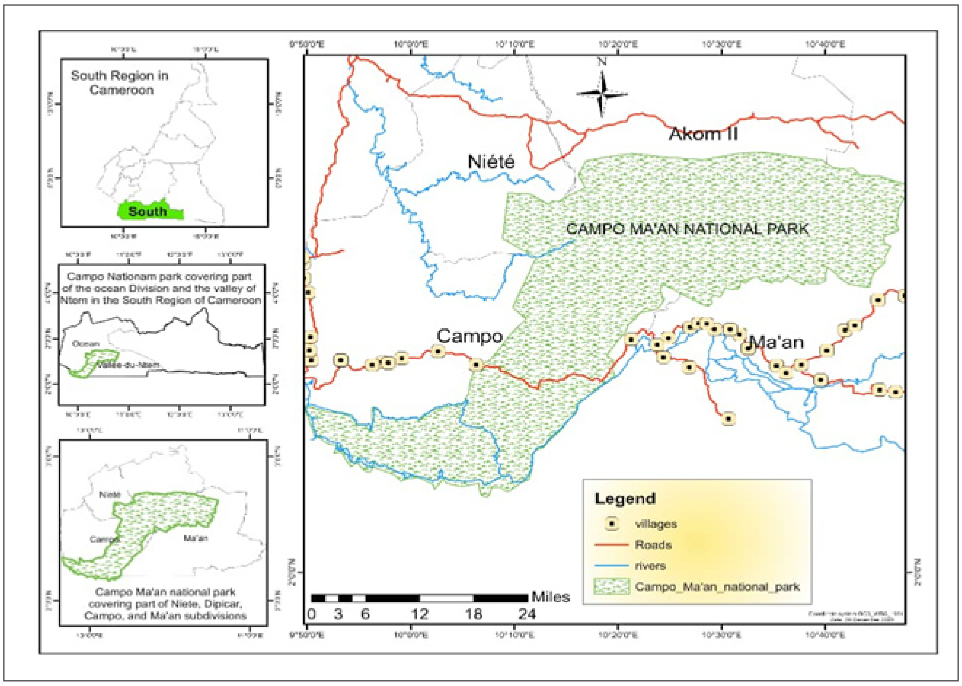

Figure 1. *Campo Ma’an National Park in the South-western Cameroon.*

The study area (799.46 km2; Fig. 2) is located in the southern section of the CMNP. It is surrounded to the west and east by forest logging concessions including, Forest Management Unit (FMU) 09-025 to the west and FMU 09-024 to the east. There are also mining companies bothering this area including, COMP MINIERE CMR MINKO to the south, SINOSTEEL CAM SA LOBE to the west and COMP MINIERE CMR BINKO to the north east. The Campo compartment is located to the west where the few villages in close proximity include Mvini, Nko'elon, Akak, Narareth whereas to the east is the Ma'an section characterized by Ebialmeyong, Ekoukoua, Abang and Oveng as those villages in close proximity with the study site.

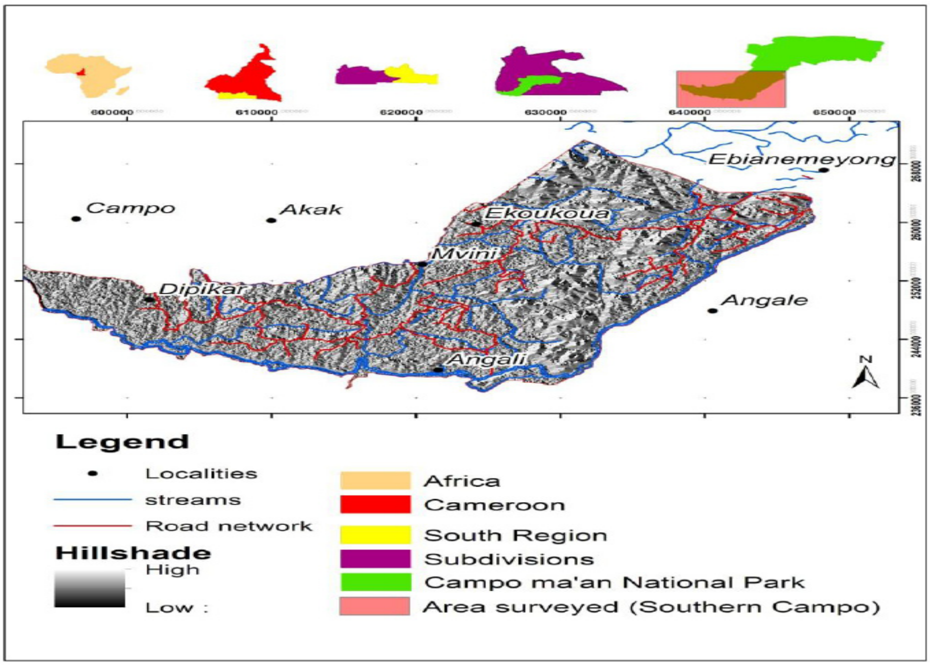

Figure 2. *Map of Campo Ma'an National Park showing location of study area*

2.2 Survey Design and Occurrence

Prior to fieldwork, a meeting was held in February 2022 with park authorities to design a plan for a recce survey (Mouafo et al., 2023). We conducted the recce survey to identify core areas of pangolin activity, focusing on pangolin presence signs, including sleeping burrows locations, feeding signs, food prints, and faecal matter (Kühl, 2008). Based on the recce surveys, we produced 20 geospatial line transects (Fig. 3), each 2 km in length in ArgGis10.2. 2 and overlaid them on a map of the study area following a systematic random design (Buckland et al., 2001)

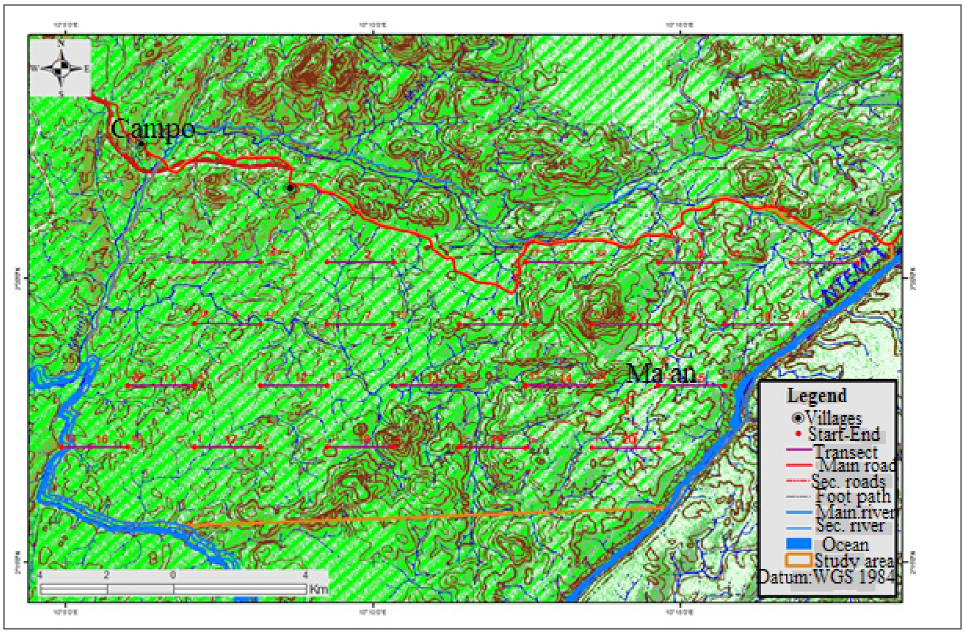

Figure 3. *Layout of line transects in the study area*

The line transects were oriented to cut across several habitat types (primary, secondary, gallery and swampy forests), and interconnected with each other by a 4 km recce-transect. In the field, the first author, two experienced forest guides and two park eco-guards surveyed recce-transects monthly from April to August 2022 (rainy season) and from October to December 2023 (dry season) for signs of pangolin activity (pangolin presence data). We recorded the presence locations of pangolins using the Global Positioning System device (Garmin etreX 10) following Mahmood et al. (2015).

Additionally, we attached five Bushnell Core T87 camera traps on trees between 30-50m above ground level along 5 transects targeting five active burrows of pangolins (Fig. 4), to increase the probability of detecting them since most of them are nocturnal.

Figure 4. *Installation of camera traps in the study site Photo credit: Ngong Kenneth*

We programmed cameras to operate to take three photographs and then continue taking a video for one minute video. After installing a camera trap in the field, the performance of the camera was checked using the "Walk Test" option to confirm that the camera sensor was functioning normally. During transect monthly visits, we inspected camera traps to replace SD cards and batteries as needed (Fotang et al., 2023).

The Relative Abundance Index (RAI) of pangolins in the study site was therefore calculated using the following expression:

$$\text{RAI} = \frac{\text{Sum of all independent photographs of pangolins for all cameras} \quad \text{X } 100}{\text{Total number of Camera trap days (Number of cameras X number of days cameras are operational)}}$$

(Fotang et al., 2021)

We collected data on local ecological knowledge and perception on pangolins from 15 randomly selected villages around Campo Ma'an which we used as background information on pangolin presence in the study area.

2.3 Data Analyses

Data collected from the field were summarized and presented using: abundance indices, maps and frequency tables. The encounter rate (ER) or Index of Kilometric Abundance (IKA) for both pangolin and human signs were estimated. The GPS points of pangolin and human indices recorded per transect were exported to ArcView computer program 3.3 and geo-referenced to produce a spatial distribution map for both data. Different symbols and colours were used to differentiate pangolin occurrence signs from those of humans. This permitted us to define important zones for pangolin species in order to determine management strategies for their conservation.

To investigate the effect of human activities on the distribution of pangolins, correlation, regression and Anova tests were carried out. These tests were first preceded by testing for normality and homogeneity between pangolin and human indices.

Normality test was done using Kolmogorovs-Smirnov test while homogeneity test was done using Levee homogeneity test. Normality test was carried out to find out if the two sets of indices obeyed the normal distribution law while homogeneity test was carried out to test the equality of variance of indices of the two sets of data. The correlation between ERs of human and pangolin indices was determined using the Pearsian correlation test. To find out to what extend human activities influenced the distribution of pangolin burrows, the coefficient of determination was calculated from the square of the correlation coefficient. To find out if there was any significant difference between pangolin distribution with forest type, and of hunters’ choice for hunting with forest type, the two-way Anova was used.

3. Results

3.1 Pangolin Presence and Abundance

A total of 181 pangolin signs were recorded (Table 1). These indices were collected on 20 transects totaling 40 kilometers in the study area. The various pangolin signs encountered include: burrows (sleeping and feeding), footprints and fecal matter.

Table 1. *Details of dynamics of different burrow types and their encounter rates in the study site*

Transect number	Number of pangolin signs				Total number of signs	Transect length (km)	IKA
	Sleeping burrows	Footprints	Feeding burrows	Fecal matter			
T1	4	2	7	0	13	2	6.5
T2	3	1	8	2	14	2	7
T3	3	1	8	1	13	2	6.5
T4	3	1	8	1	13	2	6.5
T5	4	1	9	1	15	2	7.5
T6	2	0	1	1	4	2	2
T7	2	2	3	0	7	2	3.5
T8	3	1	9	1	14	2	7
T9	3	1	3	1	8	2	2
T10	2	1	4	1	8	2	4
T11	1	0	6	0	7	2	3.5
T12	2	0	6	0	8	2	4
T13	4	1	4	0	9	2	4.5
T14	2	0	5	0	7	2	3.5
T15	1	1	3	0	5	2	2.5
T16	2	0	2	0	4	2	2
T17	2	0	5	0	7	2	3.5
T18	3	1	3	0	7	2	3.5
T19	2	1	4	1	8	2	4
T20	3	1	5	1	10	2	5
Total	51	16	103	11	181	40	4.5

Feeding burrows registered the highest IKA (2.6 signs/km, n=103), followed by sleeping burrows (1.2 signs/km, n=51), footprints (0.4sign/km, n=16) and fecal matter (0.3 sign/km, n=11; Table 2). We therefore recorded a total IKA of 4.5 signs / km for pangolin (Table 2).

Among the burrows, 43.5% (n=67) were fresh feeding while 23.4% (n=36) were old feeding burrows. The 51 sleeping burrows included 18.2% (n=28) active and 14.9% (n=23) inactive (Table 2).

Table 2. *Abundance of burrows in the study area*

Type of burrow	Burrow condition	Number of burros recorded	Total transect length(km)	IKA(signs/km)
Sleeping	Active	28	40	0.70
Feeding	Fresh	67	40	1.70
Sleeping	Inactive	23	40	0.60
Feeding	Old	36	40	0.90
Total	/	154	40	3.9

The presence of fresh soil around burrow's mouth enabled distinction of fresh from old burrows (Fig. 5).

Figure 5. *An active sleeping burrow (A) and fresh feeding burrow (B) of giant pangolin Photo credit: Ngong Kenneth*

3.2 Evidence of Pangolin Presence from Camera Trapping Records

Evidence of a giant pangolin was recorded in the study area. Its photograph was captured on the 24th of March 2022 (Fig. 6). We did not succeed to capture any image of black- and white-bellied pangolins despite evidence from visible signs and reports of their presence furnished by respondents during questionnaire surveys. The Relative Abundance index stood at 0.3 per 100 days of camera trapping.

Figure 6. *Giant pangolin Smutsia gigantea photographed by wildlife camera in Campo Ma'an National Park on 24th March 2022 Photo credit: Ngong Kenneth*

3.3 Presence and Abundance of Human Signs

A total of 31 human signs were recorded in the study area. Machete use was the most abundant index (0.4 sign/km, n=16), followed by hunting tracks (0.2 sign/km, n=8), cartridge shells (0.1 sign/km, n=5) and hunting camps (0.1sign/km, n=4). We therefore recorded a total ER of 0.8 sign/km for human activities (Table 3).

Table 3. *Presence and abundance of human signs in the study area*

Transect number	Number of human signs					Total Num-ber of signs	Transect length (km)	IKA (signs/ km)
	Machete use	Hunting camp	Cartridge shell	Hunting track	Trap			
T1	1	1	1	0	0	3	2	1.5
T2	0	0	0	0	0	0	2	0
T3	1	0	0	0	0	0	2	0
T4	2	0	0	1	0	3	2	1.5
T5	0	0	0	0	0	0	2	0
T6	1	1	1	0	0	3	2	1.5
T7	0	0	0	0	1	0	2	0.5
T8	0	0	0	0	0	0	2	0
T9	1	1	0	1	0	3	2	1.5
T10	0	0	0	0	0	0	2	0
T11	1	0	0	0	0	1	2	0.5
T12	1	0	0	1	0	2	2	1
T13	0	1	0	0	0	0	2	0
T14	0	0	0	1	0	1	2	0.5
T15	1	0	0	1	0	2	2	1
T16	2	0	1	0	0	3	2	1.5
T17	4	0	0	1	0	5	2	2.5
T18	0	0	0	0	0	0	2	0
T19	0	0	1	1	0	2	2	1
T20	1	0	1	1	0	3	2	1.5
Total	16	4	5	8	1	31	40	0.8
IKA/cate-gory	0.4	0.1	0.1	0.2	0	/	/	/

3.4 Geo-Spatial Distribution of Pangolin and Human Indices in the Study Area

Pangolin signs were encountered most in the primary forest (n= 144), followed by swampy (n=22), gallery (n=9) and least in the secondary forests (n=6). On the other hand, human signs were encountered most frequently in the primary (n=20), secondary (n=8), gallery (n=2) and swampy (n=1) forests. Figure 7 shows the geo-spatial distribution of pangolin and human signs in different parts of the Southern section of CMNP.

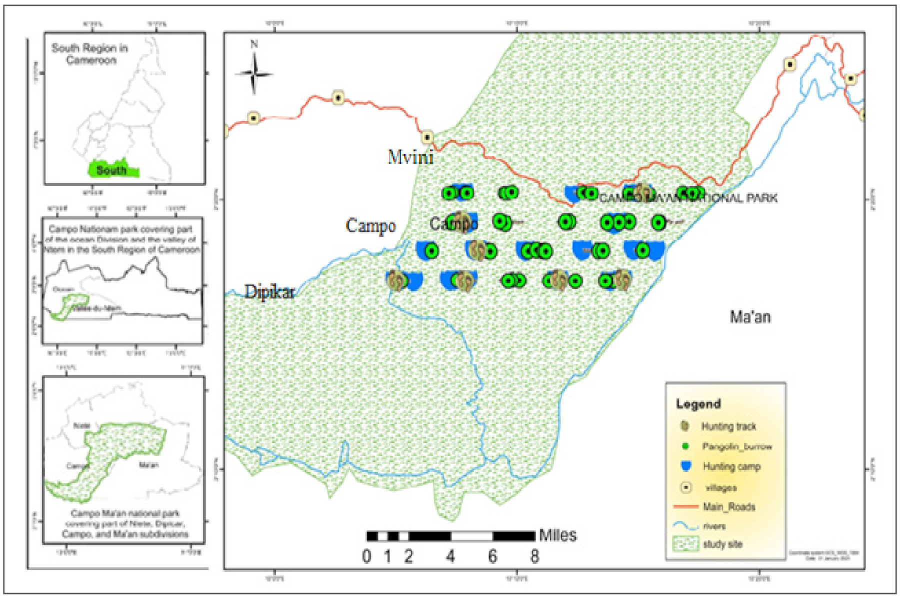

Figure 7. *Geo-spatial distribution of pangolin burrows, hunting tracts and camps*

Most hunting tracts and camps were encountered around Mvini and Campo compartments, with the greatest number encountered in the southern part of the study area, around the area leading to the Dipikar Island.

3.5 Effects of human activities on pangolin distribution

The Kolmogorovs-Smirnov test was carried out to ascertain the normality of the distribution of pangolin and human indices (Table 4).

Table 4. *Kolmogorov-Smirnov normality test to find out if the distribution of human and pangolin indices follow the normal distribution law.*

	Forest type	Kolmogorov-Smirnov			Shapiro-Wilk		
		Test statistics	Df	P-value	Test statistics	Df	P-value
Human indices	Primary Forest	0.219	15	0.040	0.862	15	0.021
	Secondary	0.260	2	.			
	Swampy	0.385	2	.	0.750	2	0.000
	Gallery	0.260	1	.			
Pangolins indices	Primary Forest	0.196	15	0.100	0.915	15	0.140
	Secondary	0.260	2	.			
	Swampy Gallery	0.269 /	1		0.949	2	0.567

Df=degree of freedom

Pangolin signs in the study area were found to follow a normal distribution whereas human signs did not (Fig. 8).

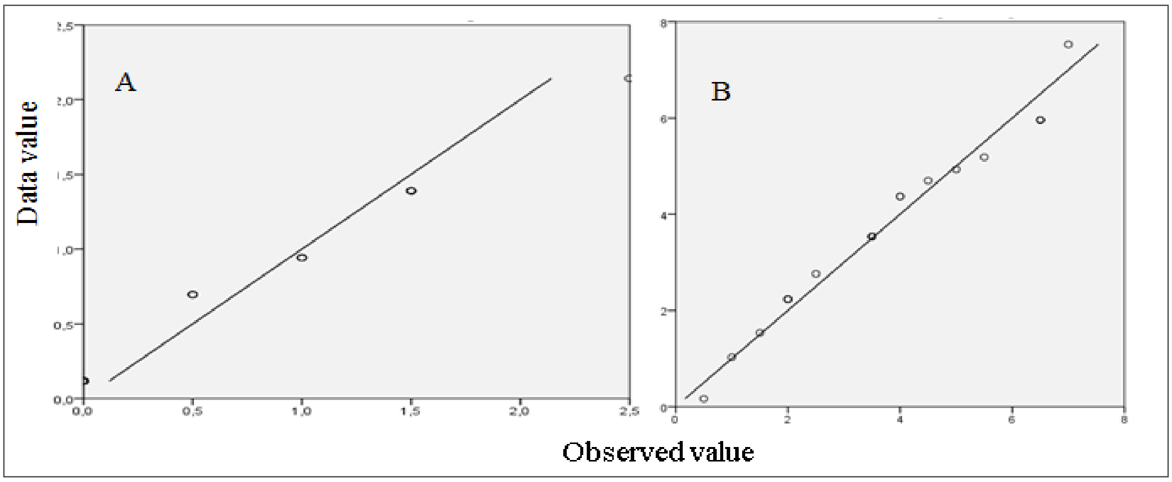

Figure 8. *Q-Q plot showing the deviation of points away from the line.*

Figure 8 shows the deviation of human signs away from the line (A) and the close packing of pangolin signs on the line (B), indicating that pangolin signs were normally distributed while human signs were not.

3.6 Test for Equality of Variance of Human and Pangolin Indices

Based on the null (Ho) and alternative (Ha) hypotheses which stated that:

I. Ho : $\sigma^2=\sigma^2$, there is no difference in variance between pangolin and human indices

II. Ha : $\sigma^2\neq\sigma^2$, there is a difference in variance between pangolin and human indices, the Levene homogeneity test gave p-values of 0.444 and 0.079 (Table 5.) for human and pangolin indices respectively which are less than 0.05, so we accepted the Ho that there is no significant difference in the variances of human and pangolin indices.

Table 5. *Test for equality of variance of human and pangolin indices.*

	Levene statistics	Df1	Df2	p-value
Human indices	0.932	2	18	0.444
Pangolins indices	2.643	2	18	0.079

3.7 Test for Correlation Between Pangolin and Human Indices

The Pearson correlation test showed that there was a negative correlation (Correlation coefficient: -0.034; Table 6) between the distribution of pangolin and human indices.

Table 6. *Correlation in distribution between human and pangolin indices*

		Human signs	**Pangolins signs**
Pearson correlation	Human indices	1.000	-0.034
	Pangolins indices	-0.034	1.000
Significant level	Human indices	.	0.439
	Pangolin indices	0.439	.
Number	Human indices	20	20
	Pangolins indices	20	20

Using the ERs of pangolins and anthropogenic activities, the scatter plot of the fitted regression line for the encounter rates revealed a weak negative correlation between the them pangolin and human signs (Fig. 9).

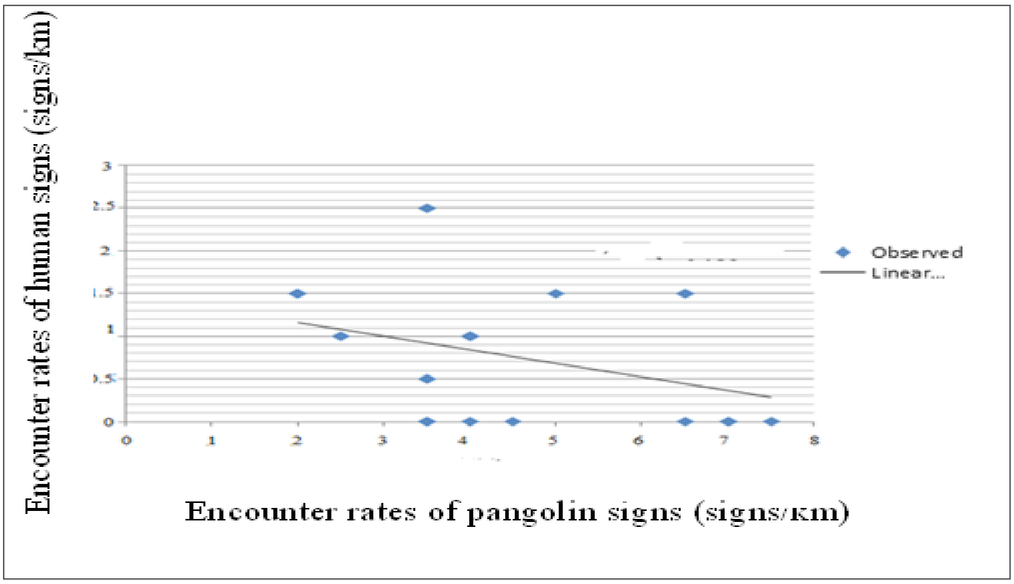

Figure 9. *Fitted regression line of the encounter rates of human and pangolin indices in the study area*

To ascertain to what extent anthropogenic activities affected the distribution of pangolins in the study area, the coefficient of determination (R^2) was computed from correlation coefficient (R) and found to be 0.001(Table 7).

Table 7. *Calculation of coefficient of determination from correlation coefficient*

Model	**R**	**R^2**	**Adjusted R^2**	**Standard error of estimation**	**Adjusted statistics**	
					Variation from R^2	**Variation from F**
	0.034	0.001	-0.046	0.767	0.001	0.024

A one way anova showed no significant difference on the ERs of human and pangolin distribution between and within forest types (F (2, 18) =0.343, p=0.795) and (F (2, 18)=2.166, p=0.126 respectively-Table. 8).

Table 8. *One way anova test to ascertain if the effect of human activities on pangolin distribution varies from one forest type to the next.*

		Sum of squares	**Degree of freedom**	**Mean square**	**F-test**	**p-value**
Human indices	Between groups	0.635	2	0.212	0.343	0.795
	Within groups	11.734	18	0.618		
	Total	12.370	20			
Pangolin indices	Between groups	20.441	2	6,814	2.166	0.126
	Within groups	59.776	18	3.146		
	Total	80.217	20			

3.8 Effect of Euclidian Distance to the Nearest Road on Pangolin Distribution

It was found that pangolin indices were more concentration in areas furthest away from roads. The ERs of pangolin signs decreased as Euclidian distance from park interior to the nearest road increased (Fig. 10). Pangolin signs were more concentration at distances close to park's interior.

3.9 Effect of Euclidian distance to villages on pangolin distribution

Euclidian distance to villages greatly influenced the occurrence of pangolin indices. Pangolin indices were more concentration around distances of 0-2000m from the study site towards human settlements with peak recorded around 1000m (Fig. 11).

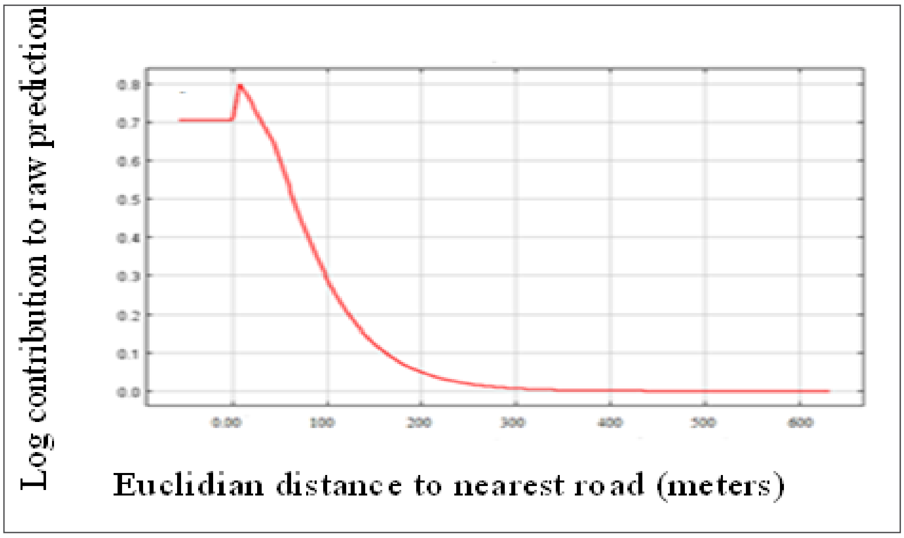

Figure 10. *Effect of Euclidian distance to roads on pangolin distribution*

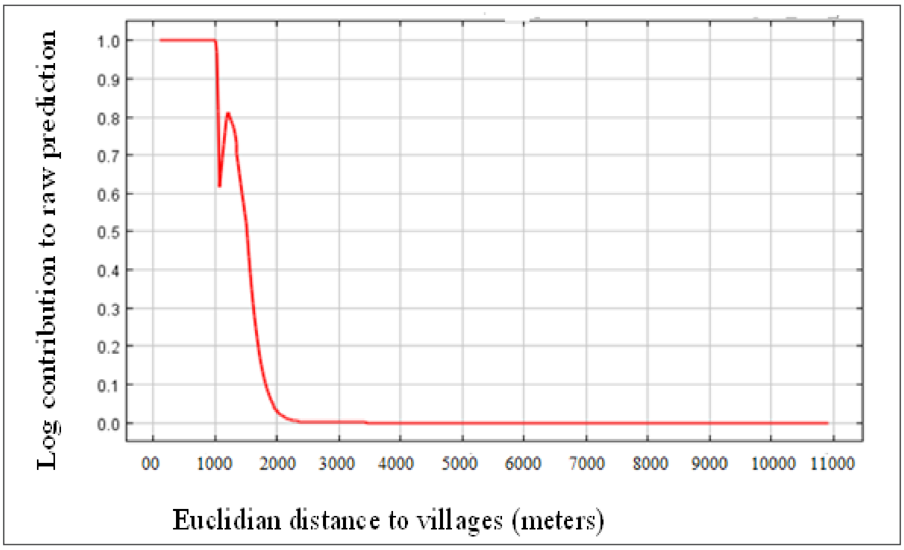

Figure 11. *Effect of Euclidian distance to villages on pangolin distribution*

4. Discussion

4.1 Abundance of Pangolins in Campo Ma'an National Park

The ER of sleeping burrows stood at 1.2 burrow/km indicating a dwindling pangolin population. The true measure of population size would however require knowledge of the rate of new burrow digging and also territory size, but comparative studies need only record number of active burrows per unit area in different habitats or sites (Maurice *et al*., 2019). Similar approaches, based on relative burrow density have been used to compare porcupine populations (Sidique and Arshad, 2004).

Our camera trapping efforts recorded only 0.3 events per 100 days (1 in 60 days) which was a giant pangolin. The low detectability of all pangolin species might be attributed to: low population densities (Willcox *et al*., 2019); sub-optimal placement, operation and suitability of camera traps for detecting pangolins (Apps and McNutt, 2018);the arboreal and/or burrowing behaviours of pangolins (which reduces their availability for detection by ground-based cameras) (Kingdon and Hoffman, 2013); and perhaps relatively slow movement rates (Hofmeester *et al*., 2019). Camera traps might conceivably be used to detect pangolins or confirm their presence in a study area and to monitor pangolins over space or time by modeling their occupancy or density (Matthews *et al*., 2023). However, studies suggest that moderately large sampling efforts are required to detect pangolins. Modelled detection probabilities for the three species suggest that minimum sampling efforts required to ensure a 90–95% chance (using a simple binomial model) of detecting pangolins if present are 446–580, 288–375, and 457–594 camera trap nights, respectively (Matthews *et al*., 2023). As an example, this could be achieved using 20 camera traps, each deployed for 30 nights. A deeper understanding of the ecology of all pangolin species, including home range size, habitat use, speed of movement, proportion of time spent on the ground (for semi-arboreal species), and microhabitat preferences could contribute significantly towards optimization of camera trap placement strategies (Hofmeester *et al*., 2019). Furthermore, camera trap technology is constantly improving in terms of battery life, memory capacity and cost (Glover-Kapfer *et al*., 2019), which increases the feasibility of achieving the very high sampling efforts required for monitoring pangolins. The labour costs of processing large amounts of camera trap data are also decreasing with the advent of new citizen-science and machine learning approaches (Willi *et al*., 2018).

4.2 Effects of Anthropogenic Activities on the Ecology of Pangolins in Campo Ma'an National Park

Hunting was the only current human activity recorded in the study area. However, there has been a rapid population increase in and around Campo Ma'an communities in recent times resulting in a corresponding increase in the demand for forest products including bush meat, animal parts for medicine, agricultural farm land, house construction space just to name a few. This was highly evident from the presence of forest logging concessions including, Forest Management Unit (FMU) 09-025 to the west and FMU 09-024 to the east of the study area (Forje et al., 2021). There are also mining companies bothering this area including, COMP MINIERE CMR MINKO to the south, SINOSTEEL CAM SA LOBE to the west and COMP MINIERE CMR BINKO to the north east. The personnel involved in these activities provide a large market thereby promoting the rampant killing and supply of pangolin meat. The regression analyses showed that the number of pangolin signs encountered per kilometer decreased with increase in anthropogenic signs. The correlation coefficient of R = -0.034 shows a weak correlation between anthropogenic activities and pangolin distribution (Tsi, 2006). The coefficient of determination (R2 = 0.001) shows that only 0.1% of changes in pangolin distribution in CMNP are under the influence of changes in anthropogenic activities (Angwafo et al., 2020). This insignificant influence of anthropogenic activities on pangolin distribution might be due to the fact that the southern section of the park is under strict patrols since the head office of CMNP is found around this area. Hunters would therefore prefer the northern and more enclaved section of the park with little disturbances from park officials. These results are different from those reported by Angwafo et al. (2020) who stated that 9.6 % of changes in pangolin distribution in the Kimbi Fungom National park (KFNP), northwest Cameroon were directly linked to anthropogenic factors. The findings also contrast those forwarded by Fotang (2014), in which his coefficient of determination was gotten as 0.375 from Mbi crater northwest Cameroon indicating a very high influence (37.5%) of anthropogenic factors on pangolin distribution. The total ER for hunting indices gave 0.8 sign/ km. These findings far contrast those reported by Fonkwo et al. (2011) which stated an ER of 2.65 sign/km for hunting in the Bakossi Landscape, southwest Cameroon, 1.87 signs/km for KFNP (Angwafo et al. 2020), and 1.46 hunting signs/km for the Nguti Council forest southwest region of Cameroon (Ekobo, 2008). Comparing CMNP with Bakossi landscape and Nguti Council forest, we can notice a directly correlation between ERs and coefficient of determination. In conclusion, these findings suggest a low poaching rate in CMNP probably due to more effective patrols by park ecogaurds than in the other areas. It might also be due to the inaccessibility of the CMNP to hunters.

The number of burrows and other signs decreased with increase in distance to villages and road. This also means that they increased with increase in distance from villages and roads. These findings are similar to those obtained in Nepal by Katuwal *et al*. (2017) who recorded more pangolin occurrence in the area with less disturbances (typically >1,000 m from human settlements and road). Wu *et al*. (2003) reported that pangolins dug burrows away from human habitation, which suggests an inclination to avoid disturbances. Gurung (1996) showed that human encroachment in the preferred habitats of the pangolin is the reason behind the decline of species in Nepal. Areas close to villages experience more frequent livestock and human activity, and pangolins have been observed to leave their burrows following such activities (Katuwal *et al*., 2017). The collection of fallen logs by humans and excessive trampling by larger-hoofed cattle result in detrimental effects on the survival of pangolins due to disturbance and decrease in prey availability. In addition, foot trails and settlements can ease the poaching of the species (Katuwal *et al*., 2017). In contrast, Sharma *et al*. (2020) recorded 51% of occurrence plots within a 1000m distance from settlement areas. Similarly, Karawita et al. (2018) revealed that burrow distribution was greater in areas with greater human disturbance (<200 m) and decreased with increased distance from human settlement. Katuwal *et al*. (2013) recorded more burrows close to the settlement area with a distance of at least 50–200 m. Katuwal *et al*. (2013) observed burrows close to the small walking trails of the humans with more recorded within the distance of 0–50 m.

5. Conclusion

We recorded 28 active sleeping burrows of pangolins in the study area. Our questionnaire surveys revealed the presence of giant, black- and white-bellied pangolins in the study area. We recorded the RAI of 0.3 pangolins per 100days of camera trapping effort which was that of giant pangolin. This was attributed to the arboreal nature of black- and white-bellied pangolins. The ER of sleeping burrows stood at 1.2 signs/km (n=51). Hunting was the only human activity recorded in the area with an ER of 0.8sign/km. the Pearsian correlation test revealed a weak negative correlation between pangolin and human signs with a coefficient of determination of 0.001 indicating a low anthropogenic influence on pangolin distribution in southern CMNP. The one-way anova test showed that there is no significant difference on the impact of human activities on pangolin distribution between and within forest types. The probability of encountering a pangolin burrow increased with increase in Euclidian distance from park interior to nearest road and village.

Recommendations

To researchers

- Publication of research findings from CMNP which will serve as baseline for subsequent studies in related fields. To the government
- Training and deployment of forest guards and related forest management staff so as to enforce legislation.
- Encourage the local hunters to divert to other alternative sources of livelihood by donating them start off domestic animals like goats, pigs, fowls etc.
- Construction of roads to villages boarding the park to ease the cost of transporting their farm produces to markets.
- Subsidize the cost of acquiring a research permit by university students and young researchers to encourage more research in CMNP.
- Law Enforcement efforts should be oriented towards producing concrete court cases against traders in pangolin species.
- Court cases should be opened against economic operators involved in wildlife law violations facilitated by their activities or committed on their premises, on the basis of negligence and collective responsibility using article 150 of the wildlife law which extends responsibility for wildlife offences to corporate bodies.
- Collaboration should be established with the local forces of law and order with no tolerance to corruption.
- Further investment in law enforcement should be conditioned with immediate results.
- Should establish a system of bonuses for Eco guards, focusing on quality of personnel rather than quantity.
- More focus on the buffer zone where the pressure is rather then inside the park.

To non-governmental organizations

- Income generating activities should be sponsored so as to diversify the economy and discourage local inhabitants from encroaching into the park. Examples include: snail farming, mushroom farming and beehive keeping.
- Sponsor research projects geared towards bringing the park to a lamb light. To the park authorities
- Regular patrols should be organized to cover the entire boundaries of the Park especially around the Akom II, Mvini and Niete compartments which are furthest away from park offices thereby giving poachers more access into the park.

- Education and sensitization campaigns against the killing and trade of pangolins should be organized at market squares in Campo Ma’an to create awareness of pangolin protection and conservation.
- All material and equipment provided by the state should be made available to research students to reduce the financial burden of carrying out an in-depth research in CMNP.

To the local communities

- The local communities should establish mechanisms to prevent hunting of vulnerable species. This might involve invoking traditional taboos, restricting use of certain hunting technologies and promoting local agreements.
- Hunters’ unions should be initiated to curb down the influx of external interest. This will ensure that only registered hunters will be eligible to hunt under supervision.

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The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability

The datasets generated and analyzed for the current study are available from the corresponding author upon reasonable request. We will not want to share it now because it is part of a still-to-be defended thesis work.

6. References

1. Akrim, F., Awan, M. S., Mahmood, T., Anjum, M. Z., Qasim, S., Khalid, J., & Andleeb, S. (2015). Threats to Red Junglefowl (Gallus gallus murghi) in Deva Vatala National Park, District Bhimber, Azad Jammu and Kashmir, Pakistan. *Annual Research & Review in Biology*, 59-65.
2. Angwafo, T. E., Chefor, F., & Fru, B. S. (2016). Status of Medium-sized Mammals in Mbi Crater Game Reserve, North West Region, Cameroon Case Study of: Blue Duiker (Cephalophus monticola) and Bushbuck (Tragelaphus scriptus). *Annual Research & Review in Biology*, 1-13.
3. Bekhuis, P. D., De Jong, C. B., & Prins, H. H. (2008). Diet selection and density estimates of forest buffalo in Campo-Ma’an National Park, Cameroon. *African journal of ecology*, *46*(4), 668-675.
4. Boakye, M.K., Pietersen, D.W., Kotze´, A., Dalton, D.L., Jansen, R., (2016). Ethnomedical use of African pangolins by traditional medical practitioners in Sierra Leone. J. Ethnobiol. Ethnomed. 10, 76.
5. Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). Introduction to distance sampling: Oxford University Press. *Oxford. Considerations and Management Recommendations: Wildlife Society Bulletin*, *34*(5), 1393-1395.
6. Bruce, T., Ndjassi, C., Fowler, A., Ndimbe, M., Fankem, O., Tabue Mbobda, R. B., ... & Olson, D. (2018). Faunal inventory of the Dja faunal reserve, Cameroon–2018. *Ministry of Forests and Wildlife (MINFOF)*.
7. Challender, D. W., & Hywood, L. (2012). African pangolins under increased pressure from poaching and intercontinental trade. *Traffic Bulletin*, *24*(2), 53–55.
8. Challender, D.W.S., Waterman, C. & Baillie, J.E.M. (2014). Scaling up pangolin conservation. IUCN SSC pangolin specialist group conservation action plan. *Zoological Society of London*. London, UK.
9. Challender, D. W., Heinrich, S., Shepherd, C. R., &Katsis, L. K. (2020). International trade and trafficking in pangolins, 1900–2019. In *Pangolins* (pp. 259-276). Academic Press.
10. Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora (2017). Appendices I, II and III [Web page].https://cites.org/sites/default/files/eng/app/2017/E Appendices-2017-10-04.pdf.
11. Dongmo, Z. N., N’Goran, K. P., Fondja, C., & Nkono, J. (2015). Evaluation de la dynamique des populations de grands et moyens mammiferes dans le domaine forestier permanent de l’unite technique operationnelle (UTO) Campo Ma’an, 103p.
12. Emogor, C. A., Ingram, D. J., Coad, L., Worthington,

T. A., Dunn, A., Imong, I., & Balmford, A. (2021). The scale of Nigeria's involvement in the trans-national illegal pangolin trade: Temporal and spatial patterns and the effectiveness of wildlife trade regulations. *Biological Conservation*, *264*, 109365.

13. Fional, M., Williamson, L., Strindberg, S., Pokempne, A., Greer, D., Stokes, Emma; Jeffery, Kathryn; Breue, Thomas; Wilkie, David, eds. (2015). Regional Action Plan for the Conservation of Western Lowland Gorillas and Central Chimpanzees 2015–2025.
14. Forje, G. W., Tchamba, M. N., & Eno-Nku, M. (2021). Determinants of ecotourism development in and around protected areas: The case of Campo Ma'an National Park in Cameroon. *Scientific African*, *11*, e00663.
15. Fotang, C., Bröring, U., Roos, C., Enoguanbhor, E. C., Abwe, E. E., Dutton, P., ... & Birkhofer, K. (2021). Human activity and forest degradation threaten populations of the Nigeria–Cameroon chimpanzee (*Pan troglodytes ellioti*) in Western Cameroon. *International Journal of Primatology*, *42*, 105-129.
16. Harvey-Carroll, J., Simo, F. T., Sonn-Juul, T., Tsafack, J. P., Aka'a, S. J., Tarla, F. N., Fowler, A., & Ingram, D. J. (2022). Continued availability and sale of pangolins in a major urban bushmeat market in Cameroon despite national bans and the COVID-19 outbreak. African Journal of Ecology, 00(2), 1–7.
17. Ichu, I. G., Nyumu, J. K., Moumbolou, C. L. M., Nchembi, F. T., & Olson, D. (2017). Testing the efficacy of field surveys and local knowledge for assessing the status and threats to three species of pangolins in Cameroon. *A Report Submitted in Partial Fulfilment [SIC] of the Requirement for the Completion of the MENTOR-POP (Progress on Pangolins) Fellowship Program. Zoological Society of London Cameroon, Yaoundé, Cameroon*.
18. Ingram, D. J., Coad, L., Abernethy, K. A., Maisels, F., Stokes, E. J., Bobo, K. S., ... & Scharlemann, J. P. (2018). Assessing Africa-wide pangolin exploitation by scaling local data. *Conservation Letters*, *11*(2), e12389.
19. Ingram, D. J., Shirley, M. H., Pietersen, D., Godwill Ichu, I., Sodeinde, O., Moumbolou, C., ... & Challender, D. (2019a). *Phataginus tetradactyla*. The IUCN Red List of Threatened Species 2019: e.T12766A123586126.
20. Ingram, D. J., Cronin, D. T., Challender, D. W., Venditti, D. M., & Gonder, M. K. (2019b). Characterising trafficking and trade of pangolins in the Gulf of Guinea. *Global Ecology and Conservation*, *17*, e00576.
21. Kaimo, N. K., Angwafo, T. E., Chuo, M. D., & Lum, G. G. (2019). Community perception and pangolins (*Manis spp*.) Conservation in the kimbi-fungom national park, North West Cameroon. *International Journal of Forest, Animal and Fisheries Research*, *3*(3).
22. Karawita, H., Perera, P., Gunawardane, P., & Dayawansa, N. (2018). Habitat preference and den characterization of Indian Pangolin (*Manis crassicaudata*) in a tropical lowland forested landscape of southwest Sri Lanka. *PloS one*, *13*(11), e0206082.
23. Mahmood, T., Irshad, N., & Hussain, R. (2014). Habitat preference and population estimates of Indian pangolin (*Manis crassicaudata*) in District Chakwal of Potohar Plateau, Pakistan. *Russian journal of ecology*, *45*, 70-75.
24. Mahmood, T., Andleeb, S., Anwar, M., Rais, M., Nadeem, M.S., Akrim, F. & Hussain, R. (2015). Distribution, abundance and vegetation analysis of the scaly anteater (*Manis crassicaudata*) in margalla Hills national park Islamabad, Pakistan. *JAPS:Journal of Animal and Plant Sciences*, *25*(5), 1311-1321.
25. Mahmood, T., Akrim, F., Irshad, N., Hussain, R., Fatima, H., Andleeb, S., & Aihetasham, A. (2017). Distribution and illegal killing of the Endangered Indian pangolin *Manis crassicaudata* on the Potohar Plateau, Pakistan. *Oryx*, *53*(1), 159-164.
26. Mahmood, T., Challender, D., Khatiwada, A., Andleeb, S., Perera, P., Trageser, S., Ghose, A., Mohapatra, R., (2019). *Manis crassicaudata* . The IUCN red list of threatened. Pakistan, *Journal of Zoology*. Downloaded on 11 February 2020.
27. Maisels, F., Williamson, L., Strindberg, S., Pokempne, A., Greer, D., Stokes, E.J., Jeffery, K.J., Breue, T., & Wilkie, D.S. (2015). Regional Action Plan for the Conservation of Western Lowland Gorillas and Central Chimpanzees 2015–2025.
28. Matthews, A., & Matthews, A. (2004). Survey of gorillas (*Gorilla gorilla gorilla*) and chimpanzees (*Pan troglodytes troglodytes*) in Southwestern Cameroon. *Primates*, *45*, 15-24. Mbenoun Masse, P. S., Nzoko Fiemapong, A. R., VandenSpiegel, D., & Golovatch, S. I. (2018). Diversity and distribution of millipedes (Diplopoda) in the Campo Ma'an National Park, southern Cameroon. *African Journal of Ecology*, *56*(1), 73-80.
29. McBeath, G. A., & Leng, T. K. (2006). *Governance of biodiversity conservation in China and Taiwan*. Edward Elgar Publishing. Mouafo, A.T., Ingram, J., D., Tegang, R., P., Itoe C. N., Mayaka, T., B., (2021). Local Knowledge and Use of Pangolins by Culturally Diverse Communities in the Forest-Savannah Transition Area of Cameroon. *Tropical Conservation Science*, *14*, 1–14.
30. Mouafo, A. T., Ingram, J. D., Binda V. A., Itoe, C. N.,

& Mayaka, T. B. (2022). Not Just an Issue in Forested Regions: Investigating the consumption and Trade of Pangolins in a Forest-Savanna Mosaic Area of Cameroon. *Tropical Conservation Science, 15*, 1-13.

31. Mouafo, A. D., Tédonzong, L. R. D., Ingram, D. J., Binda, V. A., Ngwayi, I. C. N., & Mayaka, T. B. (2023). Maximum entropy modeling of giant pangolin *Smutsia gigantea* (Illiger, 1815) habitat suitability in a protected forest-savannah transition area of central Cameroon. *Global Ecology and Conservation*, *43*, e02395.
32. Mveng, E. (1984). Histoire du Cameroun, Tome Premier.
33. Nixon, S., Pietersen, D., Challender, D., Hoffman, M., Godwill Ichu, I., Bruce, T., ... & Shirley, M. H. (2019). *Smutsia gigantea*. The IUCN red list of threatened species 2019: eT12762A123584478.
34. Owono, J. C. (2001). Case Study 8 Cameroon–Campo Ma'an. The Extent of Bagyeli Pygmy Involvement in the Development and Management Plan of the Campo Ma'an UTO. *Indigenous Peoples and Protected Areas in Africa*.
35. Pietersen, D., McKechnie, A. E., and Jansen, R. (2014). Home Range, Habitat Selection and Activity Patterns of an Arid-Zone Population of Temminck's ground pangolins (*Smutsia temminckii*). *African Zoology*, *49*, 265-276.
36. Pietersen, D., Jansen, R., Connelly, E., (2019a). *Smutsia temminckii*. The IUCN Red List of Threatened Species 2019: e.T12765A123585768.
37. Pietersen, D., Moumbolou, C., Ingram, D. J., Soewu, D., Jansen, R., Sodeinde, O., Keboy Mov Linkey Iflankoy, C., Challender, D., & Shirley, M. H. (2019b). *Phataginus tricuspis*. The IUCN Red List of Threatened Species 2019: eT12767A123586469. PNCM (2014). Plan d'Amenagement du Parc National de Campo-Ma'an et de sa Zone Peripherique. Technical Report, p. 139.
38. Roberts, T. (1977). The Mammals of Pakistan, Ernest Benn. *The Mammals of Pakistan, London*, *26*, 361.
39. Tchouto, M. G. P., Yemefack, M.; De Boer, W. F.; De Wilde, J. J. F. E.; Van Der Maesen, L. J. G.; Cleef, A. M. (2006). Biodiversity Hotspots and Conservation Priorities in the Campo-Ma'an Rain Forests, Cameroon. *Biodiversity and Conservation*, *15*(4), 1219–1252.
40. Tchouto, M. G. P., De Wilde, J. J. F. E., De Boer, W. F., Van der Maesen, L. J. G., & Cleef, A. M. (2009). Bio-indicator species and Central African rain forest refuges in the Campo-Ma'an area, Cameroon. *Systematics and Biodiversity*, *7*(1), 21-31.
41. Waseem, M., Khan, B., Mahmood, T., Hussain, H. S., Aziz, R., Akrim, F., ... & Awan, M. N. (2020). Occupancy, habitat suitability and habitat preference of endangered indian pangolin (*Manis crassicaudata*) in Potohar Plateau and Azad Jammu and Kashmir, Pakistan. *Global Ecology and Conservation*, *23*, e01135.
42. West Africa Biodiversity and Climate Change (WA BiCC). (2020). Scoping study for pangolin conservation in West Africa. 2nd Labone Link, North Labone, Accra, Ghana. 227pp.
43. Willcox, D., Nash, H. C., Trageser, S., Kim, H. J., Hywood, L., Connelly, E., Ichu, I. G., Kambale, N. J., Mousset, M. C. L., Ingram, D. J., & Challender, D. W. S. (2019). Evaluating methods for the detection and ecological monitoring of pangolins (Pholidota: Manidae). *Global Ecology and Conservation*, *17*, e00539.
44. World Health Organization (WHO). (2020). United Nations Office on Drugs And Crime. (2020). International standards for the treatment of drug use disorders: Revised edition incorporating results of field-testing.
45. Wu, S. B., Liu, N. F., Ma, G. Z., Xu, Z. R., & Chen, H. (2003). Habitat selection by Chinese pangolin (Manis pentadactyla) in winter in Dawuling Natural Reserve. Mammalia, 67(4), 493-502.