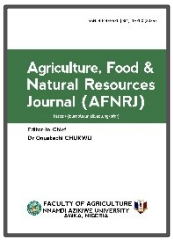
Agr. Foo. Nat. Res. J. Volume 5, Issue 2, Page: 21-28

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj



Original Article

Population structure and species diversity of ungulates in a protected derived savannah ecosystem of west Africa

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DOI: https://doi.org/10.5281/zenodo.22977553

Editor: *Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *July 28, 2026*
Accepted: *August 26, 2026*
Available online: *September 30, 2026*

Peer-review: *Externally peer-reviewed*

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Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support.*

ABSTRACT

The study assessed ungulate species diversity and population structure within a protected derived savannah ecosystem in the southern region of Nigeria. The study identified and recorded ungulate species and their structural characteristics along three designated tracks within the park. Each track was systematically surveyed twice weekly for six months, utilizing the direct animal count method. Data was analysed using descriptive and inferential statistics. A total record of 693 individuals belonging to four ungulate species (Kob - Kobus kob, Red-flanked duiker - Cephalophus rufilatus, Bushbuck - Tragelaphus scriptus, and Hartebeest - Alcelaphus buselaphus) was recorded. Both adult and juvenile females accounted for 286 individuals, and males accounted for 407, respectively. The most abundant ungulate species recorded were Kobs (490 individuals), while Hartebeest were the least with 49 individuals. Ungulate population comprising 369 individuals (53.25%) were sighted in the Maha track, 271 (39.10%) in the Ajaku-Ibuya track, and 53 (7.65%) in the Yemoso track. Relative abundance of ungulates ranged from 0.006/km² (kob) to 0.03/km² (Duiker and Hartebeest) with an overall sex ratio (range: 1.30 to 1.45; mean = 1.39) demonstrating even tighter clustering. The Shannon diversity index values show that Maha Track (H′ = 0.740) demonstrates marginally higher species diversity than Ajaku-buya Track (H′ = 0.717), whereas Yemoso (H′ = 0.268) shows substantially lower diversity. Illegal grazing accounted for the highest percentage (51.9) of illicit activities within the park, followed by illegal hunting (39.2%) and illegal logging (14%). Effective conservation strategies for long-term survival of ungulates are recommended.

KEYWORDS: *Abundance, Community composition, Conservation, Distribution, Herbivores*

INTRODUCTION

Among large mammals, ungulates are the most prominent large herbivores globally, inhabiting nearly every zoogeographical region, with 257 identified species according to Wilson and Reeder (2005), along with five extinct species attributed to human activities and several others facing critical conservation concerns; they hold significant ecological importance. Wild ungulates serve as primary prey for iconic predators such as tigers, lions, leopards, and other members of the cat family worldwide (Conroy & Carroll, 2009; Kufa & Bekele, 2019). Their grazing and browsing behaviors play a crucial role in shaping plant community structures and seed dispersal dynamics (Olajesu *et al.,* 2019). Preserving extensive landscapes is essential to accommodate the mobility of

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ungulates, contributing significantly to biodiversity conservation efforts (Kufa & Bekele, 2019).

The presence of these ungulates is important for tourism-based economies in many regions of Africa (KNBS, 2019; WTTC, 2020 cited in ALU, 2020); for example, wildlife tourism in Botswana and Tanzania contributed 11% and 14% to GDP in 2016 and 2014, respectively (WTTC 2015; WTTC 2017). The number of tourists that Nigerian national parks received is still far behind those in other countries, due to conservation challenges that the country faces. The emergence of viable wildlife-based tourism and recreation in Nigeria depends on the abundance of wildlife resources both in diversity and population, as they form a significant tool in any aspect of ecotourism growth (Okolie *et al.,* 2019).

Research on all ungulate species in Nigeria remains limited; however, studies conducted in some southern and northern regions have documented 12 species of ungulates. These include *Kobus ellipsiprymnus, Ourebia ourebi* (Akinyemi and Kayode, 2010; Oyeleke *et al.,* 2015), *Cephalophus rufilatus, Hippotragus equinus, Phacochoerus aethiopicus, Potamochoerus porcus, Sylvicapra grimmia* (Adedoyin, 2018), *Tragelaphus scriptus, Acelaphus buselaphus, Kobus kob, Redunca redunca, and Syncerus caffer* (Olajesu *et al.,* 2019; Olajesu *et al.,* 2022). These ungulates thrive predominantly in protected areas due to habitat loss and bushmeat trade outside them (Dounamou *et al.,* 2020). However, these protected areas face numerous challenges, ranging from agricultural encroachment, overgrazing, excessive exploitation of natural resources through extractive activities, and environmental pollution (Ogunjemite, 2017). More recently, these parks have also been threatened by banditry activities; through their attacks on life, making it difficult for park rangers to perform their duties of protecting the biodiversity and decimating wildlife populations (Onihunwa *et al.,* 2023; Okeyoyin, 2022). Monitoring changes in animal population trends is crucial for the development, sustainability, and efficient management of the park and its wildlife resources. Periodic assessments to determine productivity, species abundance, and distribution are necessary to establish a foundation for continuous management plans aligned with the goal of sustainable production in any protected area.

The Old Oyo National Park stands as the sole National Park within the eco-transition vegetation zone between the tropical rainforest and savannah ecosystem of Nigeria. Recent threats, including poaching, land degradation, and severe banditry occurring within and around the park, have impacted major habitats of these ungulates. Such impacts could potentially have significant adverse effects not only on the park's appeal for tourism but also on the vital role these species play in habitat regeneration. A decrease in diversity may signal local extinction, warranting further intensive research to assess the state of the affected habitat. Additionally, it is crucial to monitor species diversity to document changes resulting from human activities (Magurran 2007; Christie *et al.* 2019; Ramahlo *et al.* 2022; Chanachai *et al.,* 2022)

This study investigated the ungulate diversity and their relative abundance, and anthropogenic impacts in a derived savanna ecosystem. Additionally, analysed the population structure of ungulates and examine anthropogenic activities in the park, with a view to answer the questions of- what specie of ungulate are available, what species is most abundant, what is the population structure and prominent illegal activities affecting the park?

MATERIALS AND METHOD

Study Area

The Old Oyo National Park (8˚ 10′ and 9˚05′ N, 3˚35′ and 4˚20′ E. (Fig. 1), situated within the northern part of Oyo State, Southwest Nigeria (West Africa), the only Park in Nigeria's eco-transition zone, known as the derived savanna ecosystem. It is divided into five ranges: Marguba, Ogundiran- Tede, Oyo-Ile, Sepeteri, and Yemoso. Apart from it ecological importance, the park also has archaeological, cultural and historic significance. The vegetation of the park includes dense woodland and forest outliers in the southeastern part, mixed open savanna woodland in the central part, outcrop vegetation in the northeast and riparian grassland and fringing woodland occupying the forest plains and valleys along a perennial Ogun River water body (Jayeola, 2009).

It is rich in fauna and flora resources such as Roan antelope, (*Hippotragus equinus*), Western hartebeest (*Alcelaphus buselaphus*), Red-flanked duiker (*Cephalophus rufilatus*), Oribi (*Ourebia ourebi*), Buffon's kob, (*Kobus kob*), Buffalo (*Syncerus caffer*), and other antelopes. It has a wide variety of birds, including the endemic species, Ibadan malimbe (*Malimbeus ibadanensis*). Annual rainfall in the park ranges between 900 mm and 1,500 mm, and the main annual temperature is between 12° C and 37° C. The rainy season begins in April through September, with the highest rainfall between July and August. The dry season begins in October through early April and harmattan is usually experienced between November and February.

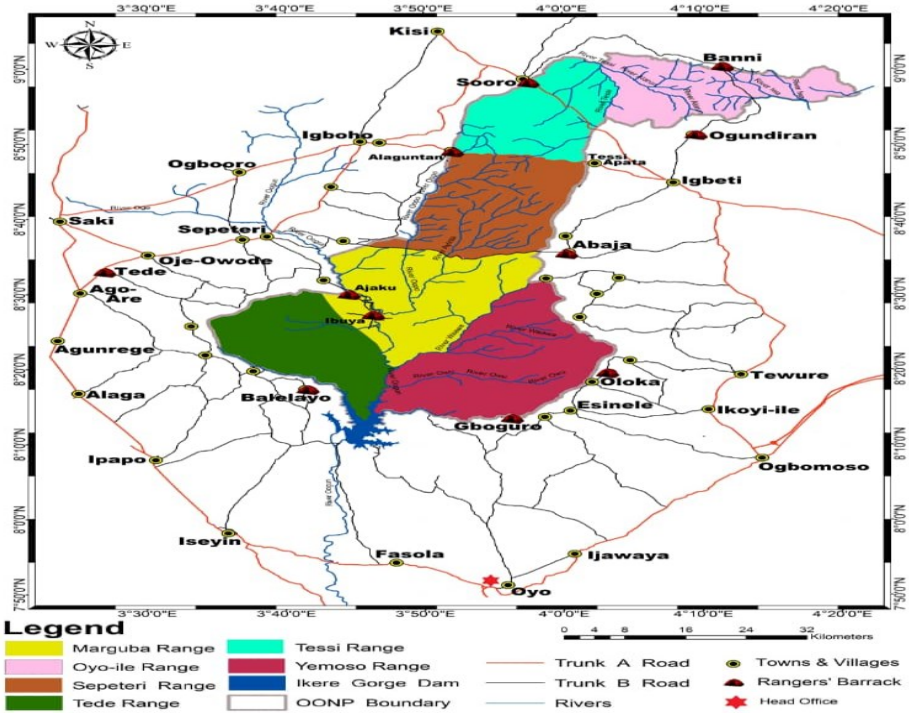

Figure 1 Map of Old Oyo National Park Showing the Ranges. Source: Old Oyo National Park, ICT Unit

Data Collection

A preliminary survey of ungulates in the park (visual count) indicates that animals were concentrated in the Marguba Range. Using Global Positioning System (GPS), three tracks established in this area, as it contains the major water source (River Ogun) that flows through the park year-round. The three tracks were: Yemoso Track (4 km, 8.26014˚N 3.47013˚E), Ajaku-Ibuiya Track (6 km, 8.27287˚N 3.46191˚E), and Maha Track (5 km, 8.27509˚N 3.46563˚E).

Direct count method was adopted the, identifying and counting animals sighted on either side of the established tracks. This method follows (Tyowua *et al.,* 2012), who used it to study Roan antelope habitat in Kainji Lake National Park, Western Nigeria. The surveys were conducted in each track from 07.00-10.00-hour GMT and 15.00-18.00 hours GMT, while looking ahead and literally in the direction of travel to detect and identify ungulate species on either side of the tracks, twice a week for six consecutive months (*June to December, 2021)*, to give 136 effective rounds (80.5 km) traversing for all tracks in an area of 540 square kilometers. Information on individuals, sex, age and species, time, location, and anthropogenic activities within each track were observed and recorded with the aid of a Mitech LS3000 rangefinder and PROMINAR® binoculars (8X42 magnification). Body size, shape, presence of horn, female genital organs and udders were indices used to determine sex, age and population structure of Ungulates. This follows after (Eliana *et al.,* 2024) whose report support that the aforementioned features usually well pronounced in ungulate are sufficient enough for sexual differentiation; as sexual dimorphism is the phenotypic difference between male and female of same species beyond gonads and reproductive glands. A review of past records on illegal anthropogenic activities affecting population and conservation of game animals was conducted with the support of the Management Information Unit of the park. Population density of key species available in the park was determined by subjecting data to the model: $D = (ns/2LW)/km^2$, where D- relative abundance, n- number of animals sighted, s- mean group size, L- Length of track and W- Mean sighting distance as recommended by (Fernanda *et. al.*, 2001).

Data Analysis

Data analysis was done using both descriptive tools such as mean, frequency percentages bar chart and inferential statistical tools such as Shannon-Wiener, Species diversity index and species evenness. R Studio (Version 4.3.1) software comprising several analytical approaches was employed to examine species diversity, community composition and population structure across study location. The analysis was structured into three main components: diversity indices calculation, species composition assessment, and population structure evaluation. Species diversity was assessed using multiple indices to capture different aspects of community structure (Magurran, 2004)

RESULTS

Altogether, 693 individuals of four ungulate species (Kob-*Kobus kob,* Red-flanked duiker -*Cephalophus rufilatus,* Bush buck-*Tragelaphus scriptus* and Hartebeest- *Alcelaphus*

buselaphus) were encountered and recorded after a kilometric effort of 80.5 km. Kobs recorded the highest number of individuals (171 males and 319 females), followed by Duikers, 92 individuals (37 males, 55 females), Bushbuck, 62 individuals (24 males and 38 females), and Hartebeest, 49 individuals (21 males and 28 females).

The density structure of ungulates along the tracks indicated that Kob had the highest density on both Ajaku-Ibuiya and Maha tracks with 0.189/km² and 0.31/km², respectively. In Yemoso, hartebeest recorded the highest density of 0.11/km², and kob density was negligible at 0.005/km². Bushbuck and Duiker densities on Ajaku-Ibuya track were 0.04/km² and 0.05/km², respectively, while an equal density of 0.07/km² was recorded on Maha track, with no record on Yemoso track (Table 1).

Table 1: Ungulates' relative abundance and population structure along tracks under study

Track	Wildlife Spp									
	Kk		Cf		Ts		Ab		Total	%
	M	F	M	F	M	F	M	F		
Ajaku-Ibuya Track	78	127	14	27	9	16	0	0	271	39.10
Density	0.189/km²		0.05/km²		0.04/km²		-			
Maha Track	92	189	23	28	15	22	0	0	369	53.2
Density	0.31/km²		0.07/km²		0.07/km²		-			
Yemoso Track	1	3	0	0	0	0	21	28	53	7.65
Density	0.005/km²		-		-		0.11/km²			
Total	171	319	37	55	24	38	21	28	693	100
RelativeAbundance	0.51±0.006/km²		0.12±0.04/km²		0.11±0.03/km²		0.11±0.03/km²			
Sex ratio	1:1.87		1:1.49		1:1.58		1:1.33			
Mean	3.39		0.44		0.43		0.32			

Kk- Kobus kob, Cr- Cephalophus rufilatus, Ts- Tragelaphus scriptus, Ab- Alcelaphus buselaphus, M-male, F-female, %- Percentage.

The descriptive summary statistics for the age structure metrics across the four species indicated that mean total population size (173.25) is substantially influenced by the large Kob population (490 individuals), with the median population size (77.00) providing a more representative measure of central tendency. The proportions of adults and juveniles indicated relatively narrow ranges, with adult proportions varying from 22.6% to 29.4% and juvenile proportions ranging from 70.7% to 77.4%. This suggesting consistent age structure patterns across species. The sex ratio metrics shows notable variation, particularly for adult sex ratios, which range from 1.33 to 2.38 (mean = 2.06), indicating considerable male bias among adult individuals; while juvenile sex ratios display less variation (range: 1.10 to 1.29; mean = 1.21), and overall sex ratios demonstrate even tighter clustering (range: 1.30 to 1.45; mean = 1.39). The interquartile ranges (IQR = 0.282) further indicated that adult sex ratios show the greatest dispersion, while juvenile and overall sex ratios demonstrate more consistent patterns across species (Table, 2).

The species diversity indices for the locations indicated that both Ajaku-Ibuya Track and Maha Track support three species each, while Yemoso exhibits a comparatively lower species richness of two species. The Shannon diversity index values suggest that Maha Track (H' = 0.740) demonstrates marginally higher species diversity than Ajaku-buya Track (H' = 0.717), with both approaching their respective maximum possible diversity values (H_max = 1.099); whereas Yemoso (H' = 0.268) shows substantially lower diversity with maximum potential diversity (H_max = 0.693). Similarly, the Simpson index, which measures the probability that two randomly selected individuals belong to different species, reveals that Maha Track (0.413) and Ajaku-Ibuya Track (0.396) exhibit comparable diversity levels, while Yemoso (0.140) demonstrates considerably lower species evenness. The evenness values, reflecting the equitability of species abundance distributions, suggest that both Ajaku-Ibuya Track (J = 0.652) and Maha Track (J = 0.674) maintain relatively balanced species communities, whereas Yemoso (J = 0.386) appears to be dominated by fewer species with uneven abundance patterns (Table 3).

Yearly distribution of arrest for various offences on Old Oyo National Park showed that grazing of livestock inside the park accounted for the highest arrest – 76.0%, 64.0%, 82.0% 61.0% and 51.9% in 2017, 2018, 2019, 2020, and 2021 respectively, followed by hunting having 21.0%, 31.0%, 18.0%, 25.0% and 39.2% in the reviewed years respectively (Table 4).

The species refraction curve for the study, being the relationship between sampling effort and observed species diversity; demonstrated that Ajaku-Ibuya and Maha tracks consistently achieve higher species diversity across all sampling intensities compared to Yemoso track; with both tracks approaching asymptotic diversity levels of approximately 2.8 to 3.0 species as sampling effort increases (Figure 2).

Table 2: Summary Statistics for Age Structure Metrics

Metric	Min.	1st Qu.	Median	Mean	3rd Qu.	Max
Total	49.00	58.75	77.00	173.25	191.50	490.00
Adult Propotion	0.2258	0.2554	0.2765	0.2681	0.2892	0.2935
Juvenile Propotio	0.7065	0.7108	0.7235	0.7319	0.7446	0.7742
Sex Ratio Adult	1.333	2.021	2.265	2.059	2.303	2.375
Sex Ratio Juveiles	1.097	1.191	1.236	1.214	1.259	1.286
Sex Ratio Overall	1.296	1.343	1.404	1.389	1.450	1.450

Table 3: Detailed Shannon Diversity Components by Location

Location	Shannon_H	H_max	Evenness_J	Species Richness	Simpson Index
AjakuIbuya Track	0.7167115	1.0986123	0.6523789	3	0.3963726
Maha Track	0.7400733	1.0986123	0.6736437	3	0.4126004
Yemoso Track	0.2675679	0.6931472	0.3860189	2	0.1395514

Table 4: Illegal activities recorded in the park

Nature Arrest	2017 n=98	2018 n=58	2019 n= 50	2020 n=52	2021 n=158
Hunting	21 (21.0%)	18 (31.0%)	9 (18.0%)	13 (25.0%)	62 (39.2%)
Grazing	74 (76.0%)	37 (64.0%)	41 (82.0%)	32 (61.0%)	82 (51.9%)
Logging	3 (3.1%)	3 (5.0%)	0 (0.0)	7 (14.0%)	3 (1.9%)
Aiding & Abetting	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (2.5%)
Farming & Fishing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	7 (4.4%)

Figures in Parenthesis are in Percent. Source: Old Oyo National Park Records

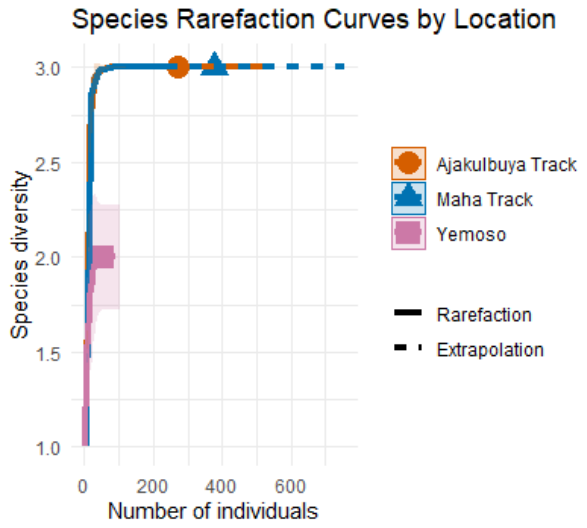

Figure 2: Species Refraction Curves by locations

DISCUSSION

Our survey identified and recorded four ungulate species in the OONP which is lower compared to previous published studies that recorded higher number of ungulate diversities in the area (Oyeleke et al. 2015; Adedoyin, 2018). For example, an earlier study identified seven species of ungulate (Kobs-*Kobus kob*, Waterbucks-*Kobus ellipsiprymnus*, Bushbucks-*Tragelaphus scriptus*, Buffalo-*Syncerus caffer*, Oribi-*Ourebia ourebi*, Redflanked duiker-*Tragelaphus scriptus*, and roan antelope-*Hippotragus equinus*), with the exclusion of Warthog-*Potamochoerus porcus* (Oyeleke et al, 2015). Other studies conducted in the area recorded only 5 species (Redflanked duiker-*Cephalophus rufilatus, Roan antelope- Hippotragus equinus, Bush pig- Phacochoerus aethiopicus, Warthog-Potamochoerus porcus, Common duiker- Sylvicapra grimmia*) respectively. Generally, the status of ungulates in West Africa cannot be generalized across species or protected areas; as some species readily recover when effectively protected whereas others may continue to decline due to habitat transformation or vulnerability to hunting as reported by (Scholte *et al.,* 2025).

The observation of four ungulate species within the park demonstrates population reduction of ungulate type within the park. However, the varying abundance of these species, with Kobs being the most abundant and Hartebeest the least abundant, suggests potential differences in habitat suitability and resource availability within the park. Despite reduced ungulate diversity, a species that was not recorded for a long period in the park was observed (*Acelaphus buselaphus*), possibly due to survey intensity, length, or period of survey. The distribution of ungulate populations across different tracks highlights the importance of habitat preferences and resource availability in shaping population dynamics within the park. Our study did not consider the influence of habitat structure on the distribution and diversity of ungulates, so we recommend that future studies investigate the effects of habitat structure on ungulate distribution and diversity.

Our findings indicate that there is variation in density of same ungulate species across locations understudied. Density discrepancies of same species of ungulate across location may be due to differences in ecological/habitat character as Maha and Ajaku-Ibuya tracks are typical lowland area with constant water body while Yemoso is an upland area. This agrees with the findings of Mohammed & Mohd Sah (2023) and Harris, *et al.* (2024) who reported that population estimate for ungulates can vary according to habitat/geographical range within same protected area and that co-occurrence of ungulates is positively influenced by precipitation or availability of rivers respectively. Ungulates population composition and structure for this study, is quite different from previously published studies (Adedoyin, 2018), which identified species from the equis family contrary to our study. Adedoyin, (2018) also observed a high adult ungulate density while we observed and recorded a high juvenile ungulate density in the area. The composition of the ungulate populations, with juveniles comprising over fifty percent of the Kob population and similar proportions observed for other species, suggests active reproduction and recruitment within the park. This indicates a healthy population structure and potential for population growth in the future. The sex ratio observations provide clues on the breeding dynamics and reproductive success of ungulate species within the park. Understanding sex ratios can help assess population health and reproductive potential, guiding conservation efforts aimed at maintaining a viable population.

The park's anthropogenic activities were reported to have increased due to the recent banditry incursion into the park. Kobs are the most abundant ungulate species in the area and supported similar observations in other parks where ungulates exist (Olajesu *et al.,* 2019). This may be due to their preference for habitat with a continuous water source throughout the year and their limited travel distance in an environment with the required food (Olajesu *et al.,* 2019). The relative abundance of kob in our study is lower than the previous study reported (Jayeola, 2009) in the same environment. Significant increase of the latter report could relate to improvement in habitat quality and protection of the animals against disturbances over the years.

Low relative abundance of duiker and bush buck had been reported earlier in the Marguba range by Popoola (2001) and our study mirror this finding. The low density could be traced to the fact that animals are solitary, thereby reducing their chances of been sighted. Contrary to our assumption, hartebeest had a high density compared to previous report (Popoola, 2001). Our study does not consider the effect of habitat structure on the distribution of ungulates and the level of anthropogenic activities within the park that can affect ungulates diversity. These two parameters were believed would shed more light on the reason for poor ungulate diversity and population structure. Park records showed that 61% arrest made in 2021 were for livestock grazing in the park while 25% were poachers. Livestock grazing, wild animal hunting, and logging were observed as the most prominent illegal activities committed by people breaking Park laws, while farming and fishing were the least (4.4%).

Unethical hunting and anthropogenic disturbances are major threats to ungulate populations and habitat destruction in the park. There is hardly a month when poachers and loggers are not arrested in the park. This is because the Park still harbours a significant number of palatable grasses and trees which are being lopped, especially during the dry season. This is not only peculiar to Old Oyo National Park, as reported by Meduna *et al*, (2009). Likewise, Ayeni *et al*., (1982) observed that the looping of *Afzelia africana, Khaya senegalensis* and *Tamarindus indica* by the cattle Fulani men in Kainji, Dagida, and Kwambana Reserves which provide cover and dry season browse material for wildlife, is a major problem which needs to be checked. Poaching activities in and around parks, as well as the unwise use of nature has been the major problem facing the park and have led to the extinction of some fauna species (Ayeni *et al*., (1982).

Earth Trend (2003), and Glenn (2006) for example reported that out of 274 known species of mammals in Nigeria, 27 and 37 species are threatened. Gubbi (2003) reported that 85% of the parks surveyed in 16 tropical countries on three continents had poaching as the first in the list of anthropogenic factors; this is because penalties levied on park law breakers are too weak to deter them from committing the same offence they were arrested for. The Old Oyo National Park is the only Park in the derived savanna of Nigeria and so it is important to protect the remaining wildlife it is housing. A detailed investigation on the effect of habitat structure and banditry should be carried out as these can provide an insight on the state of ungulates and other wildlife in the area.

Ungulate species have been reduced in the park, which may be attributed to several man-induced environmental challenges facing the park such as illegal hunting, logging, farming, and illegal grazing. A recent dilemma facing the park is banditry; this is the worst kind of threat as it not only affects wildlife resources but also threatens park protection staff of the park. In this scenario, the normal routine enabled by the parks management for habitat improvement such as controlled bush burning to improve fresh lush vegetation, anti-poaching patrol and regular surveillance of the park for ungulate have been disrupted, and truncated since mammal species diversity is often correlated with food availability and the overall quality and maintenance of the forest (Western *et al*. 2009; Tefera, 2011; Vreugdenhil, 2012).

Ajaku-Ibuya and Maha tracks supported consistently higher species diversity than Yemoso possibly because of the sampling effort (Palei *et al.,* 2023) according to the asymptotic accumulation curves which characterize the mammal community in accordance with habitat variation.

CONCLUSION AND RECOMMENDATIONS

The study recorded four ungulate species, which indicates a lower observed diversity compared to previous studies. The differences in species abundance and distribution across tracks suggest that habitat structure in different ranges and the availability of water holes may have influenced ungulate populations. Despite the relatively high proportion of juveniles, especially in the Kob population, which suggests that the population is active in reproduction, anthropogenic pressures such as poaching, illegal grazing, logging, farming, and more recently, banditry, remain major threats to ungulate the conservation. It is recommended that future studies should investigate how habitat structure and anthropogenic disturbances directly affect ungulate diversity and distribution, while regular monitoring and protection should be strengthened within the park.

Acknowledgements

Authors appreciate the management and staff National Park Service Headquarters through Old Oyo National Park (OONP) for grant approval to conduct this study. Authors also extend our appreciation to the OONP research unit for provides logistics and support for the study.

Author's Contribution

SDO managed data collection, analysis interpretation of data, writing of manuscript, and wrote the first draft of the manuscript. TKO, FLO & JKO worked on the data analysis, literature and manuscript review. SOA worked on manuscript review. All authors read and approved of the final manuscript.

Ethical Statement

Not applicable

AI Declaration Statement

The authors declare that Artificial Intelligence (AI) tool(s), Deepseek was used as a paraphrasing tool. All outputs were critically reviewed, verified, and approved by the authors, who accept full responsibility for the content of the manuscript.

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