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Evaluating the Impacts of Human Activities on Diversity, Abundance, and Distribution of Large Mammals in Nimule National Park, South Sudan

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Abstract

Globally, human activities have a significant impact on the diversity, abundance, and distribution of large mammals in Protected Areas (PAs). These disturbances increase human pressure on biodiversity and species habitats, highlighting the need for conservation. This study aimed to assess the abundance and distribution of large mammals in different habitat types within Nimule National Park (NNP) and understand the impacts of human activities on them. Data on the abundance and distribution of large mammals and their respective habitat types were collected through line transect surveys. Human activity signs were observed and recorded along the transect lines. To estimate the impacts of human activities on the diversity, abundance, and distribution of large mammal species, as well as to identify any significant differences between them and their habitat types, the study utilized the Kruskal Wallis test, Polynomial multiple regressions, and diversity indices. The findings from the Shannon-Weiner and Simpson indices indicated that large mammal species were more diverse inside the park (H' = 1.136; D = 0.570) compared to the buffer zone (H' = 0.413; D = 0.171), with 85% (443 out of 510 samples) recorded within Nimule National Park. The species abundance showed a semi-balanced status (0.58). The diversity results among different habitat types revealed that large mammals were more diverse and highly distributed in both open woodlands (244) and dense woodlands (192), while riverine vegetation had the lowest diversity (8). Statistical tests demonstrated a highly significant difference at a 99% confidence interval (p-value = 0.01) between habitat types and identified species of large mammals. Additionally,

the results highlighted the high abundance of Uganda kob (274), baboons (141), and warthog (57) across most habitat types, accounting for at least 75% of their distribution. The most prevalent human activities observed were cattle footprints (27%) and cattle dung (14%). Human footprints and tree cutting combined accounted for 9%, indicating the practice of livestock grazing, poaching, encroachment, and fuelwood collection by local communities. However, these activities did not appear to significantly impact the diversity, abundance, and distribution of large mammals in Nimule National Park. Therefore, it is crucial to foster shared responsibilities and engage relevant stakeholders in the management and conservation of large wildlife species. Regular community awareness programs should be implemented to cultivate a sense of ownership. Moreover, it is recommended that a comprehensive survey be conducted on the population status of all mammal species in Nimule National Park, including its surrounding Buffer Zone. Monitoring the impact of human activities on their behavior and habitats using satellite images should also be carried out at least every five to ten years.

Keywords

Diversity of Large Mammals, Abundance and Distribution, Impacts, Biodiversity Conservation, Human Activities, Nimule National Park, South Sudan

1. Introduction

Human activities and development, such as livestock grazing, poaching, agriculture encroachment, oil exploration and extraction, settlements, infrastructure development, and transportation networks, have posed a threat to wildlife distribution [1] [2] [3]. Farming and logging for timber have been found to have a negative impact on mammal populations [4]. In a study conducted in Bakossi National Park in Cameroon, it was discovered that high concentrations of mammals in the northern and southern areas of the park were influenced by factors such as food availability, shelter, reduced hunting, and encroachment of farmland [5]. Protected areas can suffer direct damage from activities like timber extraction, hunting, and land clearance for agriculture, all of which can have detrimental effects on wildlife populations [6]. However, a study conducted by [7] specifically focusing on the impacts of agriculture around Garamba National Park concluded that there was no evidence to suggest that the presence of human populations could be linked to a decrease in the abundance of large mammals.

Furthermore, poaching is a major threat to the survival of wildlife in many protected areas, especially in developing countries [8]. This threat often stems from the unsustainable consumption of wildlife by communities living near national parks. These communities may rely on hunting wildlife to meet their need for animal protein. Illegal hunting by communities surrounding the national park has a significant impact on ecosystem development [9] [10] [11] [12]. Con-

versely, in most national parks of South Sudan, particularly in NNP, there are no scientific studies currently highlighting the extent of illegal hunting. However, it is evident that hunting is more prevalent near the Pangalla-Uganda border than in other areas of the park, including the buffer zone. This continuous illegal hunting poses a significant conservation threat in most areas of Nimule National Park [9] [13] [14]. Additionally, fishing camps situated within the park and along the banks of the River Nile (**Figure 10**) are being utilized as bases for illegal hunting, particularly targeting ungulates and other animals at the expense of fishing. This activity is carried out by fishermen or groups of fishermen who claim to be exclusively engaged in fishing. Furthermore, the park lacks regular patrols, trained wildlife personnel, and the necessary infrastructure and logistical support, resulting in limited monitoring and surveillance. Most hunting activities tend to occur during the rainy season, with ungulates and primates being the most targeted species [15]. The result of local community hunting can be a decline in the abundance and distribution of large mammals. [16] observed that areas with low rates of poaching had a higher relative density of ungulates. However, both [17] and [18] emphasized that unsustainable hunting was a major driver of species depletion.

The rapid growth of human populations has implications for increased demand for land for settlement and agriculture. In the case of Nimule National Park, the growing human population sees the parkland as an area where they can expand for crop cultivation and community settlement. Local community members also gather building poles and fuel wood from the national park for household activities such as cooking, building, and making charcoal. [19] observed a large number of people collecting fuel wood and harvesting fish from the national park for household consumption. This access to resources by local people can change the land cover and disrupt wild animals [20]. A study by [21] showed that illegal logging for fuel wood, construction materials, and charcoal production were the most common human activities that threatened the survival of medium and large-sized mammals in Ethiopia [22]. These actions by farmers and livestock owners would ultimately result in habitat loss or degradation and competition for resources, negatively impacting wildlife survival [23] [24] [25]. Furthermore, [26] reported that encroachment due to overgrazing and grass-cutting are some of the main factors threatening mammals in the surveyed area. However, a study elsewhere suggests that human factors have a greater influence on the abundance of large mammals than other environmental factors [27]. On the other hand, a study by [28] suggests that human settlement negatively influences the numbers and distribution of wildlife.

In South Sudan, peace has returned after prolonged and escalated civil wars. As a result, many South Sudanese refugees who were previously living in neighboring countries such as Uganda and Kenya, as well as internally displaced persons, are now either passing through or settling in Nimule National Park. This influx of people is putting significant pressure on the park's wildlife resources [29]. Activities such as tree cutting for building material, cultivation, human traffic, li-

vestock grazing, fishing, and poaching are increasingly threatening the survival of biodiversity.

Given the increased human pressure on natural resources in Nimule National Park, it is crucial to focus on wildlife conservation, particularly for large mammals. This conservation effort is essential not only for the park's biodiversity but also for South Sudan's ability to meet its obligations as a signatory to various international conventions related to biodiversity conservation.

This study aims to assess and determine the human activities that influence the diversity, abundance, and distribution of large mammal species in different habitat types within Nimule National Park and its buffer zone. The study seeks to answer the following research questions: Which large mammal species exist in Nimule National Park and its buffer zone? How are these large mammals distributed across different habitats within the park? Is there a diverse and abundant population of large mammals in Nimule National Park? What are the key human activities affecting the occurrence of large mammals and their preferred habitats in the park?

However, answering these questions requires a holistic and comprehensive approach. There is complexity in understanding the perceptions and attitudes of local communities towards coexisting with wildlife and the subsequent impacts on them. These concerns often lead to conflicts between humans and large wildlife mammals within the park, requiring conservation and management efforts to harmonize their coexistence. Therefore, it is important to establish wildlife patrolling camps within NNP, train staff and rangers on how to report any illegal activity spotted within the park, offer adequate incentives and remuneration to rangers, increase the number of patrolling wildlife rangers, and equip them with logistical support and communication facilities such as radio calls, motor boats, motorbikes, and vehicles. These measures are essential for effectively conserving and managing wildlife. Additionally, community awareness campaigns and sensitization programs on the importance of wildlife and wildlife conservation should be introduced to educate the communities living around NNP. This will help them understand wildlife's social, economic, cultural services, and ecological significance for their communities.

2. Materials and Methods

2.1. Description of the Study Location

Nimule National Park (NNP) is one of the smallest parks in South Sudan. It was first established by the British colonial power in 1935 as a Game Reserve before being designated as a National Park in 1954. The Park covers a distance of about 256 km^2 and has a gazetted Buffer Zone area of 154 km^2, adding up to a total area of about 410 km^2 [30]. It is located in Magwi County of Eastern Equatoria State, in the extreme south of South Sudan, bordering Uganda [30]. Nimule National Park is situated between latitudes 3.35˚:3N and 3.490:2N, and longitudes 31.480:3E and 32.20:2E (**Figure 1**). The park has a continental type of climate

characterized by orographic and conventional rainfall, with thunderstorms. The rainy season in the park lasts from April to the end of November, while the dry season runs from December to March. The average annual rainfall in the park varies from 1000 to 1200 millimeters, and the average daily temperature is 27˚C, with minimum temperatures of 24˚C and maximum temperatures of 29˚C in March and July, respectively.

The park is home to a variety of wildlife species, including vegetation and animals. The vegetation cover consists of deciduous high woodland savannah, characterized by broad-leafed and foliage trees, some of which are deciduous and others evergreen. Most grasses in the park are perennial and grow to a height of 1 - 1.5 meters. The main purpose of establishing the park was to protect the now-extinct white rhinos (*Ceratotherium simum cottoni*). Other large mammals that can be found in the park include elephants (*Loxodonta africana*), hippopotamuses (*Hippopotamus amphibious*), Uganda kobs (*Kobus kob*), oribis (*Ourebia ourebi*), hyraxes (*Procavia capensis*), baboons (*Papio anubis*), vervet monkeys (Cercopithecus), common jackals (*Canis aureus*), and leopards (*Panthera pardus*), among many others [31]. The park also has a diverse range of herpetofauna, including Nile crocodiles (*Crocodilus niloticus*), Nile monitor lizards (*Varanus niloticus*), savanna monitor lizards (*Varanus exanthematicus*), African rock pythons (*Python sebae*), and various other lizard and amphibian species. Additionally, the park is home to a wide variety of bird species [32] [33].

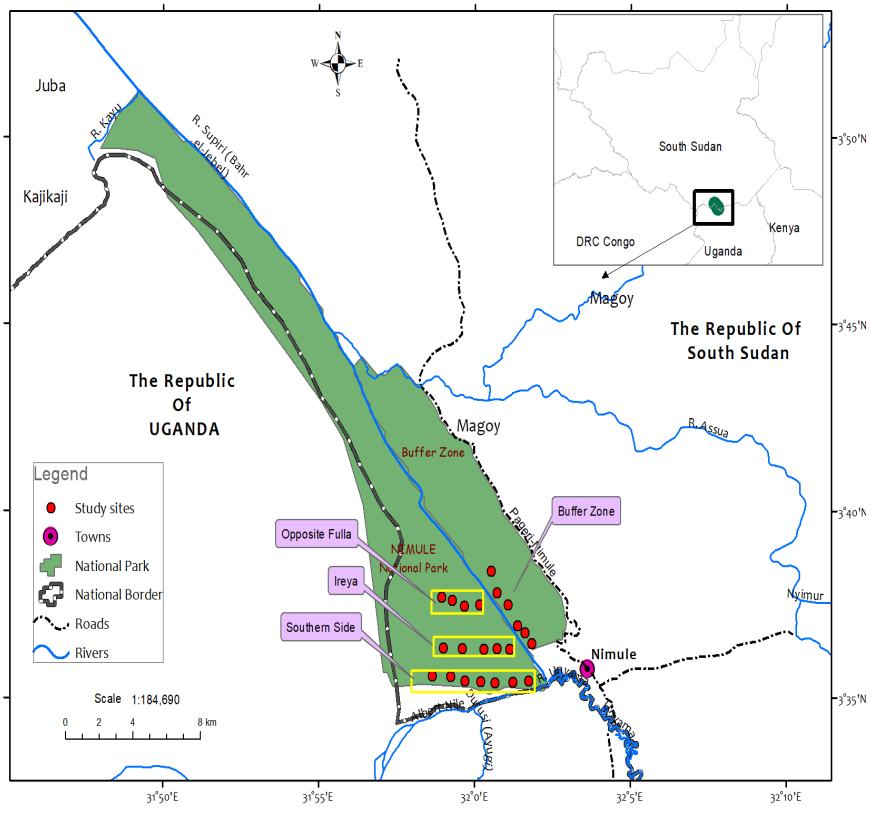

Figure 1. A location map of the study sites in Nimule National Park, South Sudan (source: primary data; Shazali *et al*.).

One of the major biodiversity components of the park is the African savanna elephant, which has managed to survive three wars. These elephants are known to expand their foraging areas beyond the park's boundaries into Adjumani District in Uganda and Magwi County in South Sudan [34] [35]. This behavior may be a response to the disturbances caused by human communities, which pose a threat to wildlife and force many large mammals to migrate [36].

2.2. The Study Design, Sample Size, and Sampling Procedures

The study utilized a cross-sectional survey to collect primary data through the layout of line transects to view large mammals in NNP. The park is divided into two zones by the river Nile—a Buffer zone where certain human activities are allowed, and a strictly Protected Area known as a "No-go zone" for wildlife. The current study has adopted a stratified sampling technique where the study area was divided into four areas: the southern area (Panzaala), the area west of Fulla Rapids, the Ireya area (west of Commando Wildlife Ranger Camp), and the buffer zone. A total of 34 transects were used for conducting large mammal surveys and collecting environmental data, with each transect line ranging from 1 to 2 km and placed 200 m apart [37]. The transects were positioned along a disturbance gradient, starting from the outer region near the community settlement and extending towards the interior of the park. Direct observations of available large mammals were made in this interior region [38] [39].

2.3. Data Collection and Instrumentation

The nature of the landscape in Nimule National Park made it unsuitable for vehicle transect counts. Therefore, all transect counts were conducted through transect walks, following the method described by [40]. These walks involved recording the number of animal species sighted along the transect line, with an average speed of 1 km/hour. A total of 34 transects were established to cover the park, with the transect walks starting between 7:00 am and 11:00 am each day. It was conducted between June and July 2017 during the rainy season. During periods of cold weather and low temperatures, it is common to observe the emergence of large mammals in the park as they search for food. This behavior may occur either in groups, reflecting a sense of solidarity, or individually. It is noteworthy that this period coincides with a rapid regrowth and regeneration of vegetation, which offers abundant food sources including young saplings and grasses. Furthermore, it is during this time that secondary adaptations are also observed. Therefore this time period was chosen because it is when large mammals are expected to be most active [41]. To survey the large mammals, line transects ranging from 1 - 2 km were systematically established within a 200 m belt, depending on visibility. Along each transect, direct observations of large mammals were made on both sides. For species identification and to guide tracks and signs of wildlife within NNP, a field guide adopted from the study conducted by [42] and [43] was used. The researchers immediately recorded the

common and scientific names of the mammal species, as well as the frequency and habitat types, in datasheets. During the observation of mammals along the line transect, any human activities were also noted and recorded, following the approach described in the study by [44]. Throughout the survey period, two observers (research assistants) were assigned ten minutes at every 200 m along the transect line to count visible mammals and document any anthropogenic activities that caused disturbances at the sites.

2.4. Data Analysis and Interpretation

The data on the distribution of large mammals in different habitats within the park underwent several statistical tests to evaluate if there were any significant differences. The Kruskal-Wallis test was used, along with the Shapiro test and a non-parametric test, to analyze the habitat distribution data, as these data were not normally distributed. The counter rate, which measures the number of human activities encountered per kilometer walked, was also measured.

Multivariate multiple linear regressions were utilized to assess the influence of multiple independent variables (human activities) and multiple dependent variables (diversity, abundance of large mammals) in the study area [45]. Shannon Weiner's and Simpson's diversity indices were calculated and used to examine the diversity of large mammal species between the park and the Buffer zone [46] [47] [48]. Scatter plots were employed to investigate the relationship between the variables and determine the level of significance and association.

To validate the assumptions of the linear models, the Global Validation of Linear Models Assumptions (GVLMA) was conducted using the GVLMA package (ver. 3.6.2) in R Studio [49]. In cases where the models did not meet the assumptions of the tests, the Non-linear Model (Polynomial Multiple Regression) was utilized to assess the impact of human activity on large mammal occurrence. This analysis was conducted using the Polynomial package (ver. 1.4-0) in R. The results were then presented in tables and graphics.

The large mammal species diversity and Abundance were computed through frequency counts for each species and calculated using the Shannon-Weiner diversity index, and Simpson dominance index, using the following formulae [50] [51]:

$$\text{Shannon-Weiner Index}\left(H'\right) = -\sum_{i=1}^{s}\left[Pi * \ln\left(Pi\right)\right] \tag{1}$$

$$\text{Simpson 's dominance index}\left(D\right) = 1 - \frac{\sum n\left(n-1\right)}{N\left(N-1\right)} \tag{2}$$

Where,

S = number of species,

N = Total number of individuals,

n = individuals of one particular species,

Pi = the proportion of n divided by N *i.e.* (n/N),

Σ = summation of [Pi*ln(Pi)],

H' = Diversity index = $-\sum[Pi^*\ln(Pi)]$,
D = Simpson diversity index,
H_{max} = (LnS).

$$\text{Evenness or Abundance (E)} = H'/H_{max} \quad (3)$$

3. Results

3.1. Species Diversity, Distribution, and Abundance of Large Mammals in Various Habitat Types

The results revealed that a total of 510 large mammals, belonging to 7 species from 3 orders (Carnivora, Primate, and Sub-order of Artidactyla), were identified and recorded. These large mammals were from 4 distinct families (see Table 1). The highest number of large mammals was recorded in open woodland (48%), followed by dense woodland (38%), open grassland (13%), and riverine vegetation, which had the least number (only 1%) (see Figure 2). In terms of species diversity, the Uganda kob had the highest number (53.73%) (see Table 1; Figure 7), followed by species of Olive Baboons (27.65%), Warthog (11.18%), and Oribi (4.31%) (see Figure 3). Additionally, species of warthog were more diverse and abundant, occurring in all four habitat types, although they were limited in numbers (Figure 8). On the other hand, species of Uganda kob, Oribi, and bushbuck were moderately abundant, occurring in three (75%) of the four habitat types, with the Uganda kob having the highest number (see Table 1, Figure 7). Species of primates, the Olive baboons and monkeys (Figure 9) and common Duiker preferred both open and dense woodland habitats, while Black backed Jackal occupied only one of the four habitat types (open woodland). The results of the Kruskal-Wallis tests further showed a significant difference (1%) in the distribution of large mammals among different habitat types (chi-squared = 11.841, df = 3, p-value = 0.007948).

Table 1. Distribution of large mammals and their abundances in the different habitat types of NNP.

Species of large mammals surveyed			Habitat type				The total number of animals observed
Common name	Species Name	Family Name	DW	OW	OG	R	
Uganda Kob	*Kobus kob*	Bovidae	96	114	64	-	**274**
Warthog	*Phacochoerus aethiopicus*	Suidae	15	37	1	4	**57**
Olive Baboon	*Papio anubis*	Cercopithecidae	71	70	-	-	**141**
Common Duiker	*Sylvicapra grimmia*	Bovidae	1	6	-	-	**7**
Oribi	*Ourebia ourebi*	Bovidae	7	11	-	4	**22**
Bushbuck	*Tragelaphus scriptus*	Bovidae	2	5	1	-	**8**
Black backed Jackal	*Lupulella mesomelas*	Canidae	-	1	-	-	**1**
Total	-		**192**	**244**	**66**	**8**	**510**

Note: Types of habitats: DW = Dense woodland; OW = Open woodland; OG = Open Grassland; and R = Riverine.

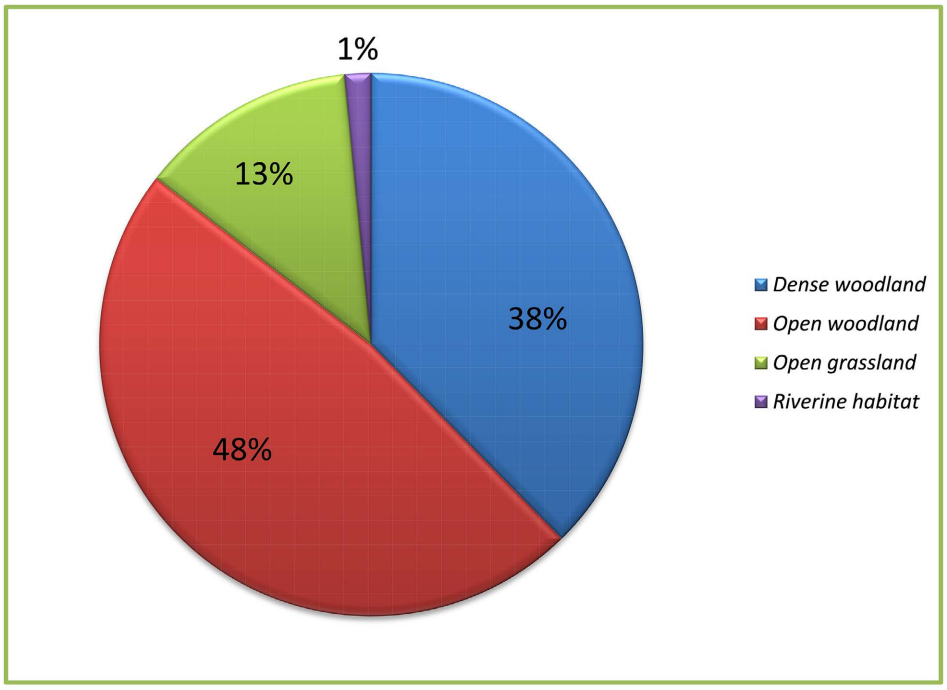

Figure 2. Different habitat types commonly inhabited by large mammals of Nimule National Park.

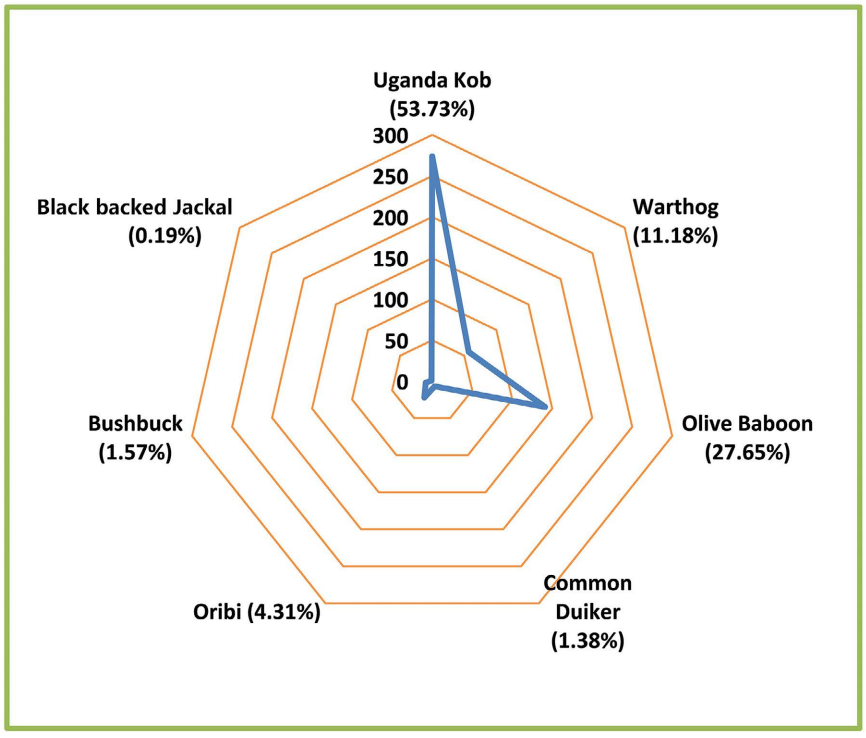

Figure 3. Radar showing the total species diversity (%) of large mammals within NNP.

3.2. Spatial Comparison of Large Mammal Species Diversity in Both NNP and Its Buffer Zone

Overall, we observed 7 distinct species of large mammals along the transect lines. However, we recorded more units and unobserved species in the Buffer Zone

protected area (Table 2). The results of the Shannon Weiner and Simpson indices indicate that large mammal species are more diverse inside the park (H' = 1.136; D = 0.570) compared to the buffer zone (H' = 0.413; D = 0.171). We found that over 85% (443) of the 510 samples of large mammal species were recorded in Nimule National Park, while only 12% (67) were recorded in the Buffer Zone protected area (Table 3). However, there was no significant difference in species diversity between the two surveyed sites (W = 0, p-value = 1.0). The abundance of large mammals in NNP (0.58) is semi-balanced compared to that in the Buffer Zone (0.21) (Table 3).

Table 2. Comparison of mammal species diversity recorded in both the Buffer zone and the NNP.

Common name	Species name	Family	Buffer zone	NNP	Method of records
Black backed Jackal	*Lupulella mesomelas*	Canidae	1	*	**
Olive Baboon	*Papio anubis*	Cercopithecidae	61	80	**
Warthog	*Phacochoerus aethiopicus*	Suidae	*	57	**
Ugandan Kob	*Kobus kob*	Bovidae	1	273	**
Bushbuck	*Tragelaphus scriptus*	Bovidae	*	8	**
Oribi	*Ourebia ourebi*	Bovidae	3	19	**
Duiker	*Sylvicapra grimmia*	Bovidae	1	6	**

** = Overall species observed during the survey; * = Not observed.

Table 3. Calculated values of Shannon Weiner (H') and Simpson's (D) diversity indices for both Buffer zone and NNP.

Description of variable	Number of species count		ni (ni-1)		Pi*ln(Pi)	
Large mammal species	Buffer zone	NNP	Buffer zone	NNP	Buffer zone	NNP
Lupulella mesomelas	1	0	0	0	−0.063	0.000
Papio anubis	61	80	3660	6320	−0.085	−0.309
Phacochoerus aethiopicus	0	57	0	3192	0.000	−0.264
Kobus kob	1	273	0	74256	−0.063	−0.298
Tragelaphus scriptus	0	8	0	56	0.000	−0.072
Ourebia ourebi	3	19	6	342	−0.139	−0.135
Sylvicapra grimmia	1	6	0	30	−0.063	−0.058
Total number of species (N) & Σ	**67**	**443**	**3666**	**84,196**	**−0.41**	**−1.14**
N(N−1)	**4422**	**195,806**				
D & H' diversity indices			**0.171**	**0.570**	**0.413**	**1.136**
Evenness/Abundance (H'/H_{max})					**0.21**	**0.58**

3.3. Impact of Human Activity on Diversity and Abundance of Large Mammals in NNP

The park's status reveals that out of the 34 surveyed transect lines, 97% predominantly show anthropogenic activities in 11 transect lines, while 3% show the absence of such activities in 23 transect lines (Figure 4). The counter rate was determined by dividing the number of human activities by the length of the transect line in kilometers. The results indicate that cattle footprints (0.27) are more prevalent in the NNP, followed by remnants of cattle dung (0.14) resulting from grazing livestock. However, human signs and tree-cutting account for only 0.05 and 0.04, respectively (Figure 5).

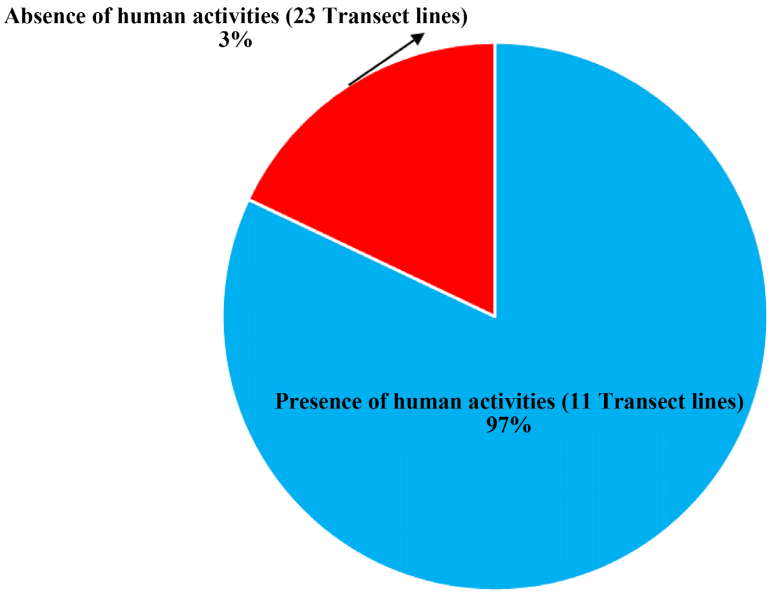

Figure 4. The status of human activities measured by their presence and absence within the 34 surveyed transect lines in the park.

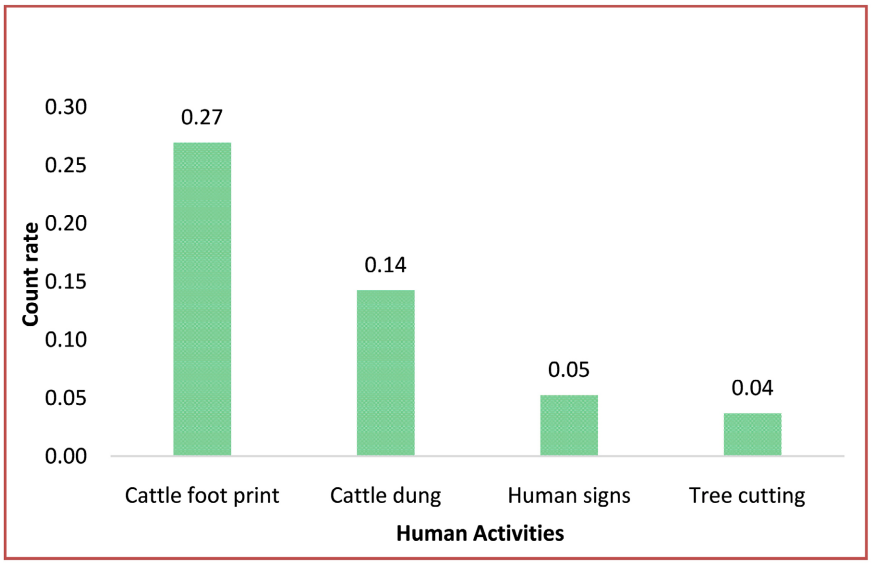

Figure 5. The counter rate of human activity observed in the study area.

3.4. The Relationship between the Occurrence of Large Mammals Along the Line Transect to Signs of Human Activities within NNP

The results showed a relationship between four species of large mammals. For this analysis, only species with a total number of individuals (frequency) observed ≥20 were chosen as response variables. These species include the Uganda kob, Olive Baboon, Warthog, and Oribi. On the other hand, the predictor variables were signs of disturbance caused by human activities in the park. These signs include cattle footprints, cattle dung, human footprints, and signs of tree-cutting /fuelwood collection. The results of the polynomial regression analysis indicated that the coefficients estimated for all predictors were not significantly different from zero. There was no significant association or relationship found between any of the signs of human activities and the number of large mammals sighted in the study area (Figure 6). Although the statistical tests showed positive values (Table 4), these values were not statistically significant.

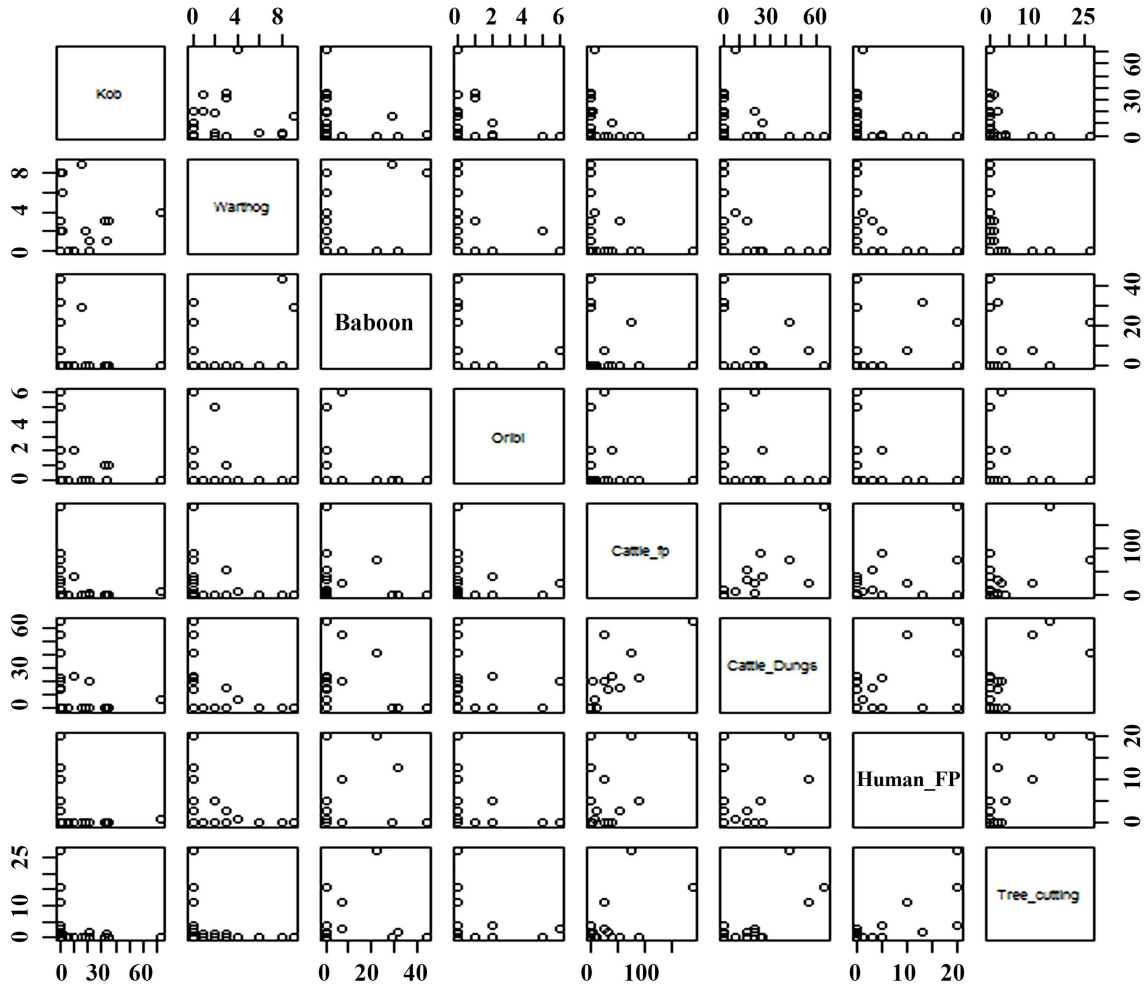

Figure 6. Scatter plot of the relationship between all the variables.

Table 4. Multiple Non-linear Regression analysis relating the occurrence of large mammals to signs of human activities.

Variables	Uganda kob		Olive baboon		Warthog		Oribi	
	t-value	p-values	t-values	p-values	t-values	p-values	t-values	p-values
(Intercept)	2.989	0.0059**	1.584	0.125	4.059	0.000378***	2.569	0.016*
Cattle FP	−0.389	0.7006	−0.745	0.462	0.539	0.594537	−0.0484	0.962
Cattle Dung	0.386	0.7025	−0.293	0.772	−0.853	0.401052	0.383	0.705
Humans FP	−0.573	0.5714	0.646	0.524	−0.903	0.37475	−0.979	0.336
Tree cutting	−0.209	0.8362	0.849	0.403	0.251	0.803865	0.094	0.926

FP = footpoint, * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Figure 7. Uganda kob browsing in open woodland and grassland inside NNP, South Sudan.

Figure 8. Species of Warthog browsing in the Buffer zone around NNP vicinity.

Figure 9. Primates: Species of Baboons and Monkeys preffered both open and dense woodland in NNP.

Figure 10. Fishing camps and human activities at the bank of River Nile, boat/canoe landing sites in NNP.

4. Discussion

4.1. Diversity, Abundance, and Distribution of Large Mammals in Different Habitat Types in NNP and Its Buffer Zone

Of a total of the 510 individuals of large mammals sighted during the survey, Uganda kob was the most abundant species in the park inhabiting atleast 75% of the species' habitat types (**Figure 7**); a fact that may be attributed to the species' habitat suitability that continue to support its existence. Additionally, the species of warthog exhibited greater diversity and abundance, being found in all four habitat types, albeit in limited numbers (**Figure 8**). The olive baboon, being the second most abundant large mammal in the park is the fact that they can occupy atleast 50% of the four habitat types and can survive in both dense and open woodland savanna of the park and buffer zone (**Figure 9**). This could be attributed to the widespread and extensive distribution of Olive baboon species that can occur in various habitats [52] [53]. Other species that recorded less frequency in the park during data collection such as the Oribi, Duicker, and Bushbuck may be due to early rainfall that avoided their free movements, and grazing as they were rarely observed.

Our findings show there was a difference in the species diversity of large mammals between the park and buffer zones. However, a study in Mexico at one zoogeographical region characterized by a large number of endemic Neotropical species, found that there was a significant difference in the diversity of large and medium mammals between preserved and disturbed areas, this is because large mammals respond to anthropogenic factors, which reflected in a decrease in their diversity [54]. The current result of Shannon Weiner's diversity shows that there was a distinctly higher diversity of large mammals in Nimule National Park compared to that in the Buffer zone, which may be linked to the fact that the buffer zone is more exposed and prone to disturbance than the park. This further could be attributed to habitat quality distortion exacerbated by human activities. Indeed, the loss of habitat and its impacts on large mammal diversity was reported by [8]. The impacts of habitat loss can proportionately affect both predators and herbivores since the loss of herbivores also directly affects the activities of predators that depend on them for food. It is reiterated

in a study by [55] who reported that large mammals are extremely sensitive to habitat structure and their distribution proved to be non-randomly related to habitat types. Besides, poor conservation and management practices of large mammal habitats within national parks have contributed to the decline of wildlife species diversity [56]. According to the wildlife officer report of 2017, Seme who is working as a game warden at Nimule National Park, reiterated that inadequate staffing and a lack of logistical support to facilitate patrolling in the park and buffer zone were key reasons for the increased levels of encroachment, illicit destruction of vegetation cover (tree cutting and firewood collection), illegal livestock grazing, fishing as well as poaching activities at the park vicinity.

There was a significant difference in the abundance of large mammals sighted in different habitat types in the study area. However, the results showed riverine habitat was not a suitable habitat type for most of the large mammals in NNP. This may be explained by differences in habitat selection and preference by different large mammal species and that riverine habitat types posed them with risks of predators as well as anthropogenic disturbances causing large mammals to migrate to safer locations. The abundance of large mammals is primarily dependent on the suitability of the environment for their survival, growth, and reproduction. The current result conforms to the study conducted in Kenya by [57] who found that large and medium-sized mammals were significantly different in the number sighted in different habitat types. In addition, a similar result was observed by [58] who also found that mammal species diversity and richness differed among habitat types. However, a study by [59] on elephant populations in Nimule National Park found that there was no significant difference in the distribution of elephants in different habitat types. This may be attributed to the fact that large mammals prefer different habitat types due to the availability of resources that they prefer for survival.

More of the large mammals were recorded in open woodland and dense woodland while least in open grassland and riverine vegetation [60]. This may be related to the fact that large mammals select one habitat type more than others according to ecosystem services that can be provided by the habitat cover e.g. food and shelter. This may be the main reason for encountering their higher distribution in open and dense woodlands. The lower distribution of large mammals found in riverine vegetation and open grassland might be probably ascribed to the presence of human disturbance like fishing along the riverbank, overgrazing of livestock, poaching of wildlife, as well as the removal of forest cover through tree cutting and fuelwood collection. These human practices and disturbances scare and threaten large mammals and thus allow them to migrate to new locations elsewhere, reducing their diversity and richness. A similar result by [61] in Brazil found that the species richness of large mammals was less in grassland due to the presence of human disturbances. Additionally, the fact that large mammals have large body sizes which are easily visible by hunting predators, may be one of the reasons for avoiding this open grassland habitat type,

thus their lower distribution [62].

4.2. Impact of Human Activities on Large Mammal Species Diversity and Abundance in NNP

Human activities such as cattle grazing, tree cutting, and human signs (footprint) were more regularly observed in both the park and the buffer zone [25]. This has made the park highly vulnerable to land degradation and vegetation cover depletion for wildlife habitats. The finding of this study is in line with that conducted by [19] in Ethiopia who found that collection of fuelwood and fishing within the park were the activities observed that threaten the distribution of large wildlife in their habitats (**Figure 10**). Furthermore, [63] reiterated that illegal hunting by communities living around the National Park is the reason for the major decline in the populations of large mammals in African developing countries [13] [64]. Emphasis was that if these activities were left to continue unrestricted, they might be responsible for influencing positively or negatively on large mammals' diversity and distribution in the future [9] [14] [65].

Although the study result showed there is no statistically significant influence of human activities on large mammal abundance, the continued presence of human activities in the study area may have an impact on wildlife survival in the future. The studies by [5] and [16] reported that the high density of large mammals was related to low rates of poaching and farmland encroachment which is contrary to our current study findings. However, [26] also observed that encroachment by grazing livestock and grass cutting was the main factor threatening mammals in Borena-Sayint National Park, South Wollo, Ethiopia. Another contrary study in Bale Mountains National Park, Ethiopia by [24] demonstrated that the major threats to large wildlife were human settlements, agriculture, and overgrazing. Nonetheless, elsewhere, a study of the impact of human activity and development on large mammals e.g. Highway road construction that bisects the protected area increased the mortality rate of large mammals due to accidents while crossing the road [66]. In our study, human disturbances like a road crossing around the Buffer zone may influence the behavior of large mammals in Nimule National Park, where the Buffer zone may record fewer large species of mammals (less abundance) as compared to those found in the park area [21]. These suggest mitigation measures to take place to reduce unnecessary entry into the park by the surrounding communities. However, our findings agree with the studies of [21] and [67] who further argued that the noise that also resulted from anthropogenic activity reduces the abundance of wildlife from their habitats [66]. However, due to the lack of historical data on the abundance, distribution, and population status of wildlife in the NNP, it becomes difficult to encounter the trend of wildlife (large mammals) in the study area. Therefore, our study suggests that further studies are required to address this gap.

5. Conclusions and Recommendations

The study concludes that large mammals are crucial wildlife species that predo-

minantly thrive in open and dense woodlands. The results concerning abundance and distribution reveal that Uganda kob, Bushbuck, and Oribi populate at least 75% of the habitats in NNP, while warthogs occupy all habitat types. Other large mammals, such as Olive baboons, common duikers, and jackals, have a lower chance of survival in certain habitat types, including open grassland and riverine vegetation. Shannon Weiner and Simpson's diversity indices demonstrate that large mammal species exhibit greater diversity within the park compared to the Buffer zone protected area.

Additionally, the study shows that human activities have a significant influence on the abundance and distribution of large mammal species in the park, particularly in various habitat types. Livestock grazing, human encroachment, tree cutting/fuelwood collection, and poaching (evidenced by human footprints) are the most prevalent human activities observed. Although the statistical analysis did not yield significant results regarding the relationship between all signs of human activities and the number of large mammals, these activities do have a positive impact on their respective habitat types.

Among the various rates, the counter rate of 27% for cattle footprints indicates that continuous livestock grazing is prevalent in the park and buffer zone. Proper management and conservation efforts are necessary to sustain the diversity, abundance, and distribution of large mammals in the study area. It is crucial to implement measures that restrict the overexploitation of park resources by the surrounding community. Additionally, effective and sustainable management of the national park requires participatory community engagement, public awareness, and sensitization campaigns regarding the benefits of wildlife conservation and protection. These efforts aim to prevent species migration and extinction in the wild. Furthermore, conducting a comprehensive survey on the population status of all mammal species in the park, as well as monitoring the impact of human activities on their behavior and habitats using satellite images every five to ten years, will provide valuable insights regarding their diversity, abundance, and distribution. Regular patrolling should also be conducted in the park and buffer zone to prevent encroachment.

6. Policy Implications and Future Areas for Research

The impact of human activities on wildlife, especially large mammals, should be a matter of concern and supported by evidence. This is particularly important in communities located near or settling around wildlife parks. It is essential to recognize that wildlife and environmental conservation play a critical role in facilitating the coexistence of humans and wildlife, especially large mammals. To achieve this, it is necessary to employ a range of sustainable policy tools that integrate socio-economic, cultural, and political frameworks. These tools will help enhance land use practices and promote the responsible utilization of wildlife resources.

The awareness of the surrounding communities about the benefits of game

and the conservation of the environment is crucial for the diversity, abundance, and distribution of large wildlife. When all stakeholders collectively engage in conservation efforts, it becomes a key factor in ensuring the co-existence of both the community and wildlife. Therefore, it is important to consider the communities' attitudes and perceptions towards their co-existence with wildlife, particularly in relation to human-wildlife conflicts. The communities often view large mammals as problem-causing animals due to the conflicts they create with human settlements. These conflicts include destroying farms, buildings, and threatening human life, as well as competing with humans for food, water sources, and shelter. They also cause blockages in movement paths.

To prevent unnecessary destruction of vegetation cover for large mammals' habitats, communities should be restricted from livestock grazing, wildlife hunting, tree cutting, and encroaching within the park. In addition to the economic use values, future studies should also focus on non-use indirect values associated with the presence of large mammals in NNP. These include cultural services, scenic landscapes (such as Fulla Falls), nature conservation, recreation/tourism, social cohesion, and spiritual integrity. The contributions of wildlife are diverse and are perceived differently by different communities. It is important to consider not only the economic values but also the potential role of market-based mechanisms in wildlife tourism and conservation. Market-based valuation entails assessing the worth of an ecosystem good or service by considering its value in exchange within market transactions. Within the arena of wildlife recreation and tourism, this may encompass factoring in the cost of entry to particular attractions, like Nimule National Park, or the pricing of visitor services provided by concessions although these values may not comprehensively capture their genuine significance [68]. This is because these lands frequently encounter unpriced utilization, such as casual access, encroachment, or the sheer enjoyment of the surrounding landscape. Ecotourism in Africa is claimed to be an "environmentally sustainable form of development" [69]. In Tanzania, for example, there are ecotourism activities in various protected areas, including national parks and Wildlife Management Areas (WMAs). When local communities receive a share of tourism revenues, they are motivated to support and participate in recreation and conservation activities. Therefore, ecotourism is seen as a way to balance wildlife conservation and economic development. Other market-based mechanisms that should be adopted and considered for large wildlife tourism and conservation in NNP include compensating biodiversity offsets for the harm caused by development projects to biodiversity to prevent a net loss of biodiversity by avoiding and minimizing damage to biodiversity habitats before turning to offsets although there is a lack of evidence supporting many of the expectations set by policy for ecological restoration [70] [71]. Forest certification is yet another market approach that should also be adopted to ensure sustainable forest management to address the impact of timber logging on the environment. It involves implementing environmentally, socially beneficial, and economically

viable practices for present and future generations [72].

As we have seen, market-based approaches may have weaknesses but are vital for combining conservation and development. Market-based conservation can be more effective and equitable if all biodiversity values are considered and distributed fairly to the rightful community owners. Additionally, proper market regulation and equal participation of all biodiversity producers and consumers are necessary. It is also important to emphasize and consider the gender dimensions of these criteria in the markets. This will help to highlight the trends and patterns of diversity, abundance, and distribution of these large animals within NNP. However, the encroachment of humans and livestock grazing in the park has led to increased hunting, poaching, and even bush burning by surrounding communities who seek to benefit from the park's wildlife resources. This can result in a decline in the value and population of these animals. As a consequence, there is a growing degradation of wildlife resources and a migration of large game animals, as they are targeted for their valuable products. Therefore, further research is needed to understand the impact of human communities on the welfare of these large mammals in NNP.

To ensure protection and effective conservation of Nimule National Park, it is crucial for the Wildlife Authority/Administration to build infrastructure that facilitates regular and easy park patrol to deter wildlife law violators. Additionally, it is necessary to impose substantial fines and penalties on individuals who encroach upon the park, violate wildlife laws, or engage in corrupt practices within the wildlife workforce. Therefore, it is essential to gain a comprehensive understanding of the reasons why the local community illegally enters the park and extracts wildlife resources or products. These factors can greatly influence the design, management planning, and conservation efforts for the park's large wildlife/mammals, both within the park itself and in the surrounding buffer zone.

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Authors Contributions

Abdallah Gordon Shazali: Conceptualization, Methodology, Data collection, Formal Analysis, Compilation, and Write-up of the original draft, and Results Interpretation. Joseph Mayindo Mayele: Review of Methodology, Formal Analysis, editing of the entire manuscript, submission of the paper to the journal, financial support in the publication process, and correspondence. Joel Emmanuel Saburi and Justin Samuel Jubara Nadlin: Write up of Introduction section and literature review, proofreading manuscript, and support publication process.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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