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Research Article

LINKING HUMAN SETTLEMENTS ON THE SPATIAL-TEMPORAL DISTRIBUTION OF THE COMMON ELAND (TRAGELAPHUS ORYX) IN NGORONGORO CONSERVATION AREA, TANZANIA

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Abstract

Ngorongoro Conservation Area (NCA) is globally well-known for its biodiversity hot spot and tourist destination, NCA is a UNESCO World Heritage Site that practices multiple land uses where pastoralism and wildlife conservation co-exist. Conservation of the NCA ecosystem necessitates consistent ecological monitoring to safeguard the sustainability of wildlife which balances between human population and settlement is in line with wildlife existence in the NCA. Presently the NCAA is leading a relocation to permit natives to move and resettle outside of the NCA to diminish the carrying volume of individuals and their livestock. The common eland (*Tragelaphus oryx*) is among the herbivores residing in NCA. Information on the influence of the human population on the spatial-temporal distribution of the common eland is limited. This study; therefore, investigated the influence of human population growth, and settlement on the spatial-temporal distribution of the Common eland in the Ngorongoro conservation area. Data was collected early in the morning (0600–1130 HRS) and late evening (1700–1830 HRS) in both wet (April) and dry (September) seasons, in 2020 and 2021, Common eland distribution was computed and mapped using ArcGIS Software Version 10. 3. The distribution of common eland across habitats was significant (F=4.235, P=0.0302). (Table 1). In the wet season, the mean difference in the distribution of the common eland across vegetation types was significant (F=3.499, P=0.0185). A comparison of population growth shows a significant difference in human population increase from 174,278 in 2012 to 273,549 in 2022 in the twenty-one wards in the NCA (Graph 1-2). The study suggests rechecking the practicability of the multiple land uses in the NCA since the human population and settlements increased, they distress the ecology and even distribution of the common eland in the NCA.

Keywords: *Tragelaphus oryx*, Distribution pattern, Human settlement, Conservation of elands, Ngorongoro Conservation Area.

INTRODUCTION

The common eland (*Tragelaphus oryx*), formerly *Taurotragus oryx*, *is* among the rare African antelopes, including sable antelope (*Hippotragus niger*), tsessebe (*Damaliscus lunatus*), roan antelope (*Hippotragus equinus*), fringed- eared oryx (*Oryx beisa callotis*), gerenuk (*Litocranius walleri*) and lesser kudu (*Tragelaphus imberbis*) [1] and it is the second largest African antelope after the giant eland (*Tragelaphus derbianus*). The common eland occurs in eastern and southern Africa and inhabits heterogeneous habitats that contain more shrubs and is frequently seen in grassland, woodland, and sub-desert bush habitats. The species is extensively domesticated in various countries, such as Kenya, Zimbabwe, and South Africa, and provides high-value and delicious bushmeat [4], [5]. The recent population status of the common eland in the East African region is estimated to be around 136,000 individuals, with a population density of 0.05 km^{-2}, of which Tanzania is the stronghold range state of free-ranging elands [6]. Populations are considered stable in countries like Tanzania, Botswana, Zimbabwe, South Africa, Malawi, and Namibia (IUCN 2009). Elands are social animals living in herds of 20-70 individuals [9]. Although the International Union for Conservation of Nature (IUCN) has categorized the species as "Least *Concern*" (LC), like other ungulates in the Ngorongoro Conservation Area (NCA), Tanzania, their numbers have been reported to decrease. The most drastic decrease where the common eland population fell from hundreds to 30 individuals is from 1964 to 1980 and 1985-2005 [10], [11], [12], while other ungulates like wildebeest (*Connochaetes taurinus*) declined from 14,000 to <9000, buffalo (*Syncerus caffer*) increased from 100 before 1970 to 2000 individuals [13] to become the dominant herbivore in the biome. Similarly, in other protected areas such as Kruger National Park, South Africa [14], [15], [16], Masai Mara National Reserve, Kenya [14] and central southern Kalahari ecosystem, Botswana, the population of the common eland was reported to decrease. The distinctive influence which was linked with the population change was anthropogenic factors. Since common eland is the largest nomadic ruminant in sub-Saharan Africa, its long-term persistence depends on unimpeded movement across large natural habitats of the landscapes, the movement that is threatened by habitat fragmentation and anthropogenic barriers where human population growth is the principal basis. Human population growth is a global agenda today according to the United Nations Development Programme [17], reaching 8.0 billion in mid-November 2022 from an estimated 2.5 billion people in 1950. Estimated to reach 10.5 billion people in 2050, this population growth is projected to pose environmental threats, particularly on natural resources. The Intergovernmental Panel on Climate Change IPCC (2021) has also shown that the impacts of climate change have already significantly affected human livelihoods and living conditions, especially of the poorest and most vulnerable, and will continue

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to undermine development during the coming century. Given the uniqueness of NCA as a multiple-land-use protected area that harbors people with their livestock, wildlife is threatened by a significant increase in human and livestock populations. This increase has already led to the expansion of bomas for settlement, and consumption of natural resources (grasses for thatching, fuel wood, medicine, grazing lands, and water). The increase in anthropogenic activities (deforestation and overgrazing) is the principal cause of habitat loss and fragmentation that influence the distribution patterns of the common eland in NCA and they are the major threats to wildlife conservation today [19], [20]. Since the information on the spatial-temporal of the common eland in NCA is limited, the present study aimed at investigating the influence of human population increase and settlement on the distribution of the common eland in NCA.

MATERIALS AND METHODS

Study area

The NCA covers an area of 8,292 km^2, it is located in Northern Tanzania between 2.798 – 4.798 S and 35.282 – 36.567 E and 3.361 – 4.475 S and 35.544 – 36.351 E [21] (Figure 1). The rainfall pattern varies depending on location and altitude, with high rainfall in the east and south of the highlands. Rainfall ranges from 400 to 600 mm per annum in lowland areas, and above 1200 mm per annum in the highlands [21]. The NCA consists of montane forest, grassland in the highlands, and semi-arid woodlands around escarpments and plains. The protected area was established in 1959 by the Colonial Government vide the Ngorongoro Conservation Area Ordinance No.413 of 1959, which was revised by the Ngorongoro Conservation Area Act CAP 284 of 2002 as a multiple-land use area designated with triple objectives of conserving natural resources, safeguarding the interest of indigenous residents and promoting tourism. NCA is a UNESCO World Heritage site the status accorded in 1979 [22] and a Man and Biosphere Reserve (MAB) (1982) and UNESCO Mixed World Heritage Site () and the UNESCO Ngorongoro Lengai Geopark (2018) (located in Northern Tanzania, adjacent to the Serengeti National Park (SNP) [22]. The area forms one of the most visited tourist destinations in Tanzania [21].

The main features of NCA include the Crater and the Ndutu Plains that support migratory wildlife species of the Greater Serengeti-Mara ecosystem. The NCA together with SNP and other protected areas of the Serengeti ecosystem supports the greatest concentration of wildlife left on earth [6]. The short grass plains of NCA are the wet-season grazing grounds for the majority of the Serengeti's migratory herds, which were approximately 1.5 million wildebeest, 470,000 gazelles, and 260,000 Zebra (*Equus quagga*) [23]. The early human footprints were discovered at the archaeological and paleontological sites located at Oldupai Gorge, Laetoli, and Ngarusi. The NCA was ascribed to the World Heritage List in 1979 after meeting three criteria of outstanding universal values as prescribed by the World Heritage Convention. The three criteria are: a) NCA contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; b) It is an outstanding example of significant ongoing ecological and biological processes in the evolution and development of terrestrial and freshwater communities of plants and animals; and c) the area includes the most significant natural habitats for *in-situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of conservation science.

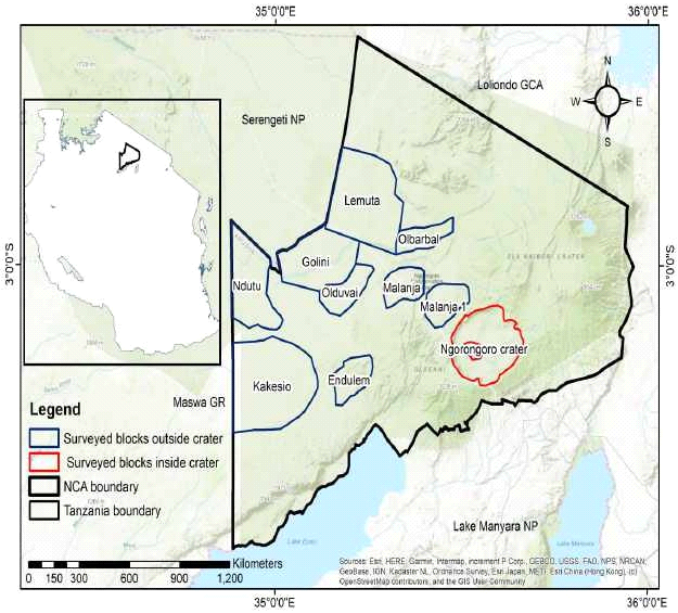

Figure 1. Map of Ngorongoro Conservation Area showing sampled areas in the study sites in Tanzania

Study design

The study site was subdivided into ten survey zones adopting pre-established blocks where routine ecological monitoring in the NCA is taking place. The blocks are Crater, Ndutu, Olbalbal, Olduvai, Kakesio, Endulen-Esirwa, Malanja A, Malanja B, and Lemuta based on known eland sightings in NCA. The adoption of similar blocks used for both dry and wet seasons; routinary ecological monitoring offers continuity of other previous works done in NCA Such study includes Downward trends in Ngorongoro Crater ungulate populations [12] and the long-term historical and projected herbivores population dynamics in the Crater [23]. Generally, the survey covered an area of 3,521 km² which is equivalent to 42.5 % of the entire NCA. A total of 82 transects with a length of 12 km each and width of 2km located 2 km apart, were surveyed. Transects for spatial-temporal distribution crossed different habitat types where eland counts were conducted. Data were collected along transects early in the morning (0600 – 1130 HRS) and late evening (1700 – 1830 HRS) in both wet (April) and dry (September) seasons, in 2020 and 2021. The distribution of transects in each vegetation ensured a wide representation of the heterogeneous habitats to avoid ecological bias during data collection in the study area (Figure 1).

Determination of Common Eland Distribution

In determining eland distribution, transects for counting common eland were established in areas where elands are acknowledged to occur [24]. Whenever an eland group was encountered the following ecological records were made; GPS coordinates, eland numbers number of groups, and vegetation type. The collected information was later recorded in a standardized ecological worksheet and then exported to NCA land cover classes (GIS shape files) and overlaid into ArcGIS Software Version 10.3 to display the distribution of eland groups in different vegetation types, [25]. Human disturbances

such as human settlements were shown using ArcGIS Software Version 10.3 to determine their influence on common eland distribution within the study area.

Human population growth

To determine Human population growth in NCA a set of human population data was obtained from the National Bureau of Statistics (NBS) whereby the available data on human population growth from the 2012 and 2022 censuses were used to calculate the human population trend (growth) from 2012 – 2022 a ten years interval. The wards selected were twenty (21) wards out of twenty-eight (28) wards reached in 2022 in the Ngorongoro district in Arusha region, Tanzania. However, the wards of interest were selected to maintain consistency for proper comparison purposes where the number of wards and people increased from 2012 to 2022.

Data analyses

Common Eland Distribution Patterns

The GPS Coordinates Shapefile, eland numbers, and several groups in different vegetation types; grassland, woodland, shrubland, and forest were recorded in the standardized ecological worksheet [26] and were overlaid to illustrate the spatial-temporal distribution of eland relative to vegetation types in both dry and wet season data on distribution were mapped using ArcGIS Software Version 10.3. Furthermore, the interaction between season and habitat was added to the model to assess if they have a cumulative impact on elands in the study area. All the analyses were performed on transformed data not fitting a normality test. Human settlements in NCA were mapped using the available land cover/land use classes of NCA which was overlaid into an NCA shape file to illustrate the settlement patterns in the common eland range, whereby the distribution results were presented in maps and table.

Human population growth

Data on human population increase in the Ngorongoro Conservation Area from the National Bureau of Statistics URT NBS of 2012 and 2022 constitute the selected twenty-one (21) wards of interest in 2012 and 2022 out of twenty-eight (28)wards in 2022 for appropriate contrast with a space of ten (10) years intervals, statistics were analyzed using Statistical Package for Social Sciences (SPSS) to compare the significance different of the population growth that can be linked with the Common eland spatial-temporal distribution in NCA and the results were presented in terms of graphs.

RESULTS

Distribution pattern

The average number of the common eland distributed across different vegetation was classified into four 4 vegetation types; grassland, shrubland, woodland, and forest for both wet and dry seasons. The mean with different letters AB across habitats presented in the table shows significant differences in common eland distribution while the mean with the single letter A or B shows differences that were not significant (Table 1). The results show the distribution of individual common eland in the dry season was statistically significant (F=4.235, P=0.0302). Additionally, in the wet season, the mean difference in the distribution of common eland across entirely vegetation types was significant (F=3.499, P=0.0185). By comparison, the distribution of the common eland in both wet and dry seasons both crater and outside the crater shows that the majority of the common eland large groups were found outside the NCA crater (8,042 km^2) than in the Ngorongoro crater (250 km ^{2}) which recorded smaller eland groups possibly because of the limitations of space and forage. (Fig 2-3). It was noted similarly in the zones of human settlements there was no common eland sighted than in the zones with no human settlements (Fig 2-3).

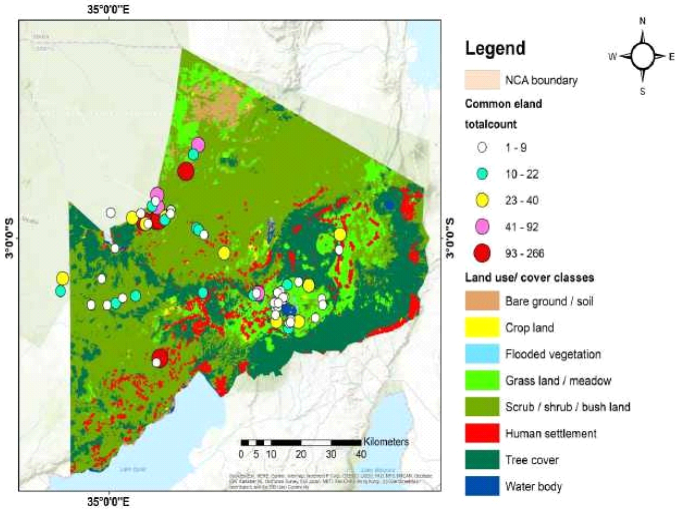

Figure 2. Common eland distribution in the wet season in Ngorongoro Conservation Area, Tanzania

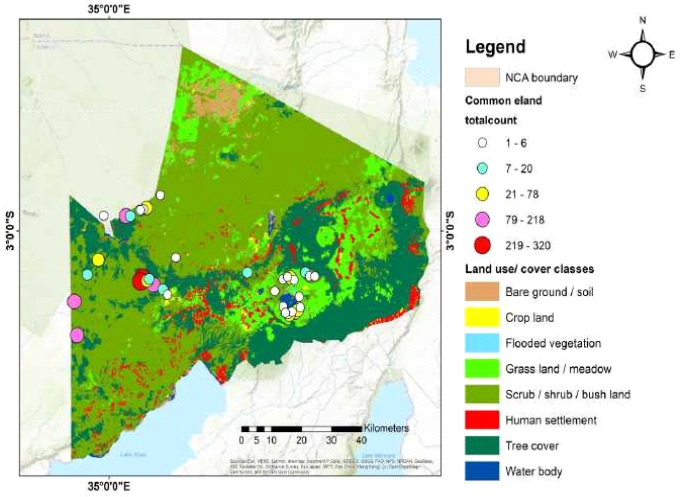

Figure 3. Common eland distribution in the Dry season in Ngorongoro Conservation Area, Tanzania

Human population growth in the Ngorongoro districts (wards) in 2012 – 2022

The results of the population increase were reported in two-sample tests of the census data of 2012 and 2022 sourced by the National Bureau of Statistics (NBS) to the twenty-one (21) wards in the Ngorongoro district, Arusha. Generally; for the two years of 2012 and 2022 results showed that there was a significant difference (t = 2.5526, df = 39.99, p-value = 0.01461) in the increase of human population from 174,278 in 2012 to 273,549 in 2022 (Graph 5), subsequently, human population growth amplified within villages from 2012 to 2022 (Graph 4).

Table 1. Distribution pattern of the common eland in vegetation types within NCA

Variable	Grassland	Shrubland	Woodland	Forest	F-value	p-value
Average No. of eland in the dry season	52.16^{A}±13.87	21.67^{AB}±11.68	2.67^{B}±1.20	0	4.235	0.0302
Average No. of Common eland in the wet season	38.90^{A}±9.48	$6.25^{B, C}$±1.84	$64.33^{A,C}$±48.66	28.00±NA	3.499	0.0185

However, this growth in line with settlements prompted the spatial-temporal distribution of the common eland in their natural environment in the NCA.

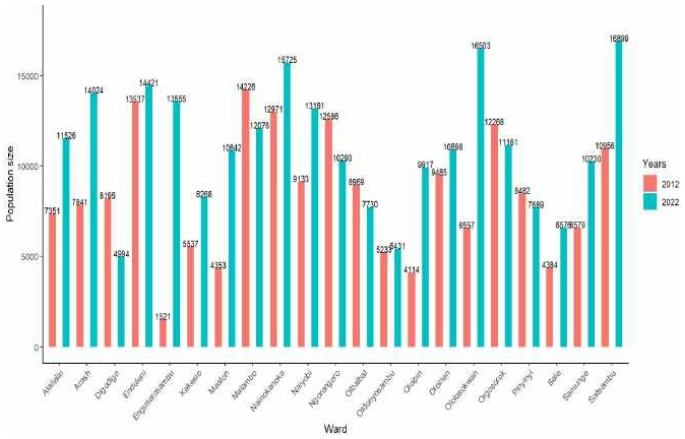

Figure 4. Human population census between 2012 and 2022 among wards in Ngorongoro

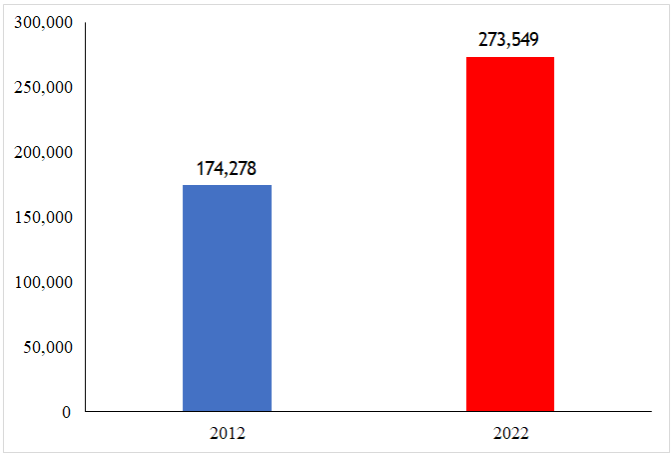

Figure 5. Human population growth fromthe 2012 and 2022 Census in Ngorongoro District

DISCUSSION

Common Eland Distribution Patterns

The NCA is a multiple-land use area where the distribution of elands is influenced by many factors including seasonality, which supports the availability of forage during the wet season and scarcity of forage during the dry season. The findings that the distribution of the common eland in NCA varied seasonally in different vegetation types suggest that the common eland movement and distribution follow the resource abundance in their habitats. (Estes 2012). The high number of eland groups and individuals in the grassland is attributed to the availability of fresh graze in the wet season, additionally, these findings support studies on habitat heterogeneity as a driver of ungulate diversity and distribution patterns e.g., Hluhluwe-iMfolozi Park, South Africa; [27]. Similarly, a study by Bukombe et al. (2018) SNP showed that the availability of forage mostly influences resource use by ungulates.

The presence of the common eland in other habitats during the dry season is associated with food scarcity [29], which forces common elands to disperse extensively to other areas in search of green pastures [30]. These findings are similar to those of Ogutu and Owen-Smith (2005) in Kruger National Park and Okello et al. (2015) Masai-Mara National Reserve in Kenya. Abundant forage in the wet season enabled elands to cluster in large groups and disperse in small groups, while during the dry season because of the scarcity of resources (food and water) [29], they moved extensively in search of resources. Additionally, the results show that the common eland groups in the crater (250 km^2) are composed of a small group size of the individual common eland compared to the large groups of common elands residing outside the Ngorongoro crater (8,042 km^2) possibly because of the spacing and forage. The results of this study agree with those of Pallas 1766 in Kenya who studied, the home range and movement of common eland (*Tragelaphus oryx*) in the Nairobi National Park Kenya.

Human population growth

human population growth is acknowledged as a global agenda today according to the United Nations Development Programme [17], reaching 8.0 billion in mid-November 2022 from an estimated 2.5 billion people in 1950. Estimated to reach 10.5 billion people in 2050, this population growth is projected to pose environmental threats, particularly to natural resources on Earth. The Intergovernmental Panel on Climate Change IPCC (2021) has also shown that human population growth in line with climate change impact has already significantly affected human livelihoods and living conditions, especially of the poorest and most vulnerable, and will continue to undermine development during the coming century. The nature of the Ngorongoro Conservation Area (NCA) multiple functional land uses where human beings and wildlife co-exist linked with human activities (livestock, settlement, and deforestation) affects the conservation of natural resources (Wildlife) in NCA. However, there was a vivid on the increasing pressure of the human population and number of households in NCA which are possibly posing a subsequent limitation on the conservation of natural resources (wildlife) in NCA. Earlier studies have shown that the human population in NCA has increased by more than threefold from 20,000 in 1990 to approximately 90,000 in 2017 [32]. The census conducted in 2022 (URT et al. 2022) shows that the number of people residing in NCA has increased to 93,136 from the 64,000 recorded in 2002. The increasing human population in the NCA has been accompanied by a prodigious increase in livestock numbers (cattle, goats, and sheep), which were over 131,509 in 2013 and reached 238,826 in 2017 based on the 2022 population census (URT et al. 2022). The results of this study are in line with the findings [31]. Studied Conservation threats from human population growth (habitat loss and fragmentation) are the major key factors for the distribution and the decline of common eland elsewhere in protected areas. Anthropogenic activities, incompatible with conservation limit the spatial and temporal movement patterns and access to resources of the common Eland in NCA. This phenomenon has been reported elsewhere in protected areas,

such as Kruger National Park, South Africa [34], and Masai Mara National Reserve where the common eland faces anthropogenic barriers, which ecologically limit the free movement within protected areas population growth due to human development [12]. Since NCA is a multiple land-use area where human livestock and wildlife coexist, it differs from other protected areas that do not practice multifunctional land uses. Thus, NCA is at a higher conservation risk of losing the common eland and other ungulate species.

Conclusion and Recommendations

Sympathetic to wildlife distribution patterns and the impacts of human population growth in terrestrial ecology is essential for appropriate wildlife management in the protected areas (PA) on Earth. The results from this study stipulate that human population increase in line with human activities is a significant factor amongst others, which influences eland distribution as the zones with human settlements have no common eland groups recorded despite having space size presumably due to human disturbances (Figure 1). On the other hand, the zones with restrictions on human activities such as the Crater and Ndutu enumerated an abundance of common eland groups. Furthermore, understanding the distribution pattern of the common eland through the influence of human population growth in the study area is critical for the management of the common eland hence responding to the two objectives of the study. Based on the current findings from the study the following recommendations are proposed:

- Rechecking the coexistence of people, livestock, and wildlife in the practicability of the multiple land use models in the current perspective within NCA based on demographic changes in human population, livestock keeping model, and human and wildlife well-being, therefore its practicability should be considered and incompatible activities towards conservation should be stopped.
- Distribution of the common eland in NCA seems to be uneven in ecology and conservation interest due to human settlement and population increase where the population of eland skewed to the zones with no human turbulences linked to settlement zones which do not record individual's common eland; therefore, this study recommends proper management of the common eland in NCA.

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