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DEPARTMENT OF ECOSYSTEM SCIENCE AND MANAGEMENT

ESTIMATION OF POTENTIAL FOR COMPETITION BETWEEN WILDLIFE AND LIVESTOCK WITHIN SANCTUARIES OF THE AMBOSELI ECOSYSTEM, KENYA AND THEIR EFFECTIVENESS AS CORRIDORS BETWEEN NATIONAL PARKS

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ABSTRACT

The Amboseli ecosystem, Kenya is home to several wildlife sanctuaries that serve as crucial corridors for traveling wildlife as well as safe places to live and reproduce. Health assessments and maintenance for these micromanaged areas is vital for preservation of the ecosystem. I assessed one aspect of viability of five wildlife sanctuaries, Osupuko, Kilitome, Kimana, Elerai-Rupet and Motikanju, within this ecosystem by examining habitat use, spatial and niche overlap and density ratios, between livestock and wildlife. I used counts of large mammal species in the early wet season 2011 to evaluate potential for competition between livestock and wildlife in each sanctuary. This would allow for an estimation of the effectiveness of each sanctuary at providing suitable wildlife habitat and serving as a connection between government-protected national parks. Also, I evaluated the effect of detection probability on inferences made from my analysis of habitat use. I found that wildlife to livestock abundance ratios increased with increasing distance of sanctuaries from national parks. I also found that there was little evidence for spatial and niche overlap in each sanctuary between livestock and wildlife. However, Ivlev's index showed that some habitats were selected by both wildlife and livestock species. Once detection probability was factored into Ivelv's index, I found that detection probability can be a confounding factor and should be considered for all studies evaluating animal use and habitat selection. Evaluations such as this can lead sanctuary managers to the development of management plans that will improve the effectiveness of sanctuaries as connections between national parks.

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Chapter 1

Introduction

Kenya has one of the largest remaining concentrations of tropical savanna wildlife in the world, making conservation of its habitats a top priority (Akama et al. 1996). Protected areas have been established to prevent human encroachment on the important habitats that support this wildlife (Homewood 2004). In recent years, Kenya has been transitioning from the colonial “fortress conservation” to “community based conservation” which attempts to include the local people in the decision process so they benefit from wildlife conservation in Kenya (Hulme and Murphree 1999). Sanctuaries were established to give the local community a direct way to monetarily benefit from the wildlife as well as to provide wildlife with habitat connectivity among government-protected national parks. (Okello, M. 2005b)

The presence of human-owned ungulate species, such as cattle, can lead to the potential for competition in many of these community-managed sanctuaries. Some ways to evaluate this potential for competition are to identify and examine overlap in habitat use and relative abundance of species. For example, a study carried out in Tana River, Kenya to determine 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 lived in similar habitats (Wahungu 1998). This led to increased competition for food, which is an important factor in determining management strategies for these species.

Land use change in the Amboseli ecosystem has threatened the viability of these wildlife sanctuaries as effective corridors between national parks. The sanctuaries from this study are located within five Maasai-owned group ranches that border national parks and conservation areas, including Tsavo West, Chyulu Hills, and Amboseli National Parks. The presence of Maasai and livestock in the area is affecting wildlife populations and the availability of suitable habitats in the form of overgrazing and environmental degradation (Okello and D'amour 2008). 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 (Okello and D'amour 2008). Researchers in this study area have found that human activities such as livestock grazing within the Kimana Group Ranch have displaced wildlife species (Okello 2009). Similarly, 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 (Sitters et. al. 2009). All of these problems degrade the available habitat for both wildlife and livestock.

A big issue surrounding sanctuaries is that their placement and environmental impact were established based solely for economic reasons (Okello 2005a). For this reason, many are improperly maintained or not managed in a way that allows wildlife to travel between national parks. Lack of knowledge about effective sanctuary management and problems or threats facing sanctuaries makes intensive conservation and viable solutions to problems difficult to achieve (Okello and Kiringe 2004).

The aim of this study was to assess factors such as relative abundance, spatial overlap, and habitat selection of both wildlife and livestock to evaluate potential for competition between them. Information that I gathered from this study may help evaluate the extent to which sanctuaries can maintain wildlife populations and therefore accomplish their intended purpose as connectors between national parks. With these data, I hope to identify alternate management strategies and livelihood practices to sanctuary managers. Wildlife use of these sanctuaries may help reduce tensions between wildlife and local people by attracting tourism to the sanctuaries (a significant source of revenue) and by preventing wildlife movement through agricultural and developed land (a significant source of conflict).

RESEARCH OBJECTIVES

The goal of this study was to assess the effectiveness of five sanctuaries in the Amboseli ecosystem, Kenya as viable wildlife corridors based on analysis of the potential for competition between wildlife and livestock. This goal was accomplished by addressing the following objectives.

1. Estimate relative abundance of livestock and wildlife
2. Estimate spatial, and niche overlap between livestock and wildlife within each sanctuary.
3. Assess relative habitat use by livestock and wildlife within each sanctuary.

Chapter 2

Materials and Methods

Study Area

There are five sanctuaries of interest located in the Amboseli ecosystem in Southern Kenya: Kimana, Motikanju, Kilitome, Elerai-Rupet, and Osupuko Wildlife Sanctuary (Appendix A). These sanctuaries are located in an area that experiences a bimodal pattern of rainfall with a short period of rain occurring November - January and a long period of rain occurring March - May (Worden et al. 2003). This study was carried out in April 2011. A low-pressure wind belt, the intertropical convergence zone, passes over Mt. Kilimanjaro, a prominent physical feature within the ecosystem and influences the moisture variability of the ecosystem. Temperatures range from 12°C in July to 35°C in February with monthly means between 21°C and 25°C (Worden et al. 2003). Thorny *Acacia tortilis* and *Balanites glabra* mostly dominate the bushland and woodland areas of these sanctuaries.

Soils in the study area are mainly dependent upon their microhabitats and parent material. Examples are andisols with volcanic origin, black cotton soils, and ash soils (Okello 2005; Okello and D'Amour 2008; Okello and Kiringe 2008). These soils are mostly nutrient deprived with poor water holding capacity and susceptible to erosion and poorly suited for agriculture and sedentary grazing. However, land use practices in the area by Maasai pastoralists included cultivation and grazing. Additionally, these sanctuaries were designated to serve as connecting passages for wildlife between national parks.

Data collection

Four groups of 2-3 people worked together to collect data in our study area (*Gerenux, Shem-anigans, Kipepeo and Shem & m's*). I used ArcGIS software (ESRI, version 9.3.1, Redlands, CA) to divide sanctuary maps into quadrants of nearly equal size and I assigned each group to a quadrant. However, Elerai-Rupet was divided into octants and data collection occurred over two days. I performed animal counts on 40-percent of each sanctuary. I recorded locations of animals within the sanctuary using a handheld GPS unit (Garmin, Etrex, Olathe, Kansas) while walking along predefined transects. I randomly selected a starting point in each quadrant. I walked transects from starting points in an east-west or north-south direction. I walked buffers, the space between transect belts where data were not collected, in a perpendicular direction from each transect. I determined buffer lengths by the maximum perpendicular sighting distance, which was multiplied three times to ensure that animals were not counted multiple times on different transects. Each maximum sighting distance was individually established per sanctuary. I established UTM directional boundaries, indicated by ArcMap software (ESRI, version 9.3.1, Redlands, CA), for every quadrant. The pre-defined dimensions and boundaries of each quadrant determined starting directions and lengths of transects (Figure 1). I classified habitats as woodland, shrubland, bushland, or grassland. Woodlands were areas dominated by trees < 20 m in height and shrublands were dominated by vegetation < 6 m in height. Bushlands were areas containing a mixture of trees and shrubs. Grasslands were areas dominated by grasses and occasional herbs (Pratt and Gwynne 1977). “Open” or “Closed” designations were assigned for each habitat based on density of vegetation. For example, closed bushland habitats contained a dense concentration of trees and shrubs, whereas open bushland habitats had fewer trees and more open space. In Motikanju, wooded grassland was differentiated from grassland because the habitat was dominated by grasses and herbs but also contained some stands of trees.

I analyzed all data by comparing guilds of wildlife species to livestock. I placed all wildlife species into one of three feeding guilds based on their diet; grazer, browser or mixed feeder. A mixed feeder is a wildlife species that both browses and grazes in its feeding habitat.

The mammal species I classified as grazers were African buffalo (*Syncerus caffer*), wildebeest (*Connochaetes taurinus)*, zebra (*Equus quagga)*. I classified gerenuk (*Litocranius walleri*), giraffe (*Giraffa camelopardalis)*, and lesser kudu (*Ammelaphus imberbis)* as browsers and the Grant's gazelle (*Nanger granti*), impala (*Aepyceros melampus*), Thompson's gazelle (*Eudorcas thomsonii*), warthog (*Phacochoerus africanus*), and elephants *(Loxodonta africana)*, as mixed feeders. Other small mammal species occurred on the sanctuaries, such as dik-dik (*Madoqua kirkii*) but were not surveyed.

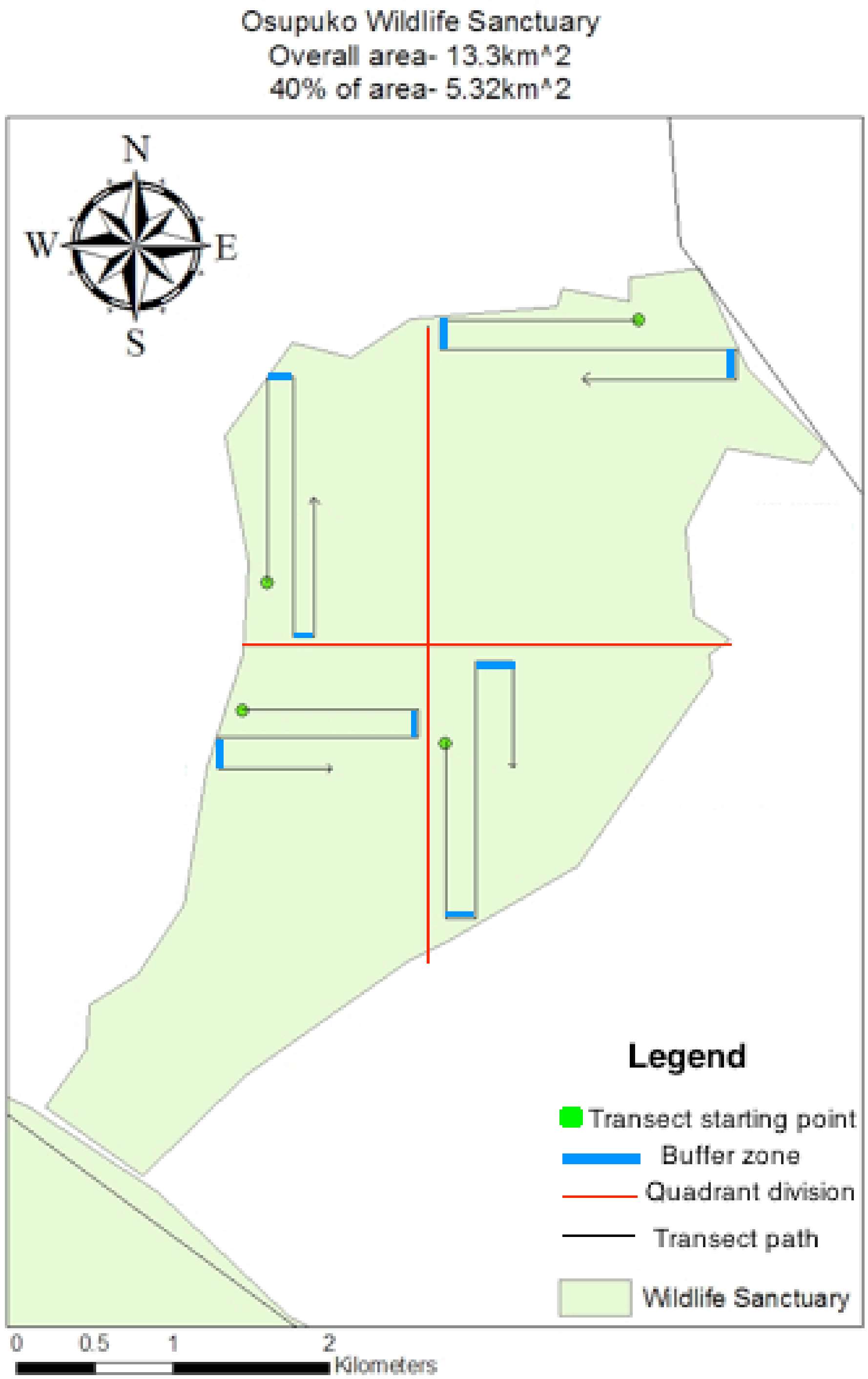


Figure 1: Example of sanctuary map outlining transect pattern and buffers where I walked and counted animals that were observed (Kenya, 2011)

Statistical Analysis

I estimated relative abundance of wildlife and livestock by comparing livestock density to wildlife density for each sanctuary. These numbers are the sum of the total number of livestock or wildlife species seen among all transects, within a particular sanctuary. After all transects were completed within the five wildlife sanctuaries, I created maps portraying spatial and habitat overlap by feeding guild. I divided each study area into 0.25-km^2 grids to plot all wildlife and livestock sightings (Kittur 2010) (Appendix C). I computed spatial overlap within each of the five sanctuaries using a Jaccard similarity index expressed as

$$S=A/(A + B + C),$$

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 (Kittur et al. 2010).

I used the Pianka niche overlap index to compare niche overlap within each sanctuary. This particular index is expressed as

$$O_{jk} = O_{kj} = \frac{\sum_{i}^{n} p_{ij}\, p_{ik}}{\sqrt{\sum_{i}^{n} p_{ij}^2 \sum_{i}^{n} p_{ik}^2}} \quad ,$$

where p_{ij} *and* p_{ik} are the proportions of the j^{th} and k^{th} species (livestock and wildlife) in each feeding guild respectively (Pianka, 1973), and $O_{jk} = O_{kj}$ represent the overlap index of species *j* on species *k*. The average for feeding guild overlap per habitat per sanctuary was multiplied by the sanctuary's respective Jaccard value to obtain one single overlap index for each sanctuary.

Values for these indices range from 0 - 1 with a value of zero indicating no overlap and a value of one indicating complete overlap.

I used Ivlev's habitat selection index to estimate habitat selection by wildlife and livestock by feeding guild, across all sanctuaries. Ivlev's index is expressed as

$$E_i = (r_i - p_i) / (r_i + p_i),$$

where E_i = measure of selection, r_i = proportion of habitat used, and p_i = proportion of available habitats within each sanctuary by habitat type, *i*. E_i ranges from -1 to 1, with negative values indicating habitat avoidance and positive values indicating habitat preference or selection.

When sampling for wildlife it is important to consider that methods used for classifying a habitat as "used", such as visual counts used in this study, may not account for the fact that there could be species that are using the habitat or resource but are not detected by the observer. This oversight could lead to misleading conclusions about habitat selection (Mackenzie, 2006).

Ivlev's index, a type of resource selection functions (RSF's) did not allow me to obtain estimates of abundance or habitat use that accounted for differential detection probability among species. However, I evaluated the potential for obtaining misleading conclusions with my data. There are certain conditions that must be met for accurate conclusions to be made based on RSF's: the probability of detecting a species must be equal in all resource units and data must have been collected from multiple surveys of each sampling unit. Because the latter condition was not met during this study due to resource and time constraints, I used a theoretical assessment of the selection indices to evaluate whether the confounding factor of detection probability adversely affected my results (Mackenzie, 2006).

For this study, I was interested in evaluating if my inferences about habitat selection among wildlife and livestock by feeding guild would change when detection probability was taken into account. To do this, I first established a ranking of each habitat type within each sanctuary on the basis of likelihood of encountering an animal based on known habitat characteristics such as short vegetation and low obstruction in open grasslands, for example. A ranking of "1" was assigned to habitats where animals were most likely to be visible. I then assumed that habitats with a higher ranking and therefore a lower likelihood of observing animals would have animal counts lower than expected. For these habitats, the observed animal count was adjusted by dividing observed counts by percentage based on the likelihood of observing animals in that habitat. For example, a ranking of "2" would exhibit a fraction of "3/4" because we are assuming that only 75% of the possible animals observed were actually recorded. I recalculated the proportion of use (r_i), proportion available (p_i), to evaluate if my inferences about habitat selection would change after incorporating these hypothetical detection probabilities in the new Ivlev's index.

Chapter 3

Results

RESULTS

Livestock and wildlife relative abundance

Livestock outnumbered wildlife species in all sanctuaries, and Motikanju had the greatest ratio of livestock to wildlife (5.85) The Kilitome sanctuary has the lowest relative density of livestock to wildlife (1.42) (Table 1).

Table 1: Summary of livestock to wildlife abundance and individual wildlife and livestock abundances (Amboseli Ecosystem, 2011)

Sanctuary	Wildlife (/km^2)	Livestock (/km^2)	Relative Abundance
Osupuko	673.54	1510.59	2.24
Motikanju	491.39	2876.35	5.85
Kilitome	563.67	800.51	1.42
Kimana	583.31	1406.80	2.41
Elerai-Rupet	131.95	239.91	1.82

Spatial and niche overlap between livestock and wildlife within each sanctuary

Kilitome and Elerai-Rupet were the only two sanctuaries with no spatial wildlife/livestock overlap. Elerai-Rupet was the only sanctuary with no spatial or niche overlap. Osupuko was the sanctuary with the most spatial and niche overlap (Table 2).

Table 2: Overall Overlap using Jaccard and Pianka values for each habitat within each sanctuary (Amboseli Ecosystem, 2011)

Sanctuary	Habitat	Jaccard's Index (S)	Pianka's Index	Average of Pianka's Indices (AO_{jk})
Osupuko	*Bushland*	0.15	1.00	0.52
	Open Bushland		0.40	
	Shrubland		0.00	
	Wooded Grassland		0.67	
Motikanju	*Closed bushland*	0.07	0.96	0.39
	Grassland		0.00	
	Open bushland		0.95	
	Open woodland		0.00	
	Shrubland		0.00	
	Wooded grassland		0.43	
Kimana	*Open Grassland*	0.04	0.10	0.22
	Open Bushland		1.00	
	Open woodland		0.00	
	Shrubland		0.00	
	Closed bushland		0.00	
Kilitome	*Open Bushland*	0.00	0.09	0.13
	Closed Bushland		0.56	
	Closed Woodland		0.00	
	Open Woodland		0.00	
	Shrubland		0.00	
Elerai-Rupet	*Closed Bushland*	0.00	0.00	0.0
	Open bushland		0.00	
	Shrubland		0.00	

Feeding guild habitat selection

I found a few situations in which both wildlife and livestock selected or preferred the same habitat types within a sanctuary. Wildlife grazers and livestock grazers both selected food from the wooded grassland in Osupuko. Wildlife grazers, wildlife mixed feeders and livestock mixed feeders all selected open bushland in Motikanju. Within Kilitome, wildlife grazers and livestock mixed feeders both selected closed bushland while livestock grazers and wildlife browsers both selected open bushland (Table 3). Kimana and Elerai-Rupet were the only two sanctuaries in which no two feeding guilds selected the same habitat.

Table 3: Ivlev's indices for wildlife and livestock feeding guilds across all sanctuaries (WL = Wildlife, LST = livestock) (Amboseli Ecosystem, 2011)

Sanctuary	Habitat	WL Grazers	LST Grazers	WL Mixed Feeders	LST Mixed Feeders	WL Browsers
Kimana	Closed Bushland	-1	-1	-0.15	-1	0.61
	Open Bushland	-0.67	0.28	-0.05	-0.56	-0.32
	Open Woodland	-1	-1	-0.15	0.91	-1
	Shrubland	0.69	-1	-0.06	-1	0.31
	Open Grassland	-1	-1	0.34	-1	-1
Osupuko	Closed Bushland	-0.32	0.02	0.24	-0.07	0.27
	Open Bushland	-0.34	-0.34	-0.8	0.39	-1
	Wooded Grassland	0.15	0.29	-0.06	-1	-0.04
	Shrubland	0.68	-1	-0.3	-1	-1
Elerai-Rupet	Closed Bushland	--	-1	-0.27	--	0.14
	Open Bushland	--	-1	0.51	--	-1
	Shrubland	--	0.89	-1	--	-1
Motikanju	Closed Bushland	-0.66	-0.11	-0.78	0.02	--
	Open Bushland	0.31	-0.18	0.24	0.22	--
	Shrubland	-1	-0.46	-1	0.01	--
	Wooded Grassland	-0.36	0.37	0.02	-0.78	--
Kilitome	Closed Bushland	0.41	-0.42	0.09	0.37	-0.24
	Open Bushland	-1	0.28	0.01	-0.68	0.23

Habitat use within feeding guilds for livestock and wildlife

I found mixed feeders to be the most abundant feeding guild represented within Osupuko, Motikanju and Kimana Sanctuaries (61.59%, 53.03%, 52.94% respectively). Grazers were the the most abundant feeding guild within Kilitome Sanctuary (68.07%) and browsers were found to be the most abundant in Elerai-Rupet (58.18%) (Figure 2).

Overall, among all sanctuaries, open and closed bushland were the most frequently used habitats. Riverine/swamp and closed woodland were the least frequently used habitats across all sanctuaries. Within Elerai-Rupet and Osupuko, closed bushland was the most frequently used habitat (75.76% and 45.65% respectively). Within Kimana, Motikanju and Kilitome, open bushland was the frequently used habitat (56.00%, 45.61%, 46.67% respectively; Figure 3). These conclusions are drawn from the following figures; the most frequently used habitat exhibited the greatest number of observed wildlife or livestock sightings.

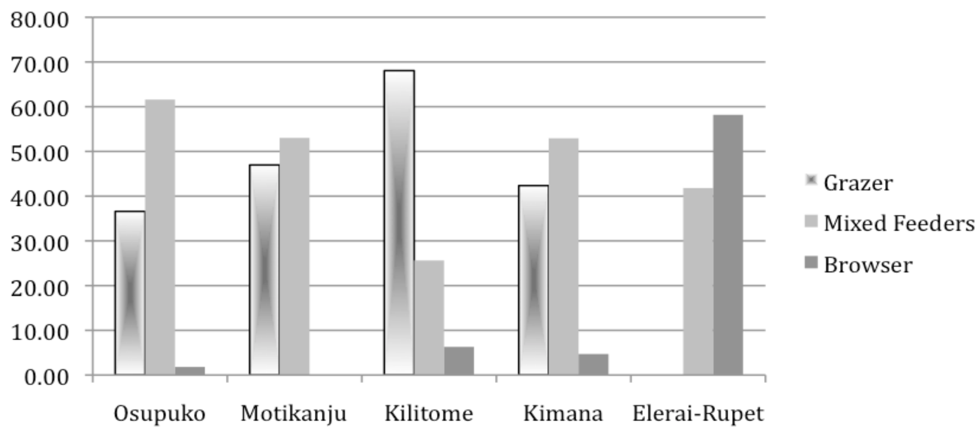


Figure 2: Relative abundance of wildlife feeding guilds within each sanctuary (excluding livestock) (Amboseli Ecosystem, 2011)

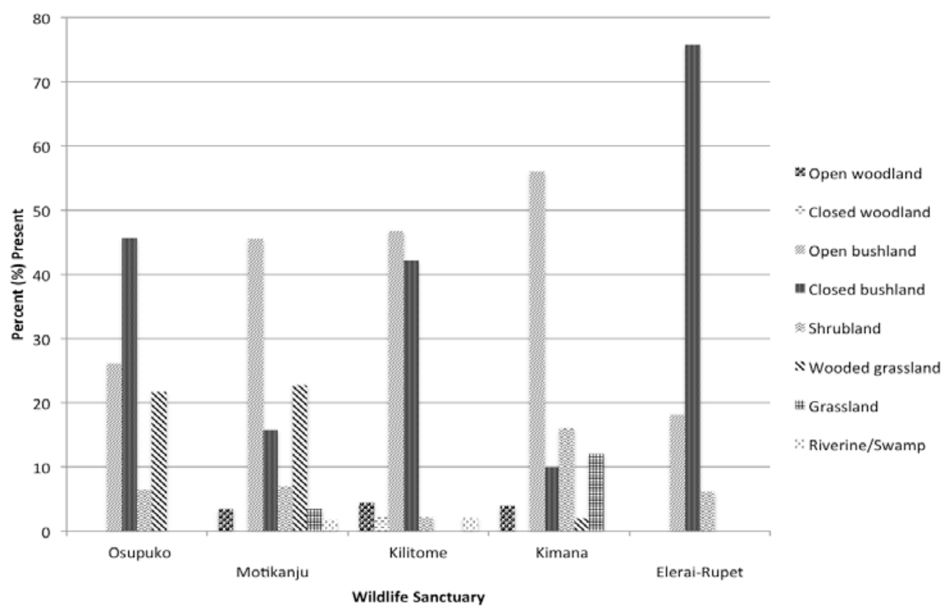


Figure 3: Percentages of habitats used by all species surveyed within each sanctuary (Amboseli Ecosystem, 2011)

Wildlife versus Livestock habitat selection

Only in Motikanju did both wildlife and livestock select the same habitat (open bushland) (Table 4). All other sanctuaries exhibit selection for each habitat by one group and avoidance by the opposite group. Although Elerai-Rupet does not have positive values for wildlife or livestock in closed bushland, the value for wildlife is zero meaning there can be no conclusion on selection or avoidance because use is equal to availability.

Table 4: Ivlev's indices for wildlife or livestock within each sanctuary (Amboseli Ecosystem, 2011)

Sanctuary	Habitat	Wildlife	Livestock
Kimana	Closed Bushland	0.31	-1.00
	Open Bushland	-0.18	0.15
	Open Woodland	-0.44	0.72
	Shrubland	0.27	-1.00
	Open Grassland	0.04	-1.00
Osupuko	Closed Bushland	0.10	-0.05
	Open Bushland	-0.60	0.34
	Wooded Grassland	0.03	-0.55
	Shrubland	0.38	-1.00
Elerai-Rupet	Closed Bushland	0.00	-1.00
	Open Bushland	0.13	-1.00
	Shrubland	-1.00	0.89
Motikanju	Open Bushland	0.27	0.04
	Wooded Grassland	-0.13	0.10
Kilitome	Closed Bushland	-0.13	0.29
	Open Bushland	0.18	-0.34

Detection Probability and adjusted Ivlev's Index

There were two circumstances (highlighted), in which the conclusion of the index changed from a habitat that was avoided to a habitat that was selected (Table 5). Although none of the other conclusions changed in this sanctuary, there may have been instances in other sanctuaries where the conclusion of the index would change with the adjusted index values.

Table 5: Comparison of Ivlev's indices at Osupuko sanctuary before and after correcting for detection probability (Amboseli Ecosystem, 2011)

Feeding Guild	Habitat Type	IE (Ivlev's)	Ivlev adjusted
	Closed Bushland	-0.32	0.01
Wildlife Grazers	Open Bushland	-0.34	-0.51
	Wooded Grassland	0.15	0.14
	Shrubland	0.68	0.43
	Closed Bushland	0.02	0.19
Livestock Grazers	Open Bushland	-0.34	-0.63
	Wooded Grassland	0.29	0.12
	Shrubland	-1.00	-1.00
	Closed Bushland	0.24	0.31
Wildlife Mixed Feeders	Open Bushland	-0.80	-0.92
	Wooded Grassland	-0.06	-0.31
	Shrubland	-0.30	-0.73
	Closed Bushland	-0.07	0.19
Livestock Mixed Feeders	Open Bushland	0.39	0.12
	Wooded Grassland	-1.00	-1.00
	Shrubland	-1.00	-1.00
	Closed Bushland	0.27	0.32
Wildlife Browsers	Open Bushland	-1.00	-1.00
	Wooded Grassland	-0.04	-0.32
	Shrubland	-1.00	-1.00

Chapter 4

Discussion

Assessment of habitat use and selection

Livestock versus wildlife density ratios

Osupuko, Kilitome, Kimana and Elerai-Rupet all exhibited livestock densities that were approximately double the respective wildlife densities and Motikanju exhibited a livestock density that was almost six times the wildlife density. A study in Kajiado, Kenya determined that cattle density was one of the most important factors determining wildlife distribution in the area (Mworia 2008). With high densities of livestock comes a decrease in herbaceous vegetation cover, which degrades local habitats and forces wildlife to find alternative sources of nourishment, especially if the competing species are of the same feeding guild (Lamprey and Reid 2004). There is an interesting trend related to location of these sanctuaries and their respective densities. Kilitome, and Elerai-Rupet have the smallest ratios and are also the closest to Amboseli National Park; livestock to wildlife ratios increase with increasing distance from the park. This could be representative of the fact that sanctuaries closest to Amboseli National Park have lower densities of people, lack suitable or preferred habitats for livestock, or simply are closer to source areas for wildlife and therefore have greater wildlife populations. This is the case in Kilitome, for example. Livestock avoided four of the six habitats seen in the sanctuary.

The sanctuaries closest to Amboseli seemed to have more wildlife because national parks are a source for wildlife species. Osupuko had the highest density of wildlife (673.54) followed by Kimana (583.31), Kilitome (563.67), Motikanju (491.39), and Elerai-Rupet (131.95). These densities followed the general trend of increasing with proximity to Amboseli National Park - a source-sink dynamic where the national parks are the source and the sanctuaries are sink habitats. High wildlife densities could lead to higher frequencies of tourist, which would provide sufficient incentive for sanctuary managers to properly manage livestock numbers and therefore maintain the health of the landscape.

Spatial and niche overlap between wildlife and livestock

Presence of overlap can be an indication of potential for competition because wildlife and livestock are in the same area and possibly using the same resources. However, absence of observed overlap is not necessarily an indication of no potential for competition because livestock are constantly moving and using resources across a large area. There were only three sanctuaries, Osupuko, Motikanju and Kimana, which demonstrated some degree of both spatial and niche overlap between livestock and wildlife. Even so, the overlap within these sanctuaries was low, which would suggest that wildlife and livestock select different habitats and therefore different resources. A study in the Kedarnath Wildlife Sanctuary, India, similarly assessed spatial overlap between a native ungulate, the tahr and local livestock species (Kittur, 2010). Kittur also found very little spatial overlap between the two species attributed to changes in habitat preference due to difference in altitude and steep terrain. Studies of mule deer (Loft et al. 1991), mountain elk (Stewart et al. 2002) and Iberian ibex (Acevedo et al. 2007) in California, Oregon, and Spain, respectively, have found that wildlife was displaced by livestock species because of competition for resources. My observed lack of overlap could mean that there is no competition or interaction between livestock and wildlife species. However, it could also mean that the wildlife populations are being displaced by livestock.

Habitat Selection and potential for competition

All sanctuaries in this study seemed to be dominated by open bushland and closed bushland and lacking or missing habitats such as shrubland, open woodland, wooded grassland and riverine (Figure 3). Poor representation of all habitats could be dangerous for the ecosystem and could ultimately lead to severe biodiversity loss as evidenced by Mwangi and Western (1998) in a study regarding habitat selection in elephants (Okello and Kiringe 2008, Western and Maitumo 2004). I have shown that certain species and feeding guilds select particular habitats and only a few habitats present could mean that the sanctuary will only support low densities of wildlife species, which may lead to decreased tourist income and increase human-wildlife conflicts.

There were habitats in each sanctuary where the most commonly sighted species actively avoided habitat types, meaning that the habitats were either inaccessible or lacking in essential resources. There were even some habitats avoided by all feeding guilds, such as open woodland and riverine in Motikanju and wooded grassland in Kimana. The large number of habitats avoided by the most commonly sighted wildlife species compared to the fewer habitats avoided by feeding guilds (including livestock) could be representative of livestock using a greater proportion of habitats, increasing the potential for competition and displacing wildlife.

Increased habitat diversity in each sanctuary could lead to a greater abundance and diversity of wildlife species. Although Kilitome, Kimana and Osupuko exhibited some representation of browsers in addition to significant representation of grazers and mixed feeders, this representation was very low and was completely missing from Motikanju and Elerai-Rupet. This same effect was seen in Amboseli National Park where large densities of elephants in the park have led to degradation of woodland habitats (Okello and Kiringe 2008). Destruction of habitat by elephants has led to local extinction of browser species such as Lesser Kudu (*Tragelaphus imberbis*), gerenuk (*Litocranius walleri*), and giraffe (*Giraffa camelopardalis*) (Okello and Kiringe 2008). If this unbalanced distribution of feeding guilds, across both livestock and wildlife species, is allowed to continue, these sanctuaries may find themselves facing significant displacement and decline of wildlife thereby jeopardizing their profitability and effectiveness as corridors.

Similarly, habitat selection is indicative of potential for competition because there are both wildlife and livestock selecting the same habitats. For example, livestock grazers and wildlife grazers both selected wooded grassland habitats in Osupuko and wildlife grazers/mixed feeders and livestock mixed feeders both selected open bushland habitats in Motikanju. These are all areas with a high potential for competition because wildlife and livestock species that use the same resources. Similar studies have been conducted on wildlife and livestock interactions in East African rangelands and have found that with an increase in livestock populations comes a decrease in some wildlife populations. For example, livestock populations increase by 97% over the course of two years in Meru

National Park, Bisanadi National Reserve and the surrounding areas and the area exhibited significant changes in vegetation structure (from open wooded grassland to bushland), and a decline in abundance of wildlife species, particularly browsers, in addition to the increase in abundance of livestock (Otuoma, J. et. al. 2009).

Effects of detection probability on assessing potential for competition between wildlife and livestock

Using a simple theoretical analysis to recalculate selection indices, I was able to show that detection probability is a significant variable that should be considered when drawing conclusions from animal point counts. There are several factors that influence a particular species' or feeding guild's habitat or resource selection such as season, competition with other species, and human influence. It is important to design field experiments in a way that will allow for proper calculation of detection probability and eliminate potential sources of error. This can be accomplished by collecting data over several days at different times of the day for each sanctuary. This would account for many of the variables influencing animal movements throughout the environment and allow for an accurate calculation of detection probability. Future studies should also try marking animals that are observed so that mark/recapture analyses could be used to accurately predict the total number of animals in a given area (Mackenzie, D. I. 2006).

It would also be interesting to assess the effect of removing livestock completely from these sanctuaries. If livestock were forbidden from grazing within the sanctuary borders, it is likely that wildlife would increase individual habitat selection and biodiversity because competition is greatly decreased. If species begin to select different sanctuaries without the presence of livestock, one might be able to conclude that livestock have been displacing those wildlife species. There is also a possibility that banning of livestock would be detrimental to a sanctuary, leading to unchecked growth of vegetation and an undesirable situation of thick vegetation growth as currently seen in Elerai-Rupet. Sanctuaries in this area would also benefit from research concerning carrying capacity, wildlife movement patterns, vegetation diversity and vegetation quality within each sanctuary and habitat.

Chapter 5

Management Implications

There are steps that each sanctuary could take to improve the productivity of the ecosystem while maintaining publicly owned lands and respecting the local people's rights to natural resources. My study indicated that special overlap of wildlife and livestock occurred and livestock outnumbered wildlife. Rotational grazing, controlled burning, and assessment of habitat composition of the landscape could help contribute to sustainable grazing and watering of livestock within the borders of the sanctuaries. These management techniques could help address this issue of spatial overlap and abundance of livestock.

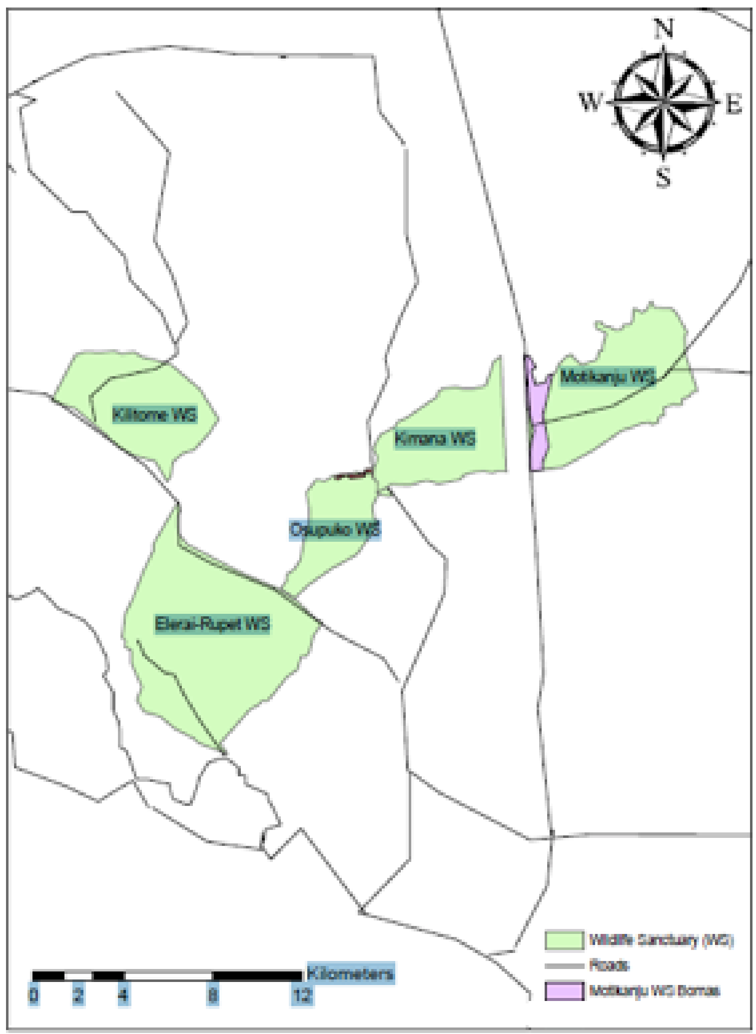
1. Sanctuaries such as Motikanju, Kimana and Osupuko could potentially benefit from a rotating grazing system because it would reduce competition with or displacement of wildlife as well as improve growth of vegetation and regeneration of habitats. I found that in these three sanctuaries, there was greater livestock and wildlife overlap as well as selection for similar habitats. Actively moving livestock throughout the sanctuary could potentially reduce spatial overlap of wildlife and livestock.

A grazing system characterized by a period of rest, which allows vegetation to grow and a schedule that outlines when grazing is acceptable in each area could be useful in Elerai-Rupet where the area suffers from dense shrub and bush vegetation, avoided by both wildlife and livestock species. Controlling growth of woody vegetation through a rotating grazing system could increase the amount of preferred habitat available and therefore reduce the potential competition.

2. Controlled burning is a useful tool that can be used if species are observed to avoid habitat with dense woody vegetation or lacking sufficient food sources, such as seen in Elerai-Rupet. Controlled burning can be combined with rotated with scheduled grazing to increase the carrying capacity of the habitat and reduce wildlife-livestock competition.

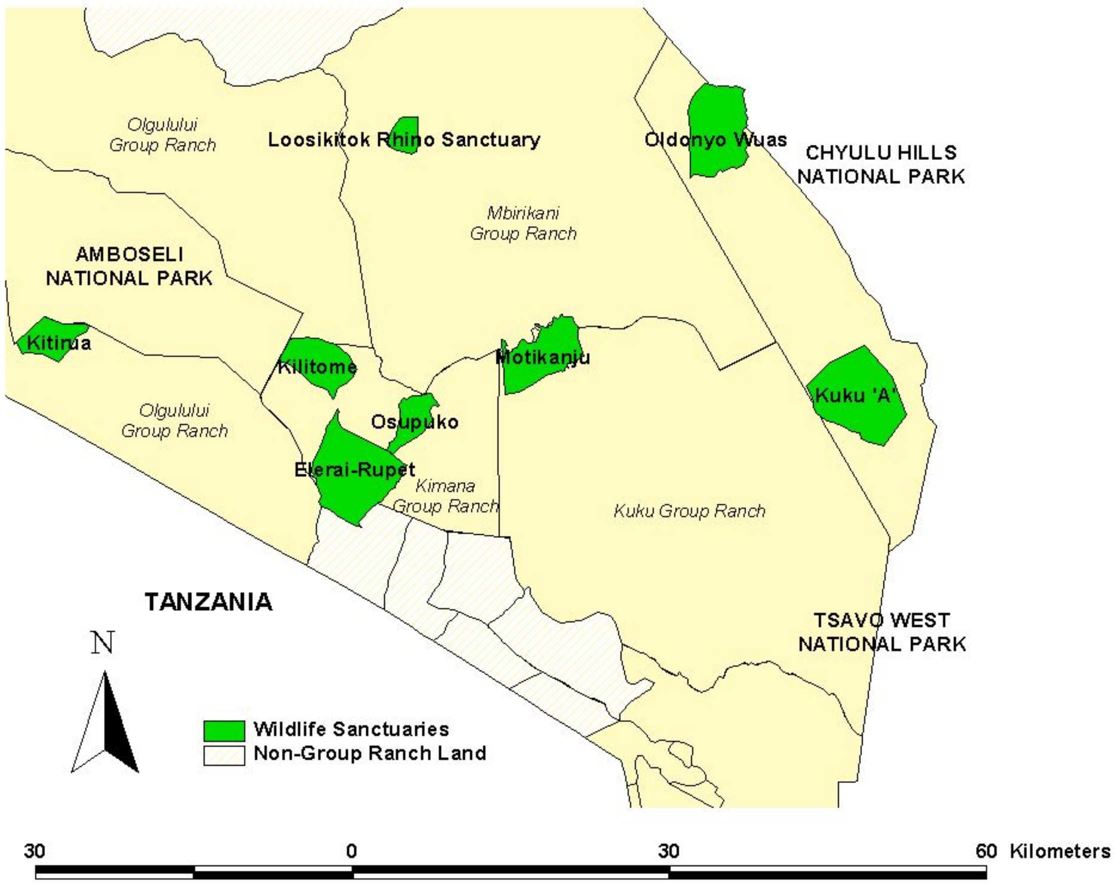
3. Data on livestock and wildlife carrying capacity and vegetation diversity of the landscape could help managers establish livestock grazing schedules and also provide data to better regulate livestock numbers, by providing information about a sustainable number of livestock that will minimize competition with wildlife. Reducing competition could potentially lead to an increase in wildlife abundance and therefore a potential increase in local tourism. The local community could directly benefit from increased income associated with safari-like tourist attractions.

Appendix A
Wildlife Sanctuaries Studied within the Tsavo-Amboseli Ecosystem



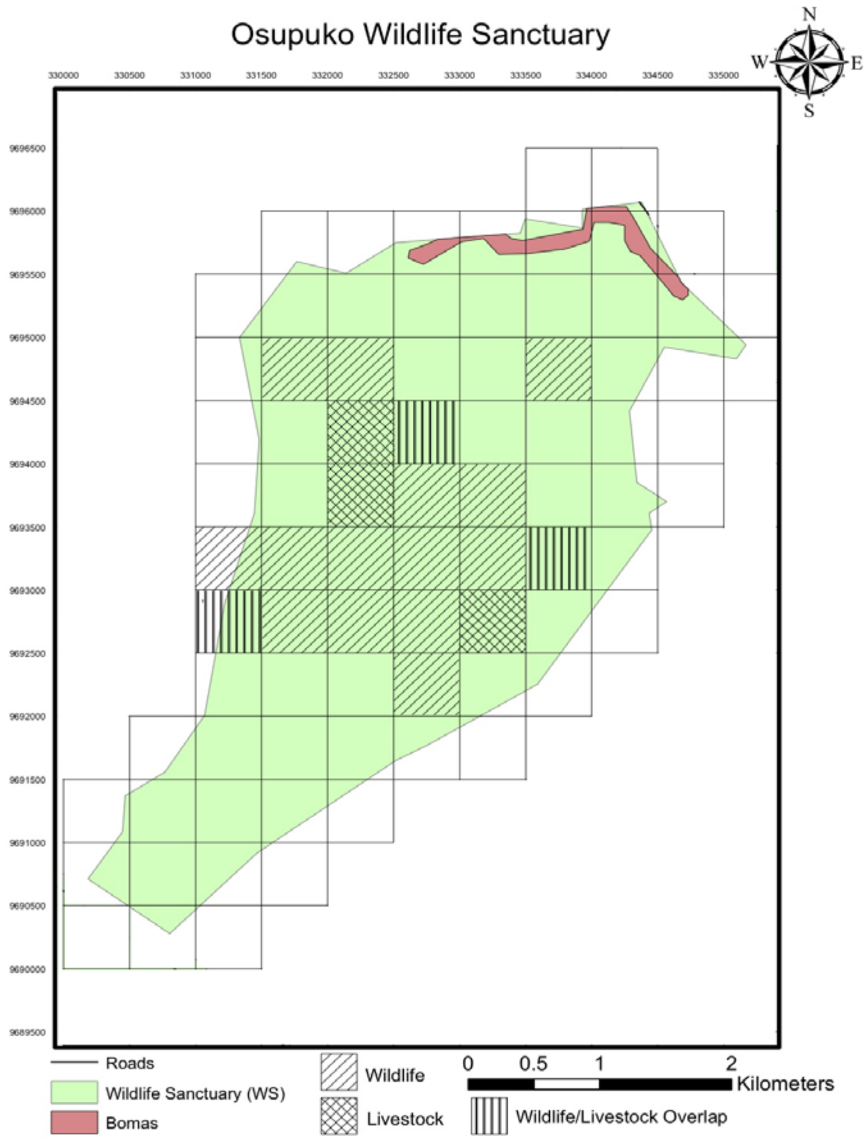
Appendix B

Wildlife sanctuaries studied within the Tsavo-Amboseli Ecosystem in relation to national parks



Appendix C

Example of spatial overlap map used to calculate Jaccard's Index



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