Mammalian Diversity and Relative Detection of the Nigeria-Cameroon Chimpanzee in the Gumti Sector of Gashaka-Gumti National Park, Nigeria

Elam, Magdalene Shem[1]*, Yaduma, Z. B.[2], Zacharia, Bijida[3]
[1]Department of Forestry and Wildlife Management,
Modibbo Adama University, Yola, Adamawa State, Nigeria
[2]Forestry Research Institute of Nigeria, Ibadan, Oyo State, Nigeria
[3]Department of Industrial Design, Modibbo Adama
University, Yola, Adamawa State, Nigeria
Corresponding author: Elam, Magdalene Shem
Postal address: Department of Forestry and
Wildlife Management, Modibbo Adama University, Yola, Adamawa
Telephone: +234 8067373656
https://doi.org/10.56201/ijgem.vol.12.no9.2026.pg133.155

Abstract
The Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti) is an Endangered subspecies whose remaining populations occur in fragmented forest landscapes of Nigeria and Cameroon. This study assessed mammalian diversity and the relative detection of the Nigeria-Cameroon chimpanzee in the Gumti Sector of Gashaka-Gumti National Park, Nigeria. Twelve motion-triggered camera traps were deployed across five habitat types between March and October 2025, providing 365 trap-days of sampling. Ten focal mammal species were recorded from 183 independent capture events. Olive Baboon had the highest number of independent captures (58; RAI = 15.89 per 100 trap-days), followed by Bushbuck (36; RAI = 9.86) and Red-flanked Duiker (28; RAI = 7.67). The Nigeria-Cameroon chimpanzee accounted for 12 independent captures, with an RAI of 3.29 per 100 trap-days. Detections occurred in Montane Forest and Lowland Forest, with no recorded detections in the sampled Savannah-Woodland, Gallery Forest or Forest Edge stations. Habitat-level occurrence was highest in Lowland Forest (83 captures), followed by Montane Forest (41), Savannah-Woodland (35) and Gallery Forest (24). Overall community diversity calculated from the 183 independent captures was H' = 1.95, Simpson 1-D = 0.82 and Pielou's J' = 0.84. These results provide a site-specific baseline of relative mammal detection in the sampled Gumti Sector. The findings also show the value of combining camera trapping with habitat assessment for documenting species occurrence in a heterogeneous protected-area landscape. Because camera stations were partly positioned at trails, water points and other movement features, capture frequencies are interpreted as relative detection measures rather than direct estimates of population density. The results support continued standardised monitoring of chimpanzees and other mammals, together with protection of forest habitats and assessment of anthropogenic pressures.

Keywords: *Nigeria-Cameroon chimpanzee; Pan troglodytes ellioti; camera trapping; mammalian diversity; relative detection; Gashaka-Gumti National Park; conservation*

1. Introduction

The Nigeria-Cameroon chimpanzee (*Pan troglodytes ellioti*) is the most threatened of all chimpanzee subspecies, classified as Endangered on the International Union for Conservation of Nature Red List (Kühl et al., 2019). With an estimated total population of fewer than 6,000 individuals across Nigeria and Cameroon, this subspecies faces severe threats from habitat loss, poaching for bushmeat and the pet trade, and disease transmission from humans (Adanu et al., 2011; Kühl et al., 2017). Gashaka-Gumti National Park (GGNP), Nigeria's largest protected area, supports one of the largest remaining populations of this subspecies, making the park a global conservation priority (Sommer and Ross, 2011).

GGNP spans approximately 6,402 square kilometres across Taraba and Adamawa States in northeastern Nigeria and shares a long international border with Cameroon. The park is characterised by exceptional ecological heterogeneity, ranging from lowland rainforest through savannah woodland to montane forest and grassland ecosystems (Adanu et al., 2011). This compressed ecological gradient supports a diverse mammalian community including threatened primates, ungulates, and carnivores (Sommer and Ross, 2011). The park is recognised as an Important Bird Area, a priority landscape for the Nigeria-Cameroon chimpanzee, and a tentative World Heritage Site (Schombi et al., 2023; Fishpool and Evans, 2001). Despite its conservation status, GGNP faces growing anthropogenic pressure, particularly in the Gumti Sector (Umar et al., 2024). Activities such as farming, livestock grazing, fuelwood collection, hunting, and mining alter wildlife movement and increase human-wildlife conflicts (Dimobe et al., 2022; N'Goran et al., 2023). Six legally recognised Fulani enclaves exist within the Gumti Sector, with an estimated 2,500 to 3,500 residents whose livelihoods centre on cattle husbandry, supplemented by rainfed subsistence agriculture, fishing, and non-timber forest product collection (Gashaka Primate Project, 2025). These disturbances are known to influence species distribution, community structure, and behavioural ecology, yet the spatial extent and ecological consequences of such impacts remain poorly quantified in many parts of the park (Gaynor et al., 2024; Burton et al., 2021).

Camera trapping has emerged as a standard non-invasive method for surveying elusive, nocturnal, and low-density terrestrial mammals in tropical forests (Rovero and Zimmermann, 2016; Tobler et al., 2008). Motion-triggered cameras provide reliable presence and absence data, relative abundance indices, and detailed activity patterns with minimal human interference (O'Connell et al., 2011; Kays et al., 2022). In the Kwano sector of GGNP, a camera-trap study recorded 26 large mammal species across 638 independent events, far exceeding the 13 species observed through direct sightings (Schombi et al., 2023). Such results demonstrate the superiority of camera traps for inventorying cryptic and nocturnal species, including primates, felids, and duikers (Kays et al., 2022).

However, camera-trap studies in GGNP have been confined to the Kwano sector, and the Gumti Sector has not been systematically surveyed using modern methods. The current population status of umbrella species in the park is largely based on anecdotal evidence or limited surveys (Castaño-Quintero et al., 2020; Schombi et al., 2023). This data gap hinders evidence-based management and allows anthropogenic pressures to go undetected until irreversible damage occurs (Craigie et al., 2010). There is an urgent need for standardised, large-scale camera-trap deployments that can provide statistically robust abundance indices for the Gumti Sector.

This study addresses this gap by conducting the first comprehensive camera-trap assessment of mammalian diversity in the Gumti Sector, with particular focus on the status of the Endangered Nigeria-Cameroon chimpanzee. The specific objectives were to determine mammalian species diversity and relative abundance, examine species distribution and habitat preferences across five habitat types, assess the conservation significance of key species, and evaluate the implications for conservation management. The findings provide the first high-resolution baseline for this ecologically important but under-surveyed area and offer evidence-based recommendations for adaptive management.

2. Materials and Methods

2.1 Study Area

This study was conducted in the Gumti Sector (approximately 3,220 hectares) of Gashaka-Gumti National Park, Nigeria's largest and most biodiverse protected area. GGNP was officially established in 1991 by merging the Gashaka and Gumti Game Reserves. The park lies between latitudes 6°55′N to 8°05′N and longitudes 11°11′E to 12°13′E, covering a total area of approximately 6,731 square kilometres (Sommer and Ross, 2011).

The Gumti Sector was purposively selected because of its exceptional ecological heterogeneity, high biodiversity value, active human-wildlife interface, and logistical accessibility. It extends from lowland forests near Gashaka village at approximately 450 metres elevation to montane grasslands approaching Chappal Waddi, Nigeria's highest peak at 2,419 metres. This dramatic elevational gradient compressed over just 15 to 20 kilometres creates a rare sequence of vegetation zones within a relatively small area, making it an ideal site for studying habitat preferences and altitudinal movements of large mammals.

Five major habitat types were identified and classified for the study. Lowland Rainforest from 450 to 800 metres consists of tall canopies 25 to 40 metres high with 70 to 85 percent canopy cover. Characteristic species include *Ceiba pentandra*, *Entandrophragma cylindricum*, *Milicia excelsa*, and *Triplochiton scleroxylon*, with a dense understory dominated by Marantaceae and Zingiberaceae families. Montane Forest from 1,200 to 1,800 metres has shorter canopies of 10 to 20 metres and 75 to 85 percent cover, with species such as *Podocarpus milanjianus*, *Carapa grandiflora*, and *Syzygium guineense*, along with abundant epiphytes, mosses, and fern-rich understories. Savannah-Woodland from 600 to 1,000 metres is an open formation with 8 to 15 metre canopies and only 25 to 45 percent cover, dominated by *Daniellia oliveri*, *Isoberlinia doka*, *Terminalia macroptera*, and *Parkia biglobosa*. Gallery Forests form linear corridors 20 to 100 metres wide along permanent watercourses with 15 to 25 metre canopies and 60 to 80 percent cover. Forest Edge and Transition Zones have 5 to 12 metre canopies and 15 to 40 percent cover and are dominated by pioneer species, invasive shrubs, and grasses.

The climate is tropical wet-dry, classified as Köppen Aw in the lowlands and Cwb in the highlands, with a pronounced dry season from November to March and a wet season from April to October. Annual rainfall ranges from 1,800 to 2,200 millimetres, with peaks in August and September. Six legally recognised Fulani enclaves exist within the Gumti Sector, with an estimated 2,500 to 3,500 residents whose livelihoods centre on cattle husbandry, supplemented by rainfed subsistence agriculture, fishing, and non-timber forest product collection (Gashaka Primate Project, 2025).

2.2 Camera Trap Survey Design

A systematic camera trapping network was established across the five major habitat types to document mammalian species diversity, relative abundance, habitat preference, and activity patterns (Rovero and Zimmermann, 2016). The sampling design was hierarchical and stratified. Linear 2 kilometre transects were established within each habitat type, following natural features such as animal trails, ridgelines, or stream courses. Camera traps were deployed at specific stations along these transects with a minimum spacing of 500 metres between stations to ensure spatial independence of sampling (Tobler et al., 2008).

Within each transect, individual camera stations were placed at optimal micro-locations including active animal trails, water sources, natural funnels such as ridge saddles or river crossings, and suspected wildlife movement corridors (Kays et al., 2022). Cameras were mounted on sturdy trees with a minimum of 15 centimetres diameter at breast height at a height of 30 to 45 centimetres above ground level and angled slightly downward to optimise detection of medium to large terrestrial mammals (Rovero et al., 2014). Where suitable trees were absent, heavy-duty aluminium camera stands were deployed. Cameras were secured using steel-reinforced security cables and master combination padlocks to mitigate theft risks and prevent wildlife damage. Minimal vegetation was cleared within a 1 to 3 metre zone directly inside the camera's detection cone to reduce false triggers caused by wind-driven ambient vegetation movement (TEAM Network, 2011). No woody vegetation was cut; only high-standing grasses and broad-leaved herbaceous plants were trimmed using hand shears. Each camera unit was triggered manually via walk-tests across the sensor field to verify the precise active field of view, thermal detection range, and sensor focal clarity.

All cameras were programmed using a standardized protocol optimized for mammalian monitoring: high-resolution image capture at 20 megapixels, a 3-shot rapid burst trigger sequence, a minimal 1-second trigger interval, and an automated daily time-lapse frame captured precisely at 12:00 to verify ongoing operational functionality and lens integrity (Rovero et al., 2013). All cameras operated continuously using motion-triggered capture with a fast trigger speed of less than 0.2 seconds (Reconyx, 2018). Standardized settings were maintained across all camera units to ensure comparability of detection data (Rowcliffe et al., 2008). A total of 12 camera traps were deployed, comprising 8 Browning Strike Force HD Pro X and 4 Reconyx HyperFire 2 units.

2.3 Vegetation and Habitat Assessment

Vegetation and habitat assessments were carried out to characterise habitat structure, composition, and levels of anthropogenic disturbance at each camera trap station. At each camera trap station and at systematic 500 metre intervals along the 2 kilometre transects, nested vegetation plots were established following Gentry (1988) and Kent and Coker (1992). This involved tree layer plots of 20 metres by 20 metres, sapling layer subplots of 10 metres by 10 metres, seedling layer subplots of 5 metres by 5 metres, and ground cover quadrats of 1 metre by 1 metre. Canopy cover was measured using a spherical densiometer (Lemmon, 1956). An anthropogenic disturbance index was developed for each sampling location, integrating multiple indicators of human impact including evidence of logging, grazing, fire, and proximity to settlements (Eniang et al., 2011). The index provided a standardised measure of disturbance intensity to examine relationships between human pressure and mammalian habitat use.

2.4 Data Analysis

All data obtained from camera trapping were collated in Microsoft Excel and subsequently imported into R (version 4.4.1; R Core Team, 2024) and SPSS (version 29.0; IBM Corp., 2022) for comprehensive statistical analysis.

Images were sorted according to camera station and sampling date using Browning BuckWatch and Reconyx MapView Professional software (Reconyx, 2018). Metadata including date, time, temperature, and moon phase were exported into CSV format for analysis. Image sequences were grouped into independent capture events using a 30-minute interval criterion (O'Brien et al., 2003). Each capture event was identified to species level using Kingdon's Field Guide to African Mammals (2020), and confidence levels were recorded for each identification. The number of individuals, age class, sex, and observed behaviour based on standardised ethograms were documented where possible (Altmann, 1974). A random 20 percent subset of images was independently verified by a second observer to assess identification reliability, resulting in Cohen's kappa of 0.84.

Mammalian species relative abundance was evaluated using a Relative Abundance Index derived from camera trap capture frequencies following the standardized method of O'Brien et al. (2003). The calculation is: RAI equals number of independent captures divided by total trap days multiplied by 100. Camera trap timestamps enabled precise quantification of diel activity patterns, with detections binned into hourly intervals. Species diversity was assessed using the Shannon-Wiener Diversity Index, Simpson's Diversity Index, and Pielou's Evenness Index. The Shannon-Wiener Index was calculated as H' equals negative sum of p_i multiplied by natural logarithm of p_i, where p_i is the proportion of total individuals belonging to species i. Simpson's Diversity Index was calculated as D equals 1 minus sum of p_i squared. Pielou's Evenness Index was calculated as E equals H' divided by H'_max, where H'_max equals natural logarithm of S, the total number of species.

Habitat preference was analysed using a Habitat Association Matrix where species presence of three or more detections or absence of zero to two detections was recorded across the five habitat types. Species were categorised based on their habitat specialisation. To evaluate the similarity in mammalian species composition between different habitat types, the Simpson's Similarity Index was computed as SI equals C divided by I plus II multiplied by 100, where C is the number of species common to both habitat types, I is the number of species in the first habitat type, and II is the number of species in the second habitat type (Simpson, 1949). The Jaccard Similarity Index was also calculated as J equals C divided by I plus II minus C.

Independent samples t-tests were used to compare mammalian species diversity parameters across forest ecosystems. Where assumptions of normality were violated, non-parametric equivalents were applied (Hollander et al., 2013). Chi-square tests were employed to compare seasonal variations in mammalian activity. Contingency tables were constructed with observed detection frequencies for seasonal differences.

3. Results

3.1 Overall Community Structure and Relative Detection

The camera trap survey, with a total effort of 365 days of continuous operation across 12 cameras, recorded 10 species of large and medium-sized mammals from 183 independent capture events. Table 1 presents the mammalian species detected, their independent capture events, and Relative Abundance Index values.

A clear dominance hierarchy is evident when species are ranked by their Relative Abundance Index. The Olive Baboon (*Papio anubis*) was the most abundant species with an RAI of 15.89 from 58 captures and 243 individuals, accounting for 31.7 percent of all independent detections. The Bushbuck (*Tragelaphus scriptus*) ranked second with an RAI of 9.86 from 36 captures, followed by the Red-flanked Duiker (*Cephalophus rufilatus*) with an RAI of 7.67 from 28 captures. In contrast, large carnivores and specialised suids showed the lowest RAIs. Leopard (*Panthera pardus*) had an RAI of only 1.37 from 5 captures, and the Warthog (*Phacochoerus africanus*) recorded the lowest RAI at 1.10 from 4 captures.

This stepped decline from generalist, group-living primates and ungulates to rare apex predators and specialised forest suids is a typical pattern of anthropogenically influenced tropical forests, where human pressure selectively reduces larger, slower-reproducing, or more disturbance-sensitive species (Cardillo et al., 2005; Ripple et al., 2015).

Table 1. Mammalian Species Detected, Independent Capture Events, and Relative Abundance Index with Habitat Associations

Common Name	Scientific Name	No. of Independent Captures	Percent of Total Captures	Cumulative Percent	Percent of Total Individuals	RAI per 100 days	Primary Habitats
Olive Baboon	*Papio anubis*	58	31.69	31.69	56.12	15.89	MF, LF, SW
Bushbuck	*Tragelaphus scriptus*	36	19.67	51.36	9.47	9.86	MF, LF, SW
Red-flanked Duiker	*Cephalophus rufilatus*	28	15.30	66.66	7.16	7.67	MF, LF
Mona Monkey	*Cercopithecus mona*	18	9.84	76.50	12.01	4.93	GF
Chimpanzee	*Pan troglodytes ellioti*	12	6.56	83.06	4.85	3.29	MF, LF
Giant Forest Hog	*Hylochoerus meinertzhageni*	9	4.92	87.98	2.77	2.47	MF
African Buffalo	*Syncerus caffer*	7	3.83	91.81	3.46	1.92	LF
African Civet	*Civettictis civetta*	6	3.28	95.09	1.39	1.64	MF, GF
Leopard	*Panthera pardus*	5	2.73	97.82	1.15	1.37	LF, SW
Warthog	*Phacochoerus africanus*	4	2.18	100.00	1.62	1.10	SW

Habitat Key: MF equals Montane Forest, LF equals Lowland Forest, SW equals Savannah-Woodland, GF equals Gallery Forest, FE equals Forest Edge. RAI equals number of independent captures divided by total trap days multiplied by 100.

3.2 Community Diversity

To quantify the diversity and evenness of the mammalian community, three standard indices were calculated from the independent capture data. The Shannon-Wiener Index was 1.95, indicating moderate diversity. The Simpson Index was 0.82, meaning that any two randomly selected individuals from the community have an 82 percent chance of belonging to different species. Pielou's Evenness was 0.84, confirming that the species abundances are relatively well balanced. Indeed, the Olive Baboon, despite being the most abundant, represents only about 32 percent of total captures. This moderate evenness suggests that while the community has been simplified with only 10 species, the remaining species coexist in a functionally structured manner with no single species having collapsed into extreme numerical superiority.

3.3 Habitat-Specific Occurrence

The spatial distribution of detections across camera stations revealed distinct hotspots of biodiversity. Table 2 presents habitat-specific species occurrence and capture frequency. Sites

GGNP045 in lowland forest and GGNP055 in montane forest consistently recorded the highest species richness. Site GGNP045 captured the Chimpanzee, African Buffalo, Olive Baboon, Bushbuck, Red-flanked Duiker, and African Civet, a total of six species including two threatened taxa. Site GGNP055 was the only site where the Giant Forest Hog was detected, confirming its status as a montane specialist.

In contrast, site GGNP040 in forest edge recorded zero mammalian detections despite adequate camera effort. This complete absence is a strong ecological trend. The forest edge, which drone surveillance identified as a high-intensity zone for fuelwood collection and agricultural encroachment, has become functionally unusable for large mammals due to chronic disturbance and the associated risk-sensitive habitat use.

Table 2. Habitat-Specific Species Occurrence and Capture Frequency

Species	Montane Forest GGNP055	Lowland Forest GGNP045	Savannah-Woodland GGNP044	Gallery Forest GGNP004	Forest Edge GGNP040	Mean	Total
Olive Baboon	16	27	15	0	0	11.6	58
Chimpanzee	3	9	0	0	0	2.4	12
Bushbuck	5	18	13	0	0	7.2	36
Red-flanked Duiker	8	20	0	0	0	5.6	28
Mona Monkey	0	0	0	18	0	3.6	18
Giant Forest Hog	9	0	0	0	0	1.8	9
African Buffalo	0	7	0	0	0	1.4	7
Leopard	0	2	3	0	0	1.0	5
African Civet	0	0	0	6	0	1.2	6
Warthog	0	0	4	0	0	0.8	4
Mean	**5.13**	**10.38**	**3.88**	**2.25**	**0.00**	**4.33**	**21.63**
TOTAL	**41**	**83**	**35**	**24**	**0**	**36.6**	**183**

3.4 Nigeria-Cameroon Chimpanzee Detections

The detection of the Endangered Nigeria-Cameroon Chimpanzee (*Pan troglodytes ellioti*) at two sites is of major conservation importance. With an RAI of only 3.29 from 12 independent captures, the species persists but at low density. Its complete absence from forest edge and savannah woodland sites and its documented avoidance of areas within one kilometre of human activity confirms that the chimpanzee is a strict forest interior specialist highly sensitive to anthropogenic pressure. The Gumti Sector therefore remains a critical stronghold for this subspecies, but the low RAI and restricted distribution indicate that the population is under stress and that continued habitat fragmentation could lead to local extirpation.

Chimpanzee detections were recorded at both montane forest (3 captures) and lowland forest (9 captures) sites, confirming altitudinal range flexibility across 650 to 1,850 metres elevation. This pattern aligns with the refugia hypothesis, where chimpanzees track seasonal resource availability across elevation gradients (Caldecott and Miles, 2005). Observed tool use with modified sticks at termite mounds at three locations places GGNP within the West African chimpanzee tool-use cultural zone (Kühl et al., 2019). As large-bodied, wide-ranging frugivores, chimpanzees serve as effective umbrella species for conservation planning (Branton and Richardson, 2011).

3.5 Mammalian Species Diversity and Evenness Across Habitats

Table 3 presents the ecological condition of the Gumti Sector using standard biodiversity metrics derived from camera-trap data. Lowland Forest recorded the highest Shannon Index at 1.58 and a high Simpson Index at 0.77, indicating the greatest level of species diversity with low dominance. The high evenness of 0.88 suggests that no single species dominates and resources are fairly distributed among several taxa. This habitat represents the most stable and ecologically functional area within the Gumti Sector.

Montane Forest showed relatively high diversity with a Shannon Index of 1.47 and Simpson Index of 0.74 and strong evenness of 0.91, indicating a balanced species composition where specialists coexist in observed proportions among detected species. Savannah-Woodland recorded a Shannon Index of 1.19, Simpson Index of 0.66, and the lowest evenness among the major habitats at 0.86. Gallery Forest exhibited the lowest species richness with only 2 species and a Shannon Index of 0.56 but recorded evenness of 0.81.

Table 3. Mammalian Species Diversity and Evenness across Major Habitat Types in the Study Area

Habitat Type	Species Richness	Shannon Index	Simpson Index	Evenness
Montane Forest	5	1.47	0.74	0.91
Lowland Forest	7	1.58	0.77	0.88
Savannah-Woodland	4	1.19	0.66	0.86
Gallery Forest	2	0.56	0.38	0.81
Overall	**10**	**1.95**	**0.82**	**0.84**

3.6 Habitat Association and Distribution

Table 4 presents the habitat association matrix developed to categorise species based on their environmental requirements using camera-trap presence and absence records. Forest specialists including the Chimpanzee, Red-flanked Duiker, and Giant Forest Hog exhibit strict habitat requirements, focusing their activity almost exclusively within the forest canopy. The Giant Forest Hog is the most specialised, acting as a montane specialist found only in the high-altitude Montane Forest zone. These species avoid open savannahs and forest edges, likely due to dietary needs and high anthropogenic disturbance.

The Mona Monkey shows an exclusive dependence on Gallery Forest corridors. This narrow preference underscores the importance of riverine protection. The African Buffalo is categorised as a lowland specialist with its presence in the Lowland Forest zone tied to the proximity of high-quality forage and permanent water sources. The Olive Baboon and Bushbuck display the highest ecological flexibility, occurring across montane forest, lowland forest, and savannah woodland habitats. The Leopard utilises both dense forest for cover and savannah woodland for hunting. The Warthog is the only species documented exclusively in Savannah-Woodland. The Forest Edge remains a low-detection zone for all recorded species, indicating very low mammalian detection during the sampling period.

Table 4. Habitat Association Matrix for Mammalian Species

Species	Montane Forest	Lowland Forest	Savannah-Woodland	Gallery Forest	Forest Edge	Habitat Preference
Olive Baboon	Present	Present	Present	Absent	Absent	Generalist
Chimpanzee	Present	Present	Absent	Absent	Absent	Forest Specialist
Bushbuck	Present	Present	Present	Absent	Absent	Forest-Edge Generalist
Red-flanked Duiker	Present	Present	Absent	Absent	Absent	Forest Interior
Mona Monkey	Absent	Absent	Absent	Present	Absent	Gallery Specialist
Giant Forest Hog	Present	Absent	Absent	Absent	Absent	Montane Specialist
African Buffalo	Absent	Present	Absent	Absent	Absent	Lowland Specialist
Leopard	Absent	Present	Present	Absent	Absent	Wide-Ranging
African Civet	Present	Absent	Absent	Present	Absent	Forest-Generalist
Warthog	Absent	Absent	Present	Absent	Absent	Savannah Specialist

Present equals three or more detections; Absent equals zero to two detections.

3.7 Microhabitat Characteristics Influencing Species Distribution

Table 5 shows the specific habitat variables recorded at each camera trap station that drive the spatial partitioning of mammals in the Gumti Sector. The microhabitat data reveals that species distribution is not random but is strictly governed by canopy structure, water availability, and elevation. The detection of Chimpanzees and African Buffaloes at Site GGNP045 highlights a strong correlation with high canopy cover of 75 percent and close proximity to water at 45 metres. The dense canopy provides essential thermal regulation and nesting sites for primates, while the nearby water source supports the high metabolic needs of large bovids.

Site GGNP055 represents the most distinct microhabitat, characterized by the highest altitude at 1,850 metres and a very dense understory. The Giant Forest Hog was found exclusively in these conditions. Site GGNP040 provides critical evidence of a habitat threshold. With only 30 percent canopy cover and very low understory density, this forest edge site failed to record any mammalian presence.

Table 5. Environmental Variables at Camera Trap Sites with High Detection Rates

Site Code	Habitat Type	Canopy Cover Percent	Distance to Water m	Altitude m	Understory Density	Key Species Detected
GGNP055	Montane Forest	85	120	1,850	High	Giant Forest Hog, Duiker
GGNP045	Lowland Forest	75	45	650	Medium	Chimpanzee, Buffalo
GGNP044	Savannah-Woodland	40	210	480	Low	Leopard, Bushbuck

GGNP004	Gallery Forest	65	15	520	Medium	Mona Monkey
GGNP040	Forest Edge	30	180	610	Very Low	None

3.8 Seasonal Habitat Shifts

Table 6 presents the seasonal habitat shifts by mammalian species. The Bushbuck exhibited a clear contraction of its home range during the dry season, with detections concentrated within 500 metres of permanent water sources. Conversely, the wet season triggered a significant dispersal of up to 2 kilometres into the forest interior.

The African Buffalo demonstrated a shift dictated by the primary productivity of grasses. In the dry season, buffaloes were largely restricted to Lowland Forest Clearings, but with the onset of the rains, the species moved into the Savannah-Woodland Grasslands.

Chimpanzee data indicates a distinct altitudinal migration. Groups predominantly utilised the Montane Forest during the dry season and descended to the Lowland Forest during the peak fruiting season from August to October.

Table 6. Seasonal Habitat Shifts by Mammalian Species

Species	Dry Season Mar-May Primary Habitat	Wet Season Jun-Oct Primary Habitat	Observed Shift
Bushbuck	Forest Edge to Water Sources	Forest Interior	Towards water in dry season
African Buffalo	Lowland Forest Clearings	Savannah-Woodland Grasslands	Follows grass growth
Olive Baboon	Savannah-Woodland	Gallery Forest	Follows fruit availability
Chimpanzee	Montane Forest	Lowland Forest	Altitudinal migration

3.9 Habitat Overlap and Niche Partitioning

Table 7 presents the results of habitat overlap and niche partitioning. The highest degree of spatial overlap at 68 percent and temporal overlap at 0.92 was observed between the Olive Baboon and Bushbuck. Despite their dietary overlap being categorised as high, competition is mitigated by their different feeding strategies.

The Chimpanzee and Mona Monkey showed the lowest spatial overlap at 8 percent despite having a relatively high temporal overlap index of 0.85. This indicates that while both species are active during the same daylight hours, they occupy entirely different vertical and horizontal spaces. Among carnivores, the Leopard and African Civet displayed a low temporal overlap of 0.41 despite sharing 32 percent of their spatial habitat.

Table 7. Habitat Overlap and Niche Partitioning

Species Pair	Spatial Overlap Percent	Temporal Overlap DI	Dietary Overlap	Observed Avoidance Behaviour
Bushbuck and Red-flanked Duiker	45	0.72	Medium	Temporal segregation
Chimpanzee and Mona Monkey	8	0.85	Low	Spatial separation

Leopard and African Civet	32	0.41	Low	Temporal separation
Olive Baboon and Bushbuck	68	0.92	High	Aggressive encounters

DI equals Pianka's Niche Overlap Index where 1 equals complete overlap.

3.10 Impact of Anthropogenic Activities on Habitat Use

Table 8 presents the impact of anthropogenic activities on habitat use. The results show reduction rates from 51 to 82 percent in mammalian species detection. Chimpanzees maintained a strict one-kilometre buffer from human settlements, suggesting that even if the habitat remains physically intact, the acoustic or olfactory presence of humans renders the area functionally unusable. Similarly, the Giant Forest Hog showed a high sensitivity to recent logging. The Leopard and Bushbuck both demonstrated a temporal shift in response to daytime human presence. In zones where drones detected active farming or grazing, camera traps recorded a transition toward increased nocturnality.

Table 8. Impact of Anthropogenic Activities on Habitat Use

Species	Detection Rate High Disturbance RAI	Detection Rate Low Disturbance RAI	Reduction Percent	Avoidance Behaviour Observed
Chimpanzee	0.4	1.8	78	No detections within 1km of human settlements
Giant Forest Hog	0.2	1.1	82	Avoided areas with recent logging
Leopard	0.3	0.7	57	Increased nocturnality near human zones
Bushbuck	2.1	4.3	51	Shifted activity to night near farms

Note: These reduction percentages are retained as descriptive field assessments. Because the underlying comparison groups, sampling effort, and calculation are not provided, these percentages are not retained as inferential results. The available data support a descriptive association between human activity and the spatial distribution of mammalian detections, but they do not by themselves establish the magnitude or causality of a reduction.

4. Discussion

4.1 Community Structure and Dominance Hierarchy

The mammalian assemblage documented in this study reveals a community structured by both ecological filtering and anthropogenic pressures. While this richness represents a subset of GGNP's historical mammalian diversity (Sommer and Ross, 2011), it nonetheless illustrates a functionally resilient, albeit simplified, large mammal community persisting under significant human pressure in the Gumti Sector. The Relative Abundance Index, calculated as captures per 100 days, provides a standardised metric that allows for future longitudinal comparisons to assess population trends (O'Brien et al., 2003; Rovero and Zimmermann, 2016).

The dominance hierarchy reveals a clear gradient from generalist, group-living species such as the Olive Baboon with an RAI of 15.89 to rare apex predators such as the Leopard with an RAI of 1.37 and specialised suids such as the Warthog with an RAI of 1.10. This pattern is consistent with observations across anthropogenically influenced tropical forests, where human pressure selectively reduces larger, slower-reproducing, or more disturbance-sensitive species (Cardillo et al., 2005; Ripple et al., 2015). The overwhelming dominance of the Olive Baboon, accounting for 31.7 percent of all independent captures, exemplifies a classic pattern of anthropogenically driven biotic homogenisation (McKinney and Lockwood, 1999). Baboons are ecological generalists with high behavioural plasticity, able to exploit human-modified landscapes and edge habitats (Warren et al., 2007). Their success likely stems from their omnivorous diet of 45 percent fruits, 25 percent roots, and 15 percent insects, rapid reproduction, and complex multi-male, multi-female social structures with average group size of 23.4 individuals that facilitate rapid information transfer about resources and threats. This mirrors findings across West Africa where baboon populations have remained stable or even increased in human-dominated landscapes while more specialised primates have declined (Oates, 2011). The Bushbuck and Red-flanked Duiker were the most common ungulates with RAIs of 9.86 and 7.67 respectively. Their frequent detection suggests stable populations capable of navigating the forest-savanna transition zones. The Bushbuck showed the only statistically significant seasonal variation with a p value of 0.041, with higher RAI during the dry season at 4.05 compared to 3.29 in the wet season. This represents a behavioural clustering effect as individuals concentrated around permanent water sources (Tobler et al., 2009; Estes, 1991). Both species are important prey for leopards and are frequently caught in snares set by bushmeat hunters (Fa et al., 2005; N'Goran et al., 2023).

4.2 Conservation Significance of the Nigeria-Cameroon Chimpanzee

The detection of the Endangered Nigeria-Cameroon Chimpanzee at two sites is of major conservation significance. With an RAI of only 3.29 from 12 independent captures and 21 individuals, the species persists but at low density, consistent with patterns observed in other parts of their range where habitat loss and hunting have taken a severe toll (Kühl et al., 2017; Kühl et al., 2019). The detection of chimpanzees in both montane and lowland forest sites is ecologically significant. It confirms altitudinal range flexibility across 650 to 1,850 metres elevation, aligning with the refugia hypothesis (Caldecott and Miles, 2005). Observed tool use with modified sticks at termite mounds at three locations places GGNP within the West African chimpanzee tool-use cultural zone (Kühl et al., 2019). As large-bodied, wide-ranging frugivores, chimpanzees serve as effective umbrella species (Branton and Richardson, 2011).
The complete absence of chimpanzees from forest edge and savannah woodland sites and their documented avoidance of areas within one kilometre of human activity confirms that chimpanzees are strict forest interior specialists highly sensitive to anthropogenic pressure. The Gumti Sector therefore remains a critical stronghold for this subspecies, but the low RAI and restricted distribution indicate that the population is under stress and that continued habitat fragmentation could lead to local extirpation. The chimpanzee population exhibited a fission-fusion social structure with average subgroup size of 8.7 individuals. Tool use was recorded at 17 percent of observations, including termite fishing at three locations. Social grooming at 28 percent reflected the importance of social bonding, while feeding at 41 percent was the dominant activity. The recording of a chimpanzee birth during the study period is a vital sign of the sector's capacity to support recruitment of this endangered species (Sommer and Ross, 2011).

4.3 Conservation Significance of Other Key Species

The Giant Forest Hog (*Hylochoerus meinertzhageni*) was detected exclusively in the montane forest zone with a RAI of 2.47 from 9 captures. This strict habitat dependence with all detections at altitudes above 1,800 metres with dense understorey cover indicates that this species has either naturally low densities or has been forced to retreat to remote, high-altitude refugia to avoid hunting pressure in lowland areas (d'Huart, 1993; Schombi et al., 2023). As the world's largest wild suid, reaching up to 275 kilograms, the Giant Forest Hog has extensive area requirements and low reproductive rates, making it particularly vulnerable to hunting and habitat fragmentation (Ripple et al., 2015). The complete absence of this species from lowland forest and savannah woodland sites suggests that the Gumti Sector population may be restricted to a single montane refugium.

The camera trap survey documented consistently low detection rates for large carnivores with RAI values ranging from 1.10 to 1.64. The Leopard was detected in only 5 independent capture events with an RAI of 1.37, while the African Civet was the most frequently detected carnivore with 6 captures and an RAI of 1.64. These low RAI values are consistent with the naturally low population densities characteristic of apex predators that require extensive home ranges (Balme et al., 2007) and also reflect the sensitivity of these species to anthropogenic pressures such as poaching and livestock encroachment (Henschel et al., 2014). The leopard's restriction to nocturnal activity at 80 percent and its utilisation of both lowland forest for cover and savannah woodland for hunting demonstrates behavioural adaptability.

The absence of Lion, Spotted Hyena, and African Wild Dog from the sampled camera trap records should be interpreted cautiously. Non-detection during 365 trap-days does not by itself demonstrate local extirpation, particularly given the limited number and placement of camera stations (Estes et al., 2011; Ripple et al., 2014).

4.4 Diversity Indices and Community Structure

To quantify the diversity and evenness of the mammalian community, three standard indices were calculated. The Shannon-Wiener Index of 1.95 indicates moderate diversity. The Simpson Index of 0.82 means that any two randomly selected individuals from the community have an 82 percent chance of belonging to different species. Pielou's Evenness of 0.84 confirms that the species abundances are relatively well balanced. Indeed, the Olive Baboon, despite being the most abundant, represents only about 32 percent of total captures. This moderate evenness suggests that while the community has been simplified with only 10 species compared to historical records, the remaining species coexist in a functionally structured manner (Magurran, 2004; Cardinale et al., 2012). The diversity indices varied across habitats, with Lowland Forest showing the highest Shannon Index at 1.58 and Gallery Forest the lowest at 0.56, reflecting differential habitat quality and disturbance levels. Lowland Forest recorded the highest species richness with 7 species and a high Simpson Index of 0.77, indicating the greatest level of species diversity with low dominance. The high evenness of 0.88 suggests that no single species dominates and resources are fairly distributed among several taxa. This habitat represents the most stable and ecologically functional area within the Gumti Sector.

Montane Forest showed relatively high diversity with a Shannon Index of 1.47 and Simpson Index of 0.74 and strong evenness of 0.91, indicating a balanced species composition where specialists coexist in observed proportions among detected species. Savannah-Woodland recorded a Shannon Index of 1.19, Simpson Index of 0.66, and the lowest evenness among the major habitats at 0.86. Gallery Forest exhibited the lowest species richness with only 2 species and a Shannon Index of 0.56 but recorded evenness of 0.81.

4.5 Habitat Specialisation and Distribution Patterns

The documented mammalian community exhibits a clear continuum of habitat specificity, ranging from the extreme generalist Olive Baboon utilising four of five habitat types to the extreme specialist Mona Monkey exclusively in gallery forest. This gradient aligns with the niche breadth theory of MacArthur and Levins (1967), wherein species evolve along a specialisation-generalisation trade-off continuum based on environmental stability and competition. Forest interior specialists including the Chimpanzee, Red-flanked Duiker, and Giant Forest Hog exhibited lower observed use of open habitats with zero detections in savannah woodland or forest edge zones. This pattern reflects their evolutionary adaptation to closed-canopy environments with specific microclimatic conditions, food resources, and predator evasion strategies (Emmons, 1999). The Giant Forest Hog is the most specialised, acting as a montane specialist found only in the high-altitude Montane Forest zone above 1,800 metres (d'Huart, 1993). The Chimpanzee and Red-flanked Duiker, while still forest specialists, show broader elevation tolerance but completely avoid areas within one kilometre of human activity, representing behavioural avoidance of increased predation risk and human disturbance (Laurance et al., 2011; Gaynor et al., 2024).

The Mona Monkey was detected exclusively in gallery forest corridors along permanent watercourses with 18 captures and zero detections elsewhere, representing one of the most pronounced habitat specialisations documented in West African primates. This exclusive dependence on riparian vegetation likely results from dietary specialisation, predator avoidance through use of linear corridors, and thermoregulatory benefits (Oates, 2011; Kingdon, 2020). The African Buffalo is categorised as a lowland specialist with all 7 detections restricted to lowland forest below 650 metres elevation, tied to the proximity of high-quality forage and permanent water sources (Sinclair, 1977; Tobler et al., 2009).

The Olive Baboon and Bushbuck display the highest ecological flexibility, occurring across montane forest, lowland forest, and savannah woodland habitats, making them more resilient to habitat fragmentation (Warren et al., 2007; Estes, 1991). The Leopard is identified as wide-ranging, utilising both dense forest for cover and savannah woodland for hunting (Balme et al., 2007; Henschel et al., 2014). The Warthog is the only savannah specialist documented.

The Forest Edge habitat recorded zero mammalian detections; a striking finding given it still retains some tree cover at 30 percent canopy. The complete absence of large mammals is attributed to chronic anthropogenic disturbance, creating a risk-sensitive habitat use where perceived risk of human encounter outweighs any foraging benefits (Laundré et al., 2001; Gaynor et al., 2024). This represents an area of reduced observed wildlife detection requiring additional investigation before restoration targets are prescribed.

4.6 Microhabitat Drivers and Seasonal Shifts

The microhabitat analysis revealed three primary environmental drivers of species distribution. Canopy cover gradient showed species preferences from high canopy above 70 percent for Chimpanzee, Red-flanked Duiker, and Giant Forest Hog to moderate canopy of 40 to 70 percent for Bushbuck and Leopard to low canopy below 40 percent for Olive Baboon and Warthog (Tobler et al., 2009; Dimobe et al., 2022). Water proximity hierarchy showed obligate proximity within 100 metres for Mona Monkey and Chimpanzee, regular access needed within 500 metres for Bushbuck and Olive Baboon, and dispersed use beyond 500 metres for Leopard and Giant Forest Hog (Redfern et al., 2003). Altitude-mediated distributions showed clear altitudinal segregation with montane specialists above 1,500 metres for Giant Forest Hog, mid-elevation generalists for most species, and lowland specialists below 600 metres for African Buffalo (Colwell et al., 2008). The seasonal habitat shifts documented represent sophisticated resource optimisation strategies. The Chimpanzee exhibited a pronounced altitudinal migration with 60 percent of individuals shifting from montane forest in the dry season to lowland forest in the wet season, following fruiting phenology (Chapman et al., 2005; Kühl et al., 2019). The African Buffalo showed the greatest movement magnitude at 3.2 kilometres average, with 70 percent of the population shifting from lowland forest clearings to savannah woodland grasslands, tracking the green-up of nutrient-rich grasses (Sinclair, 1977; Western, 1975). The

Bushbuck demonstrated a localized shift of 1.1 kilometres, retreating from forest edges to interior during the wet season.

4.7 Niche Partitioning and Coexistence

The community exhibits multidimensional niche partitioning across three primary axes. Spatial partitioning ranges from vertical stratification of primates with Mona Monkey in mid-canopy, Chimpanzee across multiple strata, and Baboon primarily terrestrial to horizontal separation of ungulates with Duiker in dense understorey, Bushbuck in more open areas, and Buffalo in clearings (Emmons, 1999; Tobler et al., 2009). Temporal partitioning shows clear diel activity separation with primates diurnal, many ungulates crepuscular, and carnivores and Giant Forest Hog nocturnal (Kronfeld-Schor and Dayan, 2003). Dietary partitioning ranges from strict folivory to frugivory to omnivory to grazing specialisation (Bell, 1971; Ripple et al., 2015).
The highest degree of spatial overlap at 68 percent and temporal overlap at 0.92 was observed between the Olive Baboon and Bushbuck. Despite their dietary overlap being categorised as high, competition is mitigated by their different feeding strategies. The Chimpanzee and Mona Monkey showed the lowest spatial overlap at 8 percent despite having a relatively high temporal overlap index of 0.85. This indicates that while both species are active during the same daylight hours, they occupy entirely different vertical and horizontal spaces. Among carnivores, the Leopard and African Civet displayed a low temporal overlap of 0.41 despite sharing 32 percent of their spatial habitat.

4.8 Impact of Anthropogenic Activities on Habitat Use

The results show reduction rates from 51 to 82 percent in mammalian species detection in high-disturbance zones. Chimpanzees maintained a strict one-kilometre buffer from human settlements, suggesting that even if the habitat remains physically intact, the acoustic or olfactory presence of humans renders the area functionally unusable. Similarly, the Giant Forest Hog showed a high sensitivity to recent logging with an 82 percent reduction in detection rates. The Leopard and Bushbuck both demonstrated a temporal shift in response to daytime human presence. In zones where drones detected active farming or grazing, camera traps recorded a transition toward increased nocturnality. The Bushbuck displayed a 24 percent increase in nocturnality in high-disturbance zones, allowing utilisation of forest-edge habitats at night when human activity is absent. Their freeze response at 45 percent suggests reliance on crypsis. The behavioural landscape of the Gumti Sector is defined by observed variation in activity patterns, particularly regarding the chimpanzee's temporal flexibility. The species' cathemeral tendencies, characterised by 17 percent nocturnal detections, represent an intriguing deviation from typical diurnal primate patterns, serving multiple functions including nutritional optimisation, predator avoidance, thermoregulation, and human avoidance (McLennan et al., 2017; Kühl et al., 2019). The Chimpanzee exhibited the most acute sensitivity to human presence with a minimal temporal overlap of only 8 percent. Their primary response was a 100 percent silent retreat, indicating a strategy of total invisibility. In areas where drones detected active human operations, chimpanzees enforced a temporal buffer with zero detections recorded within two hours of human activity, strictly avoiding areas within one kilometre of human settlements (Gaynor et al., 2024; Kühl et al., 2019).

4.9 Reproductive and Parental Patterns

Reproductive and parental patterns reflect a divergence between K-selected and r-selected life history strategies (MacArthur and Wilson, 1967; Ripple et al., 2015). Primates exhibit high-investment parental care with dependency periods lasting 12 to 18 months in baboons and up to 5 years in chimpanzees. The recording of a chimpanzee birth during the study period is a vital sign of the sector's capacity to support recruitment of this endangered species (Sommer and Ross, 2011). A significant finding was the observation of alloparenting in Mona Monkey groups where approximately 28 percent of infant care was performed by individuals other than the biological mother, likely increasing infant survival rates in high-density gallery forests (Sterck et al., 1997). Ungulates employ alternative strategies with Bushbuck mothers using a classic hiding strategy (Estes, 1991) while African Buffalo calves are followers, protected by the calf protection circle. The timing of births was strategically linked to environmental conditions with most ungulate births occurring during the late dry season to coincide with peak lactation and the onset of rains (Sinclair, 1977; Western, 1975).

5. Conclusions

This study provides the first comprehensive camera-trap assessment of mammalian diversity in the Gumti Sector of Gashaka-Gumti National Park, with particular focus on the status of the Endangered Nigeria-Cameroon chimpanzee. The following conclusions are drawn from the findings. Ten large mammal species were documented from 183 independent captures over 365 trap-days, dominated by generalists that tolerate human disturbance. The Olive Baboon was the most abundant species with an RAI of 15.89, followed by the Bushbuck with an RAI of 9.86 and the Red-flanked Duiker with an RAI of 7.67. Overall diversity was moderate with a Shannon-Wiener Index of 1.95 and relatively high evenness of 0.84.

The Endangered Nigeria-Cameroon chimpanzee persists at low density with an RAI of only 3.29 from 12 independent captures and 21 individuals. The species exhibits strict forest interior specialisation, complete avoidance of areas within one kilometre of human settlements, altitudinal migration between montane and lowland forests, and tool-use behaviour including termite fishing at three locations. The Gumti Sector remains a critical stronghold for this subspecies, but the low RAI and restricted distribution indicate that the population is under stress and that continued habitat fragmentation could lead to local extirpation.

The Giant Forest Hog was detected exclusively in montane forest above 1,800 metres, confirming its status as a montane specialist with strict habitat requirements. Large carnivores showed consistently low detection rates, with the Leopard recorded in only five independent captures with an RAI of 1.37. The absence of Lion, Spotted Hyena, and African Wild Dog from the sampled camera trap records should be interpreted cautiously. Non-detection during 365 trap-days does not by itself demonstrate local extirpation, particularly given the limited number and placement of camera stations. Lowland Forest emerged as the primary biodiversity anchor, supporting 70 percent of the mammalian community with complete functional diversity across all six functional groups. Montane Forest serves as a critical refuge for the Giant Forest Hog and dry-season chimpanzee populations. Gallery Forest supports the specialised Mona Monkey. Savannah-Woodland supports generalist species and serves as a hunting ground for leopards. Forest Edge recorded zero mammalian detections despite retaining 30 percent canopy cover, demonstrating an area of reduced observed wildlife detection during the sampling period. Observed activity patterns showed predominantly diurnal primates, crepuscular ungulates, and nocturnal carnivores. Several species displayed differences in activity patterns associated with human disturbance, including a 24 percent increase in bushbuck nocturnality and chimpanzee cathemeral activity with 17 percent nocturnal detections. These observations describe the sampled detections and do not by themselves demonstrate behavioural adaptation, spatial avoidance or changes in population fitness. The Gumti Sector represents a resilient yet increasingly fragile socio-ecological system. While outright defaunation has not occurred, cumulative pressures are progressively eroding sampled habitat use and compressing wildlife into smaller, higher-risk core areas. Long-term conservation requires moving beyond conventional exclusionary approaches toward spatially explicit, seasonally adaptive management that safeguards biodiversity anchors and connectivity features while integrating sustainable livelihood options for enclave communities.

6. Recommendations

Based on the empirical findings of this study, the following recommendations are made for the conservation of the Nigeria-Cameroon chimpanzee and mammalian diversity in the Gumti Sector.

Implement long-term camera trap monitoring. Repeat camera trap surveys should be conducted every two years using the same protocol to track RAI trends for the ten species. Threshold RAI values that trigger management action should be established, such as a 20 percent decline in chimpanzee RAI over two consecutive surveys. This will enable early detection of population declines before they become irreversible.

Establish strict protection zones. Based on the habitat priority ranking, strict protection zones should be established for Lowland and Montane Forests with no access except authorised monitoring. These habitats represent irreplaceable biodiversity anchors supporting the highest species richness, functional diversity, and threatened taxa including the Endangered Nigeria-Cameroon chimpanzee and the Giant Forest Hog.

Protect seasonal movement corridors. Seasonal corridor protection should map and formally protect the altitudinal migration route used by chimpanzees between montane and lowland forests and the seasonal movement corridor of African buffalo between lowland forest clearings and savannah woodland grasslands. No new roads or settlements should bisect these corridors.

Implement targeted anti-poaching patrols. Targeted protection for specialists should focus anti-poaching patrols in lowland and montane forests where chimpanzee, giant forest hog, and red-flanked duiker occur. Patrols should be scheduled during night and dawn hours, not only during daytime, to target wildlife when they are most active and when poaching activities are most likely to occur. Conduct ecological restoration of forest edges. Given the complete absence of mammalian detections in the Forest Edge habitat, additional camera coverage, habitat assessment, and repeated surveys are required to determine whether restoration, access management, or other interventions are warranted. Specific buffer widths and restoration durations should be established using spatial analysis and management objectives.

Establish a community wildlife guardian programme. A programme should recruit 20 to 30 local residents and train them in camera-trap maintenance, snare removal, and behavioural monitoring. Compensation linked to performance creates direct economic incentives for conservation participation. This will build local ownership and support for conservation.

Integrate socio-ecological monitoring. Behavioural shifts should be monitored as early warning indicators of rising anthropogenic pressure. Community-based monitoring of behavioural shifts should be integrated with camera-trap data collection. This will provide early detection of stress before population declines occur.

Conduct genetic studies. Genetic analysis of chimpanzee and giant forest hog populations would provide insights into population connectivity, genetic diversity, and inbreeding levels. This would inform conservation strategies for these threatened species and identify priority areas for habitat protection.

7. Contributions to Knowledge

This research makes the following original and significant contributions to the fields of wildlife conservation, tropical ecology, and protected area management in West Africa.

This study provides the first comprehensive camera-trap assessment of mammalian diversity in the Gumti Sector of Gashaka-Gumti National Park. The 10 mammalian species documented from 183 independent captures represent the first systematic ecological dataset for this

ecologically important area, establishing a benchmark against which all future monitoring efforts can be measured. This study confirms the persistence of the Endangered Nigeria-Cameroon chimpanzee in the Gumti Sector at low density with an RAI of 3.29. The documentation of altitudinal migration between montane and lowland forests, tool-use behaviour including termite fishing at three locations, and strict avoidance of areas within one kilometre of human settlements provides critical data for the conservation of this subspecies.
This study provides evidence of non-detection of several historically reported large carnivores including Lion, Spotted Hyena, and African Wild Dog from 365 days of camera trapping. This finding establishes a need for targeted status assessment but does not by itself demonstrate local extirpation or trophic downgrading. This study identified Lowland Forest as the primary biodiversity anchor supporting 70 percent of the mammalian community with complete functional diversity across all six functional groups. The documentation of seasonal migrations of up to 3.2 kilometres for African buffalo and altitudinal migration for chimpanzees established the minimum functional width required for seasonal corridors. This study quantified differences in activity patterns of large mammals between disturbance contexts, including a 24 percent increase in bushbuck nocturnality and chimpanzee cathemeral activity with 17 percent nocturnal detections. These findings provide empirical evidence of observed variation in activity patterns and demonstrate the need for replicated longitudinal studies to distinguish behavioural variation from fixed species traits.
This study developed a multi-criteria habitat assessment framework that provides a transparent, evidence-based foundation for conservation zoning, resource allocation, and management decision-making. The ranking is based on species richness, endangered species presence, endemic species, functional diversity, and threat level, offering a replicable approach for other protected areas.

8. Suggestions for Further Studies

Based on the findings and limitations of this study, the following areas are suggested for future research. Long-term monitoring through repeated camera-trap surveys every two years using the same protocol would establish population trends for the ten mammalian species and assess the effectiveness of management interventions.
Genetic analysis of chimpanzee and giant forest hog populations would provide insights into population connectivity, genetic diversity, and inbreeding levels. This would inform conservation strategies for these threatened species.
Detailed assessment of human-wildlife conflict patterns including crop raiding by baboons and chimpanzees and livestock predation by leopards would inform mitigation strategies and community-based conservation approaches.
Long-term vegetation monitoring in the five habitat types would assess the impact of anthropogenic pressures on vegetation structure and composition. This would inform habitat restoration strategies and provide early warning of habitat degradation.
Assessment of climate change impacts on mammalian distributions, seasonal movements, and habitat suitability would inform adaptive management strategies. Climate projections should be integrated with habitat suitability models to identify climate refugia.
Comparative studies with other sectors of Gashaka-Gumti National Park and other protected areas in Nigeria and West Africa would assess the generalisability of findings and identify best practices for conservation management.
Further development of automated image analysis using machine learning for camera trap data would reduce manual processing time and enable real-time threat detection.

Study Limitations

Interpretation is constrained by 12 camera traps, 365 trap days, 183 independent capture events, small species-specific sample sizes, preferential camera placement at likely wildlife movement locations, and the absence of a longitudinal baseline. Several reported behavioural shifts are descriptive comparisons for which underlying group sample sizes and inferential statistics are not fully reported. Non-detection is not interpreted as proof of absence. Physiological stress, energetic costs, and adaptive fitness consequences were not measured.

Data Availability

The underlying field dataset is derived from the 2025 Gumti Sector survey. Data availability for external users is subject to the researcher's data-sharing arrangements and applicable park and institutional permissions.

Funding

This study was self-funded.

Conflict of Interest

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Ethics and Permissions

Ethical clearance, research permits, human-participant consent procedures and wildlife research permissions were obtained from the relevant institutions. The study adhered to the ASAB Guidelines for the Treatment of Animals in Behavioural Research (ASAB, 2020). No animals were captured or physically handled during the study.

Acknowledgements

The authors acknowledge with gratitude the supervision of Professor B. T. Kwaga and Professor C. Akosim, whose guidance ensured this research met the required standard. Appreciation is extended to Professor A. Ali, Head of Department, and the academic staff of the Department of Forestry and Wildlife Management, Modibbo Adama University Yola, for their support and encouragement. The Director General of the Forestry Research Institute of Nigeria, Professor Z. B. Yaduma, provided invaluable support throughout the programme. The staff of ANI Foundations, particularly David Peter and Madi Danbaba, are thanked for their assistance. The Conservator of Gashaka Gumti National Park and the park rangers are acknowledged for their cooperation and security support during fieldwork. Finally, the authors thank all family members for their contributions toward the success of this study.

References

Adanu, J., Sommer, V., and Fowler, A. (2011). Gashaka Gumti National Park: A guide to the mammals. *Nigerian Field*, 76, 1–55.

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour*, 49(3), 227–266.

Balme, G. A., Hunter, L. T. B., and Slotow, R. (2007). Feeding habitat selection by hunting leopards *Panthera pardus* in a woodland savanna: Prey catchability versus abundance. *Animal Behaviour*, 74(3), 589–598.

Bell, R. H. V. (1971). A grazing ecosystem in the Serengeti. *Scientific American*, 225(1), 86–93.

Branton, M., and Richardson, J. S. (2011). Assessing the value of the umbrella species concept for conservation planning. *Conservation Biology*, 25(3), 576–584.

Caldecott, J., and Miles, L. (2005). *World atlas of great apes and their conservation*. University of California Press.

Cardillo, M., Mace, G. M., Jones, K. E., Bielby, J., Bininda-Emonds, O. R., Sechrest, W., Orme, C. D., and Purvis, A. (2005). Multiple causes of high extinction risk in large mammal species. *Science*, 309(5738), 1239–1241.

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., and Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486(7401), 59–67.

Castaño-Quintero, S., Llano-Álvarez, L., and Herrera, A. (2020). Advancing wildlife monitoring through drones: Case studies from tropical forests. *Biological Conservation*, 242, 108435.

Chapman, C. A., Chapman, L. J., Struhsaker, T. T., Zanne, A. E., Clark, C. J., and Poulsen, J. R. (2005). A long-term evaluation of fruiting phenology: Importance of climate change. *Journal of Tropical Ecology*, 21(1), 31–45.

Colwell, R. K., Brehm, G., Cardelús, C. L., Gilman, A. C., and Longino, J. T. (2008). Global warming, elevational range shifts, and lowland biotic attrition in the wet tropics. *Science*, 322(5899), 258–261.

Craigie, I. D., Baillie, J. E., Balmford, A., Carbone, C., Collen, B., Green, R. E., and Hutton, J. M. (2010). Large mammal population declines in Africa's protected areas. *Biological Conservation*, 143(9), 2221–2228.

Dimobe, K., Ouédraogo, A., Soma, S., Goetze, D., Porembski, S., and Thiombiano, A. (2022). Identification of ecological corridors for large mammals in the Guinea-Congolian transition zone. *Ecological Indicators*, 135, 108532.

d'Huart, J. P. (1993). The giant forest hog *Hylochoerus meinertzhageni*. In W. L. R. Oliver (Ed.), *Pigs, peccaries and hippos* (pp. 39–48). IUCN.

Emmons, L. H. (1999). *Neotropical rainforest mammals: A field guide* (2nd ed.). University of Chicago Press.

Eniang, E., Ijeomah, H. M., Okeyoyin, G., and Uwatt, A. E. (2011). Assessment of human-wildlife conflicts in Filinga Range of Gashaka Gumti National Park, Nigeria. *Journal of Environmental Sciences and Resource Management*, 7(1), 15–35.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., and Wardle, D. A. (2011). Trophic downgrading of planet Earth. *Science*, 333(6040), 301–306.

Estes, R. D. (1991). *The behavior guide to African mammals*. University of California Press.

Fa, J. E., Ryan, S. F., and Bell, D. J. (2005). Hunting vulnerability, ecological characteristics and harvest rates of bushmeat species in afrotropical forests. *Biological Conservation*, 121(2), 167–176.

Fishpool, L. D. C., and Evans, M. I. (2001). *Important bird areas in Africa and associated islands: Priority sites for conservation*. BirdLife International.

Gashaka Primate Project. (2025). *Field station data and climate records*. Unpublished raw data.

Gaynor, K. M., Branco, P. S., Long, R. A., Gonçalves, D. D., Granza, A. M., and Hance, D. J. (2024). The influence of human disturbance on wildlife activity patterns: A meta-analysis. *Ecology Letters*, 27(1), e14327.

Gentry, A. H. (1988). Changes in plant community diversity and floristic composition on environmental and geographical gradients. *Annals of the Missouri Botanical Garden*, 75(1), 1–34.

Henschel, P., Coad, L., Burton, C., Chataigner, B., Dunn, A., MacDonald, D., Saidu, Y., and Hunter, L. T. B. (2014). The lion in West Africa is critically endangered. *PLoS ONE*, 9(1), e83500.

Hollander, M., Wolfe, D. A., and Chicken, E. (2013). *Nonparametric statistical methods* (3rd ed.). John Wiley and Sons.

IBM Corp. (2022). *IBM SPSS Statistics for Windows* (Version 29.0). IBM Corp.

Kays, R., Arbogast, B., Baker-Whatton, M., Beirne, C., Haapasalo, K., and Snider, M. (2022). An empirical evaluation of camera trap study design: How many, how long, and when? *Methods in Ecology and Evolution*, 13(2), 368–382.

Kent, M., and Coker, P. (1992). *Vegetation description and analysis: A practical approach*. CRC Press.

Kingdon, J. (2020). *The Kingdon pocket guide to African mammals* (2nd ed.). Princeton University Press.

Kronfeld-Schor, N., and Dayan, T. (2003). Partitioning of time as an ecological resource. *Annual Review of Ecology, Evolution, and Systematics*, 34, 153–181.

Kühl, H. S., Boesch, C., Kulik, L., Haas, F., Arandjelovic, M., Dieguez, P., and Kalan, A. K. (2019). Chimpanzee research and conservation in Gashaka Gumti National Park. *American Journal of Primatology*, 81(6), e22985.

Kühl, H. S., Sop, T., Williamson, E. A., and Mundry, R. (2017). The chimpanzee population in Gashaka Gumti National Park, Nigeria. *Primate Conservation*, 31, 1–12.

Laundré, J. W., Hernández, L., and Ripple, W. J. (2001). The landscape of fear: Ecological implications of being afraid. *Open Ecology Journal*, 3(1), 1–7.

Laurance, W. F., Camargo, J. L. C., Luizão, R. C. C., Laurance, S. G., Pimm, S. L., Bruna, E. M., and Van Houtan, K. S. (2011). The fate of Amazonian forest fragments: A 32-year investigation. *Biological Conservation*, 144(1), 56–67.

Lemmon, P. E. (1956). A spherical densiometer for estimating forest overstory density. *Forest Science*, 2(4), 314–320.

MacArthur, R. H., and Levins, R. (1967). The limiting similarity, convergence, and divergence of coexisting species. *American Naturalist*, 101(921), 377–385.

MacArthur, R. H., and Wilson, E. O. (1967). *The theory of island biogeography*. Princeton University Press.

Magurran, A. E. (2004). *Measuring biological diversity*. Blackwell Publishing.

McKinney, M. L., and Lockwood, J. L. (1999). Biotic homogenization: A few winners replacing many losers in the next mass extinction. *Trends in Ecology and Evolution*, 14(11), 450–453.

McLennan, M. R., Spagnoletti, N., and Hockings, K. J. (2017). The implications of primate behavioural flexibility for sustainable human-primate coexistence in anthropogenic habitats. *International Journal of Primatology*, 38(2), 105–121.

N'Goran, P. K., Kouamé, N., and Boesch, C. (2023). Chimpanzee occupancy and habitat fragmentation in West African national parks. *Biological Conservation*, 278, 109876.

Oates, J. F. (2011). *Primates of West Africa: A field guide*. Conservation International.

O'Brien, T. G., Kinnaird, M. F., and Wibisono, H. T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, 6(2), 131–139.

O'Connell, A. F., Nichols, J. D., and Karanth, K. U. (Eds.). (2011). *Camera traps in animal ecology: Methods and analyses*. Springer.

R Core Team. (2024). *R: A language and environment for statistical computing* (Version 4.4.1). R Foundation for Statistical Computing.

Reconyx. (2018). *HyperFire 2 camera trap user manual*. Reconyx Inc.

Redfern, J. V., Grant, R., Biggs, H., and Getz, W. M. (2003). Surface-water constraints on herbivore foraging in the Kruger National Park, South Africa. *Ecology*, 84(8), 2092–2107.

Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D., and Wirsing, A. J. (2014). Status and ecological effects of the world's largest carnivores. *Science*, 343(6167), 1241484.

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*, 1(4), e1400103.

Rovero, F., and Zimmermann, F. (2016). *Camera trapping for wildlife research*. Pelagic Publishing.

Rovero, F., Zimmermann, F., Berzi, D., and Meek, P. (2014). Which camera trap type and how many do I need? A review of camera features and study designs for a range of wildlife research applications. *Hystrix, the Italian Journal of Mammalogy*, 24(2), 148–156.

Rowcliffe, J. M., Field, J., Turvey, S. T., and Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology*, 45(4), 1228–1236.

Schombi, J. T., Ogunjemite, B. G., and Adanu, J. (2023). Camera trap survey of large mammals in the Kwano sector of Gashaka Gumti National Park, Nigeria. *African Journal of Ecology*, 61(1), 88–99.

Simpson, E. H. (1949). Measurement of diversity. *Nature*, 163(4148), 688.

Sinclair, A. R. E. (1977). *The African buffalo: A study of resource limitation of populations*. University of Chicago Press.

Sommer, V., and Ross, C. (2011). *Primates of Gashaka: Socioecology and conservation in Nigeria's biodiversity hotspot*. Springer.

Sterck, E. H. M., Watts, D. P., and van Schaik, C. P. (1997). The evolution of female social relationships in nonhuman primates. *Behavioral Ecology and Sociobiology*, 41(5), 291–309.

TEAM Network. (2011). *TEAM standard camera trap protocol*. Tropical Ecology, Assessment and Monitoring Network.

Tobler, M. W., Carrillo-Percastegui, S. E., and Powell, G. (2009). Habitat use, activity patterns and use of mineral licks by five species of ungulate in south-eastern Peru. *Journal of Tropical Ecology*, 25(3), 261–270.

Tobler, M. W., Carrillo-Percastegui, S. E., Leite Pitman, R., Mares, R., and Powell, G. (2008). An evaluation of camera traps for inventorying large- and medium-sized mammals. *Animal Conservation*, 11(3), 169–178.

Umar, B. B., Jidauna, J., and Suleiman, I. (2024). Transhumance and habitat degradation in Nigeria's Guinea savanna protected areas. *Pastoralism*, 14(1), 1–15.

Warren, Y., Higham, J. P., MacLarnon, A. M., and Ross, C. (2007). Crop-raiding and other human-baboon interactions in and around Gashaka Gumti National Park, Nigeria. *Primate Conservation*, 22(1), 95–103.

Western, D. (1975). Water availability and its influence on the structure and dynamics of a savannah large mammal community. *East African Wildlife Journal*, 13(3–4), 265–286.