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Research Article

Population Ecology and Possible Threats to Defassa Waterbuck (*Kobus Ellipsiprymnus Defassa*) in the Nechsar National Park, Ethiopia

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Because of potential conflicts with humans, we investigated the population structure of waterbuck (*Kobus ellipsiprymnus defassa*) in the Nechsar National Park, Ethiopia, from November 2019 to August 2020, using line transect methods. The estimated population was 118 and 104 in the wet and dry seasons, respectively, and averaged 111 (+8) or 0.23/km^2. The proportion of each age group averaged 31% adult males, 45% adult females, 12% subadult males, 11% subadult females, and 2% juveniles; the large number of female individuals suggests a healthy and increasing waterbuck population. The distribution of waterbuck sightings among habitat types differed by season ($\chi^2 = 15.97$, df = 3, $p < 0.05$). Different conservation measures should be taken to create a conducive environment for waterbuck and large park biodiversity.

1. Introduction

Large herbivores, especially in Africa, have significant ecological and economic value [1], but increasing human activities are leading to the destruction of many habitats [2]. Since 1970, there has been a marked increase in the number of protected areas being established [3], and it is crucial for conservation efforts that protected areas are well-managed by maintaining wildlife populations within ecologically sustainable limits [4–6].

Waterbuck, the largest of the genus *Kobus*, are one of the heaviest antelopes (250–270 kg) and different from other antelopes in having long legs and fur [7], as well as an affinity for water sources. Their range-wide population has been greatly reduced, but significant numbers survive in protected areas [8]. The Nechsar National Park is an Ethiopian protected area established in 1974 to conserve the endemic Swayne's hartebeest (*Alcelaphus buselaphus swaynei*) and other key species, as well as preserve its inherent beauty. However, in recent decades, there has been an observed decline in the population of Defassa waterbuck (*Kobus ellipsiprymnus defassa*), which were once numerous in the park.

The population status of wildlife in protected areas is gradually declining due to grazing, invasion, growing agricultural demands, climate change, and management problems for biodiversity conservation [9], and human-wildlife conflict has been documented elsewhere in Ethiopia [10]. In and near the Nechsar National Park, a significant number of people have been observed collecting firewood and harvesting fish [11]. In addition, huge numbers of cattle were observed grazing together with wild animals inside the territory of the park. As a result, negative attitudes amongst the local Guji people regarding livestock grazing have led to frequent conflicts between the farmers and the park managers in the area [12, 13]. Thus, the current study aims to investigate and document the current population status and possible threats to Defassa waterbuck in the park.

2. Materials and Methods

2.1. Description of the Study Area. The 514 km^2 Nechsar National Park (NSNP) is situated 510 km south of Addis Ababa in the center of the Ethiopian Rift Valley (5°51′ to 6°10′ N, 37°32′ to 38°48′ E) between two major southern lakes, viz., Abaya and Chamo [14] (Figure 1). Within the park, water bodies cover 78 km^2, complemented by a diversity of forest, grassland, open woodland, and fresh water habitats [14, 15], occurring at elevations ranging from 1,100 to 1,600 m [16]. Annual rainfall follows a bimodal pattern with short rains from March to May and a main rainy season from September to November. The average annual rainfall and temperature are 919 mm and 24°C, respectively [17].

Of the 84 mammalian species recorded in the park, ten species likely compete with waterbucks for resources and space: Swayne's hartebeest (*Alcelaphus buselaphus swaynei*), Burchell's zebra (*Equus burchelli*), Grant's gazelle (*Nanger granti*), warthog (*Phacochoerus africanus*), bohor reedbuck (*Redunca redunca*), oribi (*Ourebia ourebi*), greater kudu (*Tragelaphus strepsiceros*), common bushbuck (*Tragelaphus scriptus*), grey duiker (*Sylvicapra grimmia*), and bush duiker (*Sylvicapra oreotragus*). Waterbuck adults and juveniles are vulnerable to predators such as lion (*Panthera leo*), leopard (*Panthera pardus*), spotted hyena (*Crocuta crocuta*), common jackal (*Canis aureus*), Nile crocodile (*Crocodylus niloticus*), and Anubis baboon (*Papio anubis*) [18, 19].

According to NSNP [20], 5% of the households in Gamo Gofa Zone reside within the territory of the park. These households, and others located at the periphery, access the park via illegal routes. Human activities that are believed to threaten the normal activities and habitats of waterbucks include fuel wood collection, charcoal production, illegal grass collection, poaching, overgrazing, deforestation, settlement, and illegal fire. To carry out their protection duty, protection staff undertakes the patrol throughout the day via vehicles and on foot where car access is not possible.

2.2. Methods of Data Collection. A preliminary survey was conducted in the study area before starting the actual data collection. The survey helped to stratified study area into different habitat types, identify topography, climate, infrastructure, and approximate size of the core habitat of Defassa waterbuck in the study area.

For study purpose, the study area was divided into four blocks of habitat based on vegetation types. For observation and counting purpose, transects of varying lengths were laid in each habitat. The transects' placement in each habitat type (block) was determined by the size of the habitat type, and more importantly, by the animal's abundance (density) expected to be found in each habitat [21]. Moreover, transects running along roads, ridge tops, and stream bottoms where disturbance might be apparent were avoided. The four major habitat categories in the study area were as follows:

Block 1 (grassland): this habitat type covered an estimated area of 57 km^2, where a total of 13 transects of varying lengths were laid.

Block 2 (wetland): this habitat type covered an estimated area of 21 km^2, where nine transects of varying lengths were laid.

Block 3 (ccattered vegetation with bush land): this habitat type covered an estimated area of 50 km^2, in which eleven transects of varying lengths were laid.

Block 4 (riverine forest): this habitat type covered an estimated area of 78 km^2, where seven transects of varying lengths were placed.

An in-depth data collection was undertaken from November 2019 to August 2020 to cover both the dry and wet seasons. The line transect counting method was employed. Moreover, a direct observation of the Defassa waterbuck was carried out to collect the required data. The survey was conducted on foot at an average speed of 1 km/h in the riverine forest, scattered vegetation with bushland and wetland, and 2 km/h in the grassland habitat. A silent detection method was carried out where trained observers searched carefully using binocular lenses along the center of the transect line at all times and were assured that animals on the center line of the transect were seen with certainty [22]. During transect walking, the observers recorded the start and end time, start and end of GPS locations, and GPS ID. Each time the Defassa waterbuck is seen, the observers recorded the following: time using standard wrist watch; GPS location by GPS; herd size, sex, number of Defassa waterbuck seen, and age using binocular eye inspection; perpendicular distance by using a binocular reticule; transect length, and habitat type where the animal is observed. All measurements were taken at the animal's original location.

To ensure that appropriate sampling effort is made, each habitat was surveyed twice using distance sampling method in each season [23]. The survey was carried out early in the mornings between 6 : 00 and 9 : 00 a.m. and in the late afternoon from 16 : 00 to 18 : 00 p.m. by the time when the Defassa waterbucks were active [24]. During counting, trained scouts were assigned to each habitat to record the number of individuals, season, age, and sex of the animals observed. To avoid double counting, each member, and/or herd size, and specific activities of Defassa waterbucks in different locations were noted [22]. The sexes of waterbucks were identified based on relative body size, external genitalia, and presence or absence of horns. Moreover, the age groups of waterbucks were classified as less than one year for juveniles, one to six years for subadults, and greater than six years for adults based on the observed relative body size [25]. The total number of individuals, group size, age structure, and sex ratio in each habitat was recorded in both seasons [26].

The existing possible threats to the Defassa waterbuck were surveyed using a semistructured interview. Eighteen protection staff (guards) and three management staff (totally 21 interviewees) were purposively selected because they were believed to give accurate information about the existing threats to the Defassa waterbuck species, as they usually explore the park's region. The selected interviewees were gathered, and each one of them was interviewed about the aspects he/she believed to have a negative impact on the

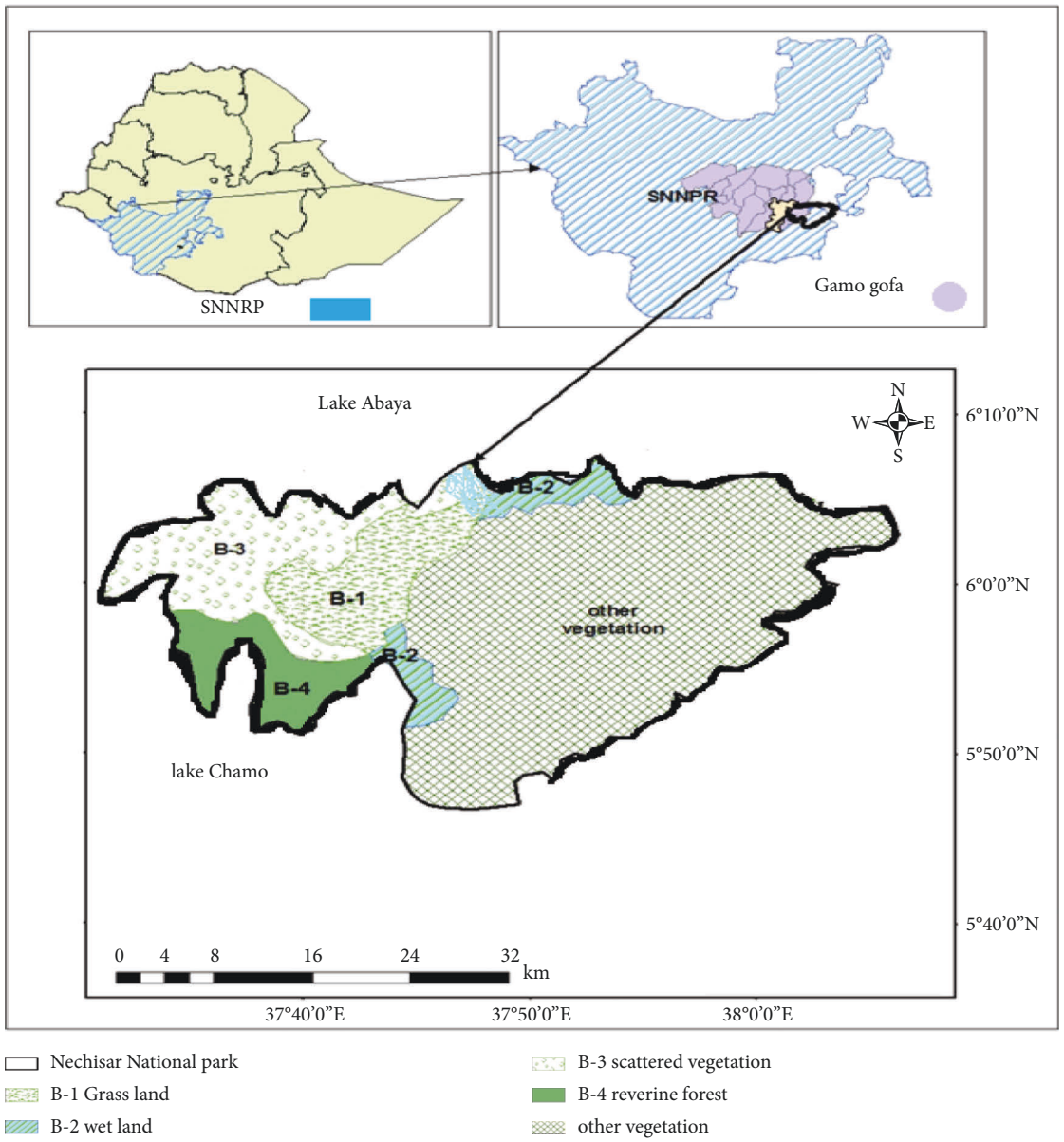

Figure 1: Map of the study area.

normal activities of the Defassa waterbuck. They were asked about the existing anthropogenic activities and natural events operating in the park and how they negatively influenced the Defassa waterbuck.

2.3. Data Analysis. The data analysis was done using Distance software version 7.3 and SPSS version 26 [23] (Buckland et al.). Before undertaking actual data analysis, preliminary analysis was done to check the data normality and model selection.

2.3.1. Data Normality Test. The Shapiro–Wilk's normality test ($p > 0.05$) [27, 28] and the visual inspection of their histograms, normal Q-Q plots, and box plots revealed that the sampled animals were collected from a normally distributed population in each habitat, with a skewness of 0.618 (SE = 0.361), −0.639 (SE = 0.481), 0.798 (SE = 0.427), −0.664 (0.403), and a kurtosis of −1.426 (SE = 0.809), −1.654 (SE = 0.935), −1.247 (SE = 0.833), −1.429 (SE = 0.788) for B1 (Grassland), B2 (Wetland) B3 (Scattered vegetation with bushland), and B4 (Riverine forest), respectively. The p value of each habitat is within ±1.96, which shows that the studied animal is normally distributed. In addition, the homogeneity of variance of the sampled animals in different habitat types was computed using Levene's Test. The test result $F(3, 126) = 0.859$, $p = 0.464$ showed that there was no significant variation in the variance of the sampled animals in each habitat type. Therefore, equal variances were assumed in each habitat.

2.3.2. Model Selection. Model selection was done in Distance software to discriminate between various candidate models (the uniform cosine, the half-normal cosine, and hazard rate), and the model that best fits the collected data was

selected. The value of Akaike's Information Criterion (AIC) and the shape criterion of the detection function computed for each model were used as the major criteria for this selection. The model selection analysis result revealed that the half-normal cosine model was the best fit among the other candidate models as it gave the lowest AIC value (Table 1), and normal detection function (Figure 2) relative to the other models. Therefore, all the computation related to detection probability, density, and abundance of the Defassa waterbuck presented in the current study was done using the half-normal key with cosine adjustment.

Descriptive statistics was used to compare the population size of waterbuck, overall sighting of sex ratios, population status, and the mean numbers of individuals. A chi-square test was used to test the seasonal difference in population structure of the Defassa waterbuck. The variation of population size within each habitat type (block) was analyzed using chi-square and ANOVA across seasons in the study area.

3. Results

3.1. Population Estimate of Waterbuck in NSNP. The population of Defassa waterbucks in the Nechsar National Park was estimated to be 111, with 104 and 118 individuals in the dry and wet seasons, respectively (Table 2). The average number of waterbucks recorded throughout the study period was 16 ± 5.31 individuals, with 17 ± 8.12 and 15 ± 2.5 individuals in the wet and dry seasons, respectively. The average population density was estimated to be $0.23/km^2$. The populations of waterbucks in each habitat type show no significant variation in both seasons (two-ways ANOVA; $F = 2.12$, $p > 0.05$).

3.2. Age Structure of the Defassa Waterbuck. Of the 15 individual waterbucks recorded during the dry season, 11 were adults, 3 were subadults, and 1 was a juvenile. Similarly, out of the 17 waterbucks recorded during the wet season, 12 were adults, 4 were subadults, and 1 was a juvenile. The age structure of the waterbuck population was dominated by adults during both seasons. On average, 76% were adults, 22% were subadults, and 2% were juveniles. There was no significant difference among age groups ($\chi^2 = 0.32$, df = 2, $p > 0.05$) during the dry and wet seasons. Proportionally, adults of both sexes have the highest number, while juveniles have the least number (Table 3). Even if the number of adult females was higher than juveniles of unknown sex during both seasons, there was no significant variation in sex ratio during the wet season ($\chi 2 = 2.94$, df = 4, $p > 0.05$).

3.3. Distribution of the Defassa Waterbuck. The distribution of waterbucks in each habitat type was almost uniform, but juveniles and subadults were mostly found in grassland and scattered vegetation (Table 2) ($\chi^2 = 4.02$, df = 6, $p > 0.05$). Therefore, there was no significant variation between age groups and habitat types during both wet and dry seasons. Moreover, the distribution of waterbuck is highly associated with the presence of permanent water sources (Table 4).

Table 1: AIC value of the candidate models.

Models	No. of adj. terms	AIC value
Uniform cosine	2	1178.54
Half-normal cosine	1	1173.41
Hazard rate	0	1181.21

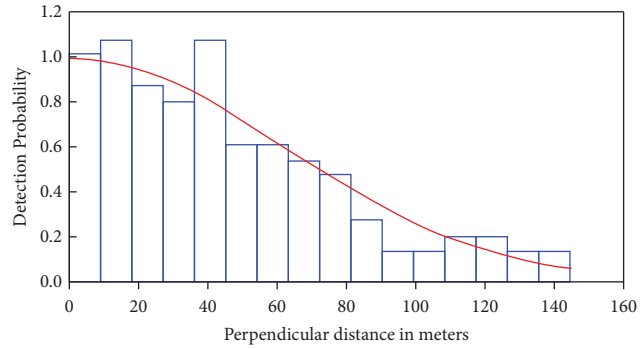

Figure 2: Detection function showing the probability of detecting the defassa waterbuck within the effective strip width (ESW).

3.4. Sex Ratio of Waterbuck in Wet and Dry Seasons. Among all the ages and sexes of the Defassa waterbuck, the maximum and minimum sex ratios were 1 : 1.94 adult male to adult female and 1 : 0.02 adult to juveniles, respectively, in both seasons. Therefore, there was no significant variation in sex ratios both in the dry and wet seasons (Table 3).

3.5. Threats to Defassa Waterbucks in the Nechsar National Park. The survey results revealed that the major threats to the existing wildlife population in general and the Defassa waterbuck in particular are anthropogenic activities. The frequent human activities and their relative intensities are observed to have a negative impact on the normal behavior of the Defassa waterbuck. This is summarized in Table 5. The interview results revealed that fuel wood collection, illegal hunting (poaching), illegal grass collection, and overgrazing were the most frequently observed threats with destructive effects on waterbucks and wildlife population, as well as on the biodiversity in general.

4. Discussion

The population of Defassa waterbucks in the Nechsar National Park was estimated to be 111, with 104 and 118 individuals in the dry and wet seasons, respectively. The large number of waterbucks recorded in the wet season is in agreement with the result of the study conducted by Fetene et al. [15] that a large number of waterbucks were recorded in the wet season in the same study area. The possible reason for the reduction in population size of waterbucks during the dry season might be due to the fact that in the dry season, vegetation dries up, leading the animals to migrate and accumulate in smaller greener areas proximal to water sources and nutritious food, permitting less visibility and encounter rate for the Defassa waterbuck. The waterbuck requires an exceptionally high amount of water [29]. As a

Table 2: Population estimate of waterbuck in the Nechsar national park (Mean ± SD).

Habitats (blocks)	Seasons	Individual animals observed	Population density (km^2)	Population estimate
Grassland (B-1)	Wet	29 ± 10.6	0.10 ± 0.03	49 ± 9.6
	Dry	14 ± 10.6	0.05 ± 0.02	24 ± 5.8
Wetland (B-2)	Wet	8 ± 4.9	0.00 ± 0.03	14 ± 9.6
	Dry	15 ± 4.9	0.01 ± 0.02	26 ± 5.8
Scattered vegetation with bushland (B-3)	Wet	21 ± 8.5	0.10 ± 0.03	36 ± 9.6
	Dry	9 ± 8.5	0.00 ± 0.02	15 ± 5.8
Riverine forest (B-4)	Wet	11 ± 8.5	0.00 ± 0.03	19 ± 9.6
	Dry	23 ± 8.5	0.10 ± 0.02	39 ± 5.8
Seasonal estimate	Wet season	17 ± 8.12	0.20 ± 0.16	118 ± 9.6
	Dry season	15 ± 2.5	0.25 ± 0.24	104 ± 5.8
Overall estimate	Mean	16 ± 5.31	0.23 ± 0.20	111 ± 7.7

Table 3: The proportion of age and sex categories of waterbucks observed in both seasons.

Age structure of waterbucks	Number of individuals (mean ± SD)		
	Wet season	Dry season	Percentage (%)
Adult male	6.00 ± 2.16	4.00 ± 1.63	30.8
Adult female	6.75 ± 4.99	7.75 ± 5.19	44.6
Subadult male	1.75 ± 0.96	2.00 ± 0.82	11.5
Subadult female	2.25 ± 1.71	1.25 ± 1.89	10.8
Juveniles	0.5 ± 0.58	0.25 ± 0.50	2.3

result, their habitat preference and abundance are highly influenced by proximity to drinking water, as well as the presence of quality grasses associated with savannah ecosystems, which grow close to water sources [30]. The need for a greater water intake is due to the consumption of mostly protein-rich grasses [31]. According to Taylor et al. [29], waterbuck are more prone to dehydration in hot weather than the average allied group. Moreover, waterbuck have been described as selective feeders to a degree [32] where they may select more nutrient-rich grass species in the wet summer season that quickly lose their nutritive value and decrease in abundance in the dry season months. In addition, Van and Peter [33] reported that the abundance of herbivores during the wet season is associated with the presence of abundant nutritious food items. Because of the specific physiological as well as behavioral nature of the waterbucks, they were found more abundantly in the wet season where there was easy access to water and protein-rich grasses. Typical density estimates obtained by aerial surveys of areas where the species is reasonably common are in the order of 0.05–0.15/km^2. Ground surveys have provided density estimates in the order of 0.4–1.5/km^2 in areas where the species is common [34].

The population dynamics of an organism can be reflected by information on sex ratio and age distribution for evaluating the viability of a species. As a result, the sex ratio and age structure of any population at any given time are indicators of the status of the population [22]. The sex ratio analysis of the Defassa waterbuck in the current study is in agreement with the study reported by Adane et al. [35]. The high number of female waterbucks recorded in this study shows that the waterbuck population has a chance to increase in the near future in the study area. However, the significant reduction in the number of juvenile waterbucks currently in the area indirectly signifies that the population is declining. The possible reason for this unbalanced sex ratio of the waterbucks might be the occasional nonselective illegal hunting by the local community, targeting mostly adult males. The reason for the low number of juvenile waterbucks might be because they usually hide in the dense, tall grasses, and shrubs of the plains and in the surrounding bushes, where they were not encountered during the survey. Moreover, they are not strong enough to run fast enough to escape from predators, so that they may get attacked [28, 36, 37]. Regarding waterbuck's population ecology, it has an average life span of 18 years and the recruitment takes place from 1 to 2.5 years of age. Its birth is all year round, but with its peak in the rainy season (September to November).

The major threats to the Defassa waterbuck are anthropogenic activities being executed in the study area. The fast growing human populations puts most wildlife population on the verge of extinction. Human activities such as poaching, deforestation, overgrazing, and hunting are common in threatening and imposing quick declines on wildlife throughout their range [38]. The waterbuck population decline observed in the current study is intensified by poor management strategies being operated in the park. The government is not allocating enough funds to undertake an effective management system. Despite the promising scientific and economic value of wildlife, anthropogenic activities remain a growing threat to their populations, particularly in densely populated communities [3].

Table 4: Correlation and coefficient of variance among habitat types and seasons.

Habitats (blocks)		Seasons								Population (N)	Mean	Standard deviation (SD)		
		Wet season				Dry season								
				No. of groups	Group size range	Group size mean	No. of groups	Habitats (strata)	Seasons	No. of waterbucks spotted				
Habitats (strata)	Grassland	3	13	9.67	6	2	2.33				130	2.4	1.2	
	Wetland	3	2	2.67	3	3	5.00							
	Scattered vegetation with bush land	4	4	5.25	3	0	3.00							
	Riverine forest	2	7	5.50	3	11	7.67							
Pearson correlation (r^2)								1	−0.19*	0.64**				
Coefficient of variation (covariance)								**1.44**	**−0.12**	**28.75**				
Seasons	Pearson correlation (r^2)							−0.19*	1	−0.86**	130	1.5	0.5	
	Coefficient of variation (covariance)									**−0.12**				**0.25** **−16.31**
No. of waterbucks spotted	Pearson correlation (r^2)							0.67**	−0.87**	1	130	65.5	37.7	
	Coefficient of variation (covariance)									**28.75**				**−16.31** **1419.17**

**Correlation is significant at the 0.01 level (two-tailed). *Correlation is significant at the 0.05 level (two-tailed).

Table 5: Possible threats with their respective mean percent based on each respondent's response ($n = 21$).

Reported possible threats	Response of each interviewee on each of the question asked (in percent) in descending order (most frequent first) (%)
Fuel wood collection	100.0
Illegal fishing	97.0
Charcoal production	95.0
Illegal grass collection	90.3
Poaching	88.0
Overgrazing	85.0
Deforestation	82.0
Settlement	78.0
Illegal fire	73.0

Note. "n" indicates the number of interviewed park staff.

5. Conclusions

The existing waterbuck population was mostly found in large numbers in habitats with better food quality near permanent water sources.

The present study documented the population estimate of Defassa waterbucks in the Nechsar National Park to be 111, with 104 and 118 individuals in the dry and wet seasons, respectively. Out of the total population of waterbucks, females were higher in number. However, the low number of juveniles indicated that the population of the Defassa waterbuck is declining. The existing waterbuck population was mostly found in large numbers in habitats with better food quality near permanent water sources. The survey revealed that anthropogenic activities are the major threats not only to the Defassa waterbuck, but also to the overall biodiversity of the study area. Because of these human activities, the population of waterbucks and other biodiversity appears to be in immediate threat. There are many conservation gaps that would greatly affect the studied species negatively in the future, if effective conservation measures were not taken. The threats in the study area include human-induced habitat loss and degradation through deforestation, livestock grazing, especially in the open plain of the park. More grass species were removed from the area over time, which may have hastened the loss of biodiversity in the study area. Though the population status of waterbuck in the study area is in good condition, the ongoing human activities are a growing concern for the population of the Defassa waterbuck and the biodiversity at large.

6. Recommendations

Based on the present study, the following recommendations are forwarded:

(i) Intensive research is required to identify the root cause of the waterbuck's population decline in the study area.

(ii) Local communities should be aware of the ecological, economic, and social values of wildlife so that they can stop threatening nature and appreciate the benefits of natural resources.

(iii) An alternative source of livelihood needs to be implemented in order to reduce the dependency of the local communities on the park and its biodiversity.

(iv) To reduce such threats, holistic conservation strategies incorporating the local communities need to be designed in order to create a sense of ownership for surrounding people.

(v) Local communities should be immediately involved in designing, planning, implementation, and evaluation of the wildlife conservation program.

Data Availability

The data sets used and analyzed during the current study are available from the corresponding author upon a reasonable request.

Ethical Approval

This research was performed in accordance with the laws, guidelines, and ethical standards of Ethiopia, where the research was done.

Conflicts of Interest

The authors declared that they have no conflicts of interest.

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References

[1] J. P. G. M. Cromsigt, S. J. Van Rensburg, R. S. Etienne, and H. Olff, "Monitoring large herbivore diversity at different scales: comparing direct and indirect methods," *Biodiversity & Conservation*, vol. 18, no. 5, pp. 1219–1231, 2009.

[2] E. Muths and V. Dreitz, "Monitoring programs to assess reintroduction efforts: a critical component in recovery," *Animal Biodiversity and Conservation*, vol. 31, no. 1, pp. 47–56, 2008.

[3] W. D. Newmark, "Isolation of African protected areas," *Frontiers in Ecology and the Environment*, vol. 6, pp. 321–328, 2008.

[4] J. T. du Toit, "Wildlife harvesting guidelines for community based wildlife management: a southern African perspective," *Biodiversity & Conservation*, vol. 11, no. 8, pp. 1403–1416, 2002.

[5] I. J. Gordon, A. J. Hester, and M. Festa-Bianchet, "Review: the management of wild large herbivores to meet economic, conservation and environmental objectives," *Journal of Applied Ecology*, vol. 41, no. 6, pp. 1021–1031, 2004.

[6] K. Canter, "Habitat use by ungulates in Thanda private game reserve, KwaZulu-Natal," M.Sc. thesis, University of KwaZulu-Natal, Durban, South Africa, 2010.

[7] G. Petres, "Mixed herd of common and Defassa waterbuck (*Kobus ellipsiprymnus defassa*) (Artiodactyla: bovidae) in northern Kenya," *Journal of Zoology*, vol. 37, no. 3, pp. 183–193, 1986.

[8] E. D. Lorenzen, B. T. Simonsen, P. W. Kat, P. Arctander, and H. R. Siegismund, "Hybridization between subspecies of waterbuck (*Kobus ellipsiprymnus*) in zones of overlap with limited introgression," *Molecular Ecology*, vol. 15, no. 12, pp. 3787–3799, 2006.

[9] A. Watkinson and S. Ormerod, "Grasslands, grazing and biodiversity," *Journal of Applied Ecology*, vol. 38, pp. 233–237, 2001.

[10] G. Amaja, H. Feyssa, and T. Gutema, "Assessment of types of damage and cause of human-wildlife conflict in Gera district, south western Ethiopia," *Journal of Ecology and the Natural Environment*, vol. 8, no. 5, pp. 49–54, 2016.

[11] F. Aramde, Y. Kumelachew, R. Prasse, and T. Hilker, "Study of changes in habitat type distribution and habitat structure of Nechisar National Park, Ethiopia," *Journal of Ecology*, vol. 4, pp. 1–15, 2011.

[12] CBD (Conservation of Biological Diversity), *Ethiopia's Fifth National Report to the Convention on Biological Diversity Ethiopian Biodiversity Institute*, CBD (Conservation of Biological Diversity), Addis Ababa, Ethiopia, 2014.

[13] C. Solomon and T. Dereje, "Threats of biodiversity conservation and ecotourism activities in Nechsar National Park, Ethiopia," *International Journal of Biodiversity and Conservation*, vol. 7, no. 3, pp. 130–139, 2015.

[14] J. Duckworth, M. Evans, R. Safford, M. Telfer, R. J. Timmins, and Z. Chemere, *A Survey of NechiSar National Park, Ethiopia: Report of the Cambridge Ethiopia Ground Water Forest*, International Council for Bird Preservation, Cambridge, UK, 1992.

[15] A. Fetene, G. Mengesha, and T. Bekele, "Spatial distribution and habitat preferences of selected large mammalian species in the NechSar National Park (NSNP), Ethiopia," *Nature and Science*, vol. 9, no. 3, pp. 80–90, 2011.

[16] A. Amare, "Wildlife resources of Ethiopia: opportunities, challenges and future directions: from ecotourism perspective: a review paper," *Natural Resources*, vol. 6, pp. 405–422, 2015.

[17] Ethiopian Wildlife and Natural History (EWNHS), *Important Bird Areas in Ethiopia*, Ethiopian Wildlife and Natural History (EWNHS), Addis Ababa, Ethiopia, 2009.

[18] D. Yisehak, B. Afework, and M. Balakrishnan, "Population status of plain zebra (*Equus quagga*) in Nechsar National Park, Ethiopia," *Journal of Tropical Ecology*, vol. 48, pp. 79–86, 2007.

[19] G. Yirga, F. Gebresenbet, J. Deckers, and H. Bauer, "Status of lion (*Panthera leo*) and spotted hyena (*Crocuta crocuta*) in nechisar national park, Ethiopia," *Momona Ethiopian Journal of Science*, vol. 6, no. 2, pp. 127–137, 2014.

[20] Nechisar National Park (NSNP), *Annual Report*, Nechisar National Park (NSNP), Ethiopia, 2016.

[21] S. H. Koster and J. A. Hart, "Methods to estimate ungulate population in tropical forest," *African Journal of Ecology*, vol. 26, pp. 117–126, 1998.

[22] D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. Foster, *Measuring and Monitoring Biological Diversity, Standard Methods for Mammals*, Smithsonian Institution Press, Washington, DC, USA, 1996.

[23] S. T. Buckland, E. A. Rexstad, T. A. Marques, and C. S. Oedekoven, *Distance Sampling: Methods and Aplications*, Springer, London, UK, 2015.

[24] R. Regassa and Y. Solomon, "Distribution, abundance and population status of Burchell's zebra (*Equus quagga*) in Yabello Wildlife Sanctuary, Southern Ethiopia," *Journal of Ecology and the Natural Environment*, vol. 5, no. 3, pp. 40–49, 2013.

[25] D. Furstenburg, "Waterbuck (*Kobus ellipsiprymnus*)," *Expert Support to the Wildlife Industry*, vol. 14, 2005.

[26] G. Rabira, G. Tsegaye, and H. Tadesse, "The diversity, abundance and habitat association of medium and large-sized mammals of Dati Wolel National Park, Western Ethiopia," *International Journal of Biodiversity and Conservation*, vol. 7, no. 2, pp. 112–118, 2015.

[27] S. S. Shapiro and M. B. Wilk, "An analysis of variance test for normality (complete sample)," *Biometrika*, vol. 52, 1965.

[28] N. M. Razali and Y. B. Wah, "Power comparison of shapiro-wilk, Kolmogorov-smirnov, liliefors and anderson-darling tests," *Journal of Statistical Modeling and Analytic*, vol. 2, no. 1, pp. 21–23, 2011.

[29] C. R. Taylor, C. A. Spinage, and C. P. Lyman, "Water relations of the waterbuck, an East African antelope," *American Journal of Physiology-Legacy Content*, vol. 217, no. 2, pp. 630–634, 1969.

[30] D. A. Melton, "Ecology of waterbuck *Kobus ellipsiprymnus* (Ogilby, 1833) in the Umfolozi game reserve," M.Sc. thesis, University of Pretoria, Hatfield, UK, 1978.

[31] R. D. Estes, *The Behavior Guide to African Mammals: Including Hoofed Mammals, Carnivores, Primates*, The University of California Press, Berkley, Los Angeles, London, 1991.

[32] B. Gutbrodt, *Diet composition of wildebeest, waterbuck and reedbuck in relation to food quality in a moist savanna of Tanzania*, Ph.D. thesis, Swiss Federal Institute of Technology, Zurich, Switzerland, 2006.

[33] S. Van and J. Peter, "Allometry and ecology of feeding behavior and digestive capacity in herbivores," *Journal of Zoology of Biology*, vol. 15, pp. 455–479, 1996.

[34] IUCN SSC Antelope Specialist Group, *Kobus Ellipsiprymnus Ssp. Defassa, the IUCN Red List of Threatened Species*, IUCN, Gland, Switzerland, 2017.

[35] T. Adane, B. Afework, and M. Balakrishnan, "Population status, distribution and habitat association of waterbuck (*Kobus ellipsiprymnus ellipsiprymnus*) in chebera churchura national park, southwestern Ethiopia," *Ethiopian Journal of Biological Sciences*, vol. 14, no. 1, pp. 31–43, 2015.

[36] S. J. Ormerod, "Applied issues with predators and predation: editor's introduction," *Journal of Applied Ecology*, vol. 39, no. 2, pp. 181–188, 2002.

[37] Y. Dereje, M. Yosph, and B. Afeworke, "Population ecology of menelik's bushbuck (*Tragelaphus scriptus* meneliki), neumann from denkoro forest proposed national park, northern Ethiopia," *International Journal of Ecology & Environmental Sciences*, vol. 37, 2011.

[38] BIDNTF (Biodiversity Indicators Development National Task Force), *Ethiopia: Overview of Selected Biodiversity Indicators*, BIDNTF (Biodiversity Indicators Development National Task Force), Addis Ababa, Ethiopia, 2010.