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Wild Animal Densities as Predictor of Cattle Disease Risks and Breed Types in South-Western Uganda

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Abstract

Background

This study investigated the spatial distribution of wild ungulates that pastoralist communities perceive as culprits in the transmission of cattle diseases outside protected areas in south-western Uganda. Diseases are hypothesized as having influence on pastoralists' choice of cattle breed types. Until the time of his study no information was available on spatial patterns of wild animal species and cattle breeds reared in Lake Mburo Conservation Area, and how diseases transmitted therein potentially influence cattle breed herd sizes.

Methods

Animal population survey was carried out on cattle and wild ungulate species along transect lines laid perpendicular to the northern boundary of Lake Mburo National Park (LMNP). Household survey generated data on costs of disease control through interview. Data were analyzed for unit cost of disease control at herd level and correlated with spatial distribution patterns of cattle breeds and wild ungulate populations.

Results

Our results show inverse association of distance away from LMNP with wild ungulate populations and the cost of disease control, which in turn favored higher abundance of Friesian cattle. Cost of disease control and cattle abortion incidences were much lower in rangelands far away from LMNP ($R^2 = 0.965$, $P < 0.001$). Mean population of indigenous cattle significantly decreased while those of exotic breed increased with increasing distance away from the park boundary.

Conclusion

Spatial distribution of wild ungulates in cattle grazing rangelands potentially influence cattle disease prevalence levels which had significant associated with spatial patterns of cattle breeds and breed herd sizes.

1. Introduction

Across the world several studies recognize the potential of wildlife and livestock interactions as a basis for understanding the transmission of zoonotic diseases and their risk pathways, and how these might influence range resource use for production of different species of domesticated animals (Godfroid et al, 2013; Marcotty et al., 2009; Muma et al, 2007; KalemaZikusoka et al, 2006). In most rangelands of various African countries national parks are not fenced hence leaving wild ungulates free to disperse into the surrounding farms and ranches. The situation is not different in Uganda where wildlife graze freely in cattle herds around protected areas (Nina et al, 2018; Averbeck et al, 2009). Once outside in private farms and ranches wild ungulates interact with livestock through sharing of resources like pasture and water, and consequently present potential risk of disease spillover to livestock (Nina et al, 2017).

In most African rangelands, research has shown that diseases affecting livestock increase the cost of production to the farmer and such increases in cost of production impose financial limitations on developmental aspirations of pastoralist communities (KagoroRugunda, 2004; Ocaido, 2008; Fungo, 2011). This situation is true for the Lake Mbro Conservation Area (LMCA) because of the unfenced LMNP (Rannestad et al., 2006). Indeed, several species of wild ungulates like zebra, impalas, and buffalos are abundant in utilized for the production of different livestock breeds depending on the absence or presence of perceived risks and associated losses.

Unlike in Kenya where the rangelands were gazette to expand wildlife habitat (Homewood and Brockington, 1999; Goldman, 2003; McCabe, 2003), part of the LMNP rangelands were degazetted to expand cattle grazing areas (Rannestad et al., 2006). Therefore, while the Maasai pastoralists of Kenya encroach on the gazetted habitats due to limited grazing space, the Bahima pastoralists of Uganda encounter wild ungulates on their farms due to reduced habitats for wild ungulates (Infield and Namara, 2001; Rannestad et al., 2006). Consequently the frequency of interaction between wild ungulates and livestock has increased. The increased interaction between wild ungulates and livestock are a source of concern to pastoralists living adjacent to LMNP, because of wild animal related disease risks.

In the Lake Mburo Conservation Area (LMCA), studies conducted by Ocaido (1995), Mugisha et al. (2005) and Ocaido et al. (2006, 2009) reported that wild animal related diseases (including tickborne diseases) are the major constraints for livestock production. The pastoralist communities in the LMCA incur economic losses when diseases transmitted by wild ungulates cause cattle mortality, reduction in live weight of cattle and milk production (Ocaido et al., 2009). These losses in turn reduce the optimal productivity of livestock in the LMCA and hence could be influencing decisions how rangelands are utilized for different cattle breeds. Another study by Ocaido et al. (2008a) further reveal that tick control constitutes about 75% of total disease control costs in the LMCA. Wild ungulates (mainly buffalos, zebras and Impalas) contribute significantly to the high populations of ticks (*Rhipicephalus appendiculatus* and *Rhipicephalus everts*) in the LMCA (Ocaido et al., 2006). In spite of the concerns about the economic impacts of wild ungulate related diseases on livestock production, there is still lack of knowledge regarding the spatial distribution of wild ungulates outside LMNP. For this reason, understanding the spatial distribution of wild ungulates in the study area may form the basis for guiding pastoralist communities on how to turn risks into opportunities and optimize economic options that game ranching could offer through tourism.

Indeed pastoral grazing systems of south western region of Uganda have high densities of wild animal and livestock populations due to well adapted semiarid climatic conditions. Despite the fact that pastoral grazing systems produce 85% of milk and 95% of meat consumed in Uganda, pastoralism in south western region is threatened by diseases. Studies around Lake Mburo National Park documented prevalence of brucellosis and tickborne diseases in cattle and wild species of ungulates like buffalo and impala (Ocaido et al., 1996, 2008). These animals are widely distributed in private farms and ranches where different breeds of cattle are kept (Rannestard et al., 2006). The lack of information regarding spatial patterns of wild ungulates and livestock limits our knowledge regarding appropriate actions to take for a wider rangeland resource management. In particular, little is known about the way disease factor interact with other economic and ecological variable to influence livestock production activities practiced in LMCA. This study aimed to test the hypotheses that: 1. spatial variation in population density of wild ungulates was correlated with the cost of diseases control and cattle mortality and; 2. this correlation influenced cattle breed types reared along a distance gradient from LMNP boundary.

2. Materials And Methods

This study was conducted around Lake Mburo National Park in southwestern Uganda. A semiarid climate, with high temperatures and bimodal rainfall characterize the study area. Six zones of 4 km each were created for household sampling along 24 km length of the study area. We established 3 transect lines across the six zones for wild animal census. Sighted animals along the transect lines were recorded and animal population considered as the number of individuals counted in each distance zone for the six zones between June 2012 and July 2013. Household survey of disease burden focused on costs of disease control and cattle mortalities. Spatial analysis identified relationship between wild ungulates population and disease burden in cattle. Further statistical analysis of wild ungulates was limited to zebra (*Equus burchelli*) and impala (*Aepyceros melampus*), because they accounted for 80.3% (3808/4740) of animals recorded in private cattle grazing fields.

2.1 Description of the study area

The study was carried out in the Lake Mburo Conservation Area (LMCA), north of Lake Mburo National Park, in Kiruhura District, southwestern Uganda. The LMCA includes the protected area, villages and pasture lands. It is part of the larger Akagera ecosystem that extends from eastern Rwanda and north–western Tanzania into mid southwestern Uganda. The dominant vegetation of the Lake Mburo Ecosystem is acacia–savannah interspersed with open grasslands. Seasonal flooded valleys are also a common occurrence (Menault, 1983; Van De Weghe, 1990). The area has an erratic bimodal rainfall pattern with annual average of 887 mm. For centuries, the savannah rangelands of the Lake Mburo Conservation Area have supported high densities of wild ungulates and livestock (Averbeck et al., 2012; Ocaido and Stefert, 1996).

2.2 Study design and sampling strategy

The data collection methods included field observations, animal surveys and semi structured questionnaire administered in face to face interviews. Data was collected on key variables such as the numbers of wild ungulate species, cattle breeds, perceptions of disease risks and disease control costs that pastoral households incurred, using a 2 phased cross-sectional survey strategy. In phase 1, distribution of wild ungulates along the distance gradient away from the park (LMNP) boundary was carried out through transect walks (Figure1). Household surveys followed animal census immediately during the same period.

In phase 2 of the data collection, socio – economic variables were collected from six zones established along the distance gradients away from LMNP's boundary, each representing a different degree of perception on disease risk and abundances of exotic and indigenous cattle breeds. About 60 interview events per strata were used to gather information from a total of 366 pastoralist households. A sample size (n) of households was determined at 95% confidence level using a formula adopted from Kothari (2004).

Z^2 x (P) x (1 – p) n = ____________ where D^2 n = Size of sample;

Z = 1.96 as per the table area under normal curve for the given confident level of 95.5%;

(P) = 0.5 being the proportion of defectiveness in the universe; (1 – p) = the proportion of non-defectives/success; D = 0.05 the level of acceptable error margin

Substituting the figures in the equation:

1. (1.96 x 1.96) x (0.5) x (1 – 0.5) n = ________ = 364
2. (0.05 x 0.05)

Hence, the minimum sample size calculated, 364, formed a basis for random selection of 61 household samples in each zone, giving a total of 366 samples, which the study used.

2.3 Data collection

A survey of wild ungulates was carried out along 3 transect lines in order to assess association between distance gradient from LMNP boundary and the type of cattle breeds reared in the rangelands. Wild ungulate survey was carried out across seasons between June and December 2011, March and July July2012, and May and November 2013. Data was collected along three transects laid perpendicular to the northern boundary of LMNP, approximately covering 24 km length. Sighted wild ungulates were counted and recorded twice a day (morning and evening) to estimate the abundance (Buckland, 2001). Each transect line was preselected and defined by UTM Easting (X-coordinate) read from a topographic sheet map of the study area at a scale of 1:50,000. The distance between three transects was about 15 km, which enabled us to avoid multiple counting of the same animal herds in each sampling event. A team of 15 trained field data collectors (Who were conservation biology students of Makerer University) used Garmin 12 XL GPS (Global Position System) receiver to record geo-coordinates together with animals sighted at a point within 500 m on each side of a transect line. All wildlife data collectors were deployed about the same time at 1 km interval along the shorter (15 km) transect and 2 km interval on longer transects (24km). The morning time period for counting wild ungulates was limited to 0700 –

1100 hours in order to maximize the types and numbers of wild ungulates identified and counted before the animals retired to shades under the bushy vegetation due to warming temperatures towards mid-day.

Socioeconomic data covered the number cattle in a herd, household stock holdings including cattle breeds, cattle disease incidences and perceived risk sources, cost of diseases control, as well as income derived from livestock production. We used face –to– face interviews and observation data sheets to collect information from 61 sampled households in each distance zone for the six distance zones. Adult household members who could recognize and distinguish different animal species (both domesticate and wild) by use of local names participated as respondents in the study. For example, indigenous cattle were identified and distinguished by long brown horns and red coat (Wurzinger et al, 2008). Respondents' perceptions regarding sources of disease risks were assessed by asking the respondent to list three sources of diseases infecting their cattle in order of economic importance. Household expenditure on ticks control focused on acaricide use in relation to the number of cattle and degree of infestation of the cattle with ticks. For instance, the type of acaricide used against ticks and its market price were recorded and multiplied by number of tins used per treatment of an average of 50 cows in a herd, and the number of repeat treatments in a month to estimate annual cost associated with the control of cattle infestation with ticks. The frequency of spraying cattle against ticks and acarcide concentration (Unit of acaricide in ml/vol. of water used to dilute the drug) were the scales of measurement considered when quantifying the cost of acaricide use. Trained interviewers, who were fluent in the local language (runyankole), participated in collecting socio-economic data using one month recall period for costs associated with diseases control (Onwujekwe et al., 2010). The cost of treating one head of cattle was determined by the average amount of money each household spent in one month on veterinary services divided by number of cattle that received veterinary treatment in the month preceding this study.

2.4 Data Analysis

A range of statistical tests were used to analyze data collected using mixed methods. Both spatial analytical tool (ESRI's ArcGIS 9.3) and statistical software (SPSS version 17) were used to analyze wild animal and livestock census data collected through sightings and counts in transect walks, as well as socioeconomic data on cost estimates for livestock disease control.

Chi Square tests compared population abundance, expressed as mean proportion of different species of wild ungulates between managed and unmanaged rangelands (see Table 1). To generate information on population mean and standard error of mean, descriptive statistical tests of SPSS version 17.0 were used. Other statistical measures of association used included Pearson Correlation test and analysis of variance (ANOVA) to examine animal population mean difference as relates to spatial distribution and abundance of different cattle breeds reared in each of the 6 distance zones. The cost of controlling cattle diseases perceived as being transmitted by resident ungulates was also estimated from the data captured using semistructured questionnaire. A monthly cost of treating one head of cattle at household level was determined from the amount of money spent on purchasing acaricides and drugs required to control ticks and treat sick cattle. The perception regarding the sources of cattle disease risks was measured in terms of proportions of the answers provided by the respondents.

3. Results

A total of 480 sightings were reported during the study period, which resulted in 4.740 wild animals being recorded a long 3 transect lines outside Lake Mburo National Park. Based on the number of observed animals during the study against the number of sightings, the results showed mean of 9.8 (8.48-11.12) for overall group size at 95% confidence interval. We also found out that one was likely to have between two and three encounters with wild animals within 1 km^2 along the distance gradient from park boundary (Table 1)

Table 1
Animal encounter rates a long distance gradient from park boundary

Survey	**Transects**		
	TS1	**TS2**	**TS3**
Total Observed animals	1845	1780	1115
Number of sightings	182	156	142
Mean group size	10.14	11.41	7.85
Standard error of mean	1.24	1.67	1.05
Minimum group size	1	1	1
Maximum group size	75	89	51
Encounter rate (mean groups/km2)	2.53	2.85	1.96

The results of wild ungulate survey showed that the populations of different wild animal species varied significantly ($p < 0.05$) between the observed and the expected equal population distribution in the study area. For example, Zebras (*Equus burchelli*) and Impalas (*Aepyceros melampus*) accounted for about 45% and 35% respectively. This means that, of all the wild ungulates counted outside the LMNP during the study period, zebra and impala alone accounted for 80% (Table 2), a clear indication of disproportionate distribution of wild animals in private farms outside protected area.

Table 2
Population abundance of wild ungulates outside LMNP

		Population Abundance				
Wild species of ungulates	Sightings	Total	% Proportion	X^2	df	p*
Zebra -*Equus burchelli*	142	2,154	45.44	848.43	36	<0.001
Impala -*Aepyceros melampus*	149	1,654	34.89	533.43	27	<0.001
Bush buck -*Tragelaphus scriptus*	64	376	7.96	1265.53	13	<0.001
Waterbuck-*Kobus ellipsiprymnus*	36	204	4.34	1550.87	11	<0.001
Duiker - *Sylvicapra grimmia*	45	143	3.09	460.45	4	<0.001
Warthogs-*Phacochoerus ethiopicus*	14	94	1.78	1084.32	6	<0.001
Buffaloes -*syncercus caffer*	12	76	1.66	1298.71	7	<0.001
Eland -*Taurotragus oryx*	18	39	0.84	678.14	4	<0.001
Total	**480**	**4,740**	**100**	**131.075**	**56**	**<0.001**

During the study we assumed that different species of animals were equally distributed outside the gazetted area. However, the results of Table 1 show that the frequency distribution of each animal species observed on private farms during the study varied significantly. A Chi Square Test for normal distribution of proportions of wild ungulate species in the Lake Mburo Region was statistically significant ($p < 0.001$).

For distance gradient, the results on animal surveys showed that there was significant decrease in the population density of wild ungulates as distance increased away from the park boundary northwards ($R^2 = 0.884$, $P < 0.001$). Association between total abundance of wild ungulates with distance ranges from the park boundary was a negative one. The mean densities of wild ungulates significantly decreased ($p < 0.001$) from 59.25 at the park boundary to less than 10.25 further north of LMNP.

Overall cattle population did not have significant progressive variations between distance zones. However, the mean population density of exotic (Friesian) cattle increased significantly from 184.25 at the park boundary to 550.5 further north. On the contrary, mean population of indigenous cattle (*Bos tauruss*) decreased from 1107 at park boundary to 164 along the same distance gradient. Shifts in spatial pattern of population densities of cattle breeds along the same distance gradient was due to pastoralists' economic choices, partly influenced by own perception and experience of pathogen infestations in cattle. Pastoralists associated incidences of cattle diseases with the presence of wild animals as potential risk factor for disease spill overs.

For example, majority of respondents at the park boundary reported frequent repeat use of acarides due to high degree of infestation of the cattle with ticks. It was for this reason that most households adjacent to the park preferred the indigenous cattle breed to exotic, since they believed that indigenous breed of cattle offers good resistance to tropical diseases compared to Friesian cattle. The probability of a household having exotic breed of cattle at the park boundary was 3 times lower (0.21, 95%CI) compared to 0.74, 95%CI for households situated further north of Lake Mburo National Park. In terms of acaricide use, cattle mortalities and expenditure on the services of veterinary personnel, pastoralist households incurred lesser costs of cattle diseases control in areas with significant decline of zebra and impala populations (Figure 2).

Majority of the respondents, over 83%, linked the presence of wildlife with diseases infecting their cattle. Most respondents held a strong view that wild ungulates, especially zebras, impalas and buffaloes, are not only abundant on private farms/ranches, but are also perceived as the transmission vehicle of various diseases affecting cattle production in LMCA (Table 3). Given high proportions of zebras and impalas in cattle grazing areas, it was likely that most wild ungulate related cattle disease risks, including brucellosis and tick-borne disease were due to these animals' grazing activities outside the protected area. It also emerged that large populations of zebra and impala have probably become permanent residents on private farms and ranches around Lake Mburo National Park.

Table 3
Sources of cattle disease risks as perceived by pastoralist communities

Sources of cattle diseases, N = 366	**Respondents**	
	Frequency	%
1. Wild ungulates on private farms	234	63.9
2. Cattle grazing within the LMNP	72	19.7
3. Moving cattle from one herd to another	35	9.6
4. Others	25	6.8
Total	**366**	**100.0**

Currently many animals trapped in private ranches/farms are unable to return to the protected areas, since people have severely encroached park buffer areas which once supported ecosystems connectivity. This situation facilitates frequent interactions between these wild ungulates and cattle in rangelands, thereby resulting in the spread of diseases.

We estimated annual cost of controlling ticks and treating sick cattle at herd level to be US $ 178 – 287 (at exchange rate of USD 1: UGX 2500). The expenditure pastoralist households incur on cattle diseases control also varied between distance zones, with communities living adjacent to the national park incurring higher costs compared to their counterparts situated further away from the park boundary. Our findings revealed that the costs of diseases control outweighed the benefits accrued from sales of milk among pastoralist households located within 8 km from the park boundary. On the contrary, the losses households located beyond 10 km away from the park incurred due to cattle diseases control were significantly lower ($p < 0.05$) than the benefits from sales of milk.

Table 4: Household incomes versus costs of disease control (in UGX 1000) by distance zone

Distance Zones (km)	No. H/holds	Mean cattle Heads	Income from Milk	Cost of Diseases	Mean Difference 95% CI	P-value
0 - 4	60	91.7 ± 10.50	4931.67	5615.01	683.33 ± 611.10	0.041
4 - 8.	58	152.2 ± 18.6	6215.52	7181.04	965.52 ± 672.99	0.053
8 - 12.	64	85.9 ± 05.80	7454.1	5149.22	2304.69 ± 294.11	0.012
12 - 16.	60	65.0 ± 04.80	8430.01	4837.51	3592.50 ± 520.95	0.005
16 - 20	62	65.0 ± 06.30	9616.13	4735.48	4880.65 ± 341.67	0.003
20 - 24	62	56.8 ± 04.20	8056.45	4460.48	3595.97 ± 987.95	0.006

Mean differences between income from sale of milk and expenditure on diseases control was statistically significant at $p \leq 0.05$.

Three breeds of cattle are reared by pastoralists in different proportions, across six distance zones. Spatial pattern of cattle breed populations illustrated in Figure 3 suggest that pastoralists' perception of disease risks as a function of distance from the Lake Mburo National Park had some influence.

4. Discussion

The Lake Mburo Conservation Area (LMCA) hosts a large number of different species of animals, which often escape from gazette area into private farms and ranches. The pastoralists and some scholars have described this situation as a phenomenon which started when the Government of Uganda removed herders with their cattle from the protected area. Rannestad et al. (2006) and Averbeck et al. (2009) reported that many species of wildlife reside outside the National Park, and the most dominant species were zebra and impala. Although the presence of buffaloes is also visible in the study area, zebra and impala constituted about 80% of all the large mammals on private livestock farms around the park. Although our findings indicate a gradual increase in the population of these two species of large mammals outside protected areas, a Chi Square Test indicated that the proportion of zebra (45%) and impala (35%) were not significantly different ($P>0.05$) from the mean results obtained by Rannestad et al. (2006), Ocaido et al. (2009) and Mugisha et al. (2011) at 43% and 33% for zebra and impala, respectively. These findings showed that wild ungulate populations, in particular zebras and impalas, have remained relatively stable outside the protected area over the years. However, their distribution once outside the protected area varied spatially from the edge of the park northwards. A decline in animal population exhibits a strong inverse association between distance range from the park boundary and animal population abundance outside the protected areas.

While the home range of zebras is above 50km^2 (Hattie et al., 2013) and hence could be located beyond the longest transect line of 24 km used in this study, the Impalas were dispersed beyond their known home range of about 6 km^2 (Averbeck et al., 2001; Leuthold, 1970; Murray, 1982a) from the boundary of LMNP. Thus, the wide dispersal of zebras and impalas far away from LMNP into private livestock farms suggests that some of them have probably become permanent residents outside the park as perceived by the locals Rising number of resident animal species like zebras and impala among others was bound to increase the frequency of interaction between these two wild ungulates and cattle, which in turn increases risks of diseases spillover from wildlife to livestock and vice versa (Ocaido et al., 2006). For instance, while we acknowledge that zoonotic infections can be carried by both wild ungulates and livestock, the pathogens are likely to cause greater danger in livestock than in wild ungulates, since wild animals have a wider range of dispersal compared to livestock For instance, diseases like tick borne may present a bigger problem in areas with significantly higher numbers of wild ungulates, because the pathogen can circulate between cattle herds rather fast due to free movements of tick infested wild ungulates across various grazing farms.

Research has shown the possibility of animal reservoirs of brucellosis (WHO, 2006; KalemaZikusoka et al, 2005; Godfroid et al., 2013) and studies conducted around Lake Mburo National Park reported rampant cases of wild animals grazing with cattle in private ranches (Ranestard et al, 2006, Averbeck, 2009; Ocaido et al, 2009). Wildlife species which are often found grazing with cattle in LMCA include buffalo (*Syncerus caffer*), zebra (*Equus burchellii*), eland (*Taurotragus oryx*), waterbuck (*Kobus ellipsiprymnus*) and impala (*Aepyceros melampus*). Elsewhere in South Africa these animals have tested serologically positive for brucellosis. However, due to infrequent interaction with domesticated animals, Gradwell et al. (1977) in Godfroid et al. (2002) noted that their role in the epidemiology of bovine brucellosis was minor. The situation in LMCA is different because these animals are found outside protected area year round, and some of them are now thought to have become permanent residents in private farms and ranches.

Majority of the pastoralists (84%) believed that most cattle diseases originate from wild ungulates grazing with cattle, either in their private farms or when people encroach with cattle into the protected area. Occasionally pastoralists take their cattle to the national park in search of pasture and water during environmental stress. Indeed, a previous study by Ocaido et al. (2006) found out that the size of the zebra population is a good predictor for the population of a tick species (*R. appendiculatus*) known to be an efficient transmitter of pathogens that cause east coast fever (ECF) in the Lake Mburo Conservation Area. Besides tick-related diseases, other studies also recognize the role of wild ungulates as reservoirs of zoonotic diseases (Marcotty et al., 2009) such as brucellosis (*Brucella abortus*) and Bovine tuberculosis that are common in the Lake Mburo Conservation Area. Thus, the presence of wild ungulates like zebra, impala and buffalo, which is a proxy for livestock disease risks, has an influence on the use of rangeland resources for different breeds of cattle in the Lake Mburo Conservation Area. This selective use of rangeland resources for production of different cattle breeds is consistent with the earlier observation made by Ford (1971) that “pastoralists are aware of the vulnerability of livestock that lack acquired immunity, and use controlled exposure to endemic diseases” such as East Coast Fever. The perception and actual experience of controlling the various types of livestock diseases have, in turn, influenced the spatial dispersal of different breeds of cattle in the Lake Mburo Conservation Area. This could be creating different economic outcomes and vulnerability levels among pastoralist households in the Lake Mburo Conservation Area.

Conclusion

This study analyzed spatial patterns of population densities of wild ungulates and cattle breeds in relation with cost of disease control at the wildlife-livestock interface. Results from animal survey showed that park adjacent rangelands had significantly higher abundance of wild ungulates compared to rangelands further north of the park. Higher abundance of wild animals had strong positive association with high economic costs of cattle diseases at household level. The longer the distance from the park the lesser the population of wild ungulates, and consequently low cost of cattle disease control around LMNP. We further observed that Ankole cattle breed (*Bos indicus*), dominated areas perceived as having higher risk of cattle diseases. In contrast, Friesian cows which are high milk yielding breed were predominantly reared in distant zones away from the park. Pastoral communities considered areas dominated by wild ungulates as unfavorable for Friesian cattle production. The pastoralists also believe that indigenous cattle were more resistant to tropical diseases unlike their exotic counterparts which are perceived to be less disease tolerant. Our findings provide the first empirical evidence that cattle breeds reared in a pastoral system at local spatial scale were differently exposed to various levels of disease risks. Although pastoralists were traditionally perceived as homogeneous group of people, a common threat to their cherished source of livelihood has the potential to render disadvantaged households vulnerable. In this study, households situated adjacent to the park boundary are the vulnerable group. These households keep indigenous cattle which are less productive in terms of units of milk production per cattle. Furthermore, high incidences of cattle diseases at the park boundary, have the potential to further reduce livestock productivity and in turn affect overall household income. Thus, compared to households located far away from LMNP, who rear high milk yielding exotic and cross breed cattle, the park adjacent communities were apparently disadvantaged. In the end, these results may have policy implications for prioritizing resource allocation for disease control around protected areas. Such a policy will ensure that resources are reaching communities with the highest economic burden of diseases transmitted at the wildlife-livestock interface. When that happens, pastoral communities will be incentivized to conserve habitats for resident animals in their farms/ranches.

Abbreviations

ARC Ankole Ranching Scheme

GIS Geographic Information System

GPS Geo-positioning System

Km^2 Square kilometre

LMNP Lake Mburo National Park

LMCA Lake Mburo Conservation Area

ML Milliliters

Declarations

Ethical Approval

This study did not include the use of human subjects for experiments. However, permission to carry out this study was granted by Uganda National Council for Science and Technology.

Consent to Publish

All authors read and approved the final manuscript for publication in the journal of ecology and environment.

Consent to Participate

The consent of study participants was obtained orally after explaining the purpose of the study prior to administering the interviews. Only those who consented were included in the study.

Authors' contribution

All authors participated in the formulating study design as well as developing data collection tools. Corresponding author was responsible for data analysis and drafting of the manuscript, which all authors read and made revisions to.

Competing interests

Authors declare that there is no conflict of interest.

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Availability of Data and Materials

All necessary data are included in the manuscript submitted for publication. Additional data is provided as appendix 1

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Figures

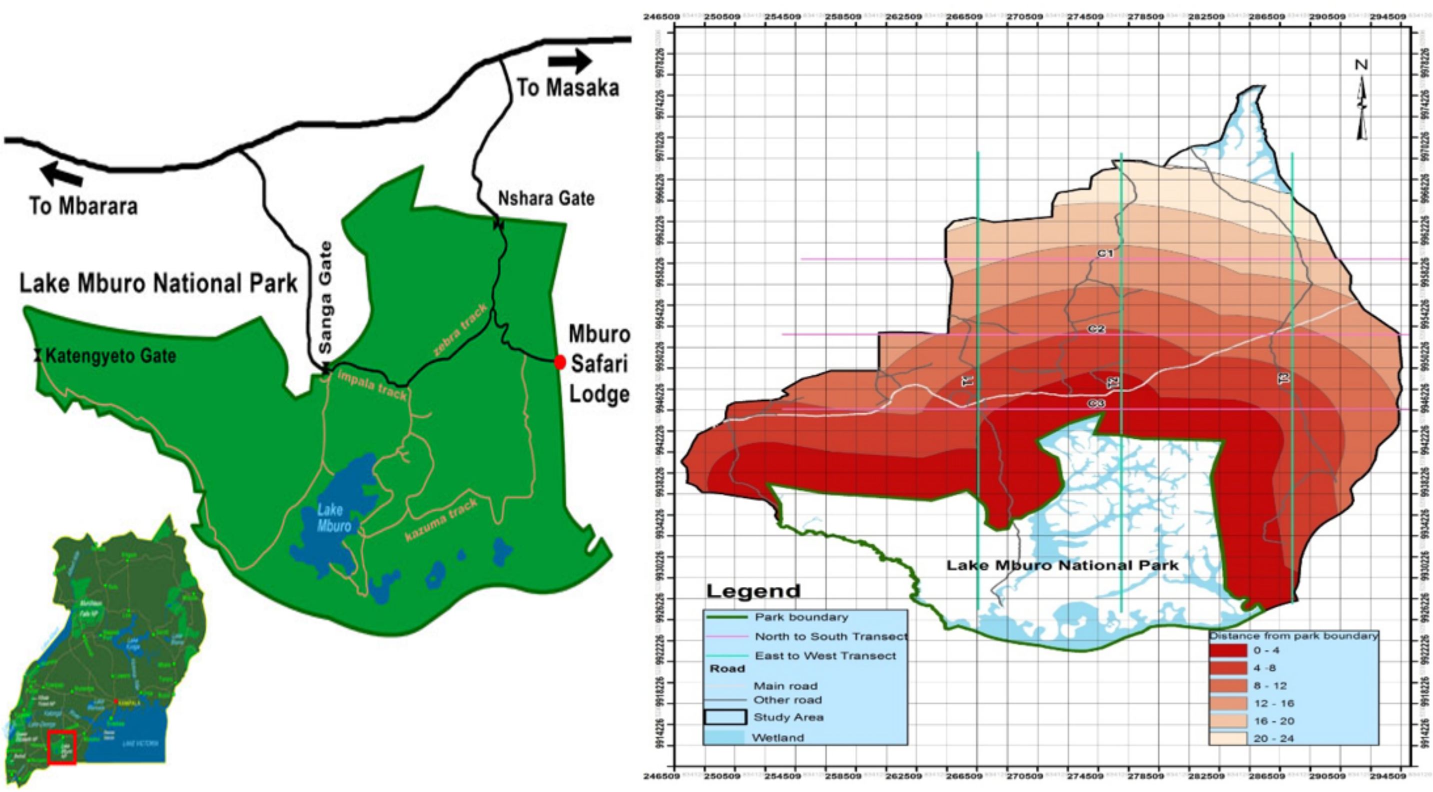

Figure 1

Map showing transect lines and six zones a long a gradient from LMNP.

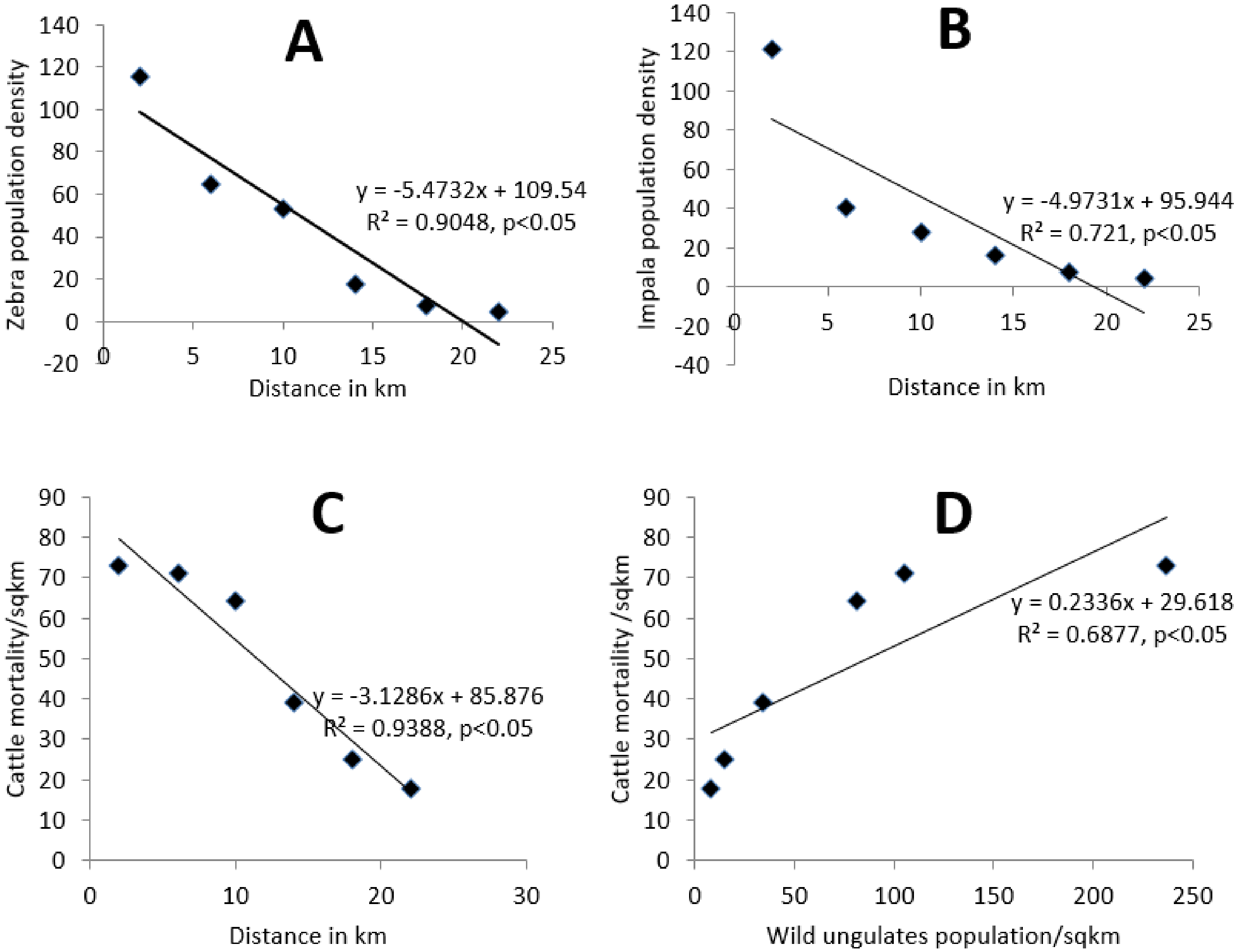

Figure 2

Spatial distribution of wild ungulates and the correlation between population densities of wild ungulates with annual cattle mortality per km² around Lake Mburo National Park in south western Uganda

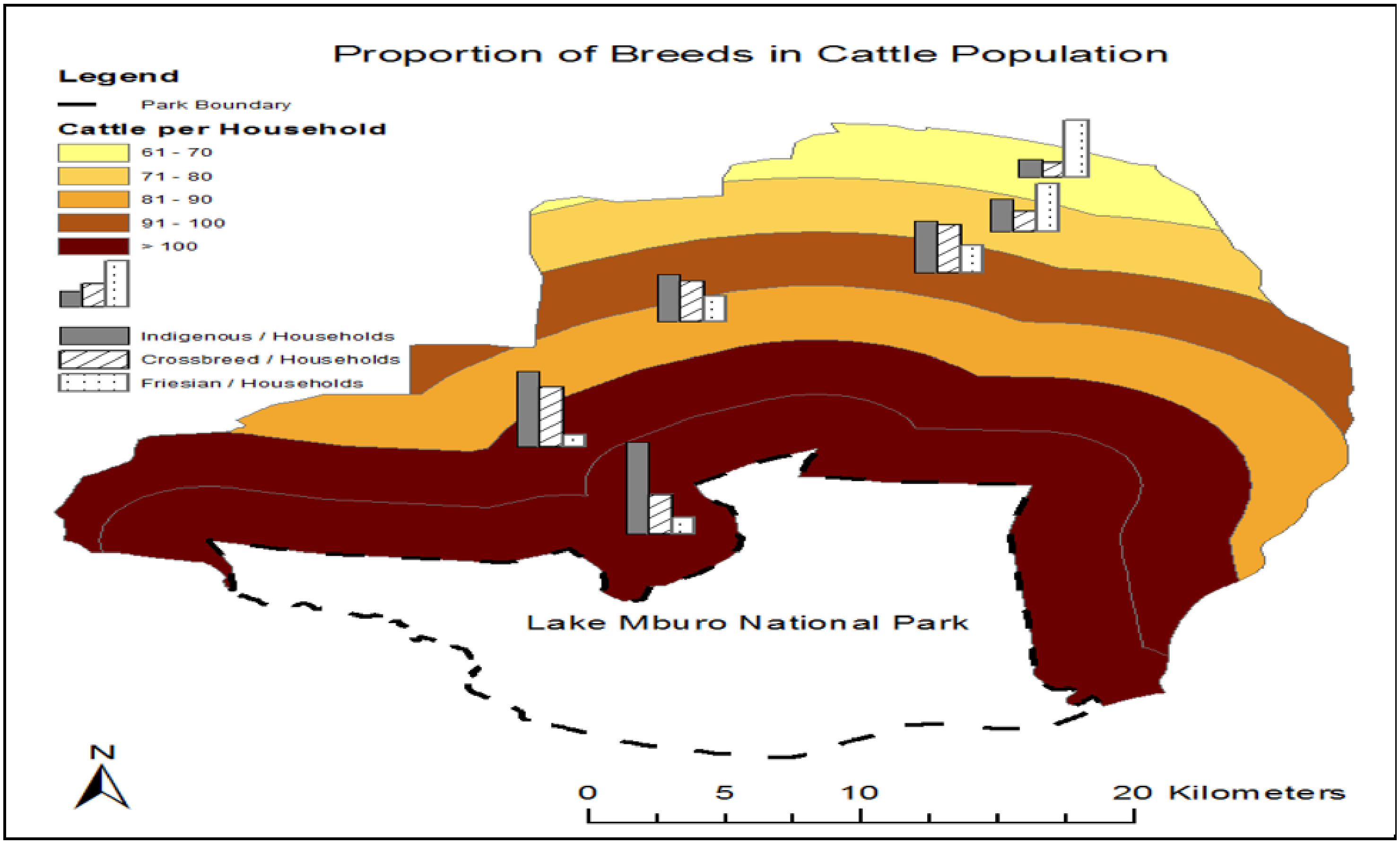

Figure 3

Spatial distribution of cattle breeds away from Lake Mburo National Park

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