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RESEARCH ARTICLE

Impact of Anthropogenic Activities on Herbivorous Mammal Diversity in the Douala-Edéa National Park, Littoral Region, Cameroon

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Abstract

The Douala-Edéa National Park (DENP), located in the Littoral Region, serves as a critical refuge for Cameroonian wildlife, encompassing a mosaic of mangroves, wetlands, and dense forests. However, its proximity to the industrial hubs of Douala and Edéa exposes this ecosystem to intense human pressure, jeopardizing habitat integrity and the survival of iconic herbivorous species. This study aims to evaluate the influence of human activities on the diversity, abundance, and spatial distribution of herbivorous mammals within the park. Data collection utilized QGIS and Google Earth to define 1 km recce-transects placed within 2 km grids on a pre-established map. Recces-transect coordinates were transferred to a Garmin 64 GPS for field tracking to record presence indices. Data analysis involved coding GPS records and importing them into QGIS for spatial distribution mapping. The correlation between anthropogenic pressure and the encountered rate (ER) was calculated. The inventories revealed a significant presence of megafauna, dominated by the African Forest Elephant *(Loxodonta cyclotis*), with high encountered rate. The findings equally indicate that poaching is the most destructive activity. A depletion of herbivores species were observed in areas with high human pressure. Species tend to concentrate in the heart of the study area where accessibility is limited, creating an imbalance in space utilization. Without an effective buffer zone and strict poaching regulations, the DENP risks becoming an empty forest, where flora remains but iconic fauna has vanished. This work underscores the urgent need for a balance between regional development and conservation to prevent the local extinction of herbivores, which are essential links in forest regeneration. To mitigate these impacts, the study suggests: Strengthening surveillance by increasing eco-guard patrols. Engaging local populations through community conservation programs and the development of alternative income-generating activities. Implementing environmental education to raise awareness of the park's ecosystem value beyond bushmeat resources.

Keywords: Abundance Indices, Anthropogenic Activities, Conservation, Herbivorous Mammals, Wildlife Diversity.

1. Introduction

1.1 Context

Globally, the world is experiencing the sixth mass extinction. Human activities have altered more than 75% of the Earth's surface, with habitat loss and resource overexploitation identified as the main drivers of vertebrate decline (IPBES, 2019). Wild herbivorous mammals act as keystone species through seed dispersal and carbon cycling, making them essential for the proper functioning and stability of forest ecosystems. In addition, they provide major food and economic resources for local communities worldwide (Célestin et al., 2021).

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Protected areas in Africa have played, and continue to play, a crucial role in safeguarding wildlife populations. However, these refuges home to the majority of fauna today are increasingly under pressure. Herbivorous mammals, which generally have larger home ranges than other animals, are especially vulnerable to habitat loss (Imbey et al., 2019). Sub-Saharan Africa hosts the greatest diversity of herbivores in the world, yet faces rapid demographic and urban growth. The Congo Basin is particularly affected by the empty forest phenomenon: forests that remain structurally intact but are biologically depleted of large fauna due to commercial poaching and bushmeat consumption (Hockings et al., 2020).

Cameroon possesses exceptional biodiversity, but its network of protected areas is under constant strain. Despite a strong legislative framework (1994 Forestry and Wildlife Law), national park management is hindered by limited resources and corruption. The country seeks to reconcile its development goals (Vision, 2035) with international commitments (Paris Agreement, CBD) (MINFOF, 2012).

Douala-Edéa National Park lies at the intersection of coastal mangroves and dense tropical forests, a critical transition zone that provides essential habitat for numerous species (Ndam et al., 2015). The diversity of herbivorous mammals in this park is vital not only for species conservation but also for maintaining local ecosystem services such as climate regulation and water purification (Bennett et al., 2015). Herbivores such as forest elephants, sitatungas, duikers, and manatees act as "ecosystem guardians," ensuring seed dispersal and maintaining forest structure. Their diversity serves as a direct indicator of habitat health (Fimbel et al., 2001). However, situated between Douala (economic capital) and Edéa (industrial hub), the park faces constant human encroachment. Upgraded from a wildlife reserve to a national park in 2018 (MINFOF, 2018a), its protection was strengthened, yet anthropogenic activities including agro-industry, artisanal fishing, and poaching remain deeply entrenched. Target species such as forest elephants (*Loxodonta cyclotis*) and small ungulates suffer from fragmentation of their migratory corridors. This study therefore aims to assess the current status of herbivore populations in DENP. While the park still harbors significant diversity, persistent hunting pressure from local communities threatens their long-term survival. This highlights the need to analyze the underlying factors driving hunting intensity in order to better understand its root causes in the region.

1.2 Problem Statement

Douala-Edéa National Park, a coastal biodiversity sanctuary in Cameroon, faces a paradox of conservation. Although protected under Decree No. 2018/606 (MINFOF, 2018a), the park is subjected to unprecedented anthropogenic pressure due to its location within a zone of intense industrial and urban activity (Douala and Edéa) (Chuo, 2026a). Herbivorous mammals, which are pillars of forest dynamics, are the first victims of these environmental changes.

Defaunation caused by poaching and hunting pressure remains one of the major threats, driven largely by the extraction of wildlife for the bushmeat trade (Chuo et al., 2026a). The growing demand for bushmeat in urban markets drastically reduces populations of large mammals (Tchamba et al., 2015). The proximity of urban centers creates a demand that exceeds the natural regeneration capacity of species (Tchamba et al., 2015). As a result, ungulates such as duikers and sitatungas are increasingly rare in easily accessible areas, leading to what biologists call the empty forest phenomenon.

Habitat fragmentation and loss, caused by the expansion of agro-industrial plantations and slash-and-burn agriculture, further degrade forest blocks. The spread of oil palm and rubber plantations has fragmented habitats, reducing migration corridors to less than 50% of their original extent (Nzooh-Dongmo et al., 2016). This fragmentation shrinks the home ranges of large herbivores such as the forest elephant (*Loxodonta cyclotis*), forcing them into human-dominated landscapes and intensifying human-wildlife conflicts (Nzooh-Dongmo et al., 2016).

Aquatic and semi-aquatic herbivores are also affected. Industrial discharges have degraded water quality and caused eutrophication of wetlands. For species such as the African manatee (*Trichechus senegalensis*), pollution and mangrove destruction pose critical threats. Ajonina, (2011) demonstrated that degradation of mangrove structure through fuelwood exploitation reduces essential grazing and breeding areas for these species.

Despite awareness campaigns directed at surrounding communities, the park continues to face serious threats such as deforestation, poaching, and urbanization (MINFOF, 2015; Ngembou et al., 2020 and Chuo et al., 2026b). These pressures directly affect mammal populations, leading to declines in both diversity and abundance (Fonkwo et al., 2023). Although the park remains important for biodiversity, research on its herbivorous mammals is still limited. Studies suggest that herbivore species richness declines linearly with proximity to human settlements. Understanding this dynamic is crucial for implementing the park's management plan (2021–2030). In light of these challenges, several key questions arise: How do different gradients of anthropogenic pressure influence the spatial distribution and diversity of herbivorous mammals within DENP? Is there a significant correlation between distance from human infrastructure and species diversity indices?

2. Materials and Methods

2.1 Description of the Study Site

The Douala-Edéa National Park, previously known as the Douala-Edéa Wildlife Reserve, is a protected area in Cameroon. It is located in the Sanaga Maritime Division. Covering an area of about 2,630 km², it stretches along the Atlantic coast south of Douala for approximately 35 km, reaching as far as the Dipombé River (MINFOF, 2018b). The Douala-Edéa National Park is geographically situated at 3° 30′ 00″ N, 9° 49′ 60″ E. Lake Tissongo, a lagoon connected to the southern bank of the Sanaga River by a five-kilometer tidal channel, is included within the reserve. This portion of state public land, set aside for wildlife preservation, encompasses the localities of Mouanko, Edéa, Dizangué, and the Manoka Islands. The park is bounded to the north by the southern suburbs of Douala, to the south by Kribi, and to the west by the Atlantic Ocean. The map below shows the Douala-Edéa National Park located in the districts of Mouanko and Edéa 1st, within the Sanaga Maritime Division, in the Littoral Region of Cameroon (MINFOF, 2018b).

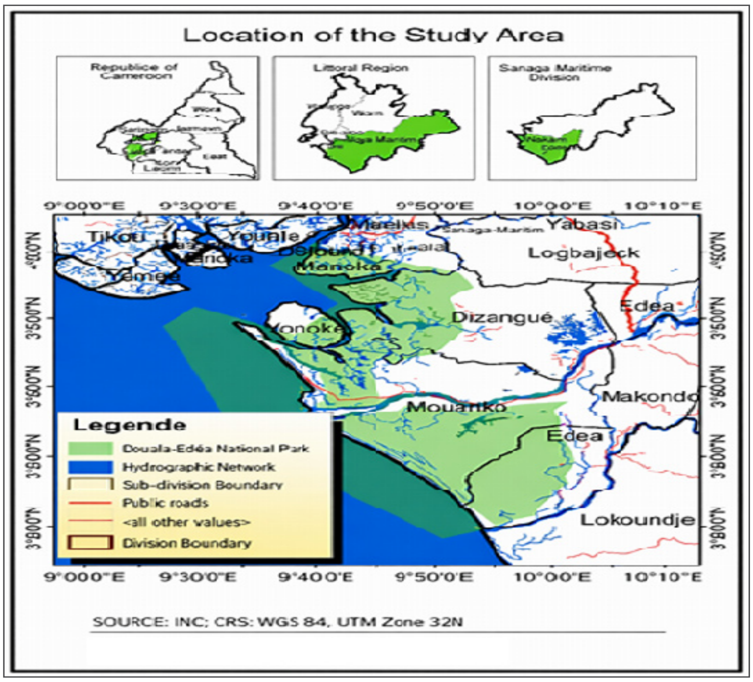

Figure 1. *Location map of Douala-Edéa National Park*

2.2 Field Data Collection with Recces-Transects

Data collection, based on both direct and indirect observations within the study area, was carried out using the recce-transect method (Buckland et al., 2001). Before fieldwork began, the choice of inventory sites was guided by the expertise of local hunters, who identified areas with high concentrations of herbivorous mammals. The geographic coordinates of these points were recorded using a Garmin 64 GPS, then processed on a computer with Google Earth. The positioning of 20 recce-transects was finalized on a pre-established map using QGIS. Each transect was one kilometer long and arranged in a specific grid: two groups of 10 transects were set up, separated by a distance of 500 meters corresponding to the width of a road (Figure 2). The coordinates of these transects were exported in KML format and re-imported into the GPS for field orientation. During field inventory, recce-transects were followed along hunting trails and animal paths across different vegetation gradients. The inventory consisted of exhaustively recording all signs of animal or human presence observed along the route. In total, a sampling effort of 20 km was realized, with an average progression speed of about one kilometer per hour. The spatial distribution of these sampling units is illustrated in Figure 2.

In line with the work of Chuo et al., (2017a), the inventory of herbivorous mammals was based on the identification of direct and indirect signs. The following were recorded: droppings (feces);

footprints; hair and molting remains; feeding signs (fruit remains, bark stripping, grazing); and any other clear evidence indicating the passage or activity of the target species. To assess human pressure within the study area, an inventory of anthropogenic activity indicators was conducted simultaneously. Human presence was quantified by recording various material signs such as: cartridge shells and traps (indicating poaching); tree stumps from logging; forest camps; and any other tools or traces of human occupation.

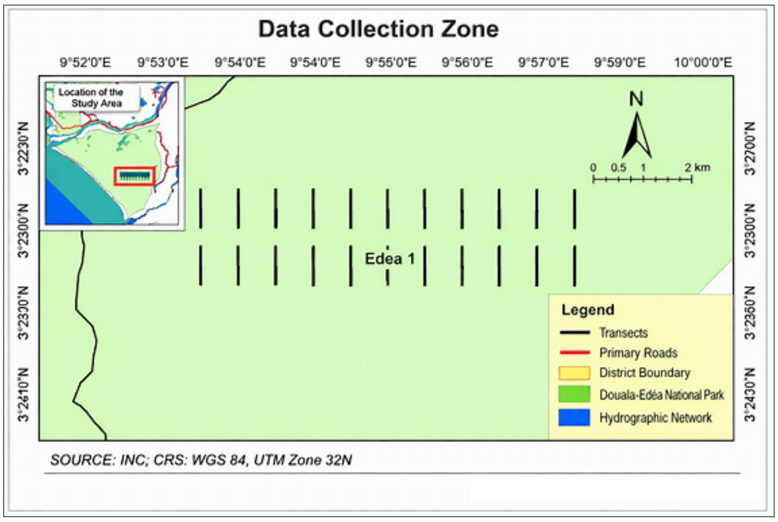

Figure 2. *Map showing the placement of recce-transects in Douala-Edéa National Park*

2.2.1 Data Collection with Camera Trapping

This technique was used to evaluate the relative abundance of herbivorous mammals across different habitats of Douala-Edéa National Park. Four camera traps were deployed randomly in favorable micro-habitats, selected based on the presence of animal activity signs (Jansen et al., 2014). To increase the probability of capturing individuals while ensuring representative spatial coverage, an average distance of 2 km was maintained between two trapping stations (Zimmermann et al., 2017) (Figure 3). The cameras were programmed with the following specifications: Trigger interval: A 15-second delay was set between consecutive shots. This configuration helps reduce redundant images (“inactive shots”) when an individual remains in front of the lens for an extended period. Power supply: Each unit was powered by rechargeable batteries, systematically replaced once depleted to ensure continuous monitoring.

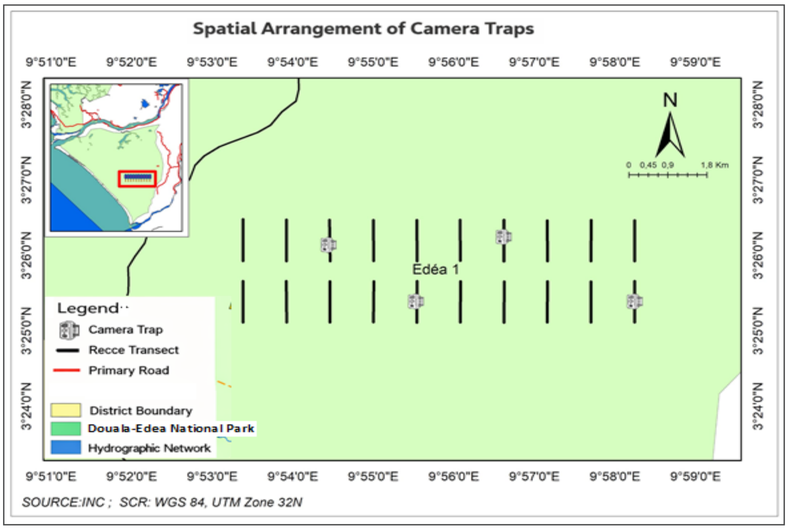

Figure 3. *Showing the placement of camera traps in Douala-Edéa National Park*

Once the site was selected, the position of each unit was recorded using a GPS receiver and permanently marked in the field. All metadata related to the installation was documented in a logbook. After installation, the devices were configured in burst mode allowing successive captures of photos or videos as soon as the motion sensor was triggered. Programming was optimized by taking into account the storage capacity of the SD cards, battery life, and the planned frequency of maintenance missions for replacing consumables. In accordance with the protocol of Jansen et al., (2014), the cameras were fixed at an average height of 50 cm above the ground. To ensure device stability and optimal strap adjustment, trees with a minimum diameter of 15 cm were preferred (Zimmermann et al., 2017). The final positioning of each camera was adjusted according to two main criteria: Visibility: Clearing the field of view to avoid false triggers caused by vegetation. Exposure: Orienting the device to prevent sensor glare during sunrise or sunset. Before leaving the site, a functionality test was systematically carried out to confirm the triggering mechanism and the effective recording of data on the memory card. The data collected were intended to estimate the abundance and activity levels of herbivorous mammals within the study area.

2.2.2 Organization of the Field Team and Data Collection Protocol

To successfully carry out the inventories, the field team was structured around four complementary roles: principal investigator who was responsible for recording data, noting on collection sheets the GPS coordinates of wildlife signs, anthropogenic activities, and the location of camera traps. Equally, handled photographic documentation using a Google Pixel 5a smartphone. A research assistant who was in charge of navigation and detection, equipped with a compass for orientation and Bushnell H2O binoculars (10x42) for long-distance wildlife observation. A guide (local hunter) with in-depth knowledge of the environment, assisted the investigator in identifying signs of presence and lightly cleared paths with a machete to facilitate movement in dense vegetation areas. A porter, who responsible for logistics, he carried technical equipment and supplies, while also helping the guide with trail clearing. And signs observation. Inventories were conducted during peak wildlife activity periods, mornings from 6:00 to 10:30, and afternoons from 15:30 to 18:00. For each sign detected (herbivorous mammals or anthropogenic activities), the following information was systematically collected: type of sign (direct or indirect), identification of the species concerned, precise geographic coordinates (GPS point), environmental variables such as vegetation type, weather conditions, and other specific observations related to the detection context.

2.3 Data Analysis

The analysis began with processing the geographic data recorded via Garmin 64 GPS. These data were transferred to a computer and integrated into QGIS software (v. 3.20). The location coordinates of the signs, extracted from the GPS were exported into QGIS and analyze to produce different kinds of maps such as the map of the study area, map for the sampling plan, maps of spatial distribution of herbivorous mammal signs and anthropogenic activities. Field data, initially entered in Microsoft Excel 2016, were exported to R software (v. 4.1.0) for statistical analyses. This step allowed the calculation of encounter rates for biological and anthropogenic signs. Relative abundance was assessed using the Kilometric Abundance Index (KAI), calculated with the following formula:

$$IKA=NL$$

Where:

IKA: Kilometric Abundance Index (or encounter rate)

N: Total number of signs observed for a given species

L: Total distance traveled (sampling effort in kilometers)

This index measures detection frequency per kilometer, estimates the relative abundance of species, and evaluates the impact (positive or negative) of anthropogenic pressures on herbivorous mammal populations within the park. To study the correlation between human activities and wildlife distribution, GPS-decoded data were cross-analyzed in the R environment. Statistical analysis relied on comparing encounter rates of herbivorous mammals with indicators of anthropogenic activities, in order to highlight spatial interactions and pressures exerted on the studied species.

The processing of data from camera traps was carried out in several stages: Images collected were reviewed on a computer to identify the species of herbivorous mammals captured. For each species, the number of capture events was determined. To ensure that two successive photos did not count the same animal multiple times, identification was based on morphological criteria (size, distinctive body markings) as well as the time interval between shots. Note: The total number of events here represents the number of distinct individuals identified, not simply the cumulative number of photos. Capture success was quantified using two key indicators: Encounter rate per station: For each camera trap, this rate was obtained by dividing the total number of events by the number of effective activity days of the camera (trapping effort). Overall relative abundance: This corresponds to the average of encounter rates calculated across all trapping stations in the study site.

3. Results

3.1 Abundance of Herbivorous Mammals and Anthropogenic Activities

3.1.1 Summary of Direct and Indirect Observations of Herbivorous Mammals

During field walk surveys, signs of herbivorous mammals were recorded. Table 1 summarizes the direct and indirect observations of four species of herbivorous mammals (elephant, antelope, duiker, and red river hog) identified in the park. These data make it possible to evaluate the frequency of signs and activity of these species in the study area, by combining visual contacts with biological traces.

Table 1. *Direct and indirect observations of herbivorous mammals in the study area*

Species	Indirect Observations					Total Indirect signs	Direct Observations	Total Direct
	DP	FP	FR	RS	CA			
Elephant	8	12	8	0	0	28	2	2
Antelope	2	6	0	2	2	12	2	2
Duiker	3	4	0	0	0	7	3	3
Bush pig	2	2	6	1	0	11	0	0
Total	15	24	14	3	2	58	7	7

Legend: *DP = Droppings, FP = Footprints, FR= Feeding remains, RS = Resting site, CA= Carcasses, OD = Direct observations*

From Table 1, it appears that the Elephant is the most represented species, with a total of 30 observations, 28 indirect signs and 2 direct contacts. The antelope follows with 14 observations, including 12 indirect and 2 direct signs. The duiker shows a more balanced detection, with 3 direct visual contacts and 7 indirect traces. The bush pig was not directly observed; its presence was confirmed by 11 indirect signs, mainly composed of feeding remains.

3.1.2 Encounter Rate of Herbivorous Mammals Based on Indirect Signs

This table presents the encounter rates of the four herbivorous mammal species (elephant, antelope, duiker, and bush pig) identified in the study area. These indices were calculated exclusively from indirect observations recorded over a total sampling effort of 20 km.

Table 2. *Encounter rate of herbivorous mammals based on indirect signs*

Species	Total Distance Traveled (km)	Number of Indirect Signs Observed	Encounter Rate (Signs/km)
Elephant	20	28	1.40
Antelope	20	12	0.60
Duiker	20	7	0.35
Bush pig	20	11	0.55
Total	20	58	2.90

From Table 2, it can be seen that the elephant has the highest encounter rate (1.40 signs/km), indicating its strong presence in the study area. The antelope follows with 0.60 signs/km, while the duiker and duiker show lower rates of 0.55 and 0.35 signs/km respectively. These results suggest that elephants are the most frequently detected species through indirect signs, reflecting their dominance in the park's herbivore community.

3.1.3 Encounter Rate by Type of Indirect Sign of Herbivorous Mammals

Table 3 presents the detailed encounter rates by type of indirect signs (feces, footprints, feeding remains, resting sites, and carcasses) for the four species studied. These rates were obtained by relating the number of observations to the total distance traveled (20 km), thus allowing the measurement of the detection frequency of each sign per kilometer.

Table 3. *Encounter rate by type of indirect sign of herbivorous mammals*

Species	TDC (km)	Indirect observations									
		DP	ER	FP	EN	FR	ER	RS	ER	CA	ER
Elephant	20	8	0.40	12	0.60	8	0.40	0	0	0	0
Antelope	20	2	0.10	6	0.30	0	0	2	0.10	2	0.10
Duiker	20	3	0.15	14	0.70	0	0	0	0	0	0

Bush pig	20	2	0.10	2	0.10	6	0.30	1	0.05	0	0
Total	20	15	0.75	24	1.70	14	0.70	3	0.15	2	0.10

Legend: *TDC= Total Distance Covered, ER = Encounter Rate of the Species (signs/km), DP = Droppings, FP = Footprints, FR= Feeding remains, RS = Resting site, CA = Carcasses*

The breakdown in table 3 highlights how different species leave distinct ecological traces, with elephants droppings being the highest encountered rate (0.40 sign/km), followed by the duiker (0.15 sign/km). The antelope and bush pig display identical rates of 0.10 sign/km, indicating regular but moderate activity. For footprints, duiker has the highest frequency (0.70 sign/km), followed by the elephant (0.60 sign/km**),** antelope (0.30 sign/km), and bush pig (0.10 sign/km). For feeding remains, only the elephant (0.40 sign/km) and bush pig (0.30 sign/km) left traces of plant consumption. Resting sites was detected only for the antelope (0.10 sign/km) and bush pig (0.05 sign/km). And only antelope carcasses were recorded during the inventory.

3.1.4 Encounter Rate of Herbivorous Mammals Based on Direct Observations

Table 4 presents the encounter rates calculated from direct observations (visual contacts with the animals) for a total sampling effort of 20 km.

Table 4. *Encounter rate based on direct observations of herbivorous mammal species*

Species	Total distance cover (km)	Direct Observations	Encountered rate (sign/km)
Elephant	20	2	0.10
Antelope	20	2	0.10
Duiker	20	3	0.15
Bush pig	20	0	0.00
Total	20	7	0.35

Looking at table 4, it shows that the duiker had the highest direct encounter rate (0.15 sign/km), followed by elephants and antelopes (0.10 sign/km each). The bush pig was not directly observed during the survey, highlighting its elusive behavior compared to the other species. Comparing the direct versus indirect encounter rates for elephants, antelopes, duiker, and bush pig, elephants stand out with a very high indirect rate (1.40 sign/km) compared to a modest direct rate (0.10 sign/km). Antelopes and duiker show more balanced patterns, while bush pig were only detected indirectly (0.55 sign/km, with no direct sightings). This visualization makes it clear how species differ in detectability. Elephants leave many traces but are rarely seen, duiker are more often spotted directly, and bush pig remain elusive.

3.1.5 Relative Abundance of Herbivorous Mammal Species in Study Area

Table 5 presents the relative abundance of the four target species, elephant, antelope, duiker, and bush pig. This estimate is based on the combination of indirect presence indices (tracks, droppings, etc.) and direct visual contacts.

Table 5. *Relative abundance of herbivorous mammal species in study area*

Species	Indirect Indices	Direct Indices	Relative Abundance (%)
Elephant	28	2	46.15
Antelope	12	2	21.54
Duiker	7	3	15.38
Bush pig	11	0	16.92
Total	58	7	100

According to Table 5, the Elephant overwhelmingly dominates the population, representing 46.15% of the total abundance. The Antelope follows with 21.54%, while the bush pig and duiker show lower and relatively similar proportions — 16.92% and 15.38%, respectively. It is noteworthy that although the bush pig ranks third in relative abundance, its presence is confirmed exclusively through indirect signs, with no direct visual contact recorded. In total, the study documented 58 indirect indices and 7 direct observations, with the cumulative relative abundance reaching 99.99%.

3.1.6 Spatial Distribution of Herbivorous Mammal in the Study Area

The spatial distribution of herbivorous mammals within Douala-Edéa National Park was developed from the compilation and analysis of encounter rates recorded along the reconnaissance transects. This cartographic document provides an accurate visual representation of their presence and helps identify the main wildlife activity zones within the study area.

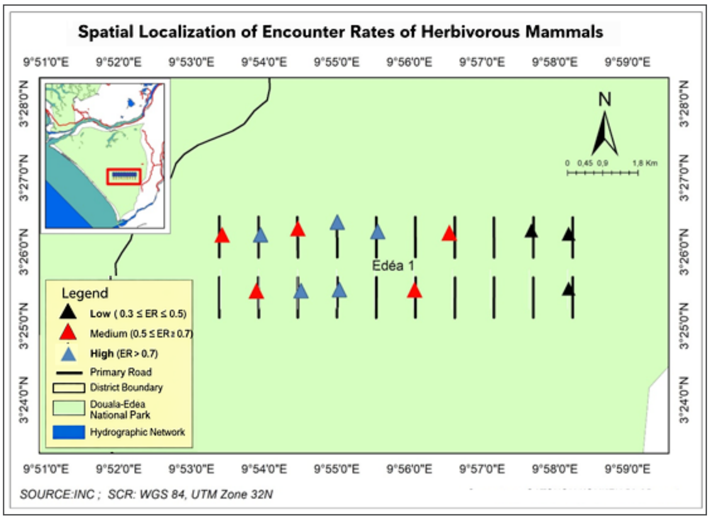

Figure 4. *Spatial Distribution Herbivorous Mammals in the Study Area*

Figure 4 illustrate how herbivore abundance varies spatially across the study area, with zones classified into low abundance (0.30 ≤ ER ≤ 0.50), medium abundance (0.50 ≤ ER ≤ 0.70) and high abundance (ER > 0.70). It provides a clear visual framework for identifying wildlife hotspots, moderate activity zones, and low-density areas. Areas with blue triangles indicate hotspots of herbivore activity, suggesting preferred habitats or feeding grounds. These zones are critical for monitoring and conservation. Regions marked with red triangles show medium encounter rates, reflecting areas of regular but less intense use by herbivores. Sparse presence: Black triangles highlight zones of low activity, which may correspond to less favorable habitats, human disturbance, or seasonal variation in resource availability. Spatial heterogeneity of encounter rates demonstrates that herbivore populations are not uniformly spread across the park, but instead cluster in specific areas. The proximity of high and medium encounter zones to hydrographic networks and primary roads may indicate movement of herbivores corridors or areas where human activity intersects with wildlife presence.

3.1.7 Encounter Rate of Anthropogenic Activities Observed in the Study Area

During recces-transect walk, signs of anthropogenic activities recorded with the total sampling effort of 20 km were used to calculate their encountered rate in the study area.

Table 6. *Encountered rate of anthropogenic activities identified in the study area*

Type of anthropogenic indices	Total distance covered (km)	Total Number of Indices Identified	Encounter Rate of Anthropogenic Indices
Illegal hunting	20	244	12.20
Unsustainable agriculture	20	9	0.45
illegal fishing	20	11	0.55
Illegal exploitation of non-timber forest products	20	4	0.20
Deforestation	20	9	0.45
Total	20	277	13.85

Table 6 shows that 277 indices were recorded and classified into five categories of human pressures. The overall encounter rate of 13.85 sign/km. Illegal hunting was the most predominant activity, with 244 indices (12.20 sign/km). It is evidenced by the presence of 167 traps, 54 poaching trails, 20 campsites, and 3 used cartridges. Illegal fishing represents the second most observed pressure (0.55 sign/km). Unsustainable agricultural practices and deforestation then follows (0.45 sign/km). The exploitation of Non-Timber Forest Products (NTFP) was the least with an encountered rate of 0.20 sign/km.

3.1.8 Spatial Distribution of Anthropogenic Activities in the Study Area

This map (Figure 5) illustrates the spatial distribution of anthropogenic pressures within study area. It was developed from the analysis of the intensity of human activity indices related to the exploitation of natural resources (wildlife and forest products), recorded along reconnaissance transects. Overall, anthropogenic activities are omnipresent in the study area. Variations in encountered rates allowed the mapping of the density of these pressures, revealing that indices of human activity were detected along almost all transects surveyed.

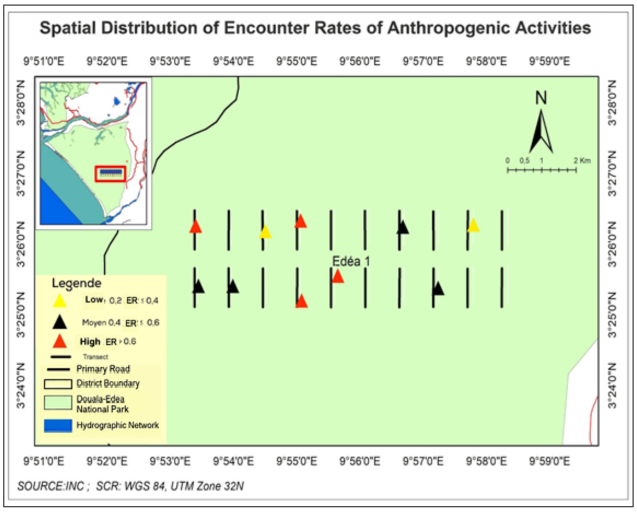

Figure 5. *Spatial distribution of anthropogenic activities in the study area*

Figure 5 shows how human pressures vary spatially across the study area, with zones of low abundance (0.20 ≤ ERAA ≤ 0.40): These zones represent areas with fewer human activity signs, possibly less accessible or less attractive for resource exploitation. Medium abundance (0.40 ≤ ERAA ≤ 0.60): These areas show moderate human pressure, likely linked to subsistence activities such as small-scale fishing or agriculture. And high abundance (ERAA > 0.60) which area concentrated hotspots of human activity, often near roads, rivers, or park boundaries, where illegal hunting, fishing, and unsustainable agriculture are most intense. High-pressure zones often overlap with hydrographic networks and primary roads, suggesting that accessibility strongly influences the distribution of human activities. The near-ubiquity of anthropogenic indices highlights the challenge of managing Douala-Edéa National Park. Even remote areas are not free from exploitation, which threatens both wildlife populations and forest resources. As seen in earlier data, hunting remains the most significant pressure, and its spatial spread confirms systematic exploitation across the park. Roads and rivers act as entry points for human activities, meaning enforcement should prioritize these corridors. Conservation strategies must focus on high-abundance zones, where human activity is most concentrated, while also monitoring medium-pressure areas to prevent escalation.

3.1.9 Influence of Anthropogenic Activities on the Relative Abundance of Herbivorous Mammals in the Study Area

In other to get the influence of anthropogenic activities on the relative abundance of herbivores mammals, the encounter rates of bio-indicator signs for species of herbivorous mammals was correlated with the different anthropogenic pressures identified in the study area as illustrated in figure 6 and 7.

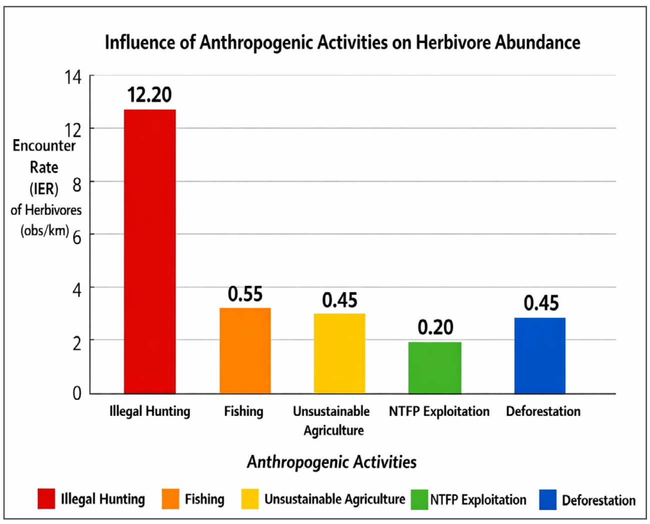

Figure 6. *influence of anthropogenic activities in the abundance of herbivores mammals in the study areas*

The red bar (Illegal Hunting) towers above all others at 12.20 sign/km, confirming it is the most destructive pressure on herbivore abundance. Orange (Fishing) and Yellow (Unsustainable Agriculture) are medium-height bars, reflecting moderate impacts. Green (NTFP Exploitation) and Blue (Deforestation) are short bars, showing minimal current influence but potential long-term risks. This visualization makes it clear that illegal hunting overwhelmingly dominates the anthropogenic pressures affecting herbivore populations in the study area.

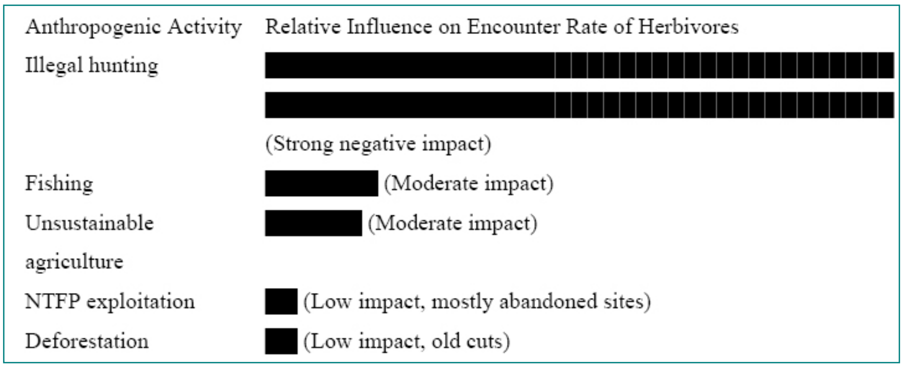

Figure 7. *Correlation between the encounter rates of anthropogenic activities and the abundance of herbivorous mammals in study areas*

The graphs correlate encounter rates of herbivorous mammal species with the different anthropogenic pressures identified in the park. Negative correlation is experience in zones with high anthropogenic activity rates, the relative abundance of herbivores tends to decrease sharply. Illegal hunting impact shows the strongest influence, as traps, poaching trails, and campsites directly reduce mammal populations through mortality and disturbance. Fishing and agriculture even though less directly lethal to herbivores, these activities fragment habitats and reduce food availability, indirectly lowering encounter rates. Deforestation and NTFP exploitation was less represented, they contribute to long-term habitat degradation, further reducing mammal abundance. Areas with high anthropogenic encounter rates correspond to zones where herbivore encounter rates are lowest, confirming the disruptive effect of human activities on wildlife distribution.

3.2. Identification of Herbivorous Mammals from Camera Trapping

During recces-transect walk, cameras traps were randomly place using opportunistic techniques. Photos and videos recordings were reviewed on a computer to identify the species of herbivorous mammals captured. Among the four camera-trap installed, three recorded capture events and one didn't. Figure 8: shows the photos of two herbivores mammals, a Bushbuck *(Tragelaphus scriptus*), and a Blue Duiker *(Philantomba monticola*) captured by camera traps in the study areas.

Figure 8. *(A) Image of a Bushbuck (Tragelaphus scriptus), and (B) Image of a Blue Duiker (Philantomba monticola) captured by camera traps.*

Equally, table 7 summarizes the frequency of capture events detected by camera traps for a given duration. This permitted to get in the encountered events and relative abundance of herbivorous mammal species present in the study area.

Table 7. *Frequency of capture events detected by camera traps for a given duration in the study area.*

Camera Number	Number of Events	Number of Days	Encountered event (event/day)	Relative abondance
1	5	35	0,14	0,13
2	3	34	0,09	
3	6	35	0,17	

Table 7 summarizes the frequency of capture events, the duration of monitoring, and the resulting encounter events and relative abundance of herbivorous mammals recorded by camera traps in the study area. From the table, camera station 3 recorded the highest number of capture events (6), suggesting relatively greater activity of herbivorous mammals in its vicinity. Camera station 1 followed with 5 events, while camera station 2 recorded the lowest activity, with only 3 events. The overall relative abundance value, estimated at 0.13, indicates confirm that herbivore presence is unevenly distributed across the monitored stations, reflecting variations in habitat quality, resource availability, and possibly differing levels of anthropogenic disturbance.

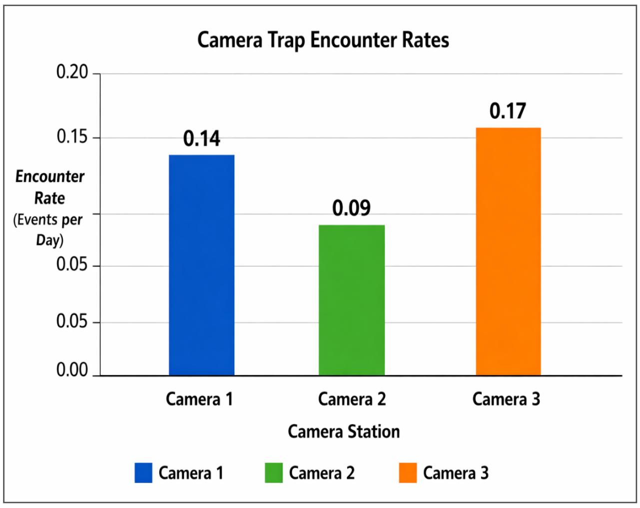

Figure 9. *Encounter events detected by different camera stations in the study area.*

The performance analysis by station reveals the following points: Camera 3 recorded the highest level of activity, with 6 events over a period of 35 days, corresponding to an encounter rate of 0.17 event/day. Camera 1 follows with 5 events for the same trapping effort (35 days), showing an encounter rate of 0.14 event/day. Camera 2 recorded the lowest capture success, with 3 events in 34 days, resulting in an encounter rate of 0.09 event/day. The comparative assessment of camera-trap stations highlights distinct variations in herbivore activity such as bushbuck *(Tragelaphus scriptus*) and the blue Duiker *(Philantomba monticola*) within the sampled zones. This value suggests that, although these herbivores persist in the area, their populations remain under pressure, likely influenced by human activities.

4. Discussion of Results

4.1 Status of Herbivorous Mammal Diversity

The results reveal a predominance of the African Forest Elephant (*Loxodonta cyclotis*) in study area, representing 46.15% of relative abundance. This strong presence, confirmed by an encounter rate index of 1.40 sign/km, underscores the importance of the park as a refuge for this threatened species. Our observations are consistent with the findings of Tchamba, (1998), who highlighted that the coastal forest zones of Cameroon provide optimal feeding habitats. However, the low visual detection rate (0.10 sign/km) suggests either flight behavior or nocturnal adaptation in response to external pressures. These observations corroborate the work of Ngaba (2015) in the clearings of Boumba-Bek National Park and N'Goran (2010) in Moukalaba-Doudou National Park, both of whom reported predominant encounter rates for elephants. Conversely, our results differ from those of Armel, (2007) in the Mambili Forest Management Unit, where elephants exhibited the lowest rate (0.44 sign/km). Such reduced density may be attributed to increased hunting pressure, either diminishing populations or displacing them into more isolated refuge areas. These comparisons highlight the influence of body size and species ecology on the detectability of indirect signs.

Regarding direct observations, the hare paradoxically displayed the highest rate (0.15 sign/km). This suggests that, despite its elusive nature, visual encounters remain an effective detection method for this species. These figures contrast with the study of Assui, (2022), who identified only one antelope species (the Yellow-backed Duiker) with a very low rate (0.06 sign/km). Such discrepancies between direct and indirect indices emphasize the need for complementary methodological approaches. Conversely, the hare exhibited the lowest indirect detection rate (0.35 sign/km). This disparity can be explained by its small body size and cryptic behavior, which make its tracks more difficult to record compared to those of larger herbivores. Our findings corroborate those of Chuo et al., (2017b) in the clearings of Kimbi-Fungom National Park and the Kom-Wum Forest Reserve, where predominant encounter rates for hares were also reported.

The case of the Red River Hog *(Potamochoerus porcus*), detected exclusively through indirect signs, illustrates strong wariness. As noted by Maisels et al., (2013), forest suids adjust their spatio-temporal activity patterns according to the intensity of poaching, becoming almost exclusively discreet in areas of high anthropogenic pressure. The natural wariness of wildlife, compounded by anthropogenic pressures such as poaching, drives animals to adopt avoidance strategies. Consequently, the combined use of indirect indices and direct observations proves indispensable for a comprehensive assessment of faunal biodiversity.

4.2 Relative Abundance of Herbivorous Mammal Species

The integrated analysis of direct and indirect indices reveals a clear dominance of the African Forest Elephant, representing 46.15% of total abundance. This predominance suggests the presence of a robust local population, potentially supported by ongoing conservation efforts within the park (Chuo et al., 2026b). In contrast, the hare was the least represented species, accounting for only 15.38% of observations. This low proportion may be attributed to its small body size and natural discretion, or may reflect a structurally lower population density in this type of ecosystem as well as overhunting. These results differ significantly from those reported by Abdou et al., (2019) in the Dosso Partial Faunal Reserve in Niger, where the hare was the most abundant species (41.79%) while the elephant was the least represented (1.49%). This marked contrast can be explained by habitat fragmentation and the reduction of natural areas available to elephants in Niger. Furthermore, strong anthropogenic pressure and the proximity of human settlements exacerbate human-wildlife conflicts, forcing elephants to migrate to more isolated areas or leading to population decline. In study area, the situation appears reversed, highlighting the role of this forest massif as a refuge for megafauna.

4.3 Spatial Distribution of Herbivorous Mammals

The distribution of herbivorous mammals within the study area is heterogeneous, closely conditioned by the intensity of human activities. Mapping results show an inverse spatial correlation, areas subject to high anthropogenic disturbance display a scarcity of animal presence signs, while better-preserved sectors concentrate most indicators of presence. This finding underscores the predominant impact of humans on the spatial ecology of these species. These observations differ from those of Ghislain et al., (2020) in Moukalaba-Doudou National Park, where mammal distribution was more homogeneous. In that Gabonese park, animal distribution was primarily dictated by food resource availability and habitat typology rather than avoidance of human activity. This difference can be explained by a significantly lower level of anthropogenic pressure in Moukalaba-Doudou, allowing wildlife to occupy all favorable habitats more evenly.

4.4 Anthropogenic Pressure and its Impact

The study reveals the omnipresence of human activities, with a total of 277 indices recorded and an overall encounter rate of 13.85 sign/km. Illegal hunting emerged as the major threat (12.20 sign/km), primarily manifested through wire-snare trapping. This intense anthropogenic pressure likely explains the spatial distribution patterns of mammals. Our results corroborate those of Foguekem et al., (2010) in other Cameroonian forest complexes, where a negative correlation was consistently observed between trap density and large mammal abundance. The concentration of anthropogenic indices across nearly all reconnaissance transects indicates that the status of “National Park” does not preclude illicit resource exploitation. These findings contrast sharply with those of Effila, (2014) in Boumba-Bek National Park clearings, where no signs of human activity were detected, and with N’Goran, (2021) in Moukalaba-Doudou National Park, who reported only 105 indices with a low rate of 0.233 sign/km. This disparity is likely explained by several factors in these comparative zones: lower demographic density in surrounding villages, stricter monitoring and security measures by management teams, and greater difficulty of access to the terrain.

4.5 Evidence of Herbivorous Mammals from Camera Trapping

The use of camera traps proved effective in this study, confirming the presence of herbivorous mammal species that are usually difficult to record through conventional observation methods. This technological efficiency is supported by Burton et al., (2015), who demonstrated that camera traps detect on average 1.5 times more species than direct observation inventories. During our sampling, two species were identified: the Blue Duiker *(Philantomba monticola*) and the Bushbuck (*Tragelaphus scriptus*). These results differ from those of N'Goran, (2021), who recorded 16 herbivorous mammal species in Moukalaba-Doudou National Park using the same method. This discrepancy is explained by sampling effort: N'Goran's study benefited from a much larger deployment, with 115 camera stations over an extended period (five months, October 2020 to February 2021). This contrast highlights that the performance of camera trapping in biodiversity characterization is closely linked to the density of camera coverage and the effective duration of unit operation in the field.

5. Conclusion

The study of the impact of anthropogenic activities on the diversity of herbivorous mammals in Douala-Edéa National Park provides a concerning overview of the ecological integrity of this protected area. The inventories revealed a significant presence of megafauna, dominated by the African Forest Elephant *(Loxodonta cyclotis*), whose high encounter rate highlights the importance of the park as a biodiversity sanctuary. The complementary use of indirect indices and camera trapping also confirmed the presence of discreet species such as the Blue Duiker *(Philantomba monticola*) and the Bushbuck *(Tragelaphus scriptus*), underscoring the value of mature ecosystems (primary forests, liana forests, and swamp forests) for the survival of herbivores.

However, this biodiversity is currently confronted with pervasive anthropogenic pressure. With an overall encounter rate of 13.85 sign/km, human activities, particularly illegal hunting exert a decisive influence on the spatial ecology of wildlife. The heterogeneous distribution of species observed confirms that wildlife avoids disturbed areas in favor of more isolated sectors, thereby creating functional habitat fragmentation.

In conclusion, although DENP retains remarkable ecological potential, the intensity of poaching poses a short-term threat to the viability of herbivorous mammal populations. To ensure the sustainability of these ecosystems, it is imperative to strengthen monitoring measures, intensify anti-poaching patrols, and promote sustainable economic alternatives for local communities to reduce their dependence on the park's wildlife resources.

Perspectives and Recommendations

In light of the results of this study, several avenues of research and action are necessary to ensure the long-term sustainability of Douala-Edéa National Park:

Increase camera-trap coverage: To address the low visual detectability of nocturnal and discreet species (such as suids and certain duikers), it would be advisable to increase the number of camera traps and extend deployment duration to cover all seasons.

- Promote alternative livelihoods: Reduce the dependence of local communities on wildlife resources by encouraging aquaculture or the rearing of small ruminants.
- Raise community awareness: Sensitize local populations to the ecological role of herbivorous mammals, transforming potential poachers into conservation actors.
- Study climate impacts: Analyze how rising water levels in coastal swamp forests may alter herbivore habitats in the long term.
- Examine plant–herbivore interactions: Investigate the direct relationship between herbivore presence and floristic diversity, particularly for species such as *Aglaonema nitidum*.

Author Contributions

Mvo Denis Chuo: Conceptualization, methodology, data collection and analysis, grant proposal writing, preparation of the initial and final versions of the manuscript. Berquèle Noumedem Tsopgni: Conceptualization, methodology, data collection, project administration, drafting and revision of the manuscript. Theodore B. Mayaka: Supervision and critical revision of the different versions of the manuscript. All authors approved the final version of the manuscript for publication.

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Conflict of Interest Statement

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

Data Availability

The datasets generated and analyzed during the present study are available from the corresponding author upon reasonable request.

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