Bristol Zoological Society / Sekakoh

Camera Trap Monitoring of Wildlife in Bénoué National Park, Cameroon

November 2025

Contents

1 Executive Summary 4

2 Résumé Exécutif 5

3 Introduction 6

3.1 Research aims 7

4 Methods 8

4.1 Study area 8

4.2 Sampling effort 8

4.3 Wildlife analysis 10

4.4 Species diversity 10

4.5 Relative abundance 11

4.6 Seasonal data 11

5 Results 12

5.1 Species diversity and distribution 12

5.2 Threatened taxa 13

5.3 Relative abundance 21

5.4 Seasonal variation 26

6 Discussion 27

6.1 Summary 27

6.2 Eland and topi 28

6.3 Giraffe 28

6.4 Threats and mitigations 29

6.5 Conservation recommendations 29

7 References 30

8 Acknowledgements and permissions 30

9 Appendix 35

How to cite

Samuel G. Penny*, Denis Nyugha, Mehdi Sadak, Romeo Omer Kamta Tchoffo, Suzanne Djuidje, Aminou, Achile Mengamenya Goué, and Caspian Johnson. (2025). Camera Trap Monitoring of Wildlife in Bénoué National Park, Cameroon. Institute of Conservation Science & Learning, Bristol Zoological Society, Bristol, UK**. DOI:** https://doi.org/10.5281/zenodo.17652014

**Corresponding author* (research@bzsociety.org.uk)

About the authors

Bristol Zoological Society, UK (Samuel G. Penny, Mehdi Sadak, Romeo Omer Kamta Tchoffo and Caspian Johnson) and Sekakoh Organization, Cameroon (Denis Nyugha, Suzanne Djuidje) designed, implemented and analysed the research presented in this report with support from Ministry of Forests and Wildlife, Cameroon (Aminou and Achile Mengamenya). An earlier phase of this project (January 2022 – January 2024) was supported by IUCN Save Our Species, co-funded by the European Union. Full contributions are provided in the Acknowledgements section.

Caption: MM. NTIECHE MOLUH Soulemane and SAIDOU Jean Bernard setting a camera trap within Bénoué National Park.

1 Executive Summary

This study presents the results of the first largescale camera trap survey conducted in Bénoué National Park (BeNP), Cameroon, undertaken collaboratively between Bristol Zoological Society, Sekakoh and the Cameroonian Ministry of Forestry and Wildlife between January and November 2023. This research establishes a baseline for long-term monitoring of mammals and the extent of human and livestock pressures within the park. A total of 38 cameras were systematically deployed across the park yielding a survey effort of 3,714 trap-days and generating over 56,000 images.

26 medium to large bodied mammal species were detected during the 2023 survey (excluding domestic animals, bats, and rodents). When combined with previous BZS camera trap monitoring (2019–2020), a cumulative total of 33 wild mammal species are present, reaffirming BeNP's status as a regional biodiversity hotspot. This compares to the 16 wild mammal species recorded by Elkan et al. (2015) during a 2015 aerial survey of the park, showing the value of camera trapping in detecting cryptic species and establishing a more complete inventory of mammalian diversity.

Species diversity and relative abundance were higher in the dry season than the rainy season, although this may be partly explained by differences in detectablilty due to grass growth. The most frequently detected wild species were tantalus monkey (*Chlorocebus tantalus*), Northern bushbuck (*Tragelaphus scriptus*), red-flanked duiker (*Cephalophus rufilatus*) and common duiker (*Sylvicapra grimmia*) while domestic cattle (*Bos taurus*) were the most common overall, indicating extensive human and livestock presence within the park.

Ten taxa threatened on the IUCN Red List were documented, with Kordofan giraffe (*Giraffa camelopardalis antiquorum*) detected at only one site. Giant eland (*Taurotragus derbianus*) were absent from the 2023 survey and 2015 aerial survey, but detected during the 2019 to 2020 survey. Only one species, topi (*Damaliscus lunatus*), was found in the aerial survey that was not detected here, which was previously represented by a single recorded individual. Together this highlights the continued decline of megafauna in the Bénoué Ecosystem Complex. Cattle and human detections showed spatial overlap with wildlife species, and while detections were greater during the rainy season, they were consistently high all year. This indicates increasing anthropogenic pressures, with overgrazing, poaching, and habitat degradation all likely affecting mammal populations.

The rarity of several species underscores the need for continued anti-poaching patrols, integration of hunting zone managers in conservation planning, and the importance of landscape-scale connectivity initiatives. We also recommend a moratorium on eland trophy hunting in the surrounding hunting zones until comprehensive population assessments are available. These baseline data provide a critical foundation for long-term biodiversity monitoring and should inform the ongoing management of this ecologically significant but increasingly threatened landscape.

2 Résumé Exécutif

La présente étude expose les résultats de la première campagne de piégeage photographique à grande échelle réalisée dans le Parc national de la Bénoué (BeNP), Cameroun. Ce travail a été conduit de manière collaborative par la Bristol Zoological Society (Royaume-Uni), l'organisation Sekakoh (Cameroun) et le Ministère camerounais des Forêts et de la Faune (MINFOF) entre janvier et novembre 2023. Cette recherche vise à établir une base scientifique solide pour le suivi à long terme des mammifères ainsi que pour l'évaluation de l'ampleur des pressions anthropiques et pastorales au sein du parc. Un total de 38 caméras a été déployé de manière systématique dans tout le parc, représentant un effort d'échantillonnage de 3 714 jours-pièges et générant plus de 56 000 images.

Au total, 26 espèces de mammifères de taille moyenne à grande ont été détectées durant la campagne de 2023 (à l'exclusion des animaux domestiques, des chauves-souris et des rongeurs). En combinant ces données avec celles issues du suivi photographique antérieur de la Bristol Zoological Society (2019–2021), le nombre cumulé d'espèces de mammifères sauvages s'élève à 33, confirmant ainsi le statut du BeNP en tant que point chaud régional de biodiversité. Ce résultat contraste avec les 16 espèces de mammifères sauvages recensées par Elkan et al. (2015) lors d'un recensement aérien du parc, ce qui souligne la valeur méthodologique du piégeage photographique pour détecter les espèces discrètes et établir un inventaire plus complet de la diversité mammalienne.

La diversité spécifique et l'abondance relative (RAI – *Indice d'Abondance Relative*) ont été plus élevées durant la saison sèche que pendant la saison des pluies. Cette différence peut en partie être attribuée à la visibilité réduite liée à la croissance de la végétation pendant la période humide, affectant la détectabilité des animaux. Les espèces sauvages les plus fréquemment photographiées ont été le singe tantale (*Chlorocebus tantalus*), le guib harnaché (*Tragelaphus scriptus*), le céphalophe à flancs roux (*Cephalophus rufilatus*) et le céphalophe de Grimm (*Sylvicapra grimmia*). Cependant, le bœuf domestique (*Bos taurus*) constituait la majorité des détections globales, révélant une forte présence humaine et pastorale à l'intérieur du parc.

Les détections de bétail et de présence humaine présentent un chevauchement spatial important avec celles des espèces sauvages. Bien que les détections soient plus nombreuses pendant la saison des pluies, elles demeurent élevées tout au long de l'année, ce qui indique des pressions anthropiques croissantes. Le surpâturage, le braconnage et la dégradation de l'habitat affectent vraisemblablement les populations de mammifères du parc.

La rareté de plusieurs espèces met en lumière la nécessité de renforcer les patrouilles anti-braconnage, l'intégration des gestionnaires de zones cynégétiques dans la planification de la conservation, et les initiatives de connectivité écologique à l'échelle du paysage. Par ailleurs, les auteurs recommandent la mise en place d'un moratoire sur la chasse aux trophées d'éland dans les zones cynégétiques périphériques jusqu'à ce que des évaluations complètes de population soient disponibles. Les données de référence issues de cette étude fournissent ainsi une base scientifique critique pour le suivi à long terme de la biodiversité et doivent orienter la gestion future de ce paysage écologiquement significatif mais de plus en plus menacé.

3 Introduction

Biodiversity and species abundance are key factors in determining the stability of ecosystems and the functions they support (Tilman et al., 2014; Oliver et al., 2015). Central Africa contains some of the world's major biodiversity hotspots but biodiversity across the region is declining sharply (Mallon et al., 2015). Historically, the Bénoué Complex in Cameroon, which comprises the Bénoué, Bouba Ndjida and Faro National Parks and 29 surrounding hunting zones (Marais et al., 2019), was considered one of the few exceptions to this trend. Indeed Mittermeier et al. (2003) considered it to be one of only two highly diverse wilderness areas, which are areas with high biodiversity that have retained 70% or more of their habitats intact, in Central Africa.

Monitoring the diversity and abundance of species is critical for anticipating declines and identifying appropriate management solutions (Yoccoz, Nichols & Boulinier, 2001). Before monitoring can begin, reliable baselines of the status of target species must exist. In the Bénoué National Park (BeNP), however, the only species for which a reliable baseline exists is the hippopotamus (Scholte, 2016), and to a lesser degree, Kordofan giraffe (Parks et al., 2024). There is no reliable baseline for the other extant megafauna species including giant eland (*Tragelaphus derbianus*) and African buffalo (*Syncerus caffer*).

Studies on wildlife population trends in the Bénoué Complex and northern Cameroon are scarce. Research by Stark et al. (1986) reported kob (*Kobus kob*), Western hartebeest (*Acelaphus buselaphus major*), African buffalo, waterbuck (*Kobus ellipsiprymnus*) and roan antelope (*Hippotragus equinus*) as the most commonly observed ungulate species in Bénoué National Park (BeNP). Surveys by Omondi et al. (2007) and Foguekem et al. (2010) registered total counts of large mammals and common ostrich (*Struthio camelus*) for Waza National Park (henceforth referred as Waza) through aerial surveys, while Elkan et al. (2015) expanded this to the wider Bénoué Complex region. Most recently, a 2022-2023 dry season aerial assessment of Waza found significant populations of large mammal species persisted in the park including at least 358 Critically Endangered Kordofan giraffe (*Giraffa camelopardalis antiquorum*), alongside high levels of livestock but no detections of African savannah elephant (*Loxodonta africana*) (WCS, 2023).

Findings suggest that populations of certain species, especially megafauna, are declining throughout this region. For example, carnivore populations in the Bénoué Complex have shown declines in the abundance of lion (*Panthera leo*) (Croes et al., 2011), cheetah (*Acinonyx jubatus*) and African wild dog (*Lycaon pictus*) (de Longh et al., 2011), the latter two now being considered functionally extinct in the complex. While Taïga et al. (2020) estimated the population of kob to have declined by 80% since 2000 in the Faro National Park. A survey conducted by Omondi et al. (2007) estimated a decline of 79% of elephant populations in Waza compared to the population estimate of 1995 by Tchamba & Elkam (1995) which coupled with the absence of any elephant detection in the 2023 survey (WCS, 2023) suggests alarming declines in the elephant populations of the Lake Chad ecosystem. Similarly, no common ostrich was detected during the 2023 survey compared to nine individuals in 2007. Omondi et al. (2007) also suggested that populations of six other megafaunal species in Waza have declined since 1995 (Tchamba & Elkam, 1995), namely those of Kordofan giraffe, roan antelope, kob, topi (*Damaliscus lunatus*), red-fronted gazelle (*Eudorcas rufifrons*) and common ostrich. Furthermore, Scholte et al. (2016) found the population of common hippopotamus (*Hippopotamus amphibius*) in BeNP to also be

declining. Counts along the 100 km stretch of the Bénoué River in the Park indicated a reduction from 400 individuals in 1987 to 188 in 2013.

Drivers behind these declines are thought to be anthropogenic with habitat destruction through agriculture, uncontrolled pastoralism, overharvesting of forest products, gold mining and climate change (especially wildfires and desertification) as the major threats in BeNP (Scholte et al., 2016; Tchobsala et al., 2021; BeNP Conservator pers. Comm. 2024). The effect of trophy hunting in the surrounding hunting zones (ZICS) on wildlife populations in the Bénoué Complex is also unknown, with one of the few studies looking into it focusing on large carnivores (Croes et al., 2011), thus a lack of data restricts the usefulness of quotas. Illegal hunting (poaching) also poses a threat to several species in the region (Weladji & Tchamba, 2003); for example, a giraffe carcass butchered for its meat was discovered in 2020 despite all forms of giraffe hunting being prohibited by Cameroonian law (Bristol Zoological Society, 2022; Classified as a Class A under Law 2024-008).

Bristol Zoological Society's and Sekakoh's wildlife research in Bénoué National Park has mostly focused on Kordofan giraffe, a subspecies of Northern giraffe (*Giraffa camelopardalis antiquorum)* (Coimbra et al. 2022). The global population numbers fewer than 2,300 in the wild and is listed as Critically Endangered by the IUCN Red List (Fennessy & Marais, 2018). Due to the small size and extensively fragmented nature of remaining Kordofan giraffe populations, the BeNP represents an important stronghold for this sub-species. Existing studies in BeNP have reported giraffe feeding preferences (Sekakoh, 2021) and documented lower occupancy of giraffe in regions of the park with higher levels of human activity (Chillingworth, 2021). A preliminary population assessment estimated that as few as 26 individuals may occur within the park (Parks et al., 2023), placing the population at elevated risk of local extinction (Colston et al., 2023) with a density of just 0.013 individuals km^{-2}. This is markedly lower than the 0.46 individuals km^{-2} estimated in Zakouma National Park, a comparatively well-protected stronghold for the species (Marneweck et al., 2025) .

This report uses camera trapping data to provide baseline estimates on species diversity, distribution and relative abundance for a wider range of species of conservation concern within Bénoué National Park. The results of this investigation improve our current knowledge of wildlife distribution and provide crucial missing data needed to establish management recommendations. Timely surveys are important, as megafaunal species are particularly vulnerable to extinction drivers and thus good early indicators of broader biodiversity losses (Ripple et al., 2015; He et al., 2023).

3.1 Research aims

This study aimed to establish a standardised programme for the long-term monitoring of medium-large mammals of conservation significance within Bénoué National Park. Our objectives were:

1. To determine relative abundance and distribution of medium-large mammal species within BeNP.
2. To investigate the anthropogenic and ecological factors that determine distribution and relative abundance.
3. To update the mammal inventory for BeNP.

4 Methods

4.1 Study area

This study was conducted in Bénoué National Park (**Figure 1Figure 1**), at the centre of the Bénoué Complex in Northern Cameroon, a 1980 km^2 protected area and UNESCO biosphere reserve (UNESCO, 2024) which abuts two community hunting zones, ZIC 01 (390 km^2) and ZIC 04 (381 km^2). BeNP falls within the East Sudanian savannah ecoregion (Olson & Dinerstein, 1998). The vegetation is mostly composed of a mosaic of wooded savannah dominated by *Isoberlinia doka*, *Anogeissus* riparian forest and more open savannah dominated by *Terminalia* and *Burkea-Detarium* (Stark & Hudson, 1985). Within the study area, mean elevation is 409 m above sea level (min. 231 m, max. 1067 m). Seasonal trends in northern Cameroon typically fall into two seasons: a distinct dry season from November to May and a rainy season from May to November where total precipitation generally exceeds 100 mm per month (**Figure 2**).

4.2 Sampling effort

The park and two adjacent hunting zones (ZIC1 and ZIC4) were discretised into 89 possible sampling units (5 x 5 km). From these, we selected 44 sites for camera trap deployment using a systematic sampling scheme to ensure full coverage of the site. However, logistical issues saw camera traps placed in only 38 locations of these (36 in the park and 2 in an adjacent community hunting zones), referred to as 'sites' or 'camera trap sites' (Figure 1). The park was divided into three zones (north, middle and south) bisected by interior roads (Buffle Noir – Banda and N13).

The camera traps (Browning Recon Force Elite HP5) were deployed as close to the centre point of grid cell as possible, affixed to trees at a 1.5m height and orientated towards a North-South axis to avoid glare. The camera position was chosen in a way that maximises capture rates of wildlife while allowing the camera to be secured, i.e. on a nearby tree facing an open area or wildlife trail. Cameras were locked in metal boxes to minimise damage and theft. Cameras were set up to capture 3 rapid burst shots per detection followed by an interval of 10 seconds.

Cameras were operational between 20/01/2023 and 05/11/2023, with the variable lengths in survey period controlled for in the analyses. Data were successfully retrieved from 30 sites, with camera theft, destruction, or security concerns preventing data collection from the remaining 8 sites. This equalled combined effort of 3,714 camera trap days (124 per retrieved camera trap). Data totalled 56,729 images, of which 1899 were wildlife and 2662 images of domestic animals and people. The remaining 52,168 images were false triggers.

For the species inventory, data were further pooled with findings from a previous Bristol Zoological Society (BZS) study (Argirova et al. 2021), which surveyed six salt licks around the Buffle Noir camp between December 2019 and April 2020 (the dry season) and between June and July 2020 (the wet season).

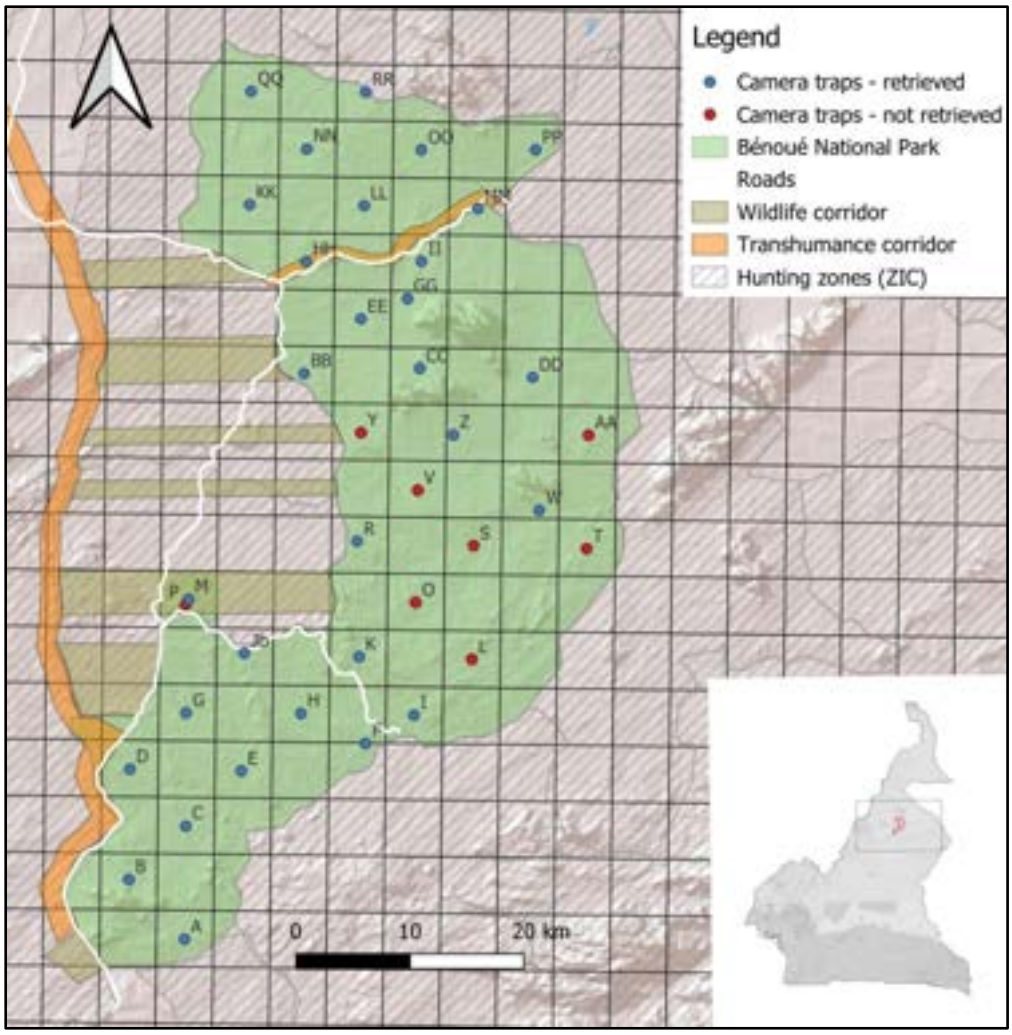

Figure 1. Location of camera traps within Bénoué National Park and hunting zones ZIC01 and ZIC04, in northern Cameroon. Blue points indicate data were successfully retrieved from camera traps; red points indicate data collection was not possible due to malfunction, logistics, vandalism, security concerns or theft.

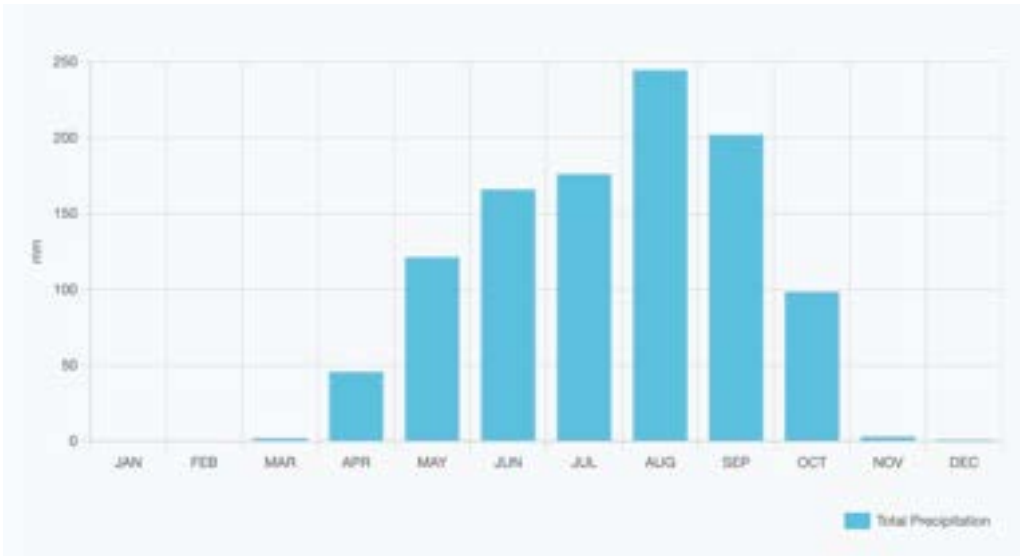

Figure 2. Total precipitation (in mm) per month in Garoua, northern Cameroon, for the year of 2023. Adapted from Meteostat (meteostat.net, 2024). For the study, May to October were categorised as the rainy season.

4.3 Wildlife analysis

Data from the 30 camera trap sites were input into Wildlife Insights (wildlifeinsights.org, 2024), which uses pattern recognition to automatically label uploaded images to the species level. To ensure accurate identification of the taxa captured, all images were manually checked and labelled with the number of individual animals per frame. The dataset was then exported as a spreadsheet and analysed in R 4.4.1 (R Development Core Team, 2024). Taxa that were not identified to species level and false triggers were excluded from all analysis.

Wildlife species were defined as all mammal species detected, excluding domestic dogs, cattle, goats and people, plus the Northern ground hornbill (*Bucorvus abyssinicus*) because it was the only large bird species recorded that is mostly terrestrial (and therefore reliably detectable by camera trap). Antelopes were defined as all species of hoofed mammals in the Bovidae family present within the park, and analysed separately as a group to reflect their targeting by hunters.

The dataset was classified into independent events whereby all images of a species detected at a given site within the same hour were condensed into a single sighting; a threshold which has been adopted by previous studies using similar methods (Wearn et al., 2013; Tobler et al. 2008; Cervera et al., 2016). To calculate total number of individuals, the maximum count of all animals present in a photo of a certain species within each independent event were summed. Camera trap sites were also categorised as falling into one of three zones (north, middle and south of the park) with these boundaries set by interior roads (Buffle Noir – Banda and N13).

It should also be noted that several species reported in Argirova et al. 2021's report were misidentified and have been corrected here during reanalysis of the data: side-striped jackal (*Lupulella adusta*) was incorrectly recorded as golden jackal (*Canis aureus*), common genet (*Genetta genetta*) as cape genet (*Genetta tigrina*), red-flanked duiker (*Cephalophus rufilatus*) as black-fronted duiker (*Cephalophus nigrifrons*), Egyptian mongoose (*Herpestes ichneumon*) as Long-nosed mongoose (*Herpestes naso*), and African savannah hare (*Lepus victoriae*) as Cape scrub hare (*Lepus saxatilis*). Four additional species were also identified: honey badger (*Mellivora capensis*), serval (*Leptailurus serval*), large-spotted genet (*Genetta maculata*) and marsh mongoose (*Atilax paludinosus*).

4.4 Species diversity

Species richness and Shannon's diversity indices (Shannon, 1948) were tallied or calculated for each site wth abundance based on total number of individuals. Detections of domestic animals and people were excluded from species diversity calculations. To test whether sampling effort influenced Shannon's diversity indices, a Spearman's rank correlation test was run. We found a significant positive relationship between sampling effort and site-specific Shannon's diversity indices (Spearman's rank, $r = 0.24$, $N = 30$, $p < 0.05$). As such, a minimum trapping effort of 40 days per survey site was adopted as a cutoff for species diversity mapping to avoid low sample size bias, as recommended by Si et al. (2014). Mapping of species diversity was done on QGIS 3.38.3-Grenoble (QGIS Development Team, 2019). Differences in Shannon's diversity between camera trap sites within the north, middle and south zones of the park were tested through a Kruskal-Wallis test as a Shapiro-Wilk test revealed the data were not normally distributed.

Finally, species richness across the protected area was evaluated using a sample-based species accumulation curve, where each sampling unit represented one camera trap operating for one week. A binary detection matrix (species presence = 1, absence = 0) was compiled for all camera-weeks, and species accumulation was modelled using random permutations (1,000 iterations) in the R package *vegan* (Oksanen et al., 2022). This approach estimates the mean cumulative number of species detected as sampling effort increases and provides 95% confidence intervals to assess sampling completeness.

4.5 Relative abundance

Similarly to the species diversity calculations, a minimum sample size of 40 camera trap days per location was used for abundance data to keep sampling effort consistent and maps comparable. Following the example of existing camera trap surveys (Jenks et al., 2011; Hedwig et al., 2018), abundance was evaluated by calculating relative abundance indices (RAI), the amount of times a species was captured per 100 camera days:

$$RAI = \frac{number\ of\ independant\ events}{camera\ trap\ effort\ (in\ days)} \times 100 \quad .$$

Scores were calculated for individual species, people, “antelopes” (defined here as nine species of hoofed mammals in the Bovidae family) and all wildlife (defined here as all species excluding domestics and people) using number of indepenent events recorded. Human data were filtered to exclude conservation and research staff from analyses. Differences in RAI scores between camera trap sites within the north, middle and south zones of the park were tested through a Kruskal-Wallis test for both antelopes and domestic animals.

4.6 Seasonal data

The dataset was divided into dry season (from January 2023 to May 2023 and November 2023 to January 2024) and rainy season (from May 2023 to November 2023) based on mean precipitation data for the 2023-24 year for the nearest city to BeNP with available climatology records (Garoua) using the Climate Explorer website (Climate Explorer, 2024). Minimal sample size for statistical analysis was lowered to 20 days per camera trapping site (compared to 40 for the whole data) due to the shorter seasonal sampling period. Using this threshold, data was recorded from 13 sites during the rainy season and 24 from the dry season. This gave a mean camera trapping effort of 163 days (from 01/05/2023 to 01/11/2023) during the rainy season and 67 days (from 20/01/2023 to 01/05/2023 and 01/11/2023 to 05/11/2023) for the dry season.

Shannon’s diversity index and RAI maps accounting for seasonality were made by calculating the mean scores for those indices for both seasons. Mann-Whitney U tests were used to test for seasonal differences in diversity and RAI (dry versus rainy season). Park-wide RAI scores for antelope and cattle per month were also calculated, whereby all independent events were summed and divided by total camera effort (then multiplied by 100).

5 Results

5.1 Species diversity and distribution

Between 25 January and 28 October 2023, a total of 26 wild mammal species were recorded (**Table 1**). This is broadly consistent with findings from a previous Bristol Zoological Society (BZS) study by Argirova et al. (2021), which documented 28 mammal species from a survey of six salt licks between 2019 and 2020 (24 in the original report plus a further 4 species detected during reanalysis). Together, this brings the cumulative number of medium-large mammals detected by camera trap in BeNP to 33, providing a comprehensive baseline for long-term biodiversity monitoring of medium to large-sized mammals in Bénoué National Park. Additionally, the accumulation curve reached a clear asymptote (**Figure 3**), suggesting that sampling effort was adequate in detecting the local species pool.

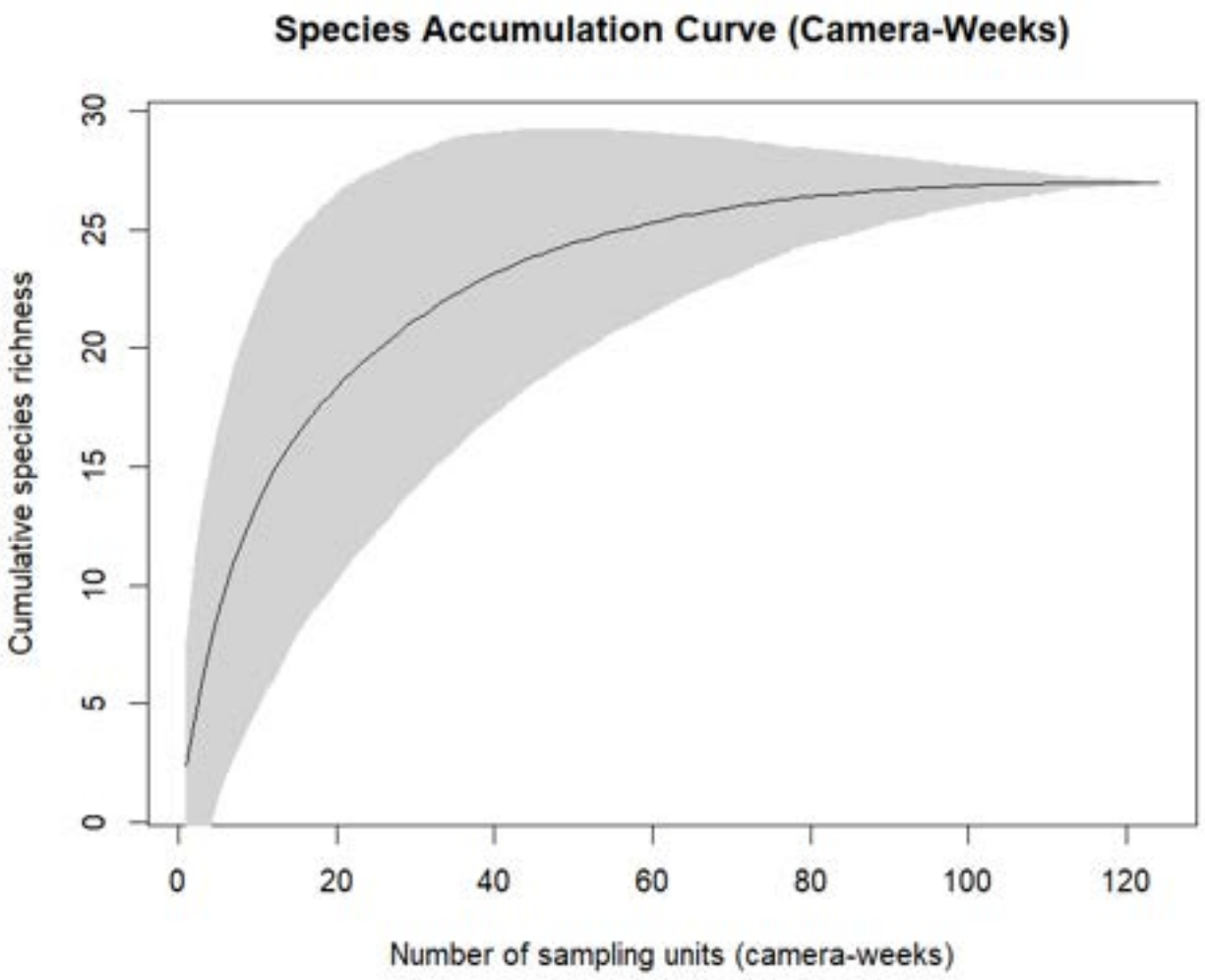

Figure 3. Sample-based species accumulation curve showing the mean cumulative number of species detected with increasing sampling effort (camera-weeks) across the study area. Shaded areas represent 95% confidence intervals derived from 1,000 random permutations.

Based on the 2023 data only, wildlife was detected at 28 out of the 30 sampled sites. Species richness was highest in site F at 17 species and lowest at site C at 0 species, both of which were within the southern region of the park (**Figure 4**). Sites that met the minimum sampling threshold (of 40 days or greater; n=19) captured an average of 5.89 species (excluding domestics and people).

The park had an overall Shannon's diversity index of 2.68 (with a mean index of 1.17 per site, **Table 2**). Northern sites recorded the highest average Shannon's Diversity Index scores (mean = 1.67), followed by the central zone (mean = 1.17) and the southern zone (mean = 1.14). The difference in scores between the zones was not statistically significant (H_2 = 2.51, df =2, p = 0.286). However, sample size was very low for the northern sites (data from only three locations), so results were skewed by just a few observations.

5.2 Threatened taxa

Out of the 34 wildlife species recorded by camera trap in the park, 10 are threatened on the IUCN Red List and therefore of conservation interest. This included 8 species detected in the 2023 survey (**Figure 5**; Figure A1**;** Figure A2): Northern ground hornbill, Northern giraffe, Buffon's kob (*Kobus kob kob*), defassa waterbuck (*Kobus ellipsiprymnus defassa*), leopard (*Panthera pardus*), African buffalo, Western hartebeest (*Alcelaphus buselaphus major*) and common patas (*Erythrocebus patas*); and two species in the 2019 to 2021 survey: giant eland and common hippotamous.

Buffon's kob was the most common threatened species with 23 events, totaling 33 individuals found across six sites (mean RAI* = 0.52) along with Western hartebeest with 15 events totalling 37 individuals also at six sites (mean RAI* = 0.79). Just two individuals of Northern giraffe were sighted at a single site (mean RAI* = 0.04), and just one of leopard (mean RAI* = 0.08).

No sightings of African savannah elephant (*Loxodonta africana*), African wild dog (*Lycaon pictus*), lion (*Panthera leo leo)*, African clawless otter (*Aonyx capensis*), spotted-necked otter (*Hydrictis maculicollis*), korrigum/topi (*Damaliscus lunatus korrigum*) were recorded from any BZS camera trap survey despite BeNP occuring within their historic range. However, ecoguards separately documented signs of elephant and lion on patrol, including six sets of lion tracks and two instances of elephant dung between 2023 and 2024 indicating their transient presence in the park. Including these species takes the count of medium to large-bodied wild mammal species present or transiently present in BeNP to 35.

Table 1. Wildlife recorded by camera trap studies in Bénoué National Park between 2019 and 2023. Excluding domestics and people, 35 species of wildlife (34 mammals and 1 bird) were detected. 27 species were detected during our 2023 survey and 28 species during Argirova's et al. (2021) salt lick survey between 2019 and 2020.

Name (English)	Nom (français)	Binomial name	IUCN Redlist	Rainy 2023	Dry 2023	Rainy 2020	Dry 2019-20
Order		**Tubulidentata**					
Aardvark	Oryctérope du Cap	*Orycteropus afer*	LC		x		x
Order		**Carnivora**					
African civet	Civette africaine	*Civettictis civetta*	LC	x	x		x
Caracal	Caracal	*Caracal caracal*	LC		x		
Common genet	Genette commune	*Genetta genetta*	LC		x	x	x
Egyptian mongoose	Mangouste ichneumon	*Herpestes ichneumon*	LC		x	x	x
Honey badger	Ratel	*Mellivora capensis*	LC				x
Large-spotted Genet	Genette panthère	*Genetta maculata*	LC			x	
Leopard[†]	Léopard	*Panthera pardus*	VU		x	x	x
Marsh mongoose	Mangouste des marais	*Atilax paludinosus*	LC			x	x
Serval	Serval	*Leptailurus serval*	LC				x
Side-striped jackal	Chacal à flancs rayés	*Lupulella adusta*	LC	x	x		x
Spotted hyena	Hyène tachetée	*Crocuta crocuta*	LC			x	x
White-tailed mongoose	Mangouste à queue blanche	*Ichneumia albicauda*	LC		x		

Wildlife recorded continued.

Name (English)	Nom (français)	Binomial name	IUCN Redlist	Rainy 2023	Dry 2023	Rainy 2020	Dry 2019-20
Order		**Cetartiodactyla**					
African buffalo	Buffle d'Afrique	*Syncerus caffer*	NT	x	x	x	x
Bohor reedbuck	Cobe des roseaux	*Redunca redunca*	LC		x		
Northern bushbuck	Guib harnaché	*Tragelaphus scriptus*	LC	x	x	x	x
Common duiker	Céphalophe de Grimm	*Sylvicapra grimmia*	LC	x	x	x	x
Common warthog	Phacochère d'Afrique	*Phacochoerus africanus*	LC	x	x		x
Northern giraffe†	Girafe du Nord	*Giraffa camelopardalis* (ssp. *antiquorum*)	CR	x			x
Giant eland	Éland de Derby	*Taurotragus derbianus*	VU				x
Hartebeest	Bubale	*Alcelaphus buselaphus* (ssp. *major*)	NT	x	x		x
Hippopotamus	Hippopotame amphibie	*Hippopotamus amphibius*	VU			x	x
Kob	Cobe de Buffon	*Kobus kob* (ssp. *kob*)	VU	x	x	x	x
Red river hog	Potamochère roux	*Potamochoerus porcus*	LC	x	x		
Red-flanked duiker	Céphalophe à flancs roux	*Cephalophus rufilatus*	LC	x	x	x	x
Roan antelope	Antilope rouanne	*Hippotragus equinus*	LC	x	x	x	x
Waterbuck	Cobe à croissant	*Kobus ellipsiprymnus* (ssp. d*efassa)*	NT		x	x	x
Order:		*Lagomorpha*					
African savannah hare	Lièvre des savanes	*Lepus victoriae*	LC		x	x	x

Wildlife recorded continued.

Name (English)	Nom (français)	Binomial name	IUCN Redlist	Rainy 2023	Dry 2023	Rainy 2020	Dry 2019-20
Order		**Rodentia**					
Crested porcupine	Porc-épic à crête	*Hystrix cristata*	LC		x	x	x
Order		***Primates***					
Mantled guereza	Colobe guéréza	*Colobus guereza*	LC		x	x	x
Olive baboon	Babouin olive	*Papio anubis*	LC	x	x	x	x
Common patas	Patas	*Erythrocebus patas*	NT	x	x		
Tantalus monkey	Vervet tantale	*Chlorocebus tantalus*	LC	x	x	x	x
Order		**Bucerotiformes**					
Northern ground hornbill*	Bucorve d'Abyssinie	*Bucorvus abyssinicus*	VU		x		
Total (species)		**34 overall**		**15**	**26**	**19**	**27**

*Northern ground hornbill, a bird species, is included here because it is the only bird species recorded during our survey that is mostly terrestrial. The abbreviation “ssp.” in the same column stands here for subspecies.

Table 2. Camera trapping effort, images recovered and overview of species diversity and richness within Bénoué National Park.

Site	Camera effort (days)	Total images	Cattle ind. events	Cattle ind. events sum	Wildlife ind. events	Wildlife ind. events sum	Shannon's Diversity Index	Species richness	Adjusted species richness †
North Zone									
HH*	243	9540	27	155	41	35	2.27	14	0.06
KK	20	15	-	-	5	5	0.95	3	0.15
LL	18	9	-	-	2	2	0.69	2	0.11
MM*	274	1874	-	-	2	2	0.69	2	0.01
NN*	271	5935	13	48	13	13	2.03	9	0.03
OO	7	16	-	-	3	2	0.64	2	0.29
PP	10	20	-	-	4	4	1.39	4	0.40
QQ	10	6	-	-	2	2	0.69	2	0.20
RR	28	2	2	-	-	-	0.00	-	-
Zone* mean	263	5783	13	68	19	17	1.67	8.33	0.03
Middle Zone			-	-					
BB	3	150	1	13	4	4	1.04	3	1.00
CC*	73	77	-	-	14	16	1.96	8	0.11
DD*	70	107	6	64	7	8	1.49	5	0.07
EE	36	20	1	9	2	3	0.64	2	0.06
GG	5	31	-	-	4	6	0.87	3	0.60
I*	281	4477	-	-	0	0	0.00	-	0.00
II*	69	147	-	-	23	28	2.03	10	0.14
K*	280	3402	-	-	2	2	0.00	1	-
R*	271	501	-	14	25	59	1.59	10	0.04
W	9	107	1	7	9	17	1.30	5	0.56
Z*	46	73	3	29	3	3	1.10	3	0.07
Zone* mean	156	1255	1	15	11	17	1.17	5.29	0.06

Species diversity metrics continued.

Site	Camera effort (days)	Total images	Cattle ind. events	Cattle ind. events sum	Wildlife ind. events	Wildlife ind. events sum	Shannon's Diversity Index	Species richness	Adjusted species richness †
South Zone									
A*	249	319	32	255	4	4	0.69	2	0.01
B*	248	1016	42	139	20	36	1.41	10	0.04
C*	240	13201	1	3	0	0	0.00	-	-
D*	243	1225	3	22	0	0	0.00	-	-
E	23	60	3	23	5	5	0.00	1	0.04
F*	243	1412	4	19	170	248	2.24	17	0.07
G*	96	186	12	129	3	3	1.10	3	0.03
H*	60	49	1	1	11	18	1.54	7	0.12
Jb*	58	14	-	-	1	1	0.00	1	0.02
M*	230	12738	31	290	13	19	0.99	4	0.02
Zone* mean	164	2254	18	122	32	48	1.14	6.29	0.05
All sites									
BeNP	**3714**	**56729**	**183**	**1220**	**385**	**552**	**2.68**	**27**	**0.01**
BeNP*	**3545**	**56293**	**175**	**1168**	**346**	**501**	**2.65**	**27**	**0.01**
BeNP* mean	**183**	**3059**	**10**	**64**	**19**	**28**	**1.17**	**5.89**	**0.05**

Sites marked with an asterisk '*' exceeded 40 days of camera trapping effort and were included in statistical analyses. Ind. events represent how detections from a given site for a single species within the same hour were classed as a single independent sighting event. Ind. events sum represents the maximum number of individuals detected for each species from a single photo within each hourly event summed. Species richness is a count of all wild species only, excluding domestics and people. † Species richness adjusted for camera trapping effort is the count of all wild species recorded in a site divided by camera trapping efforts (in days). Cells marked with a '-' indicate no wildlife was detected.

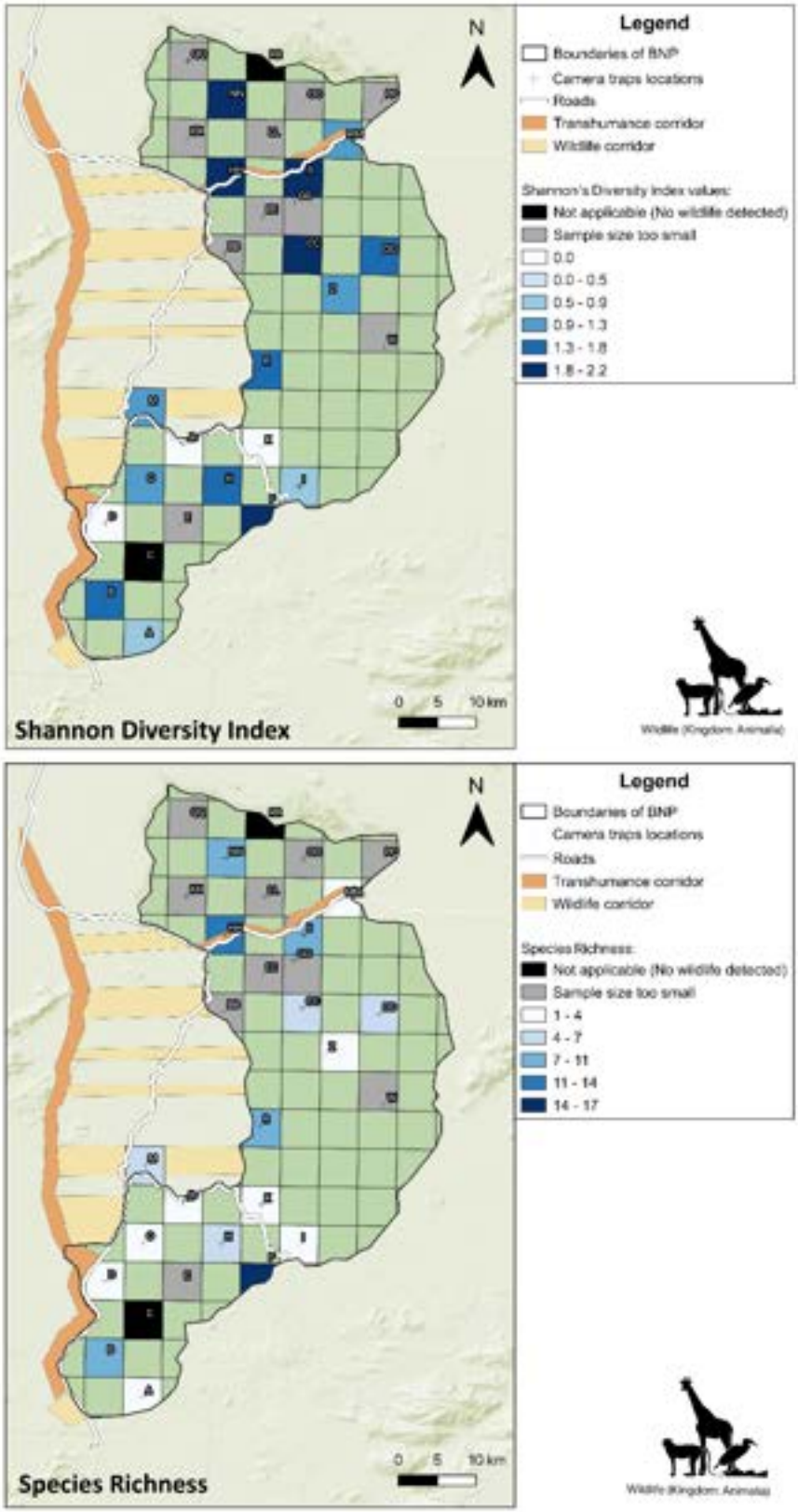

Figure 4. Shannon's Diversity Index and species richness for medium to large bodied wildlife per camera trap site in Bénoué National Park.

Figure 5. Wildlife and cattle within Bénoué National Park. Left panel, top to bottom: domestic cattle (*Bos taurus*); Roan *Hippotragus equinus*; Western hartebeest *Alcelaphus buselaphus major;* and grass regrowth detected at the same location (Site R). Right panel, top to bottom: Kordofan giraffe *Giraffa camelopardalis antiquorum* (Site K); African buffalo *Syncerus caffer* (Site F); leopard *Panthera pardus* (Site DD) and Northern ground hornbill *Bucorvus abyssinicus* (Site F).

5.3 Relative abundance

For sites that passed the 40 day sampling threshold (n=19), BeNP had a park-wide relative abundance index (RAI) of 11.52 for all wildlife (individual site mean of 9.76), 6.41 for antelope (mean of 5.19), 5.03 for domestic cattle (mean of 4.94) and 3.48 for people (mean of 11.52) (Table 3). Mean RAI for all wildlife was higher in the south zone of the park (13.57), than the middle (11.28) or north zone (6.64). However, mean antelope RAI was higher in the middle zone (7.26) than the south (6.63) or north (3.83) (Figure 7). Cattle were most abundant in the south (7.74), followed by the north (5.30) then the middle zone (2.16) (**Figure 8**). The most recorded species (as an independent events), were domestic cattle, followed by tantalus monkey (*Chlorocebus tantalus*), Northern bushbuck (*Tragelaphus scriptus*), red-flanked duiker (*Cephalophus rufilatus*), common duiker (*Sylvicapra grimmia*) (Figure 6; **Figure A3**).

Domestic cattle were recorded in 17 out of 30 total sites and people (excluding park staff) in 20 of 30 sites. As well as evidence of cattle grazing, cameras also detected herders cutting the leaves of *Afzelia africana*, a prime giraffe food source for cattle browse and proscribed burning (Figure 10). We found no significant relationship between the relative abundance index values of cattle and the RAI values of antelope at each site (Spearman's rank, r = 0.0089, df = 17, p = 0.716) (Figure 9). There was also no significant difference in relative abundance index between zones for antelope (Kruskal-Wallis, χ^2 = 0.88, df = 1, p = 0.64) or for cattle (Kruskal-Wallis, χ^2 = 2.431, df= 1, p = 0.116). Although it should be noted, low count sizes affect the accuracy of these observations and the analysis only accounted for spatial overlap but not temporal overlap.

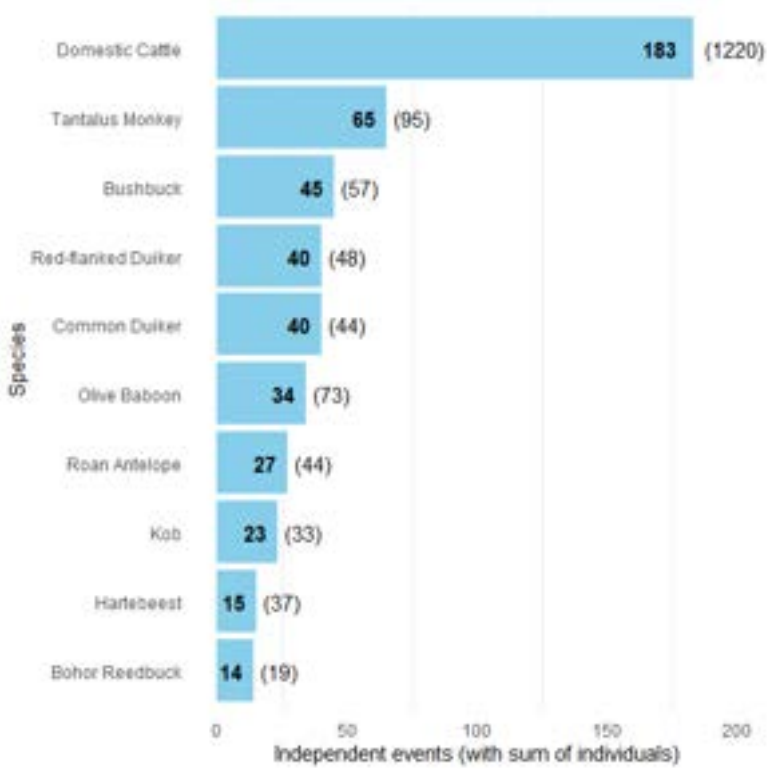

Figure 6. Most frequently detected species in BeNP. Values in bold indicate independent events (number of hours for which a species was detected across all camera trap sites). Values in brackets indicate the maximum number of individuals detected during a single photo per hourly event summed.

Table 3. Relative Abundance Index values of wildlife, antelope and species of conservation interest per site, divided by zone.

RAI

Sites	Cattle	Human	Wildlife	Antelope	Buffalo	Giraffe	Hartebeest	Kob	Leopard	Hornbill	Patas	Waterbuck
North Zone												
HH*	11.11	4.53	14.40	7.82	-	-	-	0.82	-	-	0.41	-
KK	-	-	25.00	15.00	-	-	-	-	-	-	-	-
LL	-	-	11.11	5.56	-	-	-	-	-	-	-	-
MM*	-	0.73	0.73	0.73	-	-	-	-	-	-	-	0.36
NN*	4.80	2.58	4.80	2.95	-	-	-	0.37	-	0.37	-	-
OO	-	-	28.57	28.57	-	-	-	14.29	-	-	-	-
PP	-	-	40.00	20.00	-	-	-	-	-	-	-	-
QQ	-	-	20.00	10.00	-	-	-	-	-	-	-	-
RR	7.14	-	-	-	-	-	-	-	-	-	-	-
Zone* mean	5.30	2.61	6.64	3.83	-	-	-	0.40	-	0.12	0.14	0.12
Middle Zone												
BB	33.33	-	133.33	100.00	-	-	-	-	-	-	-	-
CC*	-	-	19.18	10.96	-	-	1.37	-	1.37	-	-	-
DD*	8.57	1.43	10.00	8.57	-	-	1.43	-	-	-	-	-
EE	2.78	2.78	5.56	2.78	-	-	-	-	-	-	2.78	-
GG	-	-	80.00	20.00	-	-	-	-	-	-	40.00	-
I*	-	0.36	-	-	-	-	-	-	-	-	-	-
II*	-	4.35	33.33	18.84	-	-	-	-	-	-	2.90	-
K*	-	0.71	0.71	-	-	0.71	-	-	-	-	-	-
R*	-	2.58	9.23	8.12	-	-	2.58	2.21	-	0.37	0.37	0.37
W	11.11	11.11	100.00	66.67	-	-	-	-	-	-	-	-
Z*	6.52	13.04	6.52	4.35	-	-	-	-	-	-	-	-
Zone* mean	2.16	3.21	11.28	7.26	-	0.10	0.77	0.32	0.20	0.05	0.47	0.05

RAI continued

Sites	Cattle	Human	Wildlife	Antelope	Buffalo	Giraffe	Hartebeest	Kob	Leopard	Hornbill	Patas	Waterbuck
South Zone												
A*	12.85	5.22	1.61	0.80	-	-	-	-	-	-	-	-
B*	16.94	3.63	8.06	2.02	-	-	0.40	-	-	-	-	-
C*	0.42	0.42	-	-	-	-	-	-	-	-	-	-
D	1.23	1.65	-	-	-	-	-	-	-	-	-	-
E	13.04	17.39	21.74	21.74	-	-	-	-	-	-	-	-
F*	1.65	0.82	69.96	33.33	1.23	-	-	4.94	-	0.41	-	-
G*	12.50	5.21	3.13	2.08	-	-	-	1.04	-	-	1.04	-
H*	1.67	-	18.33	10.00	-	-	6.67	-	-	-	-	-
Jb*	-	1.72	1.72	1.72	-	-	1.72	-	-	-	-	-
M*	13.48	15.22	5.65	3.04	-	-	-	-	-	-	-	-
Zone* mean	7.44	4.03	13.56	6.63	0.15	-	1.10	0.75	-	0.05	0.13	-
All sites												
BeNP* RAI	4.94	3.10	9.76	5.19	0.08	0.06	0.42	0.62	0.03	0.08	0.14	0.06
BeNP* RAI mean	5.03	3.48	11.52	6.41	0.07	0.04	0.79	0.52	0.08	0.06	0.26	0.04
Ind. Event	183	116	385	209	3	2	15	23	1	3	8	2
Ind. event*	175	110	346	184	3	2	15	22	1	3	5	2
Ind. event sum	1220	NA	552	295	11	2	37	33	1	4	11	2
Ind. event* sum	1168	NA	501	265	11	2	37	31	1	4	5	2

*Sites that passed the 40 days threshold of minimal sample size (and thus considered for statistical analysis). Dashes indicate zeros. Zeroes were included in mean calculations.

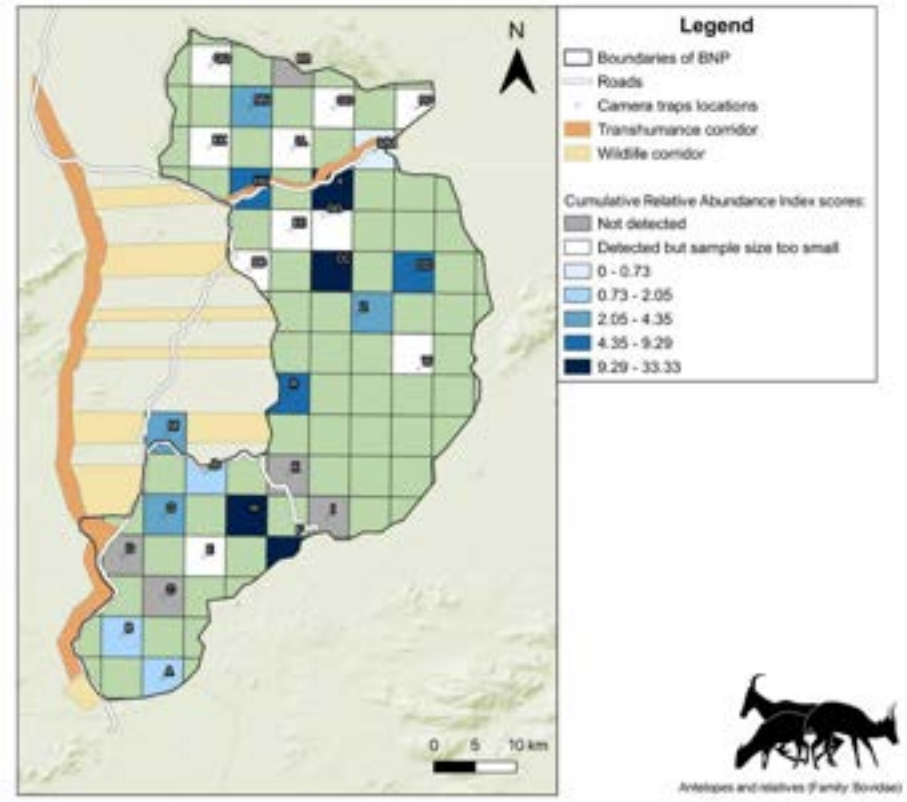

Figure 7. Distribution and relative abundance amongst sites covered for antelopes and relatives (Family: Bovidae).

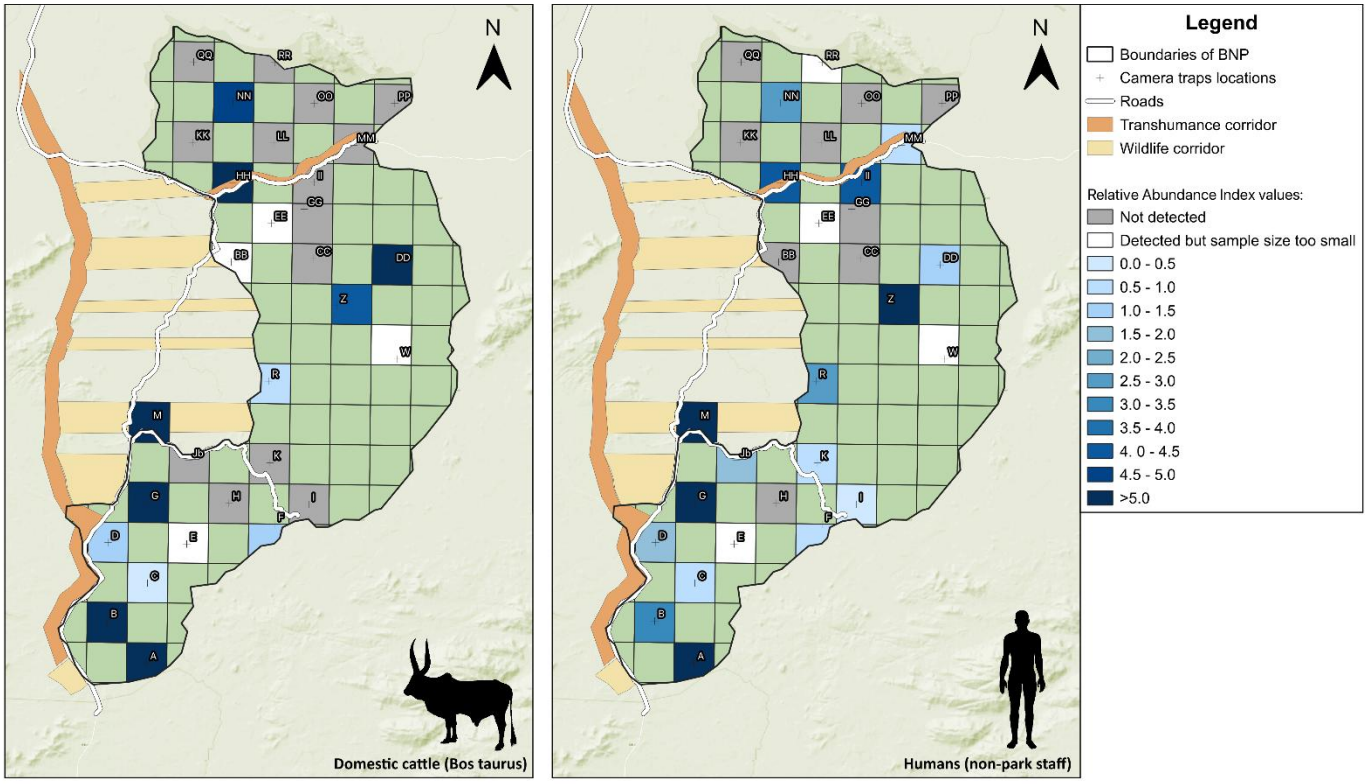

Figure 8. Distribution and relative abundance amongst sites covered for domestic cattle (*Bos taurus*, left) and human (*Homo sapiens*, right).

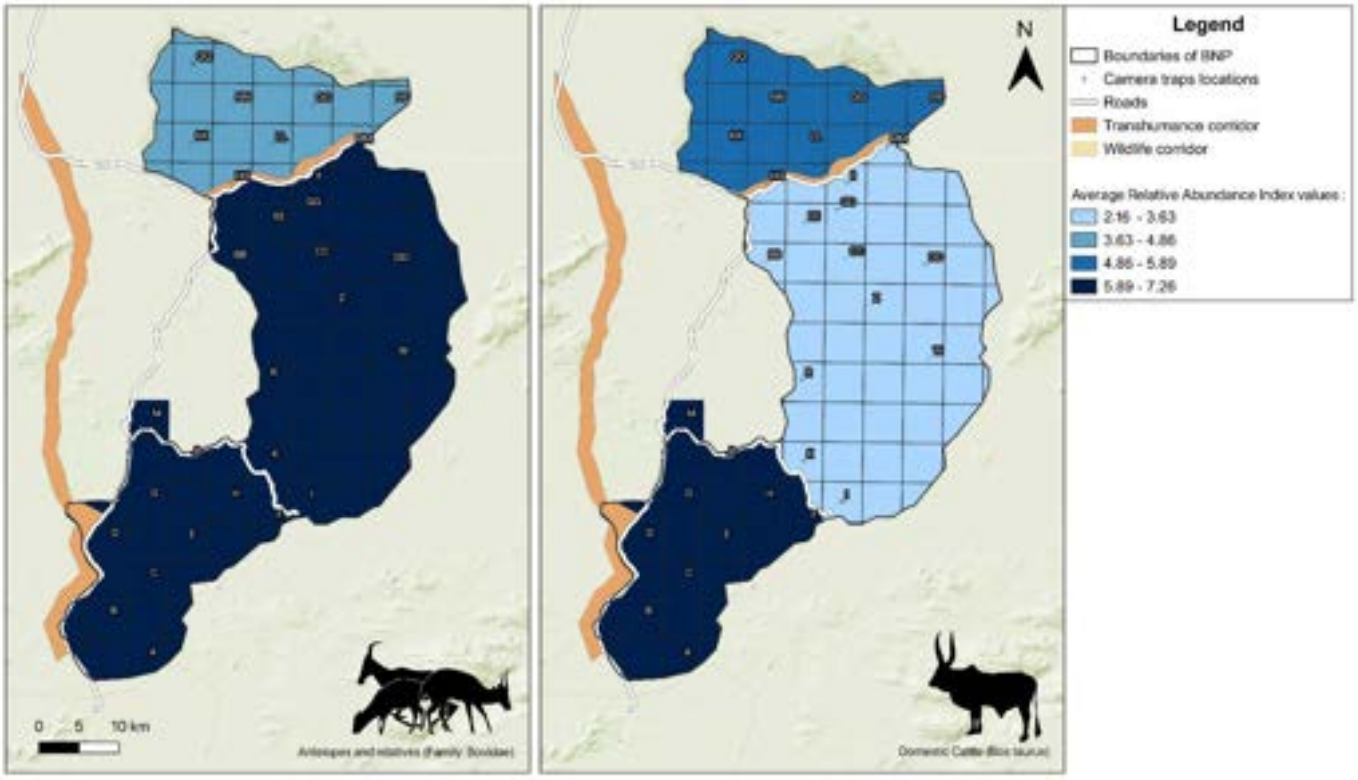

Figure 9. Comparison of relative abundance and distribution of wild antelopes and relatives (Family:Bovidae) and domestic cattle (*Bos taurus*) per zone (north, central, south).

Figure 10. Clockwise from top left: catle moving through the park; person up an *Afzelia africana tree* cutting the leaves as a food source for the cattle below; 8-days later showing denuded branches with the leaves removed; some regrowth showing with a fire in the background. It should be noted that the tree is also prime food source for giraffe.

5.4 Seasonal variation

Sites were more species diverse in the dry season (27 different species detected, mean of 4.04 species per site) than the rainy season (15 different species detected, mean of 2.85 species per site) (Table A1). When accounting for camera trapping effort, sites still recorded more species during the dry season than the rainy season (dry = mean of 0.02; wet = mean of 0.01), with this difference statistically significant (Mann-Whitney, U = 97, p = 0.009). Similary, for sites meeting the minium sample size, Shannon's Diversity Index scores were on average higher during the dry season (2.59) than the rainy season (1.97), althought this was not significantly different (Mann-Whitney, U = 172, p = 0.543).

In terms of abundance, wildlife and antelope had a higher RAI during the dry season (wildlife RAI mean: dry = 18 , rainy = 3.87 ; antelope: dry = 9.65, rainy = 2.12), with these seasonal differences in detection statistically significant (Mann-Whitney, Wildlife: U = 113, N = 37, p = 0.030; Antelope: U = 112, N = 37, p = 0.028) (**Figure A4**). In contrast cattle detections were slightly lower during the dry season than the rainy season (RAI mean: dry = 4.44, rainy = 5.29), but this difference was not statistically significant (U =184, N = 37 , p = 0.770). If park-wide scores are broken down per month, then antelope show an earlier dry season peak in the months of February, March, and April, with cattle showing a later bimodal peak between April and August, with a notable reduction in detections during June (**Figure 11)**.

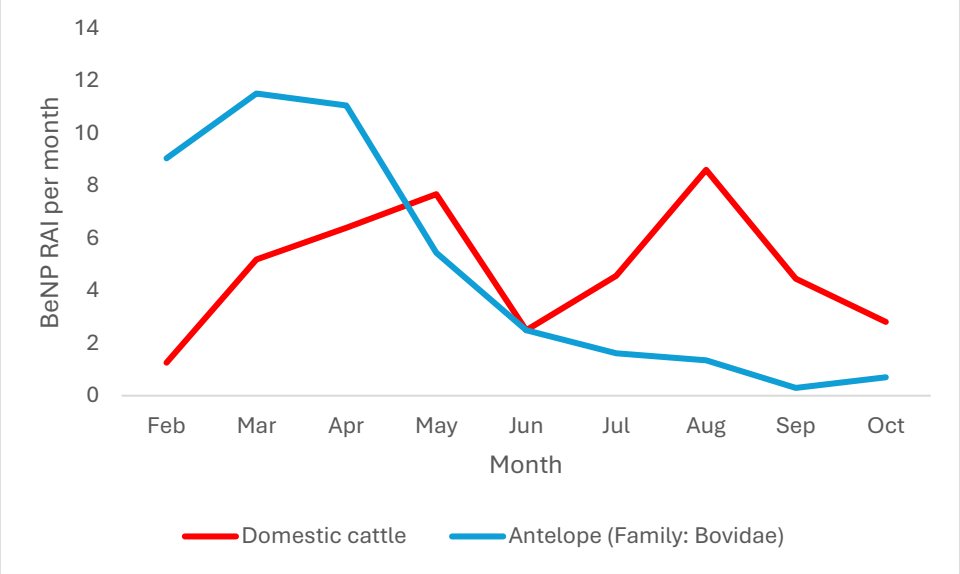

Figure 11. Park-wide Relative Abundance Index values for domestic cattle (*Bos taurus*, in red) and antelopes and relatives (Family: Bovidae, in yellow) per month. The rainy season was considered as May to October. No data is plotted for January and November due to the low sampling effort.

6 Discussion

6.1 Summary

Our camera trap survey confirms that Bénoué National Park remains a significant biodiversity hotspot within the Sudano-Sahelian zone of Central Africa. Across 3,714 trap days, we recorded 26 species of mammal. If this data is combined with the previous BZS camera trap monitoring efforts conducted between 2019 and 2021, a total of 33 wild mammal species have been recorded from the park. This compares to the 16 wild mammal species recorded by Elkan et al. (2015) during a 2015 aerial survey of the Bénoué National Park. The camera trap surveys recorded several elusive or nocturnal taxa such as aardvark (*Orycteropus afer*), caracal (*Caracal caracal*), and side-striped jackal (*Lupulella adusta*), which are typically not detectable by aerial surveys. These findings underscore the value of camera trapping in detecting cryptic species and establishing a more complete inventory of mammalian diversity. Only one species was detected in the aerial survey but not during the camera trap survey, topi (*Damaliscus lunatus*), which was represented by a single recorded individual in the 2015 survey.

Despite the use of protective lockboxes, multiple cameras were lost to theft, vandalism, or fire. These losses created gaps in spatial coverage. Nonetheless, the data collected provide a valuable baseline for future monitoring. Monitoring the abundance and distribution of large mammals over time provides advantages to park managers and conservationists by quantifying species distribution and the extent of population change and enabling the development of bespoke conservation interventions to halt or reverse declines.

Species richness varied considerably across sites, with the highest diversity recorded in the central and southern zones of the park. Sites with longer deployment periods (>40 days) yielded higher Shannon diversity indices, reinforcing the importance of sustained monitoring. While relative abundance indices are influenced by species behaviour and detectability, they still provide valuable insights into spatial and seasonal patterns. Roan antelope and kob were among the most frequently detected large, wild, herbivores, while African buffalo, giraffe and Bohor reedbuck were recorded at far fewer sites, despite occupying similar savannah habitats.

Despite the overall species richness recorded, recent surveys also highlighted the rarity—or possible local extirpation—of several species of conservation concern. Notably, there were no camera trap detections of African elephant (*Loxodonta africana*) or lion (*Panthera leo*). This is despite ecoguards documenting signs of their presence on patrol, including six sets of lion tracks and two instances of elephant dung between 2023 and 2024. Including these transient species would increase the total medium-large mammal species richness of the park to 35 (notably excluding all rodents and bats) or 36 if topi are included. A recent 2024 survey by Biodiversity Environment & Sustainable Development also failed to detect African wild dog despite anecdotal reports of signs within the park (Justin Didolanvi pers. Comm.), likely confirming its local extinction alongside black rhino and cheetah. These absences are consistent with broader patterns of megafaunal decline observed across the Bénoué Complex, likely driven by escalating anthropogenic pressures such as poaching, habitat degradation, and competition with livestock (Scholte et al. 2022). Large mammals play a critical role as ecological engineers, shaping vegetation structure and influencing ecosystem dynamics (Owen-Smith, 1988). Their vulnerability to habitat fragmentation and human disturbance makes them effective indicators of

ecosystem health (Morrison et al., 2007). As such, monitoring their abundance and distribution is essential—not only as an early warning system for ecological degradation but also to guide targeted conservation interventions aimed at reversing population declines.

6.2 Eland and topi

Perhaps the most alarming finding of the current study is the complete absence of giant eland detections from the 2023 survey. Despite a single previous record detected during a BZS study centred on salt licks (Argirova, 2021), no recent camera trap detections were made. Given their absence from this survey, just one record from 2021 survey, and their absence from the 2015 aerial assessment (Elkan et al. 2015), it is likely that eland occur at extremely low densities within BeNP. This suggests that eland may be at the threshold of local extinction in the park. Interestingly, since ecoguards began keeping records in 2023, eland prints have been recorded on 12 occasions and eland dung on 22 occasions on patrols. However, given that no direct sightings were made over this period, it remains possible that some or all these reports represent misidentified tracks or dung of African buffalo, the presence of which complicates monitoring. This highlights the need for improved detection methods, such as through placing camera traps at targeted locations such as salt licks. Until further data are established, we strongly recommend an immediate moratorium on eland hunting across the Bénoué Complex hunting zones until a comprehensive population assessment is completed. While trophy hunting can generate valuable conservation funding—especially in regions with limited ecotourism—it must be guided by a sustainable quota system rather than guess work (Lescuyer et al. 2016). The absence of topi from the camera trap surveys and patrol reports, coupled with just a single identification from 2015, also indicates that this species either occurs at very low numbers or has also been extirpated from the park.

6.3 Giraffe

The results of this survey reinforce the precarious status of the Kordofan giraffe (*Giraffa camelopardalis antiquorum*) population within Bénoué National Park (BeNP). Despite the Bénoué Complex being one of the last strongholds for this Critically Endangered giraffe, giraffe detections during the 2023 camera trap survey were limited to a single site. This low detection rate aligns with previous focused assessments suggesting that as few as 26 individuals may remain in the park (Parks et al., 2023). The limited spatial distribution and low encounter rates highlight Kordofan giraffe's vulnerability to extinction, particularly in the face of ongoing threats such as poaching, habitat degradation, and competition with livestock, with modelling by Colston et al. (2023) suggesting extirpation from the park is probable within as little as 15 years further interventions.

Notably, giraffe were absent from several areas where they had previously been recorded (Chillingworth, 2021). While some of these absences may reflect detection limitations or methodological differences rather than true absence, the contrast with the relative abundance of other large herbivores—such as kob and roan antelope—suggests that giraffe density in BeNP is low. As with eland, to improve detection and monitoring, future efforts should prioritise the use of targeted methods such as deploying camera traps at salt licks, waterholes, or known feeding sites (Sekakoh, 2021; Parks et al., 2023), particularly given that aerial surveys have also proven largely ineffective, with only two giraffe recorded in 2015 alongside zero eland (Elkan et al., 2015).

Recent work by Didolanvi et al. (2025) in the Bouba Ndjida Conservation Landscape demonstrates the value of integrating local ecological knowledge (LEK) to gain insights into giraffe presence, movement, and threats. Replicating such community-based approaches around BeNP could enhance conservation outcomes and foster local stewardship. Similarly, ecoguards have irregularly recorded giraffe on patrol with 20 sets of footprints recorded in 2023 and 5 in 2024, along with several direct sightings particularly along the road between Banda and Buffle Noir. Given that individual giraffes can be reliably identified by their unique spot patterns, the use of photographic mark-recapture methods offers a valuable tool for generating future population estimates. To support this, the development of a centralised photo-identification library across the Bénoué Complex should be actively encouraged with BZS already initiating a nascent catalogue on GiraffeSpotter (Giraffe Spotter, 2025). Additionally, the recent 2025 Cameroon National Strategy for Giraffe Conservation presents a timely opportunity to strengthen regional conservation efforts and improve the long-term viability of Kordofan giraffe populations.

6.4 Threats and mitigations

Wildlife detections were higher during the dry season, likely due to increased animal movement and visibility, with grass height reducing detectability as the rainy season progresses. Cattle presence was similar across both seasons but with a peak between May and August, likely due to changes in the availability of food resources outside of the protected area. Persistently high levels of cattle in areas utilised by wildlife may lead to competition with both grazers and browsers, as shown by photo evidence from a camera trap site showing the cutting of *Afzelia* sp., a tree favoured by giraffe during periods of food scarcity (Sekakoh, 2019), to feed to cattle. Although the drop in antelope corresponds with a rise in cattle, it is not in itself enough to establish cause and effect. It thus requires further study to establish how cattle and human disturbance affects wildlife presence, particularly during the dry season when there is greatest risk of resource competition. Likewise, it is important to compare how areas of illegal gold mining activity and associated activity affect species distribution maps to see if disturbance or hunting is a factor here too. The high rate of human detections in areas where antelopes occur suggests a potential overlap in space and time that may reflect hunting pressure.

The results of this study support calls to strengthen anti-poaching patrols and improve habitat protection, particularly in zones where giraffe and eland presence has been confirmed. Previous studies have also highlighted the role of adjacent hunting zones, such as ZIC 18, which may host more stable giraffe populations than the park itself (Parks et al. 2023). This suggests that conservation planning must extend beyond protected area boundaries, improving the connectivity of wildlife corridors and actively involving hunting zone managers as key stakeholders. Finally, mitigating seasonal competition with cattle through improved grazing management and community engagement will be essential to reduce pressure on critical giraffe habitats during periods of food scarcity.

6.5 Conservation recommendations

1. Strengthen SMART-based anti-poaching patrols to reduce illegal transhumance, mining, and hunting and improve wildlife protection.
2. Suspend and review eland hunting in ZIC surrounding BeNP and conduct a region-wide population assessment to determine their conservation status.

3. Enhance landscape connectivity to support giraffe and other large herbivore movement between protected areas and hunting zones, particularly given the stable populations documented in hunting zones like ZIC 18.
4. Engage hunting zone managers as key stakeholders in conservation planning, recognising their role in hosting viable wildlife populations.
5. Implement grazing management strategies to reduce competition between livestock and wildlife.

7 References

Argirova, E., 2021. *Seasonal variation in biodiversity and diel activity patterns of species using salt licks in Bénoué National Park, Cameroon*. Unpublished MSc thesis, University of Leicester.

Bristol Zoological Society. 2022. *Conservationists at Bristol Zoological Society have stepped in to protect one of the world's most threatened types of giraffe*. [Online]. [Accessed 30 September 2025]. Available from: https://bristolzoo.org.uk/news/bristol-zoological-society-helps-threatened-giraffes

Cervera, L., Lizcano, D.J., Parés-Jiménez, V., Espinoza, S., Poaquiza, D., De la Montaña, E. and Griffith, D.M., 2016. A camera trap assessment of terrestrial mammals in Machalilla National Park, western Ecuador. *Check List*. **12**(2), pp.1868-1868.

Chillingworth, L. 2021. *Determining the occupancy of Kordofan giraffe (Giraffa camelopardalis antiquorum) across Bénoué National Park, Cameroon and the implications for their conservation and protection*. Unpublished Master's thesis, University of Bristol.

Climate Explorer. 2024. *KNMI Climate Explorer*. [Online]. [Accessed 30 September 2025]. Available from: https://climexp.knmi.nl/.

Coimbra, R.T., Winter, S., Mitchell, B., Fennessy, J. and Janke, A., 2022. Conservation genomics of two threatened subspecies of northern giraffe: The West African and the Kordofan giraffe. *Genes*. **13**(2), p.221.

Colston, K. P., Johnson, C. L., Nyugha, D., Mengamenya Goué, A., & Penny, S. G. 2023. Viability analysis of Kordofan giraffe (Giraffa camelopardalis antiquorum) in a protected area in Cameroon. *African Journal of Ecology*. **61**, 929–944.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. and de Iongh, H.H. 2011. The impact of trophy hunting on lions (Panthera leo) and other large carnivores in the Bénoué Complex, northern Cameroon. *Biological Conservation*. **144**(12), pp.3064–3072.

Didolanvi, G.J. 2024. Conversation with Justin Didolanvi.

Didolanvi, G.J., Kamgang, S.A., Tegang, R., Tadjo, S.P., Scholte, P. and Fennessy, J. 2025. Local Knowledge of Kordofan Giraffe in the Bouba Ndjidda Conservation Landscape, Cameroon. *African Journal of Wildlife Research*. **55**(1).

Elkan, P., Fotso, R., Hamley, C., Mendiguetti, S., Bour, P., Nguertou Alexandre, V, Kenmoe, G. A. 2016. *Aerial surveys of wildlife and human activity across the Bouba N'djida - Sena Oura - Benoue - Faro landscape: Northern Cameroon and southwestern Chad: April - May 2015*. [Online]. Garoua, Cameroon: Wildlife Conservation Society; Ministry of Forests and Wildlife (MINFOF); L'Ecole de Faune

de Garoua. [30 September 2025]. Available from: https://africanelephantdatabase.org/population_submissions/493

Fennessy, J. & Marais, A. 2018. *Giraffa camelopardalis ssp. antiquorum (The IUCN Red List of Threatened Species)*. [Online]. [Accessed 25 September 2025]. Available from: https://www.iucnredlist.org/species/pdf/88420817#:~:text=The%20Kordofan%20Giraffe%20is%20listed,in%20Central%20African%20Republic%3B%20ca.

GiraffeSpotter. 2025. Giraffe Spotter. [Online]. [Accessed 30 September 2025]. Available from: https://giraffespotter.org/

Hamadou, A. Z., Hyacente, A., Paul, K., Danra, D. D., & Clautilde, M. 2021. Influence of anthropization on flora and the carbon stock of the corridor's vegetation at the Benoue National Park of Cameroon. *Environmental Challenges*. **5**, 100345.

He, F., Zarfl, C., Bremerich, V., David, J.N.W., Hogan, Z., Kalinkat, G., Tockner, K. and Jähnig, S.C. 2019. The global decline of freshwater megafauna. *Global Change Biology*. **25**(11), pp.3883–3892.

Hedwig, D., Kienast, I., Bonnet, M., Curran, B.K., Courage, A., Boesch, C., Kühl, H.S. and King, T. 2018. A camera trap assessment of the forest mammal community within the transitional savannah-forest mosaic of the Batéké Plateau National Park, Gabon. *African Journal of Ecology*. **56**(4), pp.777–790.

Iongh, H. H. de, Croes, B. M., Rasmussen, G., Buij, R., & Funston, P. 2011. The status of cheetah and African wild dog in the Benoue Ecosystem, North Cameroon. *Cat News*. **55**, 29-31.

Jenks, K.E., Chanteap, P., Kanda, D., Peter, C., Cutter, P., Redford, T., Antony, J.L., Howard, J. and Leimgruber, P. 2011. Using Relative Abundance Indices from Camera-Trapping to Test Wildlife Conservation Hypotheses – An Example from Khao Yai National Park, Thailand. *Tropical Conservation Science*. **4**(2), pp.113–131.

Foguekem, D., Tchamba, M. & Omondi, P. 2010. Aerial survey of Elephants (Loxodonta africana africana), other large mammals and human activities in Waza National Park, Cameroon. *African Journal of Environmental Science and Technology*. **4**(6).

Lescuyer, G., Ngouhouo Poufoun, J., Defo, L., Bastin, D. and Scholte, P. 2016. Does trophy hunting remain a profitable business model for conserving biodiversity in Cameroon?. *International Forestry Review*. **18**(1), pp.108-118.

Mallon, D.P., Hoffmann, M. and Philip J.K. McGowan. 2015. *An IUCN situation analysis of terrestrial and freshwater fauna in West and Central Africa*. [Online]. Gland, Switzerland: IUCN. [30 September 2025]. Available from: https://doi.org/10.2305/iucn.ch.2015.ssc-op.54.en.

Marais, A. J., Fennessy, S., Ferguson, S., & Fennessy, J. 2019. *Country profile: A rapid assessment of the giraffe conservation status in Cameroon*. [Online]. Windhoek, Namibia: Giraffe Conservation Foundation. [30 September 2025]. Available from: https://giraffeconservation.org/wp-content/uploads/2024/11/Cameroon-Country-Profile-2019.pdf

Mengamenya Goué, A. 2024. Conversation with Achile Mengamenya Goué.

Mittermeier, R.A., Mittermeier, C.G., Brooks, T.M., Pilgrim, J.D., Konstant, W.R., da Fonseca, G.A.B. and Kormos, C. 2003. Wilderness and biodiversity conservation. *Proceedings of the National Academy of Sciences*. **100**(18), pp.10309–10313.

Morrison, J.C., Sechrest, W., Dinerstein, E., Wilcove, D.S. and Lamoreux, J.F., 2007. Persistence of large mammal faunas as indicators of global human impacts. *Journal of Mammalogy*. **88**(6), pp.1363-1380.

Oliver, T.H., Heard, M.S., Isaac, N.J.B., Roy, D.B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, C.D.L., Petchey, O.L., Proença, V., Raffaelli, D., Suttle, K.B., Mace, G.M., Martín-López, B., Woodcock, B.A. and Bullock, J.M. 2015. Biodiversity and Resilience of Ecosystem Functions. *Trends in Ecology & Evolution*. **30**(11), pp.673–684.

Olson, D.M. and Dinerstein, E. 1998. The Global 200: A Representation Approach to Conserving the Earth's Most Biologically Valuable Ecoregions. Conservation Biology. **12**(3), pp.502–515.

Omondi, P., Mayienda, R. and Tchamba, M. 2007. *Total Aerial Count of Elephants, Giraffes, Roan Antelopes and other Wildlife Species and Ostrich in Waza National Park, Cameroon*. [Online]. Nairobi, Kenya: WWF Central African Region [Accessed 30 Sep. 2025]. Available at: https://www.africanelephantdatabase.org/system/population_submission_attachments/files/000/000/973/original/Omondi_et_al_2007_Waza_aerial_survey.pdf

Owen-Smith, R.N. 1988. *Megaherbivores: the influence of very large body size on ecology*. Cambridge, United Kingdom: Cambridge University Press.

Parks, C., Penny, S., Mengamenya Goue, A., Nyugha, D., Pauline, T.T., Vannier, X. and Johnson, C.L. 2023. Preliminary population estimate of Kordofan giraffe (Giraffa camelopardalis antiquorum) in two areas of the Benoué complex, Cameroon. *African Journal of Ecology*. **62**(1).

QGIS Development Team, 2019. QGIS 3.38.3-Grenoble. [Software]. [23 February 2024].

R Development Core Team, 2024. R Studio (4.4.1). [Software]. [23 February 2024].

Ripple, W.J., Newsome, T.M., Wolf, C., Dirzo, R., Everatt, K.T., Galetti, M., Hayward, M.W., Kerley, G.I.H., Levi, T., Lindsey, P.A., Macdonald, D.W., Malhi, Y., Painter, L.E., Sandom, C.J., Terborgh, J. and Van Valkenburgh, B. 2015. Collapse of the world's largest herbivores. *Science Advances*. [online] **1**(4), p.e1400103.

Ripple, W.J., Wolf, C., Newsome, T.M., Betts, M.G., Ceballos, G., Courchamp, F., Hayward, M.W., Valkenburgh, B., Wallach, A.D. and Worm, B. 2019. Are we eating the world's megafauna to extinction? *Conservation Letters*. **12**(3), p.e12627.

Scholte, P., Nguimkeng, F. and Iyah, E. 2016. Good news from north-central Africa: largest population of Vulnerable common hippopotamus Hippopotamus amphibius is stable. *Oryx*. **51**(2), pp.218–221.

Scholte, P., Pays, O., Adam, S., Chardonnet, B., Fritz, H., Mamang, J.B., Prins, H.H., Renaud, P.C., Tadjo, P. and Moritz, M. 2022. Conservation overstretch and long-term decline of wildlife and tourism in the central African savannas. *Conservation Biology*. **36**(2), p.e13860.

Sekakoh. 2020. *Sekakoh's report to giraffe conservation foundation: Kordofan giraffes in the Benue complex of northern Cameroon*. Unpublished.

Shannon, C.E. 1948. A Mathematical theory of communication. *Bell System Technical Journal*. **27**(3), pp.379–423.

Si, X., Kays, R. and Ding, P. 2014. How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. *PeerJ*. **2**, p.e374.

Stark, M.A. 1986. The numbers, seasonal distribution patterns, densities and biomass of the large herbivores, Benoue National Park, Cameroon. *Mammalia*. **50**(3).

Stark, M.A., Hudson, R.J., 1985. Plant communities' structure in Benoue National Park, Cameroon: a cluster association analysis. *African Journal of Ecology*. **23**, 21–27.

Taïga, L. K., Kamgang, S. A., Bakwo Fils, E. M., Samuel, T. C., & Rduch, V. 2021. The status and population dynamic of Buffon's kob (Kobus kob kob, ERXLEBEN 1777) in the Faro National Park, Northern Cameroon. *African Journal of Ecology*. **59**, 142–151.

Tchamba, M.N. and Elkan, P. 1995. Status and trends of some large mammals and ostriches in Waza National Park, Cameroon. *African Journal of Ecology*. **33**(4), pp.366–376.

Tilman, D., Isbell, F. and Cowles, J.M. 2014. Biodiversity and Ecosystem Functioning. *Annual Review of Ecology, Evolution, and Systematics*. **45**(1), pp.471–493.

Tobler, M.W., Zúñiga Hartley, A., Carrillo-Percastegui, S.E. and Powell, G.V.N. 2015. Spatiotemporal hierarchical modelling of species richness and occupancy using camera trap data. *Journal of Applied Ecology*. **52**(2), pp.413–421.

UNESCO, 2025. *Benoué - Man and the Biosphere Programme (MAB)*. [Online]. [Accessed 30 September 2025]. Available from: https://www.unesco.org/en/mab/benoue

WCS, 2023. *Aerial assessment in the dry season of the Waza national park and peripheral areas*. Unpublished.

Wearn, O.R., Rowcliffe, J.M., Carbone, C., Bernard, H. and Ewers, R.M. 2013. Assessing the Status of Wild Felids in a Highly-Disturbed Commercial Forest Reserve in Borneo and the Implications for Camera Trap Survey Design. *PLoS ONE*. **8**(11), p.e77598.

Weladji, R.B. and Tchamba, M.N. 2003. Conflict between people and protected areas within the Bénoué Wildlife Conservation Area, North Cameroon. *Oryx*, **37**(01).

Wildlife Insights. 2024. *Wildlife Insights: Home*. [Online]. [Accessed 30 September 2025]. Available from: https://www.wildlifeinsights.org/

Yoccoz, N.G., Nichols, J.D. and Boulinier, T. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology & Evolution*. **16**(8), pp.446–453.

8 Acknowledgements and permissions

An earlier phase of this project (January 2022 – January 2024) was supported by IUCN Save Our Species, co-funded by the European Union. Bristol Zoological Society holds a Memorandum of Understanding with the Cameroonian Minsitry of Foresty and Wildlife formalising how bidosiversity and conservation can be conducted within Bénoué National Park (valid until January 2027).

We would like to thank MINFOF for their validation of the project and their invaluable support throughout data collection. We would also like to acknowledge Jean Bernard Saidou, Bouba Samaki, Ntieche Moluh Soulemane, Harouna Nji Sangou and the entire ecoguard team of the Bénoué National Park Conservation Service who work tirelessly to protect the area's threatened species and without whom this survey would not have been possible. Additonally, we thank Jessica Bodey and Emily Dixon for their assistance with labelling images and cleaning the data. Plus wider Sekakoh team who oversaw the delivery of several work packages during the planning, deliver, and writing of this report.

9 Appendix

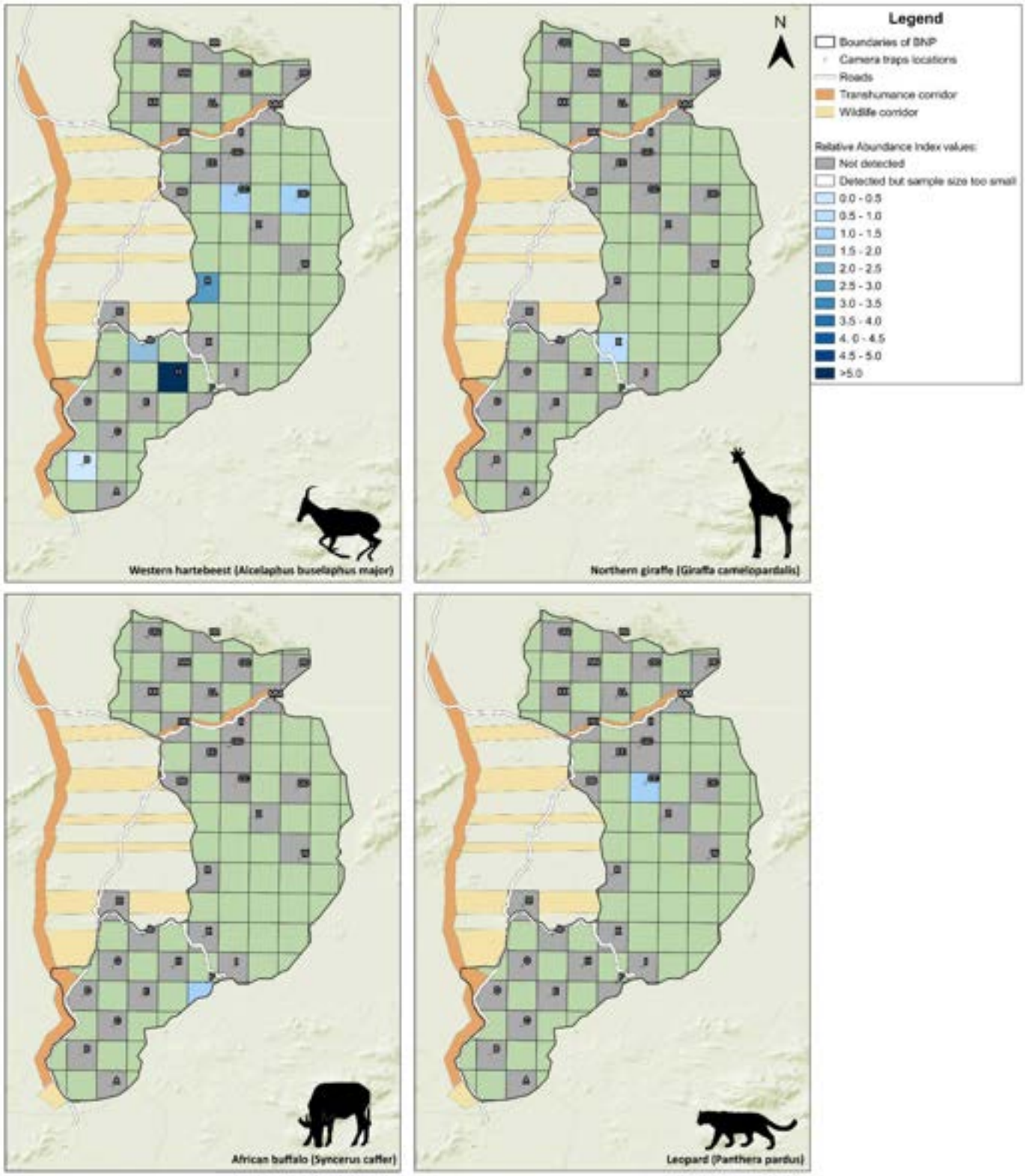

Figure A1. Distribution and relative abundance of taxa of conservation interest inside BeNP: Northern giraffe (*Giraffa camelopardalis*), Western hartebeest (*Alcelaphus buselaphus major*), African buffalo (*Syncerus caffer)* and leopard (*Panthera pardus*).

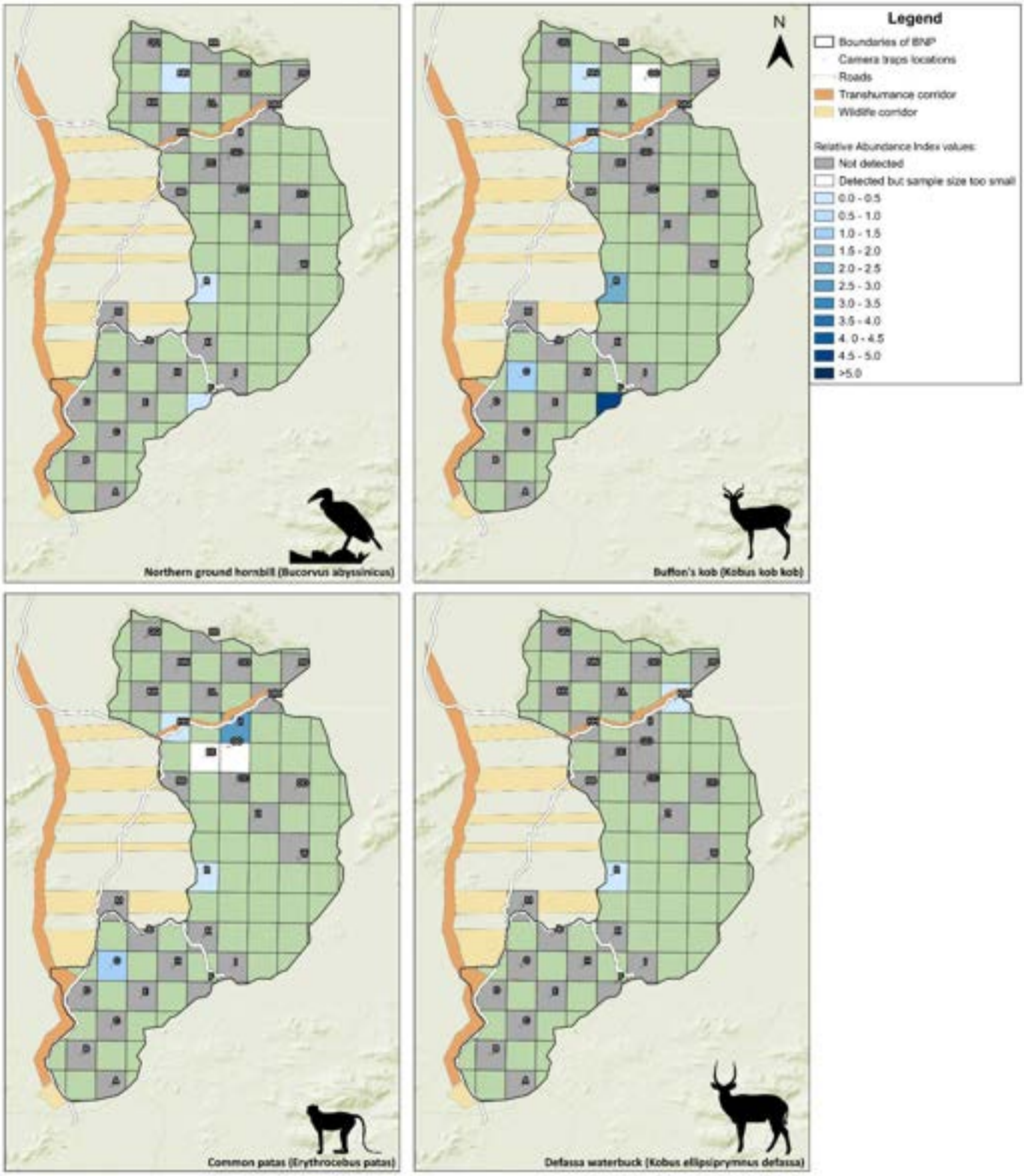

Figure A2. Distribution and relative abundance of taxa of conservation interest inside BeNP: Common patas (*Erythrocebus patas*), Northern ground hornbill (*Bucorvus abyssinicus*), Buffon's kob (*Kobus kob kob*) and defassa waterbuck (*Kobus ellipsiprymnus defassa*).

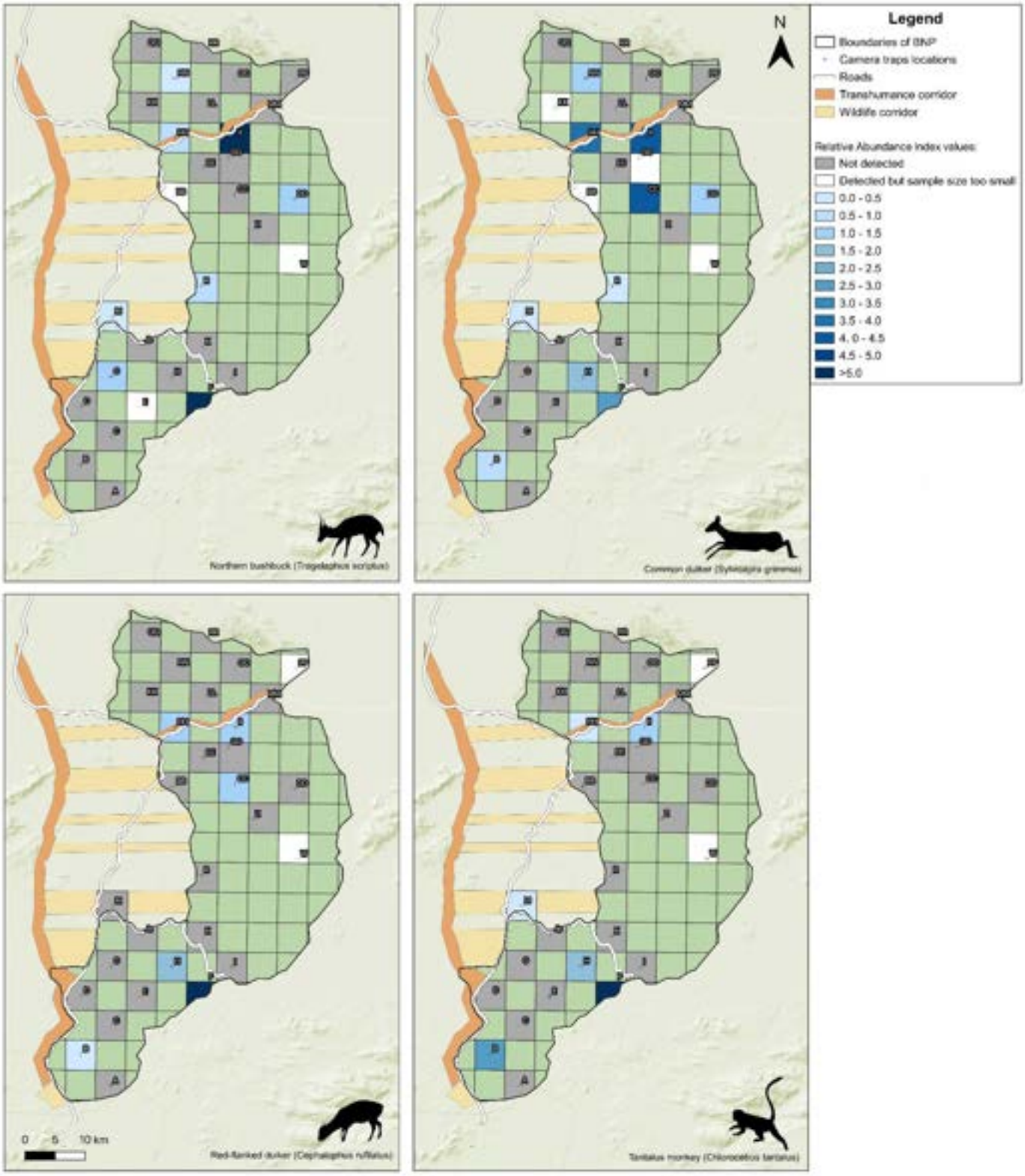

Figure A3. Distribution and relative abundance amongst sites tested of the four most common species noted in BeNP during our survey, Northern bushbuck (*Tragelaphus scriptus*), common duiker (*Sylvicapra grimmia*), red-flanked duiker (*Cephalophus rufilatus*) and tantalus monkey (*Chlorocebus tantalus*).

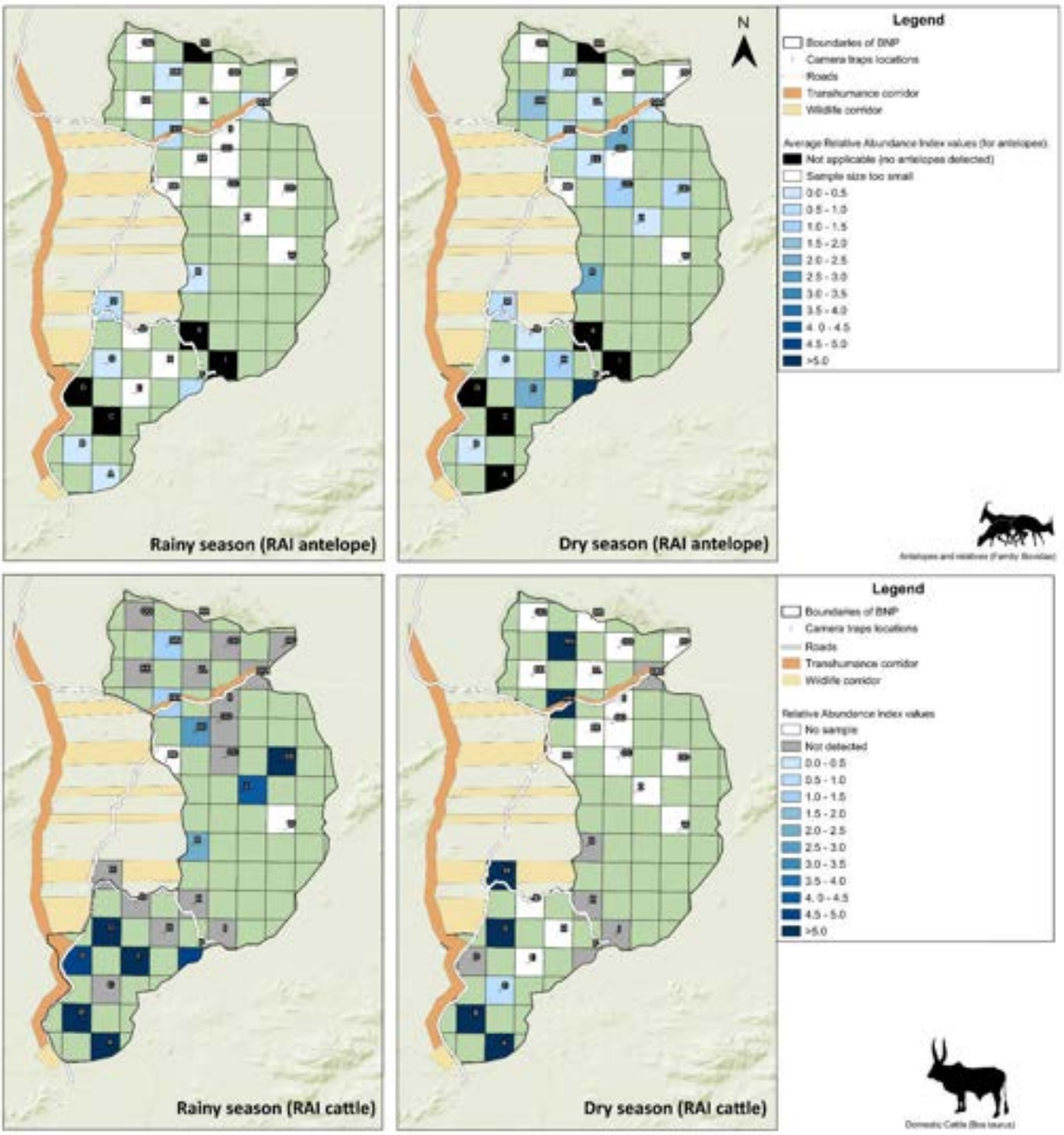

Figure A4. Mean Relative Abundance Index values for antelopes and relatives (Family: Bovidae) (top) and cattle (bottom) and during the rainy and dry seasons.

Table A1. Species diversity and relative abundance per site for rainy and dry seasons. Rainy and dry season sites that did not pass the 20 days minimal sample size effort are marked with a *and † respectively, and were not included in statistical analysis.

	Camera Effort		Shannon Diversity Index		Species Richness		Adj. species richness †		Wildlife RAI		Antelope RAI		Cattle RAI		Human RAI	
Site	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
A*†	182	67	0.69	0.00	2	0	0.01	0.00	2.20	0.00	1.10	0.00	6.59	29.85	4.40	7.46
B*†	181	67	1.30	1.15	6	6	0.03	0.09	4.42	17.91	1.66	2.99	15.47	20.90	2.21	7.46
BB	0	3	NA	1.04	NA	3	NA	1.00	NA	133.33	NA	100.00	NA	33.33	NA	0.00
C*†	175	65	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	1.54
CC*	0	73	NA	1.96	NA	8	NA	0.11	NA	19.18	NA	10.96	NA	0.00	NA	0.00
D*†	178	65	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.62	0.56	4.62
DD*	0	70	NA	1.49	NA	5	NA	0.07	NA	10.00	NA	8.57	NA	8.57	NA	1.43
E*	0	23	NA	0.00	NA	1	NA	0.04	NA	21.74	NA	21.74	NA	13.04	NA	17.39
EE*	0	36	NA	0.64	NA	2	NA	0.06	NA	5.56	NA	2.78	NA	2.78	NA	2.78
F*†	180	63	1.64	2.21	7	17	0.04	0.27	13.33	231.75	6.11	111.11	0.00	6.35	1.11	0.00
G*†	31	65	0.69	0.00	2	1	0.06	0.02	6.45	1.54	3.23	1.54	19.35	9.23	12.90	1.54
GG	0	5	NA	0.87	NA	3	NA	0.60	NA	80.00	NA	20.00	NA	20.00	NA	0.00
H*	0	60	NA	1.54	NA	7	NA	0.12	NA	18.33	NA	10.00	NA	1.67	NA	10.00
HH*†	154	89	1.97	1.80	9	8	0.06	0.09	14.29	14.61	7.14	8.99	16.88	0.00	3.25	0.00
I*†	180	101	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00
II*	0	69	NA	2.03	NA	10	NA	0.14	NA	33.33	NA	18.84	NA	0.00	NA	4.35
Jb*	0	58	NA	0.00	NA	1	NA	0.02	NA	0.00	NA	0.00	NA	0.00	NA	1.72
k*†	179	101	0.00	0.00	1	0	0.01	0.00	1.12	0.99	0.00	0.99	0.00	0.00	0.56	0.99
KK*	0	20	NA	0.95	NA	3	NA	0.15	NA	25.00	NA	15.00	NA	0.00	NA	0.00
LL	0	18	NA	0.69	NA	2	NA	0.11	NA	11.11	NA	5.56	NA	0.00	NA	0.00
M*†	129	101	1.12	0.45	4	2	0.03	0.02	6.98	3.96	4.65	0.99	20.93	3.96	16.28	13.86
MM*†	184	90	0.00	0.00	1	1	0.01	0.01	0.54	1.11	0.54	1.11	0.00	0.00	0.00	2.22
NN*†	182	89	0.67	2.08	2	8	0.01	0.09	2.75	8.99	2.75	3.37	6.59	1.12	3.30	1.12
OO	0	7	NA	0.64	NA	2	NA	0.29	NA	28.57	NA	28.57	NA	0.00	NA	0.00
PP	0	10	NA	1.39	NA	4	NA	0.40	NA	40.00	NA	20.00	NA	0.00	NA	0.00
QQ	0	10	NA	0.69	NA	2	NA	0.20	NA	20.00	NA	10.00	NA	0.00	NA	0.00
R*†	184	87	0.90	1.85	3	10	0.02	0.11	2.72	22.99	2.72	19.54	0.00	2.30	0.54	6.90

Season data continued.

	Camera Effort		Shannon Diversity Index		Species Richness		Adj. species richness †		Wildlife RAI		Antelope RAI		Cattle RAI		Human RAI	
Site	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
RR*	0	28	NA	0.00	NA	0	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00
W	0	9	NA	1.30	NA	5	NA	0.56	NA	100.00	NA	66.67	NA	11.11	NA	11.11
Z*	0	46	NA	1.10	NA	3	NA	0.07	NA	6.52	NA	4.35	NA	6.52	NA	13.04
All sites																
BeNP	2119	1595	2.39	2.63	15	27	0.01	0.02	3.87	19.00	2.12	10.28	5.29	4.45	2.55	3.89
BeNP*	2119	1533	2.39	2.62	15	26	0.01	0.02	3.87	18.00	2.12	9.65	5.29	4.44	2.55	3.98
BeNP* mean	163.00	66.65	0.69	0.84	2.85	4.04	0.02	0.06	4.21	19.28	2.30	10.56	6.65	4.82	3.51	4.28

Species richness is a count of all wild species only, excluding domestics and people; species richness adjusted for camera trapping effort is the count of all wild species recorded in a site divided by camera trapping efforts (in days). Sites that had no camera trap effort are marked as NA.