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Seasonal Resource Use Interactions between Wildlife and Livestock in Wildlife Sanctuaries in The Amboseli Ecosystem, Kenya

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Abstract

Wildlife sanctuaries in the Amboseli ecosystem serve a dual purpose of wildlife dispersal areas and livestock grazing areas. It is therefore important to determine whether the presence of livestock affects wildlife resource use within the sanctuaries. Foot transects were conducted in Osupuko, Motikanju, Kilitome, Kimana, and Elerai-Rupet wildlife sanctuaries during early wet season 2010, late dry season 2010, and early wet season 2011 to assess temporal and spatial presence of wildlife and livestock. Jaccard's similarity index, Pianka's habitat use overlap index, Simpson's diversity index, and Ivlev's habitat selection indices were used to assess seasonal resource use interactions between wildlife and livestock. Overall, the presence of potential for competition through resource overlap indices did not dictate the same trends in wildlife diversity and habitat selection in any sanctuary. In three out of five wildlife sanctuaries there was a trend in which wildlife and livestock selected different habitats in the early wet season and similar habitats in late dry season. No trend was established among the sanctuaries in seasonal habitat selection. Livestock presence did not always negatively affect wildlife; indicating possible coexistence between the two. Seasonal grazing plans should be established in the sanctuaries to ensure coexistence of wildlife and livestock.

Key Words: Dispersal Area, Habitat Overlap, Spatial Overlap, Diversity, Livestock

INTRODUCTION

Kenya has one of the highest remaining concentrations of tropical savanna wildlife in the world. For this reason, conservation of natural resources and wildlife uniquely abundant in Kenya has become a top priority (Akama *et al.*, 1996). Ecotourism in conservation areas is a major component of Kenya's economy making it even more essential to manage natural resources and habitats to capably sustain a large number and wide variety of charismatic wildlife. In order to do this, there is a need for protected areas that have been established to prevent human encroachment on habitats used by wildlife (Homewood, 2004). There has been a push for a transition from the colonial "fortress conservation" in the protected areas to "community based conservation" outside of the traditional protected areas which attempts to include the local people in the management, decision making process, and benefits that coincide with wildlife conservation in Kenya (Hulme and Murphree, 1999). In light of this transition some local community members in wildlife rich areas especially in group ranches in Kenya have established wildlife sanctuaries that act as dispersal or migratory areas for wildlife to and from national parks and reserves, and provide local people with direct economic benefits from wildlife. Private land owners within similar areas have also established wildlife sanctuaries. Wildlife sanctuaries prevent human from encroaching core wildlife habitats in national parks and reserves, and prevent their subsequent degradation and fragmentation.

Initial establishment of sanctuaries was purely for economic reasons and thus has not been properly researched or supported by sound science (Okello, 2005a). Additionally, some sanctuaries are not properly managed to support wildlife. These oversights have hindered the ability of the sanctuaries to support viable wildlife populations and habitats, and therefore prevent the expected ecotourism and capital. Lack of knowledge concerning the needs of wildlife within the sanctuaries makes intensive conservation efforts difficult to achieve (Okello and Kiringe, 2004).

Several socio-economic factors including human population expansion, subdivision of group ranches, subsequent land use change including the increase in agricultural activities, heightened human-wildlife conflict, and unsustainable use of natural resources have compromised both wildlife conservation and the traditional pastoral Maasai lifestyle in the Amboseli ecosystem (Okello *et al.*, 2011). These factors are affecting the ability of sanctuaries within the ecosystem to sustain viable wildlife populations and habitats, and the livelihoods of the surrounding human communities. Other problems that face wildlife populations and the availability of suitable habitats within the Amboseli ecosystem include environmental degradation within sanctuaries that has led to negative consequences for both the wildlife and local people. Overgrazing by the combined pressures of livestock and wildlife causes increased soil erosion, vegetation loss, trampling and compaction of soil, and sedimentation of water sources all of which degrade habitats for all users (Okello and D'amour, 2008). Mwasi and Acker (2015) also observed an increase in overall habitat degradation in wildlife sanctuaries within the Amboseli ecosystem. Increase in human population has prompted the development of roads, lodges, and buildings that encroach upon necessary dispersal and migratory routes for wildlife in the Amboseli ecosystem (Okello and Kiringe, 2004). Competition between local communities and wildlife further limits availability of water and other critical resources, generating negative attitudes towards wildlife conservation by the local people who are bearing the burden of living with wildlife (Okello and D'amour 2008).

Many studies have already been conducted within the Amboseli ecosystem to evaluate the viability of certain regions as wildlife dispersal areas. Okello (2009) observed that the viability of a sanctuary as a wildlife dispersal area is dependent on the coexistence of livestock and wildlife in a sustainable way; inability to do so results in loss of habitats and ability to maintain wildlife populations within a sanctuary. Okello (2009) observed human activities such as livestock grazing to severely displace wildlife species, thereby greatly reducing the suitability of Kimana Group Ranch as a wildlife dispersal area. Sitters et al. (2009) found that pastoral mobility is the key for sustainable resource use and that proper spatial partitioning between livestock and wildlife will prevent wildlife displacement. The creation of community based wildlife sanctuaries was intended to encourage spatial partitioning as well as to provide an alternative land-use opportunity for communities. Properly managed, these sanctuaries could economically benefit local people and reduce negative views of conservation within the local community about wildlife.

In order to properly manage the wildlife sanctuaries, interaction of the wildlife with their habitats and the livestock around them must be understood. Understanding resource utilization by presence of competition and temporal trends of wildlife informs managers of the most effective management practices to use in the sanctuaries. There have been many studies conducted to assess the extent of resource utilization by wildlife and livestock and how this utilization affects the habitat and one another. Mpanduji *et al*. (2008) and Loarie *et al*. (2009) found that African elephant (*Loxodonta africana*), a species requiring a large home range with diverse green vegetation, requires a variety of habitats in order to thrive. Ziv (2003) and Cromsigt *et al.* (2009) found that heterogeneity of habitats facilitates wildlife diversity. In their previously mentioned study, Loarie et al. (2009) also found that implementation of man-made structures can alter habitats and possibly increase human-wildlife conflict. Wallgren *et al*. (2008) found that proximity to villages and extent of cattle ranges had prominent effects on wildlife richness and dispersal. Increased cattle ranges decreased or changed wildlife ranges. Wahungu (1998) study on feeding behavior and extent of habitat overlap by the Tana crested mangabey (*Cercocebus galeritus)* and yellow baboon (*Papio cynocephalus*) showed that during certain seasons, both species had similar feeding strategies and therefore similar habitats. This overlap led to increased competition for food. Such resource competition is often found between wildlife and livestock (Voeten and Prins, 1999; Mishra *et al.,* 2004; Young *et al*., 2010; Wallgren *et al.,* 2008; Odadi *et al*., 2011). However, many studies have also found that this competition does not always exist as it is seasonal (Voeten and Prins 1999; Mysterud, 2000). When competition does not exist wildlife has even been found to facilitate livestock productivity (Odadi *et al.*, 2011). Young *et al*. (2005) found that the negative effects of cattle on plains zebra (*Equus burchelli*) were negated by the presence of elephants or forb-preferring animals. Mwangi and Western (1998) confirmed in their study of large wild herbivores in Lake Nakuru National Park, Kenya that depending on the season, species exhibited varied habitat selectivity leading to increased ecological separation.

The aim of this study therefore was to assess seasonal changes in wildlife and livestock interactions occurring within sanctuaries in the Amboseli ecosystem. The ecological viability of the sanctuaries for wildlife depend on whether these interactions are detrimental to wildlife or not. This study strove to increase understanding of the habitat and resource needs of wildlife for more effective management of conservation areas. The information gathered in this study could help to determine whether the sanctuaries can maintain wildlife populations and benefit local communities simultaneously.

The objectives of the study were to determine (i) seasonal spatial overlap, habitat overlap, and subsequent potential for resource competition between wildlife and livestock, (ii) seasonal species diversity in each habitat and if this is affected by resource competition potential and (iii) seasonal habitat selection by wildlife and livestock within Kimana, Kilitome, Motikanju, Elerai-Rupet, and Osupuko wildlife sanctuaries, that form the Kimana wildlife corridor in the Amboseli ecosystem.

MATERIALS AND METHODS

Study Area

The study area included five sanctuaries located in the Amboseli ecosystem in Southern Kenya: Kimana (22.9 km^2), Motikanju (32.4 km^2), Kilitome (24.0 km^2), Elerai-Rupet (52.5 km^2), and Osupuko Wildlife Sanctuaries (13.3 km^2). Kimana, Kilitome, and Osupuko sanctuaries are located within Kimana Group Ranch. Kilitome sanctuary shares its western border with Amboseli National Park. Motikanju sanctuary is located within Kuku Group Ranch. Elerai-Rupet sanctuary is located in Kimana Group Ranch and extends into privately owned land to the south of Kimana (Fig. 1). These sanctuaries form the Kimana wildlife corridor. They have critical dispersal habitats for the wildlife of Amboseli National Park. The area experiences a bimodal pattern of rainfall with short rains occurring from November through January and long rains occurring from March through May. Temperature usually range from 12°C in July to 35°C in February with average between 21°C and 25°C each month (Worden *et a*l., 2003). These sanctuaries are mostly dominated by thorny *Acacia* spp. and *Balanites glabra* in bushland and woodland, and spear grass (*Heteropogon contortus)* in grassland. Soils in the area are mainly dependent upon their microhabitats and parent material. They range from shallow andisols with volcanic origin, black cotton soils, ash soils, dark red sandy loams, to black clay soils (Okello and Kiringe, 2008). These soils are mostly nutrient deprived with poor water holding capacity, making them susceptible to erosion and largely unfit for agriculture and sedentary grazing. Despite this fact such uses for land have been increasing in the area.

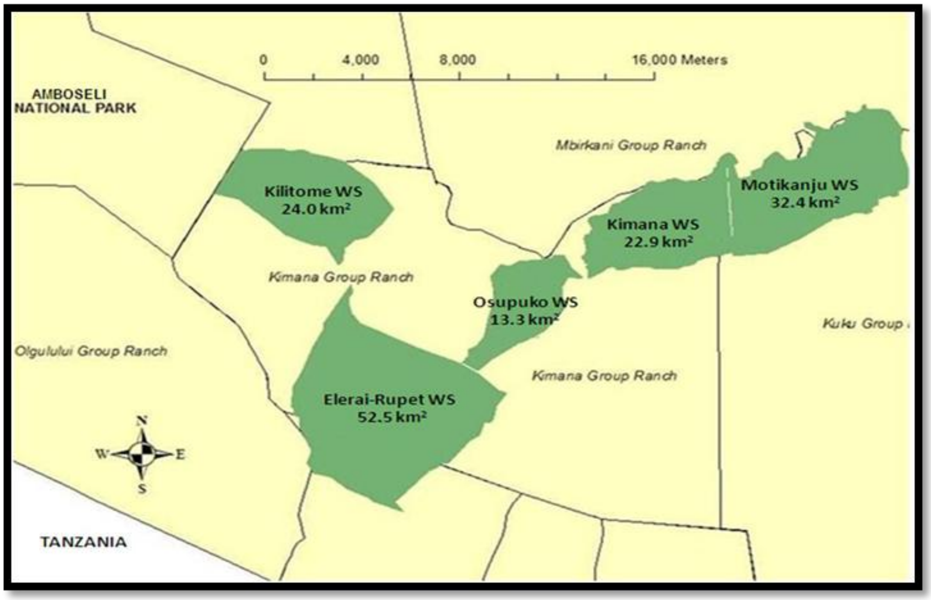

Figure 1. Location of the Study Area

Field Procedures

This study was carried out in early wet season of 2010, late dry season of 2010, and early wet season of 2011. ArcGIS software (version 9) was used to generate maps of each sanctuary which were roughly divided into four quadrants. Elerai-Rupet sanctuary was divided into eight almost equal sampling sites, due to its relatively larger size. The data for the early wet season were collected during the month of April of 2010 and 2011 respectively, while the late dry season data were collected during the month of November of 2010. Data collection was done in 40% of each sanctuary to achieve a statistically significant sampling area. Foot transects oriented in the north-south or south-north direction were used to collect data. Starting points of the first transects were randomly chosen. Buffers were walked in a perpendicular direction of each transect depending on the original orientation of transects. The maximum perpendicular sighting distances were used to determine the buffer width by multiplying that distance by three. This was done to ensure that wildlife was not double counted.

Along each transect, wildlife species, number of individuals observed, UTM coordinates of the location of an individual animal or herd, perpendicular sighting distance to the individual animal or center of a herd from the transect, habitat type, and dominant vegetation type where the animals were observed were recorded. The distance (m) moved along the transect was added to the appropriate easting of the area to get the actual eastings of the location while the perpendicular sighting distance (m) was added to the appropriate northing of the area to get the correct northing of the location. The easting and northing constituted the UTM coordinates. Only mammalian wildlife and livestock larger than a dikdik (*Madoqua kirkii*) were counted. Habitats were classified as open or closed woodland, shrubland, open or closed bushland, wooded or open grassland, or riverine/swamp land based on Pratt and Gwynne (1977) physiognomic vegetation classification system for rangelands. Woodland was characterized as land supporting a stand of trees up to 20 m in height. Shrubland as land supporting vegetation not exceeding 6 m in height; and bushland was characterized as land supporting an assemblage of trees and shrubs. A grassland was defined as land dominated by grasses and occasional herbs.

Data Analysis

After all transects were completed within the sanctuaries, gridded maps showing animal dispersal as well as wildlife-livestock spatial overlap with 500 m by 500 m grids were created using ArcMap in ArcGIS version 9 following Kittur et al., (2010). Jaccard's similarity index developed at the beginning of the 20th century (Mueller-Dombois and Ellenberg, 1974) was then calculated for each sanctuary using the equation:

$$S = \frac{A}{A + B + C}$$

where A is the number of grids used by both wildlife and livestock, B is the number of grids used only by wildlife, and C is the number of grids used only by livestock . This index indicated the extent of spatial overlap between wildlife and livestock.

Pianka's (1973) index was used to determine habitat overlap of wildlife feedings guilds with livestock feeding guilds. Pianka's index of overlap was calculated using the equation:

$$O_{jk} = O_{kj} = \frac{\sum_i^n P_{ij}\, P_{ik}}{\sqrt{\sum_i^n P_{ij}^{\,2}\ \sum_i^n P_{ik}^{\,2}}}$$

where P_{ij} is the proportion of livestock individuals either in the sanctuary or within their respective feeding guilds within the habitat and P_{ik} is the proportion of wildlife individuals either in the sanctuary or within their respective feeding guilds within the habitat. Pianka's index requires species to be separated into feeding guilds which was done using Kingdon's (1997) descriptions of general species diets. Wildlife grazers comprised of African buffalo (*Syncerus caffer*), wildebeest (*Connochaetes taurinus*), common zebra (*Equus quagga*), bohor reedbuck (*Redunca redunca*), and common waterbuck (*Kobus ellipsiprymnus*). Livestock grazers included cattle and donkeys, and wildlife mixed feeders included elephant (*Loxodonta africana*), impala (*Aepyceros melampus*), Thomson's gazelle (*Gazella rufifrons*), Grant's gazelle (*Gazella granti*), common warthog (*Phacochoerus africanus*), and bushbuck (*Tragelaphus scriptus*). Shoats (sheep and goats) were considered livestock mixed feeders. Wildlife browsers comprised of Maasai giraffe (*Giraffe camelopardis tippelskirchi*), gerenuk (*Litocranius walleri*), and lesser kudu (*Tragelaphus imberbis*). The product of Jaccard's similarity index and Pianka's indices provided a more inclusive index of potential resource competition between livestock and wildlife within the habitats in each sanctuary.

Simpson (1949) diversity index was used to assess species richness and evenness within the sanctuaries and within the habitats. The diversity was calculated using the equation:

$$D_s = 1 - \sum \frac{n(n-1)}{N(N-1)}$$

where n is the number of individuals of the same species observed and N is the total number of animals observed. The trends in spatial overlap, habitat overlap, potential resource competition, and diversity were compared to each other to assess the effects of livestock on wildlife.

Ivlev's (1961) index was used to determine if the habitats within each sanctuary were utilized equally by wildlife and livestock or if each selected for or against specific habitats. Habitat selection was calculated using the equation;

$$E = \frac{(r_i - p_i)}{(r_i + p_i)}$$

where r_i is the proportion of wildlife or livestock observed within a specific habitat and p_i is the proportion of all the habitats that is available as that specific habitat to the wildlife and livestock. E ranges from -1 to +1, where a -ve value shows avoidance, 0 shows random selection and +ve value shows active selection.

RESULTS

Seasonal Wildlife-Livestock Resource Competition Potential and Diversity

In Osupuko sanctuary, spatial overlap increased over time. The Jaccard's indices of 0.13 in the late dry season and 0.15 in the early wet season of 2011 indicate mild spatial overlap between livestock and wildlife (Fig. 2a). Pianka's index increased in all habitats except shrubland indicating fairly high habitat use overlap in the rest of the habitats by early wet season in 2011 (Fig. 2b). As a result of the general increase in both spatial and habitat overlap, the potential for resource competition increased over time in all habitats except shrubland (Fig. 2c). In most habitats, as the resource competition potential increased, species diversity decreased. The only exception was in shrubland. The overall species diversity of the sanctuary did not change significantly over the seasons (Fig. 2d).

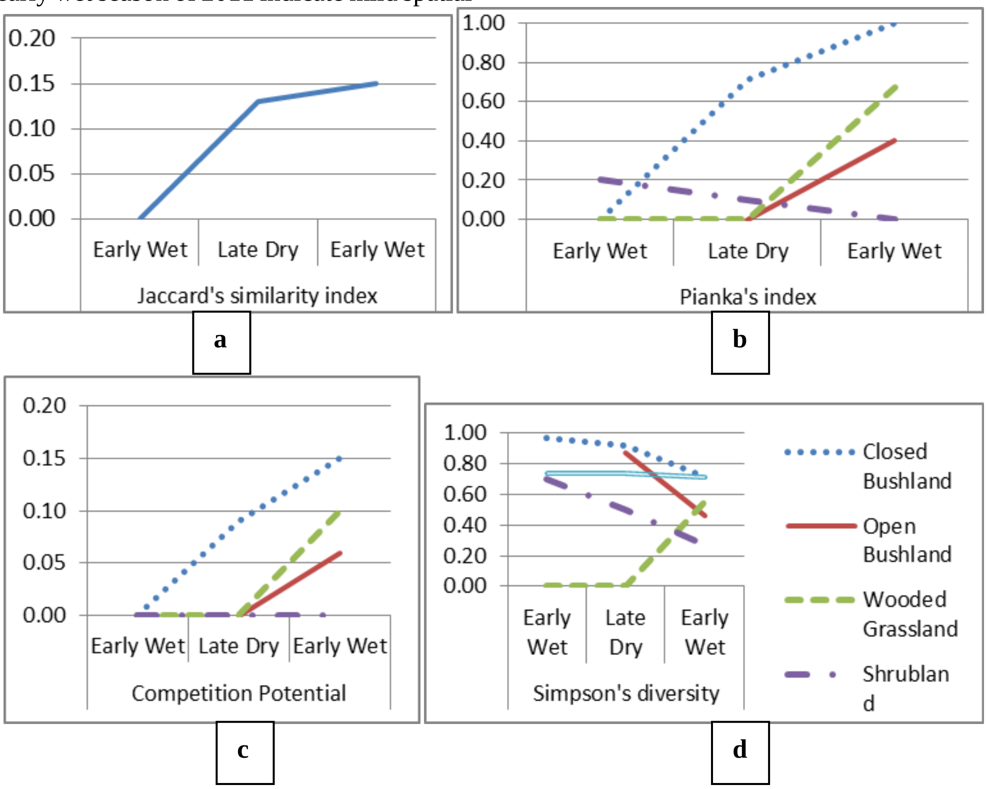

Figure 2. Seasonal Changes in a) Jaccard's Index, b) Pianka's Index, c) Index of Competition Potential, and d) Simpson's Diversity Index in Osupuko Sanctuary

Within Motikanju sanctuary, spatial overlap increased from zero overlap in early wet season 2010, to moderate overlap in the late dry season, to fairly low overlap in early wet season 2011 (Fig. 3a). Habitat overlap followed the same pattern as spatial overlap within wooded grassland. It increased from zero during the late dry season to high in the next early wet season (Fig. 3b). Resource competition potential within wooded grassland followed the same pattern as spatial overlap while in closed bushland and open bushland resource competition potential increased from dry season to the early wet season. All other habitats had no resource competition potential (Fig. 3c). The diversity within wooded grassland and open bushland followed the same seasonal pattern as resource competition potential. Both of these habitats as well as closed bushland followed the same pattern as that of habitat use overlap. The diversities of the sanctuary overall and wooded grassland followed the pattern of spatial overlap (Fig. 3d).

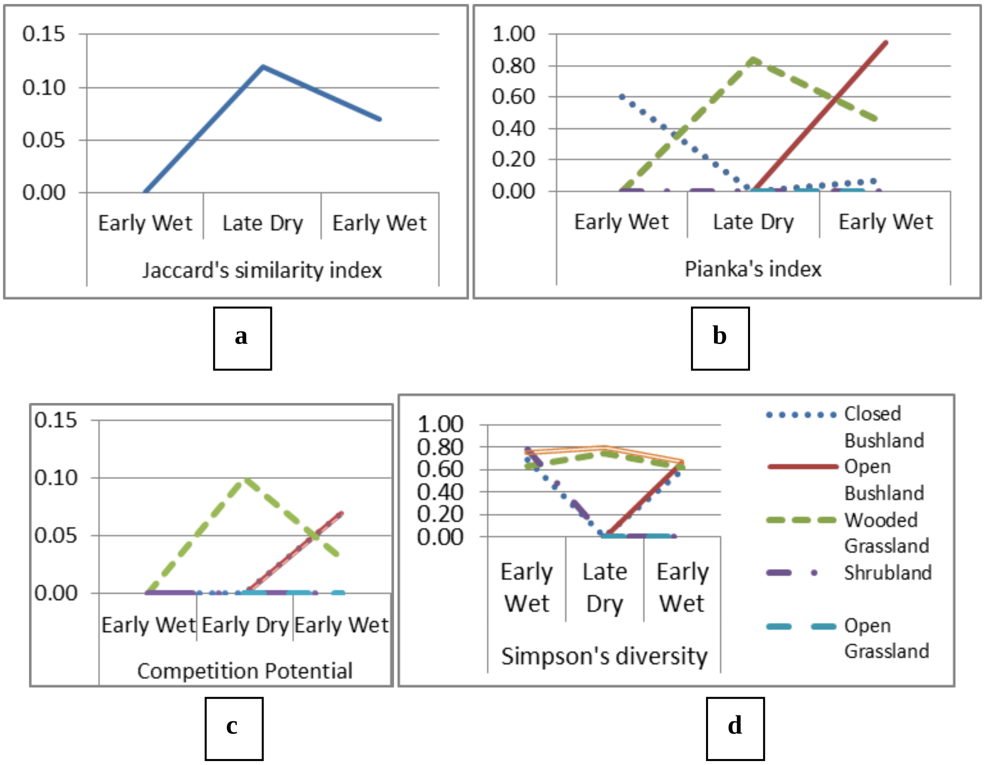

Figure 3. Seasonal Changes in a) Jaccard's Index, b) Pianka's Index, c) Index of Competition Potential, and d) Simpson's Diversity Index in Motikanju Sanctuary.

Within Kilitome sanctuary only closed bushland experienced drastic changes in habitat use overlap; it decreased from very high in 2010 early wet season to moderate in the late dry season and increased again in the next early wet season (Fig. 4a). There was consistent pattern observed between habitat use overlap and species diversity in any of the habitats except in open bushland; where there was an increase from late dry season to early wet season. Species diversity in closed bushland and shrubland decreased over time and increased in open bushland. The overall species diversity of the sanctuary increased from early wet season to late dry season but then decreased drastically during the next early wet season (Fig. 4b).

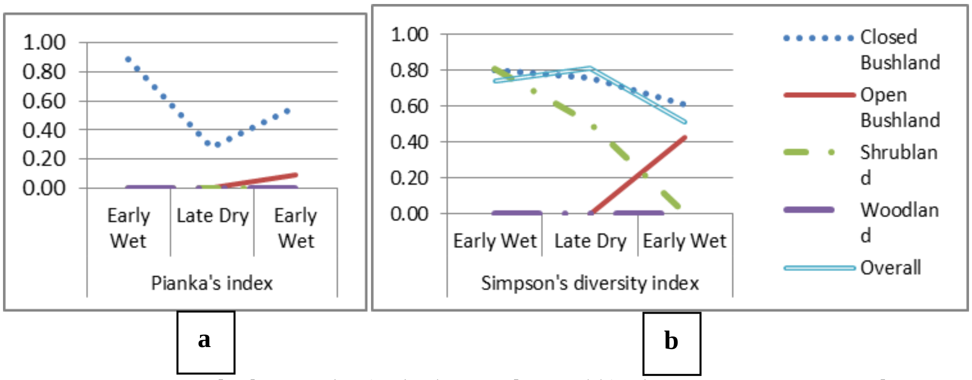

Figure 4. Seasonal Changes in a) Pianka's Index and b) Simpson's Diversity Index in Kilitome Sanctuary (Jaccard's Similarity Index and Index for Competition Potential were Always 0)

In Kimana sanctuary, spatial overlap between wildlife and livestock decreased from late dry season to early wet season (Fig. 5a). There was an increase in habitat use overlap in closed and open bushland from late dry season to early wet season (Fig. 5b). There was little to no change in resource competition potential between seasons except only within bushland (Fig. 5c). Species diversity decreased in open and wooded grassland while it increased in open and closed bushland. There was little to no change in the overall diversity and shrubland diversity (Fig. 5d).

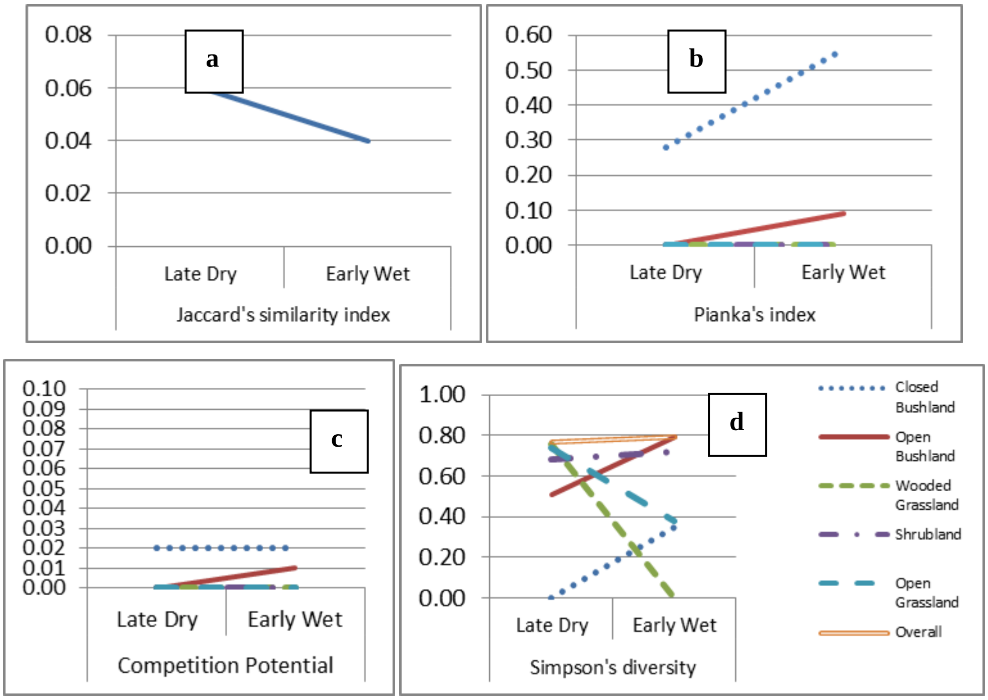

Figure 5. Seasonal Changes in a) Jaccard's Index, b) Pianka's Indices, c) Indices of Competition Potential, d) and Simpson's Diversity Index in Kimana Sanctuary

In Elerai-Rupet sanctuary, species diversity in shrubland increased in late dry season with no diversity in both early wet seasons. The diversity in closed bushland increased over time. The overall diversity within the sanctuary was highest in the early wet seasons and lowest in the late dry season (Fig. 6). There was no spatial or habitat use overlap and thus no resource competition potential.

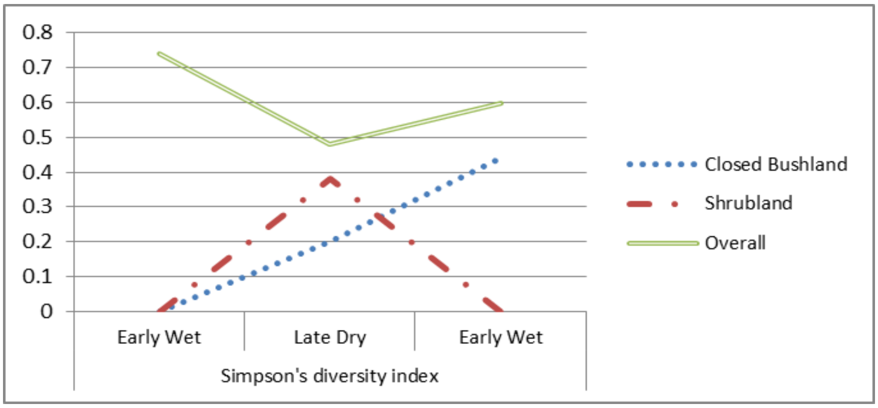

Figure 6. Seasonal Changes in Simpson's Diversity Index within Elerai-Rupet Wildlife Sanctuary (Pianka's Index, Index for Competition Potential, and Jaccard's Index = 0)

Habitat Selection

For habitats in all sanctuaries, throughout the seasons, wildlife and livestock were opposite in their selection for or against the same habitat 57.4% of the time. There were more cases of livestock and wildlife selecting the same habitats within the late dry season than in the early wet seasons. In Osupuko and Kimana sanctuaries, both wildlife and livestock selected open bushland in the late dry season, though the selection by wildlife was weaker in Kimana sanctuary. In Motikanju both selected wooded grassland, though livestock's selection was weaker. In Kilitome sanctuary, they both selected shrubland. No habitats were consistently selected throughout the seasons. No habitats were consistently strongly selected in both early wet seasons. Most Ivlev's indices were close to 0, indicating that habitats were more or less randomly selected. Woodland was the only habitat that was not selected (Table 1).

Table 1. Seasonal Ivlev's Habitat Selection Indices for Wildlife and Livestock (- Indicates that no Wildlife or Livestock was Observed)

	Early Wet Season 2010		Late Dry Season 2010		Early Wet Season 2011	
	Wildlife	Livestock	Wildlife	Livestock	Wildlife	Livestock
Osupuko						
Closed Bushland	-0.19	0.38	-0.06	-0.12	0.10	-0.05
Open Bushland	-	-	0.45	0.44	-0.60	0.34
Wooded Grassland	0.33	-1.00	-1.00	0.49	0.03	-0.55
Shrubland	0.05	-0.47	-	-	0.38	-1.00
Motikanju						
Closed Bushland	0.07	0.24	-1.00	-0.37	-0.72	-0.04
Open Bushland	-	-	-1.00	-0.79	0.27	0.04
Wooded Grassland	-0.04	-1.00	0.20	0.03	-0.13	0.10
Shrubland	-0.23	-1.00	-0.76	0.19	-1.00	-0.19
Kilitome						
Closed Bushland	0.12	-1.00	0.01	-0.43	-0.13	0.29
Open Bushland	-	-	-0.86	0.16	0.18	-0.34
Wooded Grassland	-1.00	0.61	-0.39	-1.00	-	-
Shrubland	-0.09	0.29	0.25	0.71	-1.00	-1.00
Woodland	-	-	-0.06	-1.00	-0.83	-1.00

Kimana						
Closed Bushland	-	-	-0.76	-1.00	0.31	-1.00
Open Bushland	-	-	0.09	0.88	-0.18	0.15
Wooded Grassland	-	-	0.13	-1.00	-1.00	-1.00
Shrubland	-	-	-0.33	-1.00	0.27	-1.00
Open Grassland	-	-	0.02	-0.43	0.04	-1.00
Elerai-Rupet						
Closed Bushland	0.06	-	-0.33	-	0.01	-1.00
Shrubland	-1.00	-	0.68	-	-1.00	0.89

DISCUSSION

In Osupuko sanctuary, increased spatial and habitat overlap and subsequent increase in resource competition potential between wildlife and livestock in open and closed bushland may have led to the low species diversity in these habitats. If there is a high diet overlap between livestock and wildlife then a high livestock density will greatly decrease food availability causing high competition and wildlife decline (Mishra *et al.*, 2004). Diet overlap was not part of the parameters investigated in the study so while it might be a possible cause of low species diversity, there is no evidence adduced to it in the study. Wallgren *et al.* (2008) showed that higher frequencies of cattle are associated with lower wildlife species richness. As species richness was a component of Simpson's diversity index, the diversity in areas with higher cattle disturbance would most likely be lower than in areas lacking cattle disturbance. High abundance of livestock can also degrade habitats drastically thus decreasing the diversity and abundance of wildlife (Okello and D'amour 2008). Our findings suggest that livestock within open and closed bushland in Osupuko sanctuary were detrimental to the wildlife there. However, in wooded grassland and shrubland, habitat use overlap and resource competition potential followed the same pattern as species diversity; when habitat use overlap and resource competition potential increased or decreased so too did habitat species diversity. This suggests that there was no competition between wildlife and livestock, and instead there was sharing of abundant resources within these habitats similar to Mysterud's (2000) findings. This is usually seen on a seasonal basis where there is competition when resources are scarce, such as in the dry season or early wet season and sharing when resources are abundant as in the full wet season (Voeten and Prins, 1999; Mysterud, 2000; Odadi *et al.*, 2011). However, increased habitat use overlap and diversity were independent from season. It is possible that other habitats were becoming degraded by overuse causing both wildlife and livestock to move to less used habitats. Both wildlife and livestock may have been substituting original resources with alternative available resources in order to achieve coexistence (Abrams, 1988). Livestock may be detrimental to wildlife within some habitats and may have no effect on wildlife in other habitats. In the early wet seasons, wildlife and livestock always selected for different habitats from one another. Even though there was potential for competition, selection actually suggested that wildlife and livestock selected different habitats. There was no consistent trend as to which habitats were selected for by which group of animals. In the late dry season both wildlife and livestock selected fairly strongly for open bushland. There was no resource competition potential in open bushland during the late dry season as the wildlife were mixed feeders and the livestock were grazers; the animals coexisted perhaps due to the mixed feeders' ability to supplement graze with browse or perhaps due to differences in diets and niches not observed in this study (Abrams, 1988; Mwangi and Western, 1998). Animals may have avoided sharing habitats in the early wet season but overlap and potential resource competition still exist due to necessity of using the same areas and resources.

In Motikanju Wildlife Sanctuary spatial and habitat overlap and potential competition within wooded grassland, closed bushland, and open bushland did seem to follow a seasonal pattern. In accordance with Voeten and Prin's (1999), Mysterud (2000), and Odadi *et al*. (2011) findings, the habitat overlap and potential for resource competition in wooded grassland was greatest in the late dry season when resources were expected to be most scarce. Spatial overlap within the sanctuary also followed this pattern. However, the diversity also increases in the late dry season suggesting that resources were actually abundant within wooded grassland. In this way, the high potential resource competition combined with high diversity does not agree with Wallgren et al. (2008) deduction that presence of cattle decreases species richness. Closed and open bushland followed the opposite pattern in which habitat overlap, resource competition potential, and diversity were higher in the early wet season than in the dry season. The opposition of the habitats' aspects may be due to seasonal habitat selection as observed by Mwangi and Western (1998). In fact, both wildlife and livestock selected for wooded grassland in the late dry season while both selected for each of the bushland in the early wet seasons. This is consistent with the patterns observed in the habitat overlap, potential resource competition, and diversity in these three habitats.

In Kilitome sanctuary species diversity decreased over time in both closed bushland and shrubland while it increased in open bushland. As in Osupuko sanctuary, livestock and wildlife consistently selected for different habitats in the early wet seasons. In fact, wildlife selected for closed bushland in both the first early wet season and late dry season. When livestock selected for closed bushland in the last early wet season wildlife selected for open bushland. This may show evidence of avoidance of livestock rather than avoidance of a specific habitat. This change in wildlife range in response to changes in livestock range is consistent with Wallgren *et al.* (2008). Livestock selected for shrubland in both the first early wet season as well as in the late dry season. Wildlife selected for shrubland in the late dry season with the livestock. Both groups selected strongly against shrubland in the last early wet season. It is possible that the combination of wildlife and livestock use of the shrubland depleted the resources available causing them to select for different habitats to supplement the previously selected resources in the last early wet season (Abrams, 1988; Mishra *et al*., 2004; Okello and D'amour, 2008). If livestock is interrupting the normal selection and activities of wildlife, even without direct competition for resources, then livestock are reducing the sanctuary's viability as a wildlife dispersal area.

In Kimana sanctuary habitat use overlap as well as species diversity in open and closed bushland increased from late dry season to early wet season. There was no potential for competition or habitat use overlap in any other habitats in the sanctuary. Species diversity in wooded and open grassland decreased from late dry season to early wet season. Once again in the early wet season both wildlife and livestock selected for different habitats in accordance with Wallgren *et al.* (2008). Wildlife selected for all of the habitats that had been avoided in the late dry season again due to seasonal selection (Mwangi and Western, 1998). Both wildlife and livestock selected for open bushland during the late dry season. However, as the potential for competition was very low, wildlife and livestock most likely coexist successfully in the late dry season similar to findings of Abrams (1988).

In Elerai-Rupet sanctuary there was no overlap between wildlife and livestock and thus there was no resource competition potential in any of the seasons. Species diversity in closed bushland was very low but gradually increased over time while the diversity in shrubland was low in the late dry season with no diversity in either of the early wet seasons. There is evidence of seasonal habitat selection as wildlife selected for closed bushland in the early wet seasons and for shrubland in the late dry season. In early wet season of 2011 when there was livestock in the sanctuary, it was spatially very far from any wildlife and inhabited shrubland which wildlife avoided with or without livestock. Even though there was very little livestock in the sanctuary, there is also very little wildlife. The habitats within this sanctuary may not have been heterogeneous enough for wildlife to survive; within Elerai-Rupet sanctuary there were only three major habitats while all of the other wildlife sanctuaries observed contain at least four habitats. According to Ziv (2003), habitat heterogeneity was essential for general species diversity by allowing some species to avoid interspecific competition and thus retain viable populations. Other studies have also shown that habitat variety is necessary for wildlife survival and diversity (Mpanduji *et al*., 2008; Cromsigt *et al*., 2009; Loarie *et al*., 2009). Despite having no possibility of resource competition between livestock and wildlife, Elerai-Rupet may have lacked heterogeneous habitats necessary to attract a wide variety and abundance of wildlife.

CONCLUSION

The presence of resource competition potential and habitat use overlap did not dictate the same trends in wildlife species diversity and selection of habitats in any sanctuary within the Kimana wildlife corridor. In Osupuko, Kilitome, and Kimana sanctuaries there was a seasonal trend in which wildlife and livestock selected completely different habitats in the early wet season and the same habitat in late dry season. In Elerai-Rupet there was no livestock in the late dry season but in the early wet season, wildlife and livestock again selected different habitats. There was no consistent trend observed among the sanctuaries as to which habitats were seasonally selected. Presence of livestock did not always negatively affect wildlife species diversity; this may indicate coexistence between these animals when resources are abundant during the wet season.

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