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Waterhole use patterns at the wildlife/livestock interface in a semi-arid savanna of Southern Africa

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Abstract

Based on wildlife and domestic herbivore waterhole use count data collected in the South Eastern Lowveld of Zimbabwe between 2008 and 2011, we tested whether there was any significant overlap by wild and domestic herbivores in the use of waterholes located; 1) inside a wildlife protected area, 2) at the boundary of the protected and agricultural areas and 3) in the agricultural areas. We also explored whether species diversity at these three land uses vary significantly. Our results showed overlap in place and time between wild and domestic herbivores especially in the use of waterholes located at the boundary of the protected areas and at one waterhole located in the agricultural areas. Results also indicated that overall, 95% of wild herbivores prefered using waterholes located inside the protected area.Results of this study further demonstrated that animal species diversity declines significantly along a gradient from protected areas to agricultural areas. Overall, results of this study imply that the current emerging disease interface between wildlife and livestock may not necessarily be due to direct physical interaction between disease reservoir hosts or even sharing of same waterholes at the same time but rather an indirect contact. These findings could provide an important avenue of investigating livestock and wildlife disease outbreaks at the domestic -wildlife interface which are disturbing current efforts to improve livestock production as well as biodiversity conservation in African savannas.

Keywords: Waterhole, Wild herbivores, Domestic herbivores, Interaction ,Gonarezhou national park, Agricultural areas, Overlap

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1. Introduction

Increased wildlife and livestock interactions especially in Southern African savanna environments in recent years has mainly been explained by increasing human populations and the attendant expansion of human settlements (Wolanski, 2001). Specifically, as the human population expand, settlements also tend to encroach into adjacent protected areas resulting in the transformation of natural landscapes into agricultural landscapes (Hibert et al. 2010). This together with growing densities of livestock populations (Ottichilo et al., 2000) is leading to an increase in chances of livestock getting in direct contact with wild herbivores especially during resource limiting periods such as the dry season or during droughts (Mishra et al., 2004). To this end, dense human populations in close proximity to protected areas pose the greatest challenges to biodiversity conservation in many countries especially where livestock holdings and agriculture are the main strategies of rural livelihoods (Distefano, 1998; Mworia, 2008). On the other hand, the successful recovery of the once declining wild herbivore species populations in Southern Africa (Chamaille-James et al., 2008) through wildlife conservation has also increased the chances of wildlife being forced to move out of the protected areas into adjacent agricultural landscapes to maintain their home ranges.

Besides exposing such wild herbivores to poaching, movement of wildlife out of protected areas has also led to increased competition for water and forage use, (Putman, 1996) as well as increased interaction resulting in increased chances of disease transmission between domestic and wild herbivore species (East, 1998). In addition, the coming down of fences due to fence damage, as well as a general lack of maintenance along park boundaries across Southern Africa has made wildlife and livestock movements inside and outside the protected areas even more prevalent thus increasing their overlap in the use of scarce resources particularly water. To the best of our knowledge, the nature and timing of this overlap between wild and domestic herbivores that result from these increased movements has received little attention in previous studies. This is despite the fact that understanding the extent of such resource use overlap is important since the fate of animal biodiversity inside and outside of protected areas is often dependent on the strength of interactions between wildlife and livestock since they tend to compete for scarce resources (Young et al., 2005) as well as transmitting diseases to each other. Thus, understanding the patterns of wildlife and livestock overlaps, as well as the factors driving these overlap patterns is critical for conservation and rangeland management purposes in savanna semi arid environments.

Water availability has largely been hypothesized as a major factor driving the interaction between wild and domestic herbivores, particularly in landscapes dominated by seasonal water sources. In the semi arid savanna landscapes of Southern Africa, surface water availability varies spatially and temporally mainly due to seasonality of rainfall but also due to variability in the intensity of use by wild and domestic herbivores

(Auer, 1997). For example, the wet season is normally characterized by water abundance which favors widespread distribution of herbivores across the landscape (Trash, 1995). In this scenario of abundant water resources, there is minimal direct physical interaction between wild and domestic herbivores, as most of them would prefer ranging in their favorable sites. However, in the dry season, surface water resources in savanna semi arid landscapes contract significantly to only a few permanent water sources leading to increased use of permanent water holes by both domestic and wild herbivores. Previous studies have demonstrated that in savanna rangelands, waterhole aggregation and the resultant interaction between domestic and wild herbivores is a major driver of disease transmissions between these groups of herbivore species (Thomson, 1999; Lomax, 2007). Thus, understanding overlap patterns between domestic and wild herbivore species in the use of water resources could be an important prelude towards understanding pathways and patterns of disease transmissions between livestock and wildlife species in semi arid environments.

Although, it is widely hypothesized that domestic and wild herbivore overlaps are largely driven by water availability, most studies have focused on overlaps in waterhole use between wild herbivores especially elephants and other wild herbivores species (Berger and Cunningham 1998; Valeix 2007; Pringle 2008). To the best of our knowledge not much attention has been given to investigate the extent of wildlife and livestock overlaps that are driven by spatial and temporal waterhole use patterns at the wildlife/livestock interface. Instead, most studies on overlaps have mainly focused on the overlaps between wild and domestic herbivores within the framework of forage usage (de Leeuw et al., 2001; Sitters et al., 2007; Shrestha and Wegge, 2008).

In this study, we tested whether and to what extent there is spatial and temporal overlap in the use of water sources located in three different land uses by wild and domestic herbivores. We focused our attention on waterholes located 1) inside a wildlife protected area, 2) at the boundary of the protected area and agricultural area and 3) in the agricultural area. We tested the extent of water use overlap by determining and comparing species diversity at water holes in these three land use types. We tested these hypotheses using data obtained through focal counts of wild and domestic herbivore populations visiting waterholes inside the protected area of Gonarezhou National Park (hereinafter called GNP), in the agricultural areas and at the boundary of GNP and the adjacent agricultural areas between 2008 and 2011. We expect wild and domestic herbivores to overlap only during the dry season at waterholes located especially at the boundary of agricultural areas and protected areas.

2. Materials and methods

2.1. Study area

Gonarezhou National Park (GNP) covers an area of 5053 square kilometers in the South Eastern Lowveld of Zimbabwe (Figure 1). The area is characterized by generally low altitude of below 400m above mean sea level. Average daily maximum temperatures range from 27 degrees Celsius in June to 36 degrees Celsius in January. Minimum temperatures ranges from 8 degrees Celsius in June to 24 degrees Celsius in January

(Torrence, 1981). The area receives a relatively low rainfall ranging from a minimum of 84 mm to a maximum of 896 mm per year (Torrence, 1981). Severe droughts (annual rainfall less than 200 mm) have occurred twice since 1961.The most recent drought in 1991/92 was particularly severe resulting in the death of large numbers of wildlife and livestock (Frost, 1993).

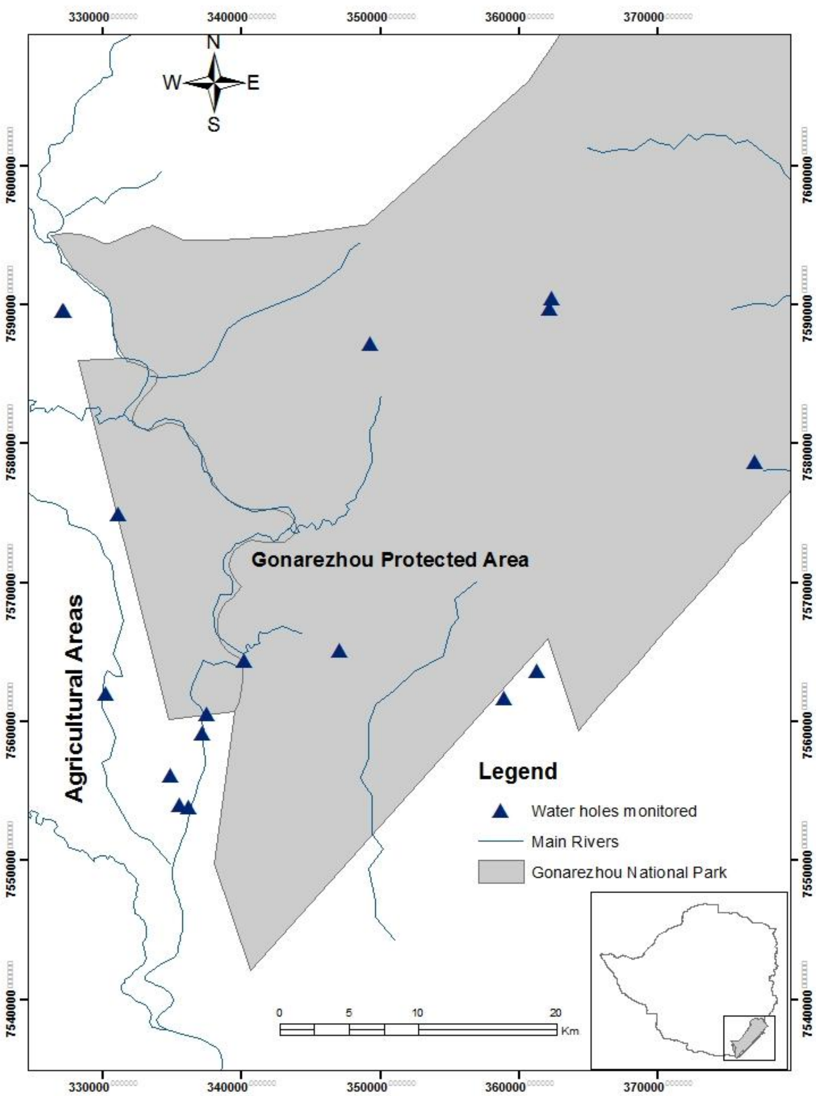

Figure 1. Location of the study area. Location is measured in metres based on the WGS84 spheroid

The South Eastern Lowveld of Zimbabwe is part of the Great Limpopo Transfrontier Conservation Area (GLTCA)-a large Pan –African conservation area that includes South Africa's famed Kruger National Park, and Mozambique's Limpopo National Park and the adjacent areas. The dry conditions which characterize the area make rain fed crop production unsustainable. As a result cattle ranching, wildlife production and irrigated farming are the dominant activities practiced under different land tenure systems (Child, 1988). In addition, the expansion of human and livestock population in areas adjacent to GNP has resulted in their encroachment on natural habitats. Human encroachment on the natural habitats is suggested as one of the most critical challenges facing biodiversity conservation in Southern Africa (Bagchi et al., 2004). In addition, the boundary fence between GNP and the communal areas is permeable in most areas and this promotes movement of both wild and domestic herbivores in and out of GNP especially during resource limiting periods thus creating conflicts between people, livestock and wildlife.

Three drainage systems traverse the park; the Save and Runde systems in the north, the Mwenezi system in the south and the Guluene/Chefu system in the centre of the Park. The first two systems have much of their catchments located some distance from the Park but the catchment area of the smaller Guluene/Chefu system is largely contained within the Park. These river systems have water along their entire courses during the wet season. However during the dry season only their persistent perennial routes contain water (Torrence, 1981) forcing both wild and domestic herbivores to move long distances to access water at these permanent sources. GNP and its surrounding areas have numerous seasonal pans on the cretaceous sandstones that provide widespread and abundant water during the rainy season. However, most of them become dry from mid May in normal rain years only retaining water throughout the year after exceptionally heavy rains (Torrence, 1981). The drying up of these seasonal pans create challenges for rangeland managers as animals will be forced to travel long distances to access water at few permanent waterholes. This scenario has been worsened by the fact that provision of water especially to wild herbivores in the GNP has been left for nature to take its course after the program to supplement water provision in the area was discontinued in order to create a more heterogeneous natural ecosystem.

2.2. Wild and domestic herbivores data

The aim of this study was to explore the extent to which wild and domestic herbivores overlap in the use of water resources as well as determine species diversity variations at waterholes along a gradient from protected areas to agricultural areas. To this end, we selected sixteen waterholes; six located inside the protected area (GNP), five in the agricultural areas and five at the boundary of GNP and the agricultural areas (i.e + – one kilometre inside or outside of the GNP boundary (Figure 1). Our selection of the sixteen waterholes was based on expert knowledge from GNP rangers and interviews with elderly cattle owners in the surrounding agricultural lands. Based on this knowledge, we were able to identify permanent, as well as seasonal waterholes to be used for our herbivore counts surveys in each of the three land use types.

We conducted a total count of all herbivore species that came to drink during our census sessions during the wet season (November to April) and dry season (May to October) for the period 2008 to 2011. For the dry season, we conducted the counts during the months of July when most seasonal waterholes would just have dried and October when the demand of water was highest among herbivores. Wet season counting was conducted during the months of March when seasonal waterholes were still containing water and November when the first rains falls. Procedures for counting herbivores at waterholes were adopted from Senzota and Mtahiko (1990). Both twelve hour and twenty four hour counts were conducted all starting from 0600 hours to 1800 hours and for twenty four hour counts ending at 0600 the following day. Twenty four hour counts were conducted during full moon periods to increase visibility.

Table 1. Characteristics of the monitored water holes

Waterhole	Type of waterhole	Permanent/Seasonal	Land use
Wrightstower	River pool	Permanent	Protected area
Manyanda	Pan	Seasonal	Protected area
Maguni	Pan	Seasonal	Protected area
Nyamugwe	Pan	Seasonal	Protected area
Gorwe	Pan	Seasonal	Protected area
Makonde	Pan	Seasonal	Protected area
Malipati	Dam	Permanent	Protected area/Agricultural area boundary
Masukwe	Dam	Permanent	Protected area/Agricultural area boundary
Bossman	River pool	Seasonal	Protected area/Agricultural area boundary
Pahlela	Pan	Seasonal	Protected area/Agricultural area boundary
Nyakasikana	River pools	Permanent	Agricultural area
Manjinjana	River pools		Agricultural area
Mawange	Dam	Permanent	Agricultural area
Manjinji	Dam	Seasonal	Agricultural area
Magangeni	Pan	Seasonal	Agricultural area
Makwakweni	Pan	Seasonal	Agricultural area

Counts were conducted by two people one of them being an experienced ranger for animal species identification and for safety purposes. We performed the counts from either tourists viewing platforms or from blinds in trees and on rocks for the rest of the waterholes. The counting platforms (census points) were located at a distance between 200m to 500m from the water hole to avoid disturbing the animals especially wild herbivores. This distance was deemed sufficient based on expert knowledge. A pair of binoculars was used to identify species during times of poor visibility. For all the herbivores visiting the waterhole, we recorded the herbivore species, total number per group, time of arrival at the waterhole, time when the first member of the group starts drinking water, time when the last member of the group would finish drinking and the time when all the members of the group would disappear from the waterhole. Altogether, we had 1440 hours of herbivore counts. Of these hours 768 hours (53.33%) were for the wet season while 672 hours (46.66%) were for the dry season. The difference in counting hours is due to the fact that the wet season had all the sixteen waterholes containing water compared to the dry season when seasonal waterholes are usually dry.

2.3. Statistical analysis of wild and domestic herbivore data

Our first objective was to test whether there was a significant spatial overlap by wild and domestic herbivores in the use of waterholes located at three different land uses. To accomplish this, we used ANOVA to compare the mean number of wild and domestic herbivores counted at the different waterholes in the three different land uses. To reduce variance,our count data was transformed to stabilize the variance (Lomax, 2007).

Waterhole use overlap between wild and domestic herbivores was measured using Schoener's index of overlap. Values of waterhole use overlap vary from 0 when no waterhole is shared to 1 when there is the same proportion of wild and domestic herbivores using the same waterhole.

Although there are no critical levels for the comparison of overlap values,(Schroeder and Schroeder, 1984) suggested that values greater than 0.6 or 60% should be considered as biologically significant. However, in terms of disease transmissions, any level of overlap has the potential to act as a pathway for pathogen transmission especially between wild and domestic herbivores. Overlap was tested using the formula:

$$O_{12} = O_{21} = 1.0 - 0.5 \sum \left| P_{i1} - P_{i2} \right| \qquad \textit{Equation 1}$$

where: P_{i1} is the proportion of all individuals of species 1 that attended waterholes in landuse i.

Overlap between species 1 and 2 is complete when $O_{12} = 1$ and is null when $O_{12} = 0$. Next we calculated animal diversity at waterholes located at three different land uses using the Shannon Weiner Index using the following formula:

$$H' = -\sum\left[\left(\frac{ni}{N}\right) \times ln\left(\frac{ni}{N}\right)\right] \qquad \textit{Equation 2}$$

where: *ni* is the number of individuals of each species (the *ith* species). *N* = total number of individuals for the site, and ln = the natural log of the number. We used the Shannon Weiner Index because it is fairly sensitive to actual site differences (Olff et al., 2002). It usually ranges from 1.5 to 4.5.

To test whether there was a significant difference in the means of animal diversity between the three land uses, we used ANOVA. Differences in diversity between seasons within the same land use were tested using the z-test. We also tested whether there was any significant difference in the arrival times of wild and domestic herbivores at waterholes. Specifically, we calculated the frequency of arrivals every two hours from 0600hrs to 1800hrs and then used a z-test to determine whether there was a significant difference in the proportions of wild and domestic herbivore species arriving at two hour intervals at waterholes located at the boundary of GNP and the agricultural areas. In this study, more than 95% of herbivores visited waterholes during the day that is between 0600 to 1800.Thus our analysis only focused on these time periods.

3. Results

Overall, 95% of wildlife species was drinking at waterholes inside the protected area. Six wild herbivore species, i.e.,buffalo (*Syncerus Caffer*), giraffe (*Giraffa camelopardalis*), waterbuck *(Kobus ellipsiprymmus*), zebra (*Equus burchelli*) wildebeest (*Connochaetes taurinus)* and nyala *(Tragelaphus buxtoni)* avoided waterholes located at the boundary and those located in the agricultural areas which were frequently used by domestic herbivores (Tables 3 and 4). Wild herbivores such as the elephant(*Loxodonta africana)*, impala *(Melumpus aepyceros)*, kudu *(Trageluphus strepsciceros)* and warthog ***(****Phacochoerus aethiopicus****)*** overlapped spatially with cattle in the use of waterholes located at the boundary of GNP during both the wet and the dry season (Table 3).

Table 2. Mean number of wild and domestic herbivore species counted during the wet and dry season at five monitored waterholes inside the protected area (n = the number of 12 hour counts at each waterhole)

Species	**Mean Herbivores counted per waterhole**										**Mean number per species counted at the five waterholes**
	Nyamugwe Pan (n=15)		*Gorwe Pan (n=16)*		*Makonde Pan (n=13)*		*Wrights tower (n=36)*		*Many and Pan (n=21)*		
	Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	
Impala(*Melumpus aepyceros*	200	0	130	0	84	0	640	1855	63	0	595
Elephant(*Loxodonta africana*)	83	0	221	11	227	0	145	433	256	0	275
Buffalo(*Syncerus cafer)*	33	0	221	15	175	0	130	337	231	0	228
Kudu(*Trageluphus strepsciceros*)	21	0	133	5	23	0	144	377	19	0	144
Nyala(*Tragelaphus buxtoni)*	0	0	0	0	0	0	83	171	13	0	53
Warthog(*Phacochoerus aethiopicus*)	12	0	17	5	5	0	87	135	27	0	58
Waterbuck(*Kobus ellipsiprymmus*)	0	0	0	0	0	0	156	177	0	0	67
Zebra(*Equus burchelli*)	11	0	43	3	7	0	78	97	61	0	60
Giraffe(Giraffa camelopardalis	3	0	2	0	20		0	0	4	0	6
Wilderbeest(*Connochaetes taurinus*),	0	0	0	0	0	0	15	32	0	0	9

Table 3. Mean number of wild and domestic herbivore species counted during the wet and dry season at four monitored waterholes located at the boundary of agricultural area and protected area (n = the number of 12 hour counts at each waterhole)

Species	**Mean number of herbivores counted per waterhole**								**Mean number per species counted at the five waterholes**
	Masukwe dam(n=13)		*Bossman Pools(n=10)*		*Malipati Dam(n=33)*		*Pahlela Pan (n=8)*		
	Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	
Impala(*Melumpus aepyceros)*	0	0	51	21	157	337	18	0	146
Cattle	493	731	137	87	2254	2546	87	0	1584
Kudu(*Trageluphus strepsciceros*)	0	0	21	7	35	55	0	0	30
Elephant(*Loxodonta africana*)	0	2	23	7	15	11	0	0	15
Warthog(*Phacochoerus aethiopicus*)	2	3	0	0	15	27	0	0	12

Table 4. Mean number of wild and domestic herbivore species counted during the wet and dry season at five monitored waterholes located in the agricultural areas(n = the number of 12 hour counts at each waterhole)

Species	**Mean number of herbivores counted per waterhole**										**Mean number per species counted at the five waterholes**
	Nyavasikana (n=24)		*Manjinjana (n=8)*		*Magangeni (n=9)*		*Manjinji (n=12)*		*Mawange (n=13)*		
	Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	
Impala (*Melumpus aepyceros)*	0	0	0	0	0	0	31	0	0	0	6
Cattle	87	225	129	0	143	0	223	0	345	667	364
Goats	2	11	57	0	0	0	175	0	47	129	84

Table 5. Mean number of wild and domestic herbivore species counted during the wet and dry season during full moon monitoring sessions (n = the number of full moon counting sessions at each waterhole)

Species	Mean number of herbivores counted per waterhole			Mean number per species counted
	Malipati dam (n=6)	*Wrightstower (n=12)*	*Nyavasikana (n=6)*	
Elephant	15	345	0	120
Buffalo	0	231	0	77
Cattle	10	0	0	3

Impala had the highest overlap of 25% during the dry season while the kudu had the lowest overlap of 7% during the wet season. Although some impala, kudu, warthog and elephant were observed at waterholes located at the boundary of protected areas and the agricultural areas, the largest proportions of these wild herbivores (80%) used waterholes inside the protected area. Of particular interest was 0.8% of impala populations that were observed at one pan (Manjinji) located further in the agricultural areas (Table 4). Elephant visits to waterholes located at the boundary of GNP and agricultural areas were confined to midnight hours between 2200 hrs and 0200 hrs (Table 5) .However elephant visits to waterholes located inside the protected area were across the whole day. ANOVA showed a significant difference in herbivores counted at waterholes in the three different land uses in the wet season ($F_{2.15}$= 3.68, p=0.002).

There was a significant difference between species diversity at waterholes located at the three different land uses (ANOVA $F_{3.144,}$=3.44, p=0.04 for species richness and $F_{1.13}$ =6.7,p=0.02 for species diversity). The highest mean species diversity was observed at waterholes located inside the protected area during the dry season while the lowest mean species diversity was at waterholes located in the agricultural areas (Figures 2 and 3). Mean species diversity for the wet and dry seasons was not significantly different at water holes in each of the three land uses (Figure 3). However mean species richness for the protected area differed significantly between the wet and the dry season ($F_{1.13}$ = 6.1; P = 0.028). Mean species richness for the wet season was significantly different across all the land uses (Figure 3). Species richness was also significantly different across all land uses for the dry season ($F_{2.144}$=2.44, p=0.025).

Figures 4 and 5 illustrates that the largest mean number of cattle (80%) visited waterholes located at the GNP boundary during the afternoon. The mean arrival times ranged between 1300 hours and 1600 hours unlike their wild counterparts which preferred visiting these waterholes either early in the morning or late in the evening. The mean arrival times for wild herbivores at waterholes located at the boundary ranged between 0600 hours and 1000 hours in the morning and between 1700 hours and 1800 hours in the evening (Figures 4 and 5). This trend was consistent for both the wet and dry seasons. Mean arrival times of cattle at waterholes in the agricultural areas did not differ much with those recorded at the GNP boundary.

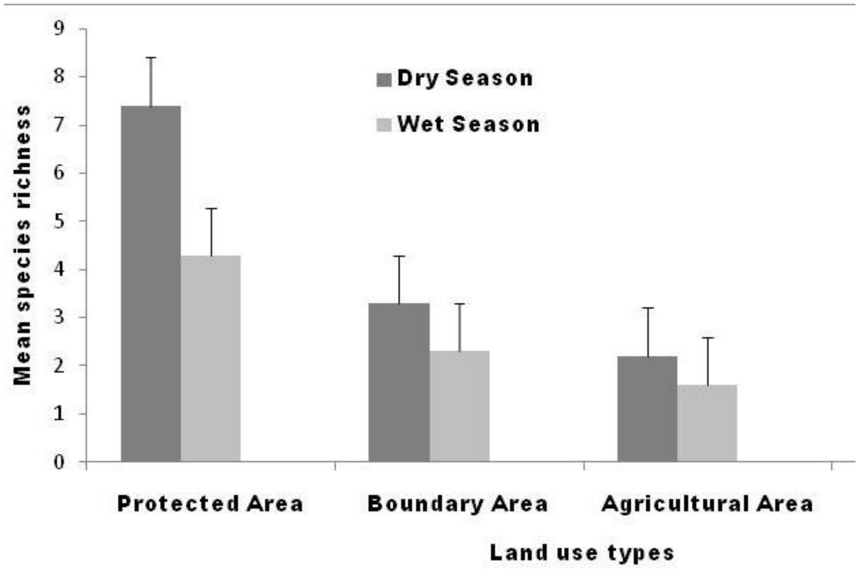

Figure 2. Mean animal species richness at waterholes located inside the protected area, at the boundary of protected area and agricultural area and in the agricultural area

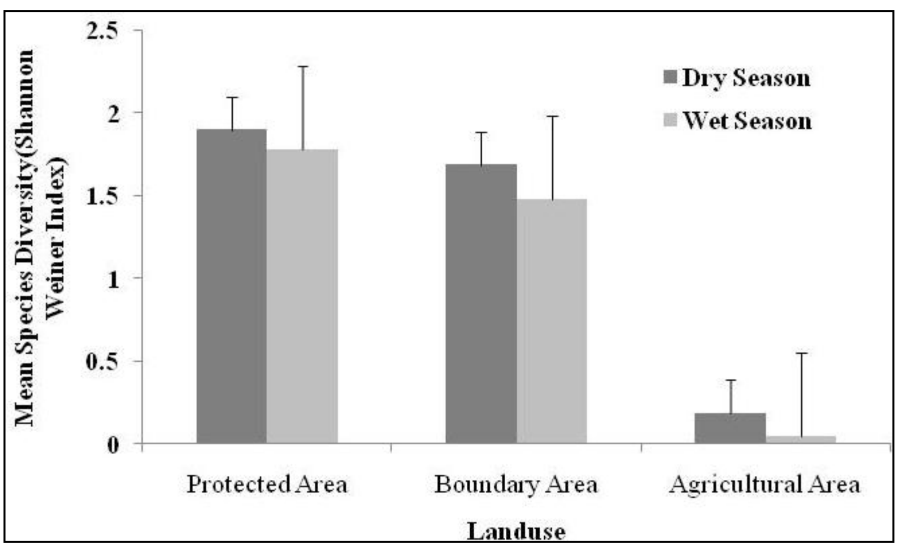

Figure 3. Mean animal species diversity at waterholes located inside the protected area, at the boundary of protected area and agricultural area and in the agricultural area

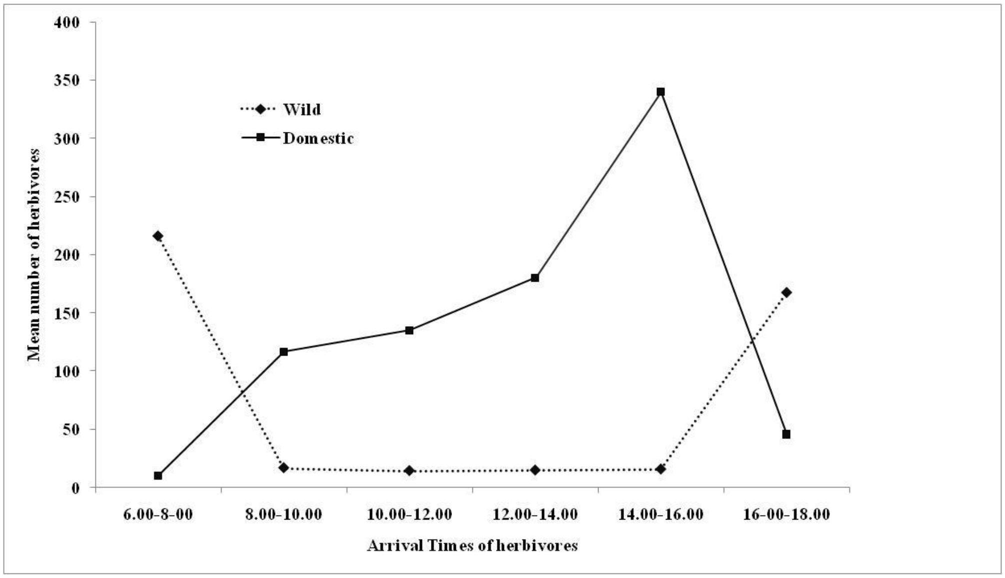

Figure 4. Two hourly arrival times of herbivores in the dry season at waterholes located at the boundary of protected areas and agricultural areas

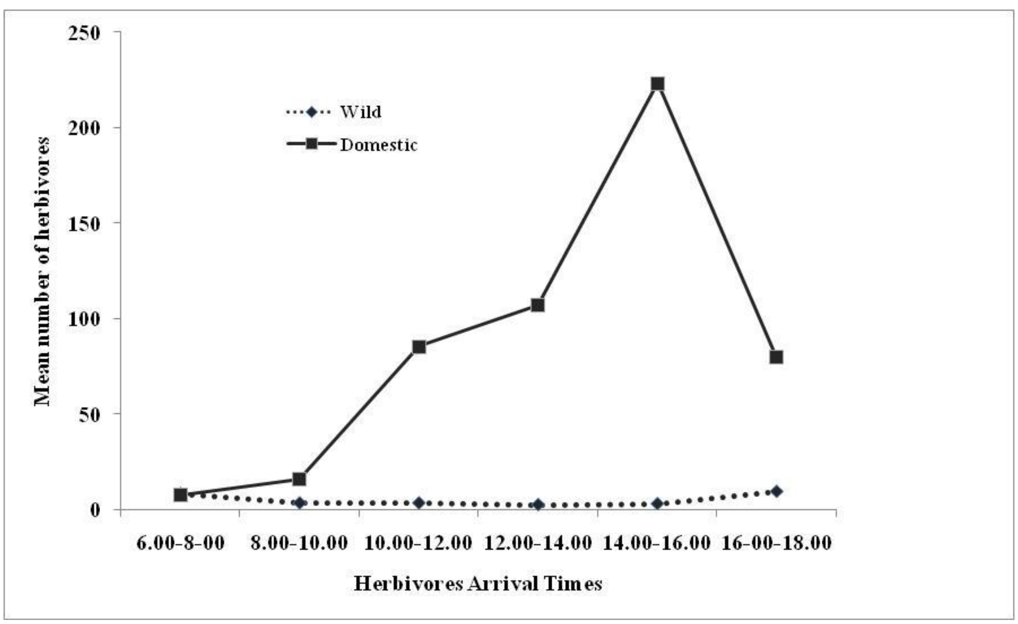

Figure 5. Two hourly arrival times of herbivores in the wet season at waterholes located at the boundary of protected areas and agricultural areas

Impala also overlapped with cattle (0.05%) in the wet season in their arrival times (between 1500 and 1600) at one waterhole located in the agricultural areas. There was no overlap in the agricultural areas between domestic herbivores and other wild animals besides the impala.

4. Discussion

Results in this study indicate that most wild herbivores prefer to use waterholes inside the protected area. This could be explained by the fact that such waterholes are characterised by less human disturbance. This is suppoted by our observation that elephants tended to visit waterholes close to agriculrural areas during the night when chances of human disturbance are reduced. This contrasts with elephants visits at waterholes inside the protected areas which was observed across the whole day. Previous studies have demonstarted that wild herbivores tend to decrease along a human disturbance gradient up to a scale when they completely disappear (Bergstrom and Skarpe 1999; de Leeuw et al. 2001). In a related study, Bonington etal (2007) also found that areas heavily utilised by livestock are used to a lesser extent by wild herbivores. Thus, our observation is consistent with the hypothesis that densities of large herbivores are a significant function of levels of human distrubance along the landscape (Hoare 1999).

The high species diversity of wild herbivores at waterholes inside the protected areas found in this study contradict findings by Western (1975) and de Leeuw et al (2001) who found that in Kenya the largest diversity of wildlife was outside of the protected areas.This could be explained by Kenya's wildlife conservation policy which declares any form of hunting illegal (Mworia et al. 2008). Thus, we deduce that hunting outside of the wildlife area in our study area might be leading to wildlife shying away from these areas even during periods of water scarcity.

In this study, we predicted that overlap in the use of water resources should be more pronounced during the dry season when resources are constrained. However results of this study demonstrated that overlap in the use of waterholes located at the boundary of GNP tended to occur across all seasons (Table 3, Figures 4 and 5). For wild herbivores we claim that this could be explained by site fidelity, where certain groups of animals will always prefer to use certain waterholes even if there could be alternative waterholes within the vicinity (Woodroffe and Ginsberg,1998). However for domestic herbivores the choice to use particular waterholes is usually determined by cattle herders who tend to be looking after their cattle for most of the cases throughout the year.

In the context of waterhole use by wild herbivores in semi arid savannas, we showed that time represented an important niche axis, over which they might reduce the effects of interference from humans, and livestock as demonstrated in previous studies (Valeix et al. 2007). In fact, this study provides evidence that domestic herbivores were concentrated at waterholes between 1300 hours and 1600 hours while their wild counterparts preffered visiting waterholes,either early in the morning between 0600 hours and 1100 hours or late in the afternoon between 1700 hours and 1800 hours (Figures 3 and 4). This could be explained by the observation that during these time periods disturbances from cattle, motor vehicles,and people is minimal.

The evidence of overlap in the use of the boundary waterholes especially between cattle and wild herbivores such as impala, kudu and warthog highlighted in this study raises some health concerns. This is because previous studies by (Thomson 1999) suggest that antelopes can provide indirect contact between infected buffalos inside the protected area and the cattle outside the protected area. In this regard, they can act as intermediary hosts of diseases between cattle and buffalo which is the only known long term carrier and transmitter of threatening viruses (Condy and Hedger 1988; Forgin and Taylor 1996). We thus claim that our findings provide an important clue towards understanding wildlife to livestock, as well as livestock to wildlife disease transmission at the interface of agriculture and wildlife areas. In fact, the results raise an important question: Is it the direct interaction between buffalo and cattle that result in disease transmission or in fact this happens through intermediate hosts such as small antelopes?

5. Conclusion

The main objective of this study was to test the extent of the spatial and temporal waterhole use patterns by wild and domestic herbivores as a way of identifying waterholes where overlaps between wild and domestic herbivores is common. Two main conclusions can be made based on the results of this study. Firstly, we conclude that largest percentage of wild herbivores preffered to use water resources inside the protected area.It is also at these waterholes that the highest animal diversity was recorded .Secondly, we also conclude that overlap between wild and domestic herbivores is common at the boundary between GNP as well as in the adjacent agricultural areas and is mainly limited to the interaction between small antelopes and cattle.

These findings could provide an important avenue of investigating livestock and wildlife disease outbreaks at the domestic wildlife interface which are disturbing current efforts to improve livestock production and biodiversity conservation in African savannas.

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