EFFECT OF CATTLE BOMAS ON QUALITYAND QUANTITY OF WILDLIFE HABITAT IN LEWA WILDLIFE CONSERVANCY, KENYA

MUKOMA ANNE WAMBUI

A THESIS SUBMITTED TO THE DEPARTMENT OF WILDLIFE MANAGEMENT FOR AWARD OF THE DEGREE OF MASTER OF SCIENCE IN WILDLIFE MANAGEMENT.

UNIVERSITY OF ELDORET.

October 2015

DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been submitted for any academic award in any institution; and shall not be reproduced in part or full, or in any format without prior written permission from the author and/or University of Eldoret.

Mukoma Anne Wambui **Signed ………………..** **Date ………………….**

(REG: NRM/PGW/05/09)

Declaration by Supervisors

This thesis has been submitted with our approval as University supervisors.

Prof. Geoffrey Wahungu **Signed ……………..** **Date ………………..**

National Environmental Management Authority (NEMA)

Dr. Johnstone Kimanzi **Signed ………………..** **Date …………………**

University of Eldoret

DEDICATION

This thesis is dedicated to my family;

My dear parents Mr. & Mrs. Mukoma, brothers, sister and my loving son, Mike Robin.

Special thanks to you all for working tirelessly to secure an education for me.

God bless you.

ABSTRACT

Cattle bomas are fenced livestock enclosures meant to protect cattle at night when predators are active, and this has an effect whereby trampling of the enclosed cattle breaks down the moribund grass. This dissertation aims at assessing the effect of cattle bomas on vegetation and wildlife habitats in Lewa Wildlife Conservancy, Kenya. This is done in three treatments, the boma, grazed and control areas, of both mixed and black cotton soils in both dry and wet season. Grass quantity, quality and diversity were measured by use of $1m^2$quadrat, by clipping and sun drying the grass and measuring biomass, analysis of nutrients and visual estimation of diversity, while wildlife use was estimated by use of scan sampling and dung count. This was done for a period of six months; dry season, September to November 2010 and wet season from late October 2011 to early January 2012. Animals observed were significantly higher in boma area than the grazed and control area, and there was a significant difference in the number of animals observed and the three treatments, ($F_{2,323}=8.326$, $p<0.0001$), this was the same with dung density. Magnesium was significantly higher, ($F_{2, 68}=4.505$, $p= 0.015$) in boma than in control and grazed area, while there was no significant difference among other nutrients and the grazing treatment. Grass diversity was significantly higher in the control areas, than in grazed and boma area, and there was a significant difference in grass diversity and the grazing treatments, ($F_{2, 65}=14.437$, $p<0.0001$). Grass biomass was significantly higher in the control areas, than in grazed and boma area, and there was a significant difference in grass biomass and the grazing treatments, ($F_{2, 425}=46.696$, $p<0.0001$). Results indicate that, most grazing animals prefer areas with low biomass and are seen in bomas that were abandoned earlier.

Key-Words: Lewa Wildlife Conservancy, Cattle boma, dry season, wet season, grass quantity, grass quality, grass species diversity

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OFABBREVIATIONS, ACRONYMS AND SYMBOLS

ANOVA	-Analysis of variance
Ca	-Calcium
HRM	-Holistic Range Management
K	-Potassium
LRD	-Lewa Research department
LWC	-Lewa Wildlife Conservancy
M	-Meter (s)
N	-Nitrogen
P	-Phosphorus
SPSS	-Statistical Package for Social Sciences

ACKNOWLEDGEMENT

The completion of this work has been achieved through immense contribution by many people and departments. First of all I would like to thank the Almighty Lord for successfully seeing me through my degree programme despite the many challenges which came my way during the study period.

I would wish to acknowledge the assistance and guidance given to me by my knowledgeable supervisors, Prof. Geoffrey Wahungu, Dr. Johnstone Kimanzi and the Late Dr. Karanja, without whom this study wouldn't have come to a successful conclusion, I also appreciate assistance given to me by Duncan Kimuyu from Mpala Research Centre. Thank you all for the constant commitment, guidance, comments, suggestions and constructive criticism throughout my study.

Special thanks to my sponsors the MARWELL FOUNDATION for funding my project. The Research Department; Mr. Geoffrey Chege, Mary Mwololo, Edwin Kisio, Felix Kasyoki, the security staff who assisted in the field, Accommodation and Catering staff Carlo, Diana, Fridah and the Late Phillip Omwenga for ensuring I was comfortable during my stay. And all other staff of Lewa Wildlife Conservancy who in any way contributed and assisted through my entire field work.

Special thanks to my beloved family members, my parents Mr. and Mrs. Mukoma for their financial support, prayers and encouragements all through the entire study period. My son Mike with whom I felt encouraged through my project period.

To all those whom I didn't mention by name but in one way or another passed on me some of their knowledge about the various aspects of this study, I say thank you and God bless you all.

CHAPTER ONE:

INTRODUCTION

1.1 Background of the study

Grazing systems are controlled grazing management practices that manipulate livestock to systematically control periods of grazing, deferment or rest. They were developed as an important tool to increase rangeland productivity. Heitschmidt *et al*, (1982b) described three means by which grazing systems could possibly increase productivity of our rangelands, (1) Increased forage quality, (2) increased forage quantity, and (3) increased efficiency of harvest of animal production.

Lewa wildlife conservancy, a rangeland, located in northern Kenya consists of five diverse ecosystems: open savannah, Acacia forests, rocky gorges and ravines, mountain forests and the Lewa swamp (Botha, 1999). The grassland in Lewa Wildlife Conservancy has become moribund over time due to under utilization by the wild mammalian herbivores which occur at low densities. These moribund grasslands of Lewa Wildlife Conservancy are overgrown with more than 5000kg/Ha biomass; they have very low species diversity, are coarse and are mainly dominated by *Pennisetum stramineum* and *Pennisetum mezianum* grass species which are nutritionally poor to plains game thus are not preferred by wild mammalian herbivores (Lewa Wildlife Conservancy, 2007).

Prescribed burning has been conducted in Lewa Wildlife Sanctuary which were intentionally started under favorable climatic and environmental conditions and designed to modify habitat structure, such as reduction of shrubby vegetation without destroying major habitat components. In Lewa this was done during the October rains to promote the regeneration of grasses and trees to benefit the grazing plains game. Grass assessment surveys were conducted in June when grass is fruiting to determine which areas need to be burned. However, this was seen to have negative effects upon invertebrates, reptiles, woody vegetation and small mammals.

Intensive but controlled livestock grazing and trampling is an alternative treatment that can be used to reduce and control moribund grasslands. It is also beneficial as it causes minimal damage to woody vegetation, small plains game, invertebrates and reptiles. Livestock grazing and trampling is also assumed to have the potential of significantly improving the diversity and productivity of grassland vegetation (Lewa Wildlife Conservancy, 2007).

Grassland areas left entirely to wildlife often become rank; this prevents new growth of nutritious grass and reduces the overall carrying capacity of the range. Rank areas are thus a manifestation of under-grazing often seen in pure wildlife systems. Traditionally fire was used as a tool to remove and rejuvenate rank areas. However heavy controlled grazing can have the same effect as fire and, in certain circumstances, may be less damaging, thus, Cattle grazing can be used to clear rank grass areas; clearly wildlife cannot be used in the same way.

In 2007, in LWC a programme based on intensive, but controlled grazing of large densities of community cattle was implemented as part of the holistic management of rangelands in the Conservancy. This approach has both ecological and socio-economic benefits for Lewa’s landscape and the neighboring communities.

This study aimed at assessing the effects of cattle grazing in improving vegetation quality for grazing wildlife in three treatments with different intensities of cattle grazing and trampling. The cattle corrals (bomas) which had the highest intensity of cattle grazing and trampling, the grazed treatments had moderate intensities of cattle grazing and trampling while the control treatments had zero effects of cattle grazing and trampling.

Lewa Wildlife Conservancy is host to a range of grazing wildlife species including the endangered Grevy’s zebra, *Equus grevyi* and if rangeland can be improved it can lead to significant benefits of these species. It is apparent that proper land and grazing management techniques need to be utilized to optimize forage production, thus when properly applied; cattle grazing systems are powerful tools that can help rangeland managers achieve management objectives. However, selection of the proper grazing system is contingent upon the uniqueness of the setting in which it is applied (e.g., topography, soils, vegetation types, climate, etc.).

1.2 Problem statement

LWC is a critical refuge for diversity of species ranging from grazers, browsers to mixed feeders. The Lewa Research department has demonstrated through past research that grassland within Lewa exhibiting > 5000 Kg/Ha biomass is usually moribund and therefore nutritionally poor. These grassland areas are mostly dominated by *Pennisetum stramenium* and *Pennisetum mezianum* grass species and are not preferred by plains game.

LRD initiated a program of grassland improvement with the specific goal of improving the diversity and productivity of moribund grassland through the use of intensive cattle grazing, cattle are being used to intensively graze and trample the moribund grassland in order to break it down and stimulate the production of more palatable vegetation for the benefit of all grazing species.

Initial results indicates that there are visible reductions in the proportion of moribund grass and increase in the diversity of palatable species, however there has been no scientific assessment of the effects of these grazing management activities or of the response of wildlife to the resultant high diversity vegetation, therefore, the project aimed at quantifying the effects of a controlled grazing management upon vegetation in order to determine whether there are significant improvements in vegetation quality, quantity and diversity including wildlife response to these areas.

1.3 Justification of the study

It is often assumed that, if rangelands can be improved in ways that attracts wild grazers and improves their health and in return their population, then important aspects of habitat management can be opted. Past research by the LRD has demonstrated that grassland within Lewa is usually moribund and nutritionally poor thus are not preferred by plains game (Lewa Wildlife Conservancy, 2007).

In the past moribund grass has been reduced and controlled through prescribed burning, however, fire has detrimental effects upon invertebrates, reptiles and woody vegetation among other things. In this study, intensive but controlled livestock grazing is an alternative treatment that can be used to reduce and control moribund grasslands. Using cattle from local communities may therefore prove to be a much less invasive and more productive management technique. Through intensively grazing community cattle on pre-determined blocks that has high biomass, thus benefiting communities especially during periods of dry seasons; this has in return created a good interaction between the surrounding community and Lewa management thus collaborating in conservation efforts.

On the other hand, LWC is a critical refuge for grevy’s zebra containing 22% of the global wild population and providing a key birthing area and dry season refuge for these species. Currently, the limiting factors on the growth of the grevy’s zebra population on Lewa have been identified as interspecific competition with the ubiquitous plains zebra (*Equus burchelli*), and predation. However, though zebras are hind- gut fermenters, preferring quantity, it’s likely that the quality of vegetation has a significant impact, especially upon the breeding females. Improvements in vegetation productivity and diversity should improve the quality of the grassland for grazing species. If the response to these improvements is strong enough, it should then lead to an increase in population size of wild animals.

1.4 Main Objectives

The main objective of this study was to assess the effects of cattle trampling and grazing on improving wildlife habitats.

1.4.1Objectives

1. To examine the effect of cattle trampling and controlled grazing upon grass quality and diversity for grazers.
2. To determine the effect of different grazing treatments on grass biomass
3. To determine whether the trampling and grazing treatments influences habitat use by grazers.

1.4.2 Hypothesis

1. $H_{o:}$ There is no significant effect of cattle trampling and controlled grazing upon grass quality.

2. $H_{o:}$ There is no significant effect of cattle trampling and controlled grazing upon grass diversity.

3. H_o: The amount of grass biomass in different trampling and grazing treatments is the same

4. $H_{o:}$ There is no significant influence of trampling and grazing treatments upon habitat use by grazers

CHAPTER TWO

LITERATURE REVIEW

2.1 History of livestock grazing

Specialized grazing systems were first conceptualized in the United States at the turn of the 20th century and became a major focus of range researchers and managers by the 1950s (Holechek *et al*., 1998). In the intermountain West, deferred-rotation received considerable attention during the 1950s, followed by rest-rotation during the 1970s. Within the last 40 years, however, livestock grazing is increasingly being used as a tool to improve wildlife habitat. In 1964, Oregon wildlife managers implemented cattle grazing system designed to increase forage for wintering elk (*Cervus elaphus*) on the Bridge Creek Wildlife Management Area. Subsequent elk numbers increased from 320 to 1190 within 10 years (Anderson & Scherzinger 19750).

Livestock grazing is a widespread land use in western North America with approximately seventy percent of the land in the western United States being utilized by the livestock industry over the course of a year (Fleischner, 1994). Since the rise of the livestock industry, the detrimental effects of poor range management have been documented in detail with much emphasis on the loss of animal biodiversity and the decline in population densities presumed to be due to competition for resources and disruption to habitat (Vavra, 2005; Fleischner, 1994; Chaikina & Ruckstuhl, 2006). However, research in past decades has emphasized that livestock and wildlife can be compatible on the same range and that the biodiversity can be maintained, provided that the management is coordinated with the objectives of the area and the ecology and physiology of the rangeland resources (Anderson & Scherzinger, 1975; Vavra, 2005; Anderson & McCuistion, 2008).

The initial research evaluating compatibilities of livestock and wildlife was focused on big game and wild ungulate species, such as deer and elk (Anderson & Scherzinger, 1975). However, recent research has induced a gradual shift of concern from competition of livestock with big game species to a concern for all wildlife and biodiversity (Bleich *et al*., 2005; Vavra, 2005). The recognition of impacts to and value of wild ungulate, upland bird, riparian, and threatened and endangered species has provided a foundation for designing comprehensive range management plans. Consequently, many range management plans are being revised to account for the requirements of domestic livestock and multiple wildlife species (Anderson & McCuistion, 2008; Beck & Mitchell, 2000; Bleich et al., 2005; Bock *et al*., 1993; Fitch & Adams, 1998).

2.2 Livestock Interactions with Wild Ungulates

Early research indicated that an overabundance of livestock influences wild ungulate species by causing competition for food resources. Although cattle and wild ungulates often focus on different types of vegetation, diet overlap increases when forage becomes less available in the winter and early spring (Chaikina & Ruckstuhl, 2006). Heavy livestock grazing also affects wild ungulate habitat by altering plant biomass, species composition, and structural components, such as vegetation height and cover. Additionally, the physical presence of cattle can cause behavioral changes that make foraging less productive. The combined result of resource competition, modification in rangeland structure, and the presence of livestock can contribute to reduced fat content, reproductive rates, and survival in many wild ungulate species (Chaikina & Ruckstuhl, 2006; Bleich *et al*., 2005).

At the same time, there are several pathways by which native biodiversity negatively impact the enterprise of livestock production (Dunham *et al*, 2003). First, wildlife competes with livestock, consuming forage resources, altering livestock behaviors, and reducing livestock productivity (Odadi *et al*, 2011).Second, pastoralists lose livestock—ranging from sheep and goats to cattle and camels—to wild predators (Atickem *et al*. 2010). Lastly, there are complex disease interactions among wildlife, livestock, and other domestic animals, with negative repercussions for all of these guilds (Grootenhuis *et al*1999).

Even though there are several cases that demonstrate the negative impacts of heavy livestock grazing on wild ungulates, there are a considerable number of examples that reveal compatibility between livestock and wild ungulate species (Anderson & Scherzinger, 1975; Chaikina & Ruckstuhl, 2006). In fact, properly managed and specialized livestock grazing systems can maintain or improve habitat for wildlife (Vavra *et al*., 2007; Bleich *et al*., 2005). In various ecosystems, grazing is an important ecological process that can increase the chances of survival of some species and enhance community and landscape diversity (West, 1993; Bock *et al*., 1993).

Seminal research conducted by Anderson and Scherzinger (1975) suggested that specialized livestock grazing systems are capable of manipulating the physiology of forage plants to increase the amount and nutritional quality of winter vegetation for elk. Subsequent research has indicated that moderate amounts of livestock in a deferred or rest rotational system can improve forage production for deer by increasing forb production through reduced competition from grass. Cattle can create conditions that are beneficial to elk by promoting growth of more nutritious forage plants through the removal of the residual unpalatable vegetation from previous years (Anderson & McCuistion, 2008; McCarthy, 2003). Moderate levels of livestock grazing during the fall have the potential to increase grass and total biomass availability the following spring and allow elk and deer easier access to succulent and nutritious vegetation in the summer (Taylor *et al*., 2004).

2.3 Effects of livestock grazing on plant diversity

Livestock can exert a considerable change on the diversity, composition, structure, and development of native plant communities (Popolizio *et al*., 1994; Vavra *et al*., 2007; Orodho et al., 1990). However, the degree of change is highly dependent upon the ecosystem and plant community, the current environmental conditions, and the intensity and timing of grazing (Bock *et al*., 1993; Milchunas, 2006). Much of the literature indicates that the change has been more drastic and evident in ecosystems where native grazing ungulates were historically scarce or absent (Bock *et al*., 1993; Milchunas, 2006).

Livestock also may have overall effects on plant diversity that are similar to those of wild large herbivores (Olff & Ritchie 1998). Yet, there are also substantial differences between the diets, behavior and sometimes densities of livestock and those of large wildlife, which can influence their respective effects on plant communities and successional patterns (Vázquez & Simberloff 2004) (Riginos & Young 2007; Riginos *et al*. 2012). For example, the replacement of wild browsers by livestock may alter competition and facilitation among plant communities (Veblen & Young 2010), patterns of tree recruitment (Tobler, Cochard & Edwards 2003; Goheen *et al*. 2010) and nutrient distribution (Augustine 2003a).

The short grass steppe ecosystem within the Great Plains is among the most grazing tolerant plant communities in the world because herbivory by native ungulates has played an important role in the ecological and evolutionary history (Milchunas, 2006; Bock *et al*., 1993). For this reason, the impacts to native plant communities from excessive grazing have been three times less than that of other vegetation communities throughout the world. In contrast, the effects of inappropriate grazing practices and poor livestock management have been more substantial in the Intermountain West because many of the vegetation communities did not evolve with large ungulate species (Bock *et al*., 1993; Knapp, 1996). Research evaluating the impacts is variable, but the predominant effects include changes in species composition, reductions in individual plant density and species diversity, and modifications in plant succession (Fleischner, 1994).

2.4 Livestock grazing on invasive plants

An increasing threat to rangeland biodiversity and health is the invasion by non-native plant species (Frost & Launchbaugh, 2003; Society for Range Management, n.d.). Some of the most prevalent and problematic invasive plants include diffuse knapweed, spotted knapweed, yellow star thistle, leafy spurge, and cheat grass

(DiTomaso, 2000). The vast majority of invasive plants have been introduced from other continents. Cheat grass, the most widespread and dominant invasive plant in the Intermountain West, was introduced during the mid- to late-1800s by means of imported grain from Eurasia (DiTomaso, 2000; Knapp, 1996).

The dispersion of non-native plants was originally linked to direct human activity, particularly along railroad lines (Knapp, 1996). However, the proportion of non-native plant species began to increase as the livestock industry expanded and human populations began to flourish. Poorly managed grazing destabilized many native plant communities and encouraged the spread of non-native plants because native perennial grasses do not have high seedling vigor and some do not readily recover from grazing (DiTomaso, 2000). The reduced competition from native plants perpetually favors the spread of invasive plants because many are unpalatable, aversive, or toxic to livestock (DiTomaso, 2000).

Livestock can also promote the spread of non-native plants through ground disturbance and the physical dissemination of seeds. Disturbance appears to be an important aspect in the establishment of non-native plant populations because many invasive plants are adapted to soil disturbance, such as that caused from trampling (Vavra *et al*., 2007). Therefore, high intensities of livestock have been suggested to increase invisibility (Loeser *et al*., 2001). Livestock can disperse seeds by serving as transportation vectors. Seeds are dispersed by adhering to the coats of animals; others are dispersed as they pass through digestive tracts (Frost & Launchbaugh, 2003; Fleischner, 1994)

2.4.1 Impacts of Invasive Plants

Invasive plants can have a significant impact on an array of ecological facets. Invasive plants have reduced species richness, plant diversity, and community productivity. Wildlife habitat and forage have been degraded; soil erosion and stream sedimentation has increased; soil moisture and nutrient levels have been depleted; and fire regimes have been altered (Frost &Launchbaugh, 2003; Wallace *et al*., 2008). These ecological changes combined suggest that invasive plants can significantly alter ecosystem processes, cause ecosystem instability, displace native plant species that are vital to wildlife and livestock, and reduce the capacity for ecosystems to provide the services required by society, (Knapp, 1996; Masters & Sheley, 2001).

The invasion of non-native plant species not only produces various ecological modifications, but also results in substantial socioeconomic impacts, particularly to the livestock industry and land management agencies responsible for fire suppression. Invasive plant species cause more economic loss on rangeland than all other pests combined. Invasive plants reduce the carrying capacity for livestock by lowering the forage yield. Consequently, the costs of managing and producing livestock increase (DiTomaso, 2000).

The most wide spread invasive species in LWC is *Datura stramonium* that dominate swamps, along the sirkio river and most of the disturbed areas e.g. road drains and abandoned cattle bomas; they prevent the growth of grass and herbaceous plants. Other identified invasive plants included; *Lantana camara, oputia exaltata*, *Khaki weed, Castle oil, Lippia javanica, Oputia vulgaris* among others that appear to dominate most disturbed areas, (Low *et al*, 2005).These plants in no way impact negatively on the ecological processes or disrupt normal animal behavior patterns.

2.5 Livestock grazing compared to prescribed burning

Africa has the most extensive area of tropical savanna in the world, characterized by a grassy under storey that becomes extremely flammable during the dry season. As a result, Africa is known as the "Fire Continent" (Komarek, 1965) and prescribed burning is practiced as a widely recognized and essential ecological factor for managing its grassland and savanna ecosystems. The primary reason for prescribed burning in areas with high loads of fuel is to reduce fire intensity, thus reducing the negative effects of fire. Other reasons as shown by the Forest Resources Assessment Program (FRAP), (2001) for burning rangelands as in nature conservation are: to remove moribund grass material, to prevent encroachment of undesirable plants, to encourage wildlife to move to less preferred areas and to create or maintain an optimum relationship between herbaceous and woody vegetation where necessary.

In African grasslands and savanna areas used for nature conservation and game ranching, there is general consensus that fire has occurred naturally since time in memorial and that it is often essential for the ecological well-being of these ecosystems (Trollope, 1990; Trollope & Trollope, 2004). Experience gained through research on the effects and use of fire in south and east African grasslands and savannas has led to the conclusion that the broad groups of grasses and trees generally react similarly to the different fire regime components and, therefore, general guidelines can be formulated for prescribed burning (Trollope, 1983; 1989; Trollope & Trollope 1999).

Further research investigating fire regime effects on the biotic and a biotic component of the ecosystem has led to a general understanding of the effects of type and intensity of fire and season and frequency of burning on the grass and tree components of the vegetation. This in turn has clarified the use of fire as a range management practice (Trollope & Trollope, 1999). The need to retain or restore a mosaic combined with concern for restoring natural processes has also led to conservationists tolerating or encouraging fires (Sutherland, 2000). Burning, however, has negative effects on amphibians, reptiles, small mammals, invertebrates and woody vegetation. Burning is also costly if a large team is needed to extinguish the fire, there is a threat that the fire may escape and spread, people may be injured, and equipment may be lost. Also, the smoke and pollution produced by prescribed burns may violate regulations, such as the Clean Air Act, and may impact surrounding communities (Davison, 1996). Because of air quality concerns and the need for correct fire-weather conditions, there is usually a narrow period of time in which prescribed burning can be conducted (Nader *et al*., 2007).

Prescribed burning has been conducted in LWC which were intentionally started under favorable climatic and environmental conditions and designed to modify habitat structure, such as reduction of shrubby vegetation without destroying major habitat components, this was done during the October rains to promote the regeneration of grasses and trees to benefit the grazing plains game. Grass assessment surveys were conducted in June when grass is fruiting to determine which areas need to be burned. The benefits of burning were realized immediately after the rains as dozens of plains game made local migrations to the burnt areas to exploit the tender grasses.

Studies have also shown that herbivores prefer grazing on post-fire regrowth compared to unburned grass swards (e.g., Moe *et al*. 1990, Gureja & Owen-Smith 2002, Tomor & Owen-Smith 2002, Archibald & Bond 2004, Archibald *et al*. 2004). Within burned areas, the spatial distribution of grazing is governed mainly by local differences in regrowth age, the amount of dead stem material in the sward, grass cover, and the distance to water sources.

Burning also opens up thick bushes that reduce the risk of predation especially to the endangered Grevy’s zebra species. However, fire has detrimental effects upon invertebrates, reptiles and woody vegetation, destruction of bird nests by fire, particularly among shrub and ground-nesting species among other things.

2.6 Grazing management

Research has indicated that livestock can reduce fuel loads by removing and consuming vegetation and by incorporating fine fuels into the soil via trampling (Nader *et al*., 2007).It is apparent that proper land and grazing management techniques need to be utilized to optimize forage production and livestock production, while still maintaining biodiversity and consideration of the ecosystem. Through the utilization of grazing systems and making sure to allow proper recovery periods for regrowth, both the livestock and ecosystem will benefit. Along with recovery periods, producers can keep a low density on a pasture, so as not to overgraze. Although grazing can be problematic for the ecosystem at times, it is clear that well-managed grazing techniques can reverse damage and improve the land.

Grazing management therefore, plays a large role in the quality and extent of wildlife habitat. Livestock grazing can affect wildlife habitat in a number of ways. Although there is much debate over proper use grazing (Menke & Bradford 1992), most would agree that persistent, heavy grazing can be detrimental to wildlife populations and the rangeland resource itself (Fleischner, 1994). Overgrazing can lower both plant and animal species diversity (Reynolds and Trost, 1980), aboveground biomass (Webb & Stielstra, 1979), range productivity (Fleischner 1994) and deplete watershed function (Kauffman & Krueger, 1984)

When properly applied, grazing systems are powerful tools that can help rangeland and livestock managers achieve management objectives related to rangeland and livestock production (e.g., forage production, average daily gain), as well as those related to ecosystem structure (e.g., wildlife habitat) and function (e.g., erosion control, water quantity and quality). However, selection of the proper grazing system is contingent upon the uniqueness of the setting in which it is applied (e.g., topography, soils, vegetation types, climate, etc.).

2.6.1 Grazing management strategy in LWC

LWC began grazing management following the recognized Allan Savory Holistic Management Model, (Savory A. Butterfield J., 1999). This management practice was developed by Allan Savory and is practiced in Zimbabwe, South Africa and the American West. In LWC, this method entailed intensively grazing community cattle on pre-determined blocks that have high grass biomass. At night, the cattle would be confined in large holding enclosures (mobile bomas) that can be dismantled and moved to new locations as necessary. (Plate 1). The average cost of a boma is approximately $600, including labour.

Plate 1: A mobile Boma at Lewa Wildlife Conservancy (From the Research department, LWC, 2010)

2.7 Holistic Range Management

Some critics of Sandfords thesis, Sandford S. (2006) “Too many people, too few livestock: the crisis affecting pastoralists in the greater horn of Africa” put forward that the technical possibilities of improving the productivity of rangeland (changing the output-to-land ratio) and livestock are in fact not limited. Referring to successful examples of holistic range management in Zimbabwe and Namibia they aim to show that indeed the number of livestock on the ranges does not need to be reduced but increased! Allan Savory (LEAD/Alive e-conference) suggests that rapid biological decay, essential to the health of grasslands in seasonal rainfall environments, can only be maintained by high number of large herbivores and that the two things which lead to wide plant spacing and a high percentage of bare soil between plants are simply too few large herbivores (domestic or wild) wandering around. Savory points out that the number of people the dry lands can sustain depends on the effectiveness of rainfall.

According to the Holistic Range Management theory, the beneficial effects of animal impact depend on having high impact for a short duration (Keppel, 2005). Overgrazing is not so much a function of animal numbers as of the time the pasture is exposed to grazing. Private farms can easily apply HRM principles on their pastures. However, HRM methods have often proved unsuccessful in situations of open access of grazing areas, because as soon as a group of pastoralists leaves the grazing area so that it can recover, others herders may use it, hindering the recovery process or even degrading the land. HRM of common grazing areas is possible only if strict and disciplined herding is monitored by a group of people who have secure communal land rights. This group has to be able to react quickly and flexibly to the observed changes in pasture vegetation.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

3.1.1 Location

The LWC lies between latitudes 0° 06′ and 0° 17′ N and longitudes 37° 21′ and 37° 32′ E in the northern foothills of Mount Kenya, about 65km northeast of the town of Nanyuki. It is located along Isiolo Road, two Kilometers from Meru/Isiolo/Nanyuki junction and is approximately 260 Kilometers from Nairobi on a paved road; (Figure 1). It is a 62,000-acre wildlife sanctuary and consists of five extremely diverse ecosystems: Open savannah, Acacia forest, rocky gorges and ravines, Mountain forest and the Lewa swamp. (Botha, 1999).

3.1.2 History of Lewa Wildlife Conservancy

The Craig family had owned Lewa Downs since the 1920s and for 50 years managed it as a cattle ranch, but in 1995 sickened by the sight of rare species falling prey to the poachers gun, Ian Craig turned Lewa into a wildlife conservancy, 55,000 (22, 250 hectares) acres of open grassland, woodlands, wetlands and the rolling hills of the Rift valley became the Lewa Wildlife Conservancy, one of the most successful examples of wildlife conservation in Africa, (Botha, 1999). Today the 62,000 acre conservancy holds more than 19 per cent of the worlds threatened Grevy’s zebra population, indigenous black rhino (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*) an abundance of the Big Five as well as 65 other mammal species native to east Africa and a prolific birdlife. (Botha, 1999).

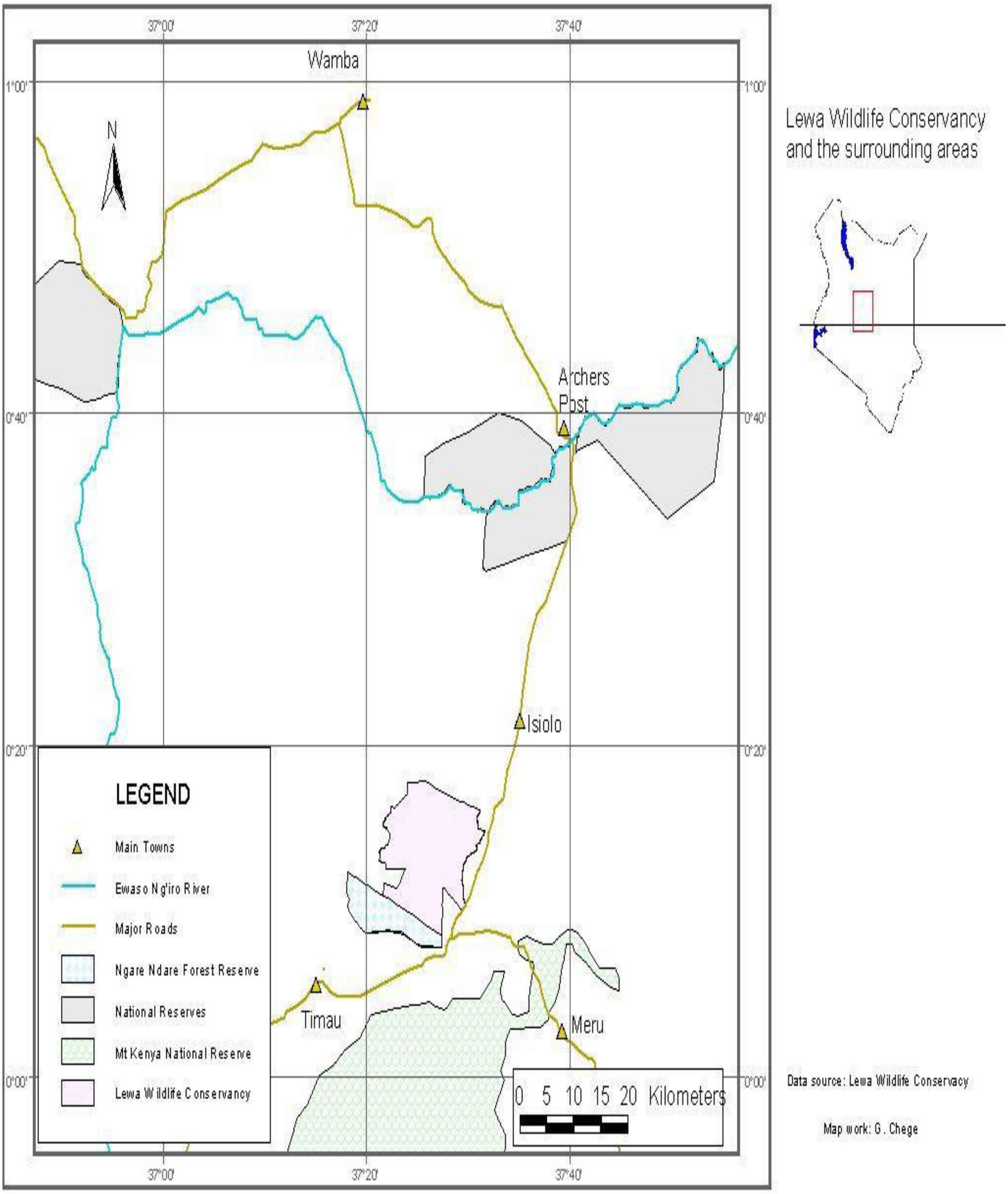

Figure 1: Location of Lewa Wildlife Conservancy and the neighbouring areas (From the Research department, LWC, 2010)

3.1.3 Climate.

Rainfall on Lewa follows a typical bimodal distribution pattern of the Kenyan Highlands. The long rains fall in March to May while the short rains fall in October to December.The daily maximum temperature on Lewa range from 24 to 32°c, and the daily minimum temperature from 8 to 16°c (Linsen & Giesen, 1983). According to Botha (1999), the daily maximum temperatures during the wet season are lower than during the dry season.

Conversely, the daily minimum temperatures during the wet season are higher than during the dry season. A marked temperature difference occurs along the altitudinal gradient with the north being warmer than the south.

3.1.4 Soils.

Botha (1999) conducted a survey of the soils of Lewa by analysing about 21 soil samples and found 7 dominant soil types; nitisols, vertisols, cambisols, luvisols, solonetz, fluvisols and gleysols. The Lewa soils are mainly derived from erosion of geological formation, some transported by river action and run-off. The black cotton,vertisols are predominant and are known to impede drainage. Some areas have solonetz soils-red, extreme erodable, low resilience and poor recovery potential; hence vegetation on these has low grazing capacity.

3.1.5 Vegetation.

The vegetation of Lewa forms a transition from a semi-arid highland to arid lowland. Most of the area can be physiognomically described as savannah, or more precise a grassland with a tree and shrub cover of more than 2% but less than 20% (Pratt & Gwynne 1977).

According to Edwards and Bogdan (1951), the area can also be called “scattered tree grassland”, which is the most extensive vegetation type which occurs at elevations in Kenya. In LWC there are four types of habitats; the low open woodland, short closed grassland, low thicket and tall sparse shrub land

Lewa vegetation has been divided into 11 plant communities and 26 sub-communities, as identified by Botha (1999), (Figure 2). The vegetation of Lewa is placed into 4 management units, which forms the basis of the management plan for Lewa devised by Botha. These four management units are the Forest management unit, the Plains management unit, the Riverine management unit, and the Hills and Rocky Outcrops management unit.

The woody vegetation around Lewa is predominantly the Acacia species, with *Acacia seyal* and *Acacia drepanolobium* being dominant. The *Acacia drepanolobium* dominates the areas above 1650m in altitude, while *Acacia mellifera,* often associated with *Acacia tortilis, Acacia nilotica,* and *Commiphora* species, dominates areas below 1650m. *Acacia xanthoploea* is dominant in virtually all the riverine and swamp vegetation. The dominant grass species are *Pennisetum stramineum,* often accompanied by *Pennisetum Mezianum,* which are increaser species with less *Themeda triandra*, and *Sorghum versicolor*.

These are some of the invasive plant species occurring on Lewa and some of the neighbouring community areas, these species include; *Lantana camara, Khaki weed, Castle oil, Datura stramonium, oputia exaltata, Lippia javanica, Oputia vulgaris* among others. These plants in no way impact negatively on the ecological processes or disrupt normal animal behavior patterns.

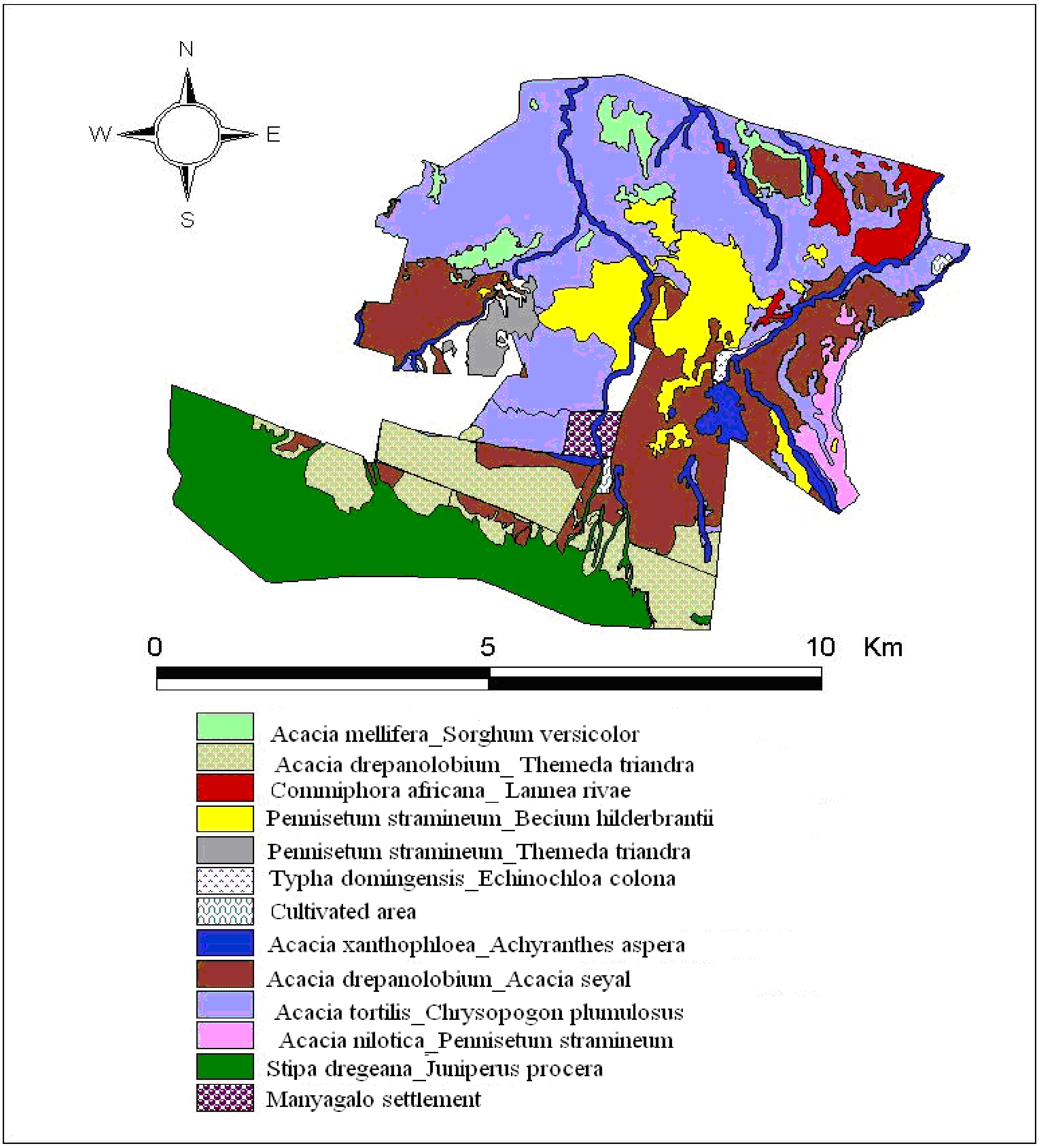

Figure 2: Vegetation types in Lewa Wildlife Conservancy (From the Research department, LWC, 2010)

3.1.6 Animals

These ecosystems support over 440 species of birds and more than 61 different mammals, including some rather rare exotic and endangered ones. It is one of the last three remaining habitats of the aquatic sitatunga (*Tragelaphus spekii*).

The conservancy holds more than 19% of the world’s threatened Grevy’s Zebra population, indigenous black rhino and white rhino, an abundance of the big five as well as 65 other mammal species native to East Africa, including; impala (*Aepycerotini melampus*), common zebra, gerenuk (*Litocranius walleri*), elephant (*Loxodonta africana*), bush buck (*Tragelaphus scriptus*), hartebeest (*Alcelaphus buselaphus*), hippopotamus (*Hippopotamus amphibus*), lion (*Panthera leo*), water buck (*Kobus ellipsiprymnus*), buffalo (*Syncerus caffer*), cheetah (*Acinonyx jubatus*), grant gazelle (*Gazella granti*), greater kudu (*Tragelaphus strepsiceros*), eland (*Tragelaphus* (*Taurotragus*) *oryx*), klipspringer (*Oreotragus oreotragus*), beisa Oryx (*Oryx gazella*), Giraffe (*Giraffa camelopardalis*) among others, and over 440 species of birdlife. Lewa also holds one of the last three remaining habitats of the aquatic sitatunga. Lewa also boasts an ever-increasing population of reticulated Giraffe, and also hosts a pack of elusive wild dog (*Lycaon pictus*).

3.2 Data collection methods

3.2.1 Selection of Boma sites

The study was carried out in Lewa Wildlife Conservancy for a period of six months and data was collected on both dry and wet season. Dry season data was collected from September to November 2010 while the wet season data was collected from late October 2011 to early January 2012.

The whole process of setting up the cattle bomas was done long before the data collection began; Cattle boma were both set during the dry and wet season. In the dry season, the overnight pens were shifted every seven days, whilst it took two nights to smoother grass in a similar pen in the wet season (Plate 2). This method entailed intensively grazing community cattle on pre-determined blocks that have high grass biomass; the cattle were confined in large holding enclosure (mobile bomas) that were dismantled and moved to new locations as necessary. Grazing in Lewa, land was systematically divided into blocks and separated into categories by species and biomass of grass.

Cattle were separated in two herds, one for calves and the other for mature herds, and would spend the night in mobile pens while grazing in specific areas during the day in a strictly controlled and rotational manner. Two herds of 600 cattle each were kept in two mobile bomas, which had a diameter of 50m.The residency period in one site would depend on the season.

The development of predator proof enclosures (bomas) were to protect cattle, especially at night when predators are active, and this had an effect whereby trampling of the enclosed cattle would break down the moribund grass.

In total, there were 12 boma sites which were randomly selected for Sampling. These were selected from different boma age, habitat type and different soil type. They were already abandoned bomas. Sampling was carried out in two bomas which were active in the months of April and May and two in the month of December 2008. The same was also carried out for bomas from the months of May, August, November and

December 2009 and on some recently abandoned bomas from the months of January, February, March and June of 2010. Following this regime, the oldest abandoned bomas sampled were two years old and the youngest were two months old.

Sampling occurred in two soil types; black cotton soils and mixed soils. There are three dominant soil types in Lewa: Black cotton soils (Vertisols), mixed soils and red soils (Solonetz). However, the proportion of black cotton soils and mixed soils is greater than that of the red soils and most of the abandoned cattle bomas were situated on the black cotton and mixed soils making it impossible to get enough replicates of abandoned bomas on the red soils.

The habitat types were low open woodland which is low density forest forming open habitats, short closed grassland which were areas where the vegetation is dominated by grasses and other herbaceous plants, and tall sparse shrub land.

Plate 2: Two days old active boma in Lewa with cattle leaving during the wet season (Source: Author, 2015)

Data collection was done in three treatments within boma sites; (a) trampled area (boma) that is; the holding pens where cattle spent the night, (b) the grazing area where the cattle would graze during the day in specific areas in a strictly controlled and rationale manner and (c) the controlled areas where cattle were excluded. The average diameter of a single boma area was 50m; (Plate 3).A boma site included an area with three treatments; that is the boma area, the grazed area and the control area.

Plate 3: An abandoned boma in Lewa during the dry season (Source: Author, 2015)

3.2.2 Sampling points

Vegetation survey was done in the twelve abandoned boma sites. At each treatment, six vegetation plots were established in each of the two seasons, resulting into thirty six samples in each site. For the twelve boma sites therefore, four hundred and thirty two vegetation plots were sampled. In every vegetation plot, vegetation quality, quantity and diversity was estimated.

Two 100m line transects were established both in the grazing area and the controlled areas and a 1 m^2 quadrat was dropped after every 30metres. Because of the irregular shapes of bomas, it was not possible to use 100m line transects, therefore random points equal to the number of sampled points in the grazing area and the controlled areas were taken.

3.3.3Habitat use by herbivores

To determine the level of utilization on abandoned bomas by herbivores, both direct and indirect methods were used.

3.3.3.1 Direct animal observation

This method involved visual animal observation by use of scan sampling technique. (Altmann, 1974). A whole group of subjects was rapidly scanned and the behavior of each individual (what each animal in the group was doing) at that instance was recorded, the range of behaviors recorded included; grazing, standing, walking, sleeping/resting and looking out. Sampling was conducted at two evenly spaced times of the day; early in the morning and late in the evening. Surveys were made from defined observation points to avoid animal disruption and by use of binoculars and with the fact that all boma sites that were sampled could easily be surveyed from a hill top or vehicle, thus access was available around the boma site.

Whenever a group was identified, scan duration of 5minutes was selected with a focal interval of 30seconds; such that, in every 30seconds a quick scan was made of the whole group and general activity in most group members was recorded. It took an hour to scan the entire boma set, 20minutes in every treatment, and this was replicated 10 times in every season

In total there were 10 scans within 5minutes focal, that is, 2 scans per minute x 5minute scan. There were 40 scans per treatment; that is, 10 scan in 20 minutes per treatment (120 scans in the entire boma site). This was replicated 10 times in every season (20 times in the entire period) and it was done two times a day (early morning and late evening). In total there were 4800 scans in entire study period.

Animals to be observed included mixed feeders like impalas, grants gazelle, eland and elephants. Grazers like; Grevy's zebra, common zebra, buffalo, warthog, water buck, and browsers like the giraffe.

3.3.3.2 Dung density

Indirect method involved use of dung count, where dung piles were identified in every treatment at each of the twelve sites. This method was conducted to find out the types of animals that visited the grazing treatments either at night or when direct animal observation was not done. Though this method has its own draw backs in that the actual activity in which the animal was engaging in at that particular time remains unknown, the only justification of using this method was to evaluate if there were other animals that visited the different treatments.

At the grazing and control areas of every boma site, two belt transects of 100m were used, while in the boma area, four belt transects of 50m were used. The belt transects were shorter in the bomas because the bomas were circular and it was impossible to put up long transects otherwise they would cut out of the bomas. This meant walking along 2meters from the belt on both sides, and involved squashing any dung identified to avoid any chances of double counting. This was done once every two weeks for a period of three months on each season. The number of dung piles along transects were identified to the source species based on the identification by Chris and Stuart (1994).

3.3.4 Measuring grass quality

Grass samples from the quadrats were used to estimate grass quality. This was done by randomly selecting samples in each of the three treatments. In total 72 samples were randomly selected. That is, six samples in each boma site, two in the boma area, two in the grazed area and two in the controlled area in all twelve boma sites. Analysis for nutrients was carried out at the Kenya Agricultural Research Institute (KARI) at the department of National Agricultural Research Laboratories (NARL). Nutrients tested included: Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Iron, Copper, Manganese and Zinc.

3.3.4.1 Procedure for plant tissue analysis

a) Method:

Digestion in tubes with H_2SO_4 - salicylic acid - H_2O_2 and selenium

This digestion is in particular suited for routine work on large series of plant samples and automated determinations. It is applied for the determination of Na, K, Ca, Mg, P, N-total, Mn, Cu, Fe and Zn in plant. Elements such as Na and K are determined with a flame photometer, P is determined calorimetrically on spectrophotometer, N-total is measured by distillation followed by titration with standardized 0.01 *N* HCl; and Ca, Mg, Cu, Zn, Mn & Fe with Atomic Absorption Spectrophotometer (AAS).

b) **Principle:**

The larger part of organic matter is oxidised by hydrogen peroxide at relatively low temperature (100^0C). After decomposition of the excess H_2O_2 and evaporation of water the digestion is completed by concentrated sulphuric acid at elevated (330^0C) temperature under the influence of Se as a catalyst.

3.3.5 Measuring grass diversity

For every quadrat that was placed along the line transect, that is after every 30m, before the grass was clipped to measure biomass, visual estimation was done to record the percentage of the ground covered by bare ground and other grass species. This was done during the dry and wet season. Counts and identification was done and they were calculated using Shannon - Weiner index (Shannon & Weiner, 1963)

3.3.6 Measuring grass biomass.

Grass biomass was measured by placing1m^{2}quadrats along the line transect, per 100m transect, three quadrats were laid, thus six quadrats in two transects. The grass in the quadrat was then cut with hand shears as close as possible to ground level without collecting any soil. The grass clippings were put in individual bags and labeled; they were then sun dried for a period of one week and weight recorded.

3.4 Data Analysis

Data was entered, organized and managed using Ms – Excel for Windows while SPSS version 21.0 was used for all statistical analysis. All tests were considered significant at $p < 0.05$.

3.4.1 Habitat use by herbivores

3.4.1.1 Direct animal observation

One way ANOVA was used to test for the mean difference in the different activities animals were engaged in the different treatments.

Factorial ANOVA was used to test for the difference among the mean number of animals between different treatments (boma, grazed and control), boma age (2008, 2009, and 2010) as well as in the different habitat type (low open woodland, tall sparse shrub land and short closed grass land).

3.4.1.2 Dung density

Factorial ANOVA was used to test for the difference in the number of dung piles between different treatments and the wet and dry seasons.

3.4.2 Grass quality

One way Analysis of variance was used to test for the mean difference among the different nutrient levels in different treatments.

Factorial ANOVA was used to test for the difference among the mean difference in nutrient levels between treatments, dry and wet season as well as test for the difference in nutrient levels in the soil types (mixed and black).

3.4.3 Grass diversity

Grass species diversity was analyzed using the Shannon - Weiner index, $H' = -\Sigma pi \ell npi$ (Shannon & Weiner, 1963) which is an effective measure of diversity as it accounts for species richness and abundance.

Where: H'= index of species diversity

pi = proportion of total sample belonging to the i^{th} species

ℓn= natural logarithm of the proportion

This was then converted into effective number of species (ENS), which is calculated as exponential (Shannon - Weiner index), which is the real diversity and allows comparing of diversity with other communities, (Mac Arthur, 1965). Converting indices into true diversity gives them a set of common behavior and properties permitting the development of truly general index formulas and analytical techniques like ANOVA. Data for testing the differences in species diversity between the dry and wet seasons were heteroscedastic and thus were log – transformed before analysis.

Factorial ANOVA was used to test for the difference in grass diversity among the treatments and the season, the soil types and boma age.

3.4.4 Grass biomass

Factorial Analysis of variance was used to test for the difference among the mean biomass between treatments, seasons and among the soils. Data for detecting difference in biomass between treatments was not normally distributed was therefore log - transformed before analysis.

CHAPTER FOUR

RESULTS

4.1 Habitat use by herbivores

4.1.1 Direct animal observation.

Different activities were observed in three treatments; boma, grazed and control areas, (Figure 3). Grazing was significantly higher in boma than grazed and control areas, walking was higher in control areas, followed by grazed and least in the boma area, standing and resting/sleeping mainly occurred in grazed areas. There was relatively the same amount of browsing in the grazed and control treatments; whereas there was no browsing in the boma.

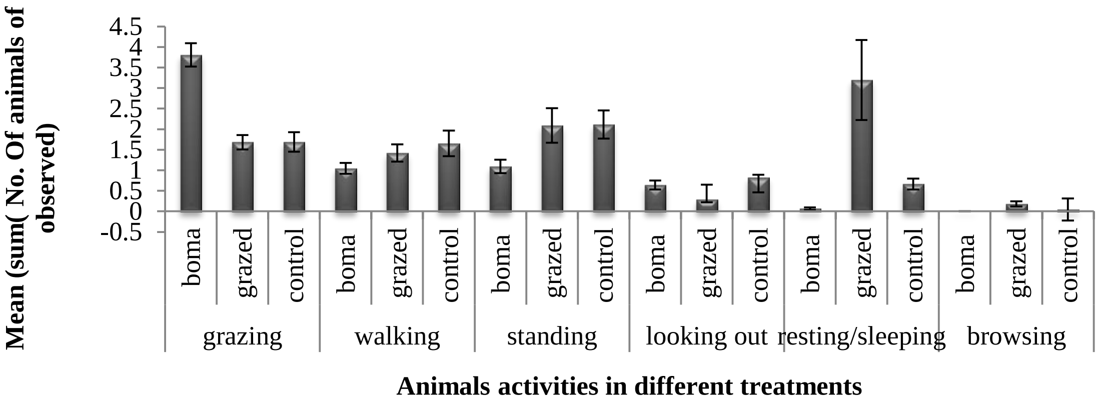

Figure 3: Different animal activities observed in different treatments

There was significant difference in the following activities that were observed in the three treatments; grazing, ($F_{2,337} = 24.601$ $p<0.001$), standing ($F_{2, 337} = 4.379$ $p=0.013$), resting/sleeping ($F_{2,337}=10.904$ $p<0.001$) and browsing ($F_{2,337}=7.214$

p=0.001), while there was no significant difference in walking (F $_{2,337}$=2.313 p=0.101) and looking out (F $_{2,337}$= 1.820 p=0.164). Sequential Tukey test was used to show where differences in activities occurred among the three treatments. Grazing was significantly higher in boma than the other two treatments, (Table 1). Standing was significantly higher in control area than boma, whereas grazed area showed ambiguous results for standing, (Table 2).

Table 1: Tukey test results showing difference in grazing among the three treatments

zone	N	Subset for alpha = 0.05	
		1	2
grazed	100	1.6800	
control	90	1.6889	
boma	150		3.8067
Sig.		1.000	1.000

Table 2: Tukey test results showing difference occurrence in standing among the three treatments

zone	N	Subset for alpha = 0.05	
		1	2
boma	150	1.0933	
grazed	100	2.0900	2.0900
control	90		2.1111
Sig.		.050	.999

There was a significant difference in the number of animals observed and the three treatments, (F $_{2,323}$ =8.326, $p<0.0001$). Tukey test showed that boma area had significantly higher number of animals observed than the grazed and control area, (Table 3). There was a significant difference in the number of animals observed and the season (F $_{1,323}$ =27.329, $p<0.0001$), with wet season having the highest number

(9.95±1.002) than the dry season (4.95±0.204). There was no significant interaction on the number of animals observed between three treatments and the season, (*p*=0.152).

Table 3: Tukey test results showing difference in the number of animals observed among different treatments

zone	N	Subset	
		1	2
control	120	5.58	
grazed	150	6.61	
boma	70		11.00
Sig.		.642	1.000

There was a significant difference in the number of animals observed and the boma age ($F_{2,323}$ =7.285, p=0.001). Tukey test showed that boma age for the year 2008 had significantly higher number of animals observed than those for the year 2009 and 2010 (Table 4). There was a significant interaction in number of animals observed between the three treatments and the boma age, ($F_{4,323}$=35.192, p<0.0001).In all three treatments, boma sites for the year 2008 had the highest number of animals observed (11.2±0.79), followed by boma sites for the year 2009 (5.80±0.830), and least in boma sites for the year 2010 (5.26±0.742). Boma areas for the year 2008 had the highest number of animals while those for the year 2010 had the least number of animals, (Figure 4).

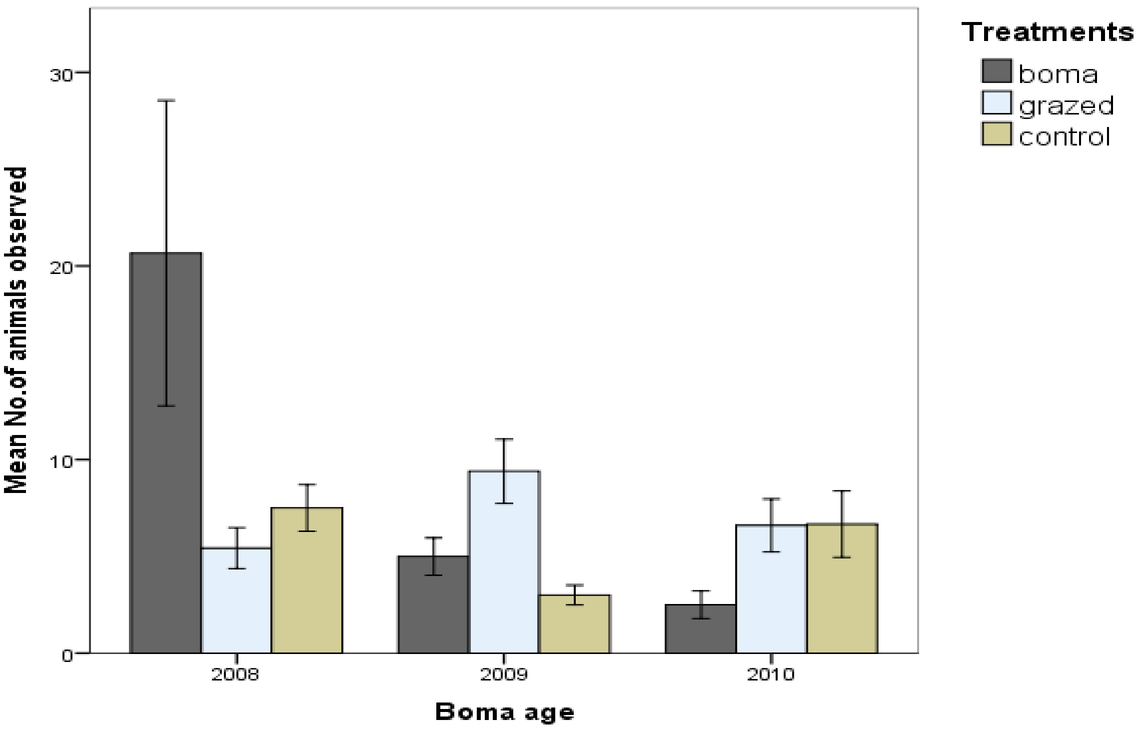

Figure 4: Mean number of animals observed in different boma age in the three treatments.

Table 4: Tukey test results showing difference in number of animals observed among different boma age

boma age	N	Subset	
		1	2
2009	90	5.58	
2010	130	6.00	
2008	120		9.58
Sig.		.910	1.000

There was a significant difference in the number of animals observed and the different habitat types, ($F_{2,\ 323}$=15.895, *p*>0.0001). Tukey test showed that short closed grassland habitat had significantly higher number of animals observed than tall sparse woodland and low open woodland, (Table 5). The number of animals observed in the three treatments was also influenced by the different habitats as this showed a significant interaction, ($F_{3,\ 323}$=19.141, p<0.0001), in all boma area, short closed grassland had the highest number of animals observed (20.0±1.39), while tall sparse shrub land had highest number observed in the grazed area (10.2±1.74) with no animal observed in the boma area, (Figure 5).

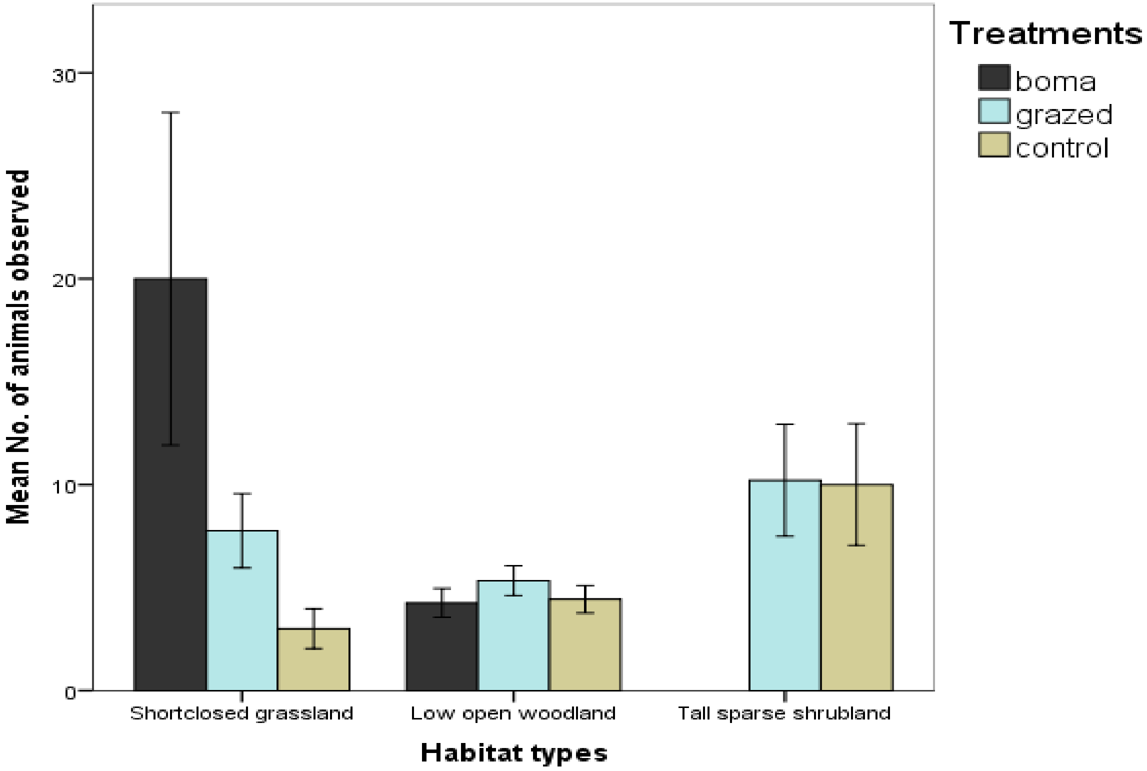

Figure 5: Mean number of animals observed in different habitats in the different treatments

Table 5: Tukey test showing difference in the number of animals observed in different habitat type

habitat type	N	Subset	
		1	2
low open woodland	200	4.80	
tall sparse shrub land	49		10.08
short closed grassland	91		10.75
Sig.		1.000	.811

4.1.2 Dung density

Results indicate that Common zebra and Grant gazelle had the highest dung piles, followed by the Impala while white rhino, hartebeest and Black rhino had the least dung piles, (Figure 6).

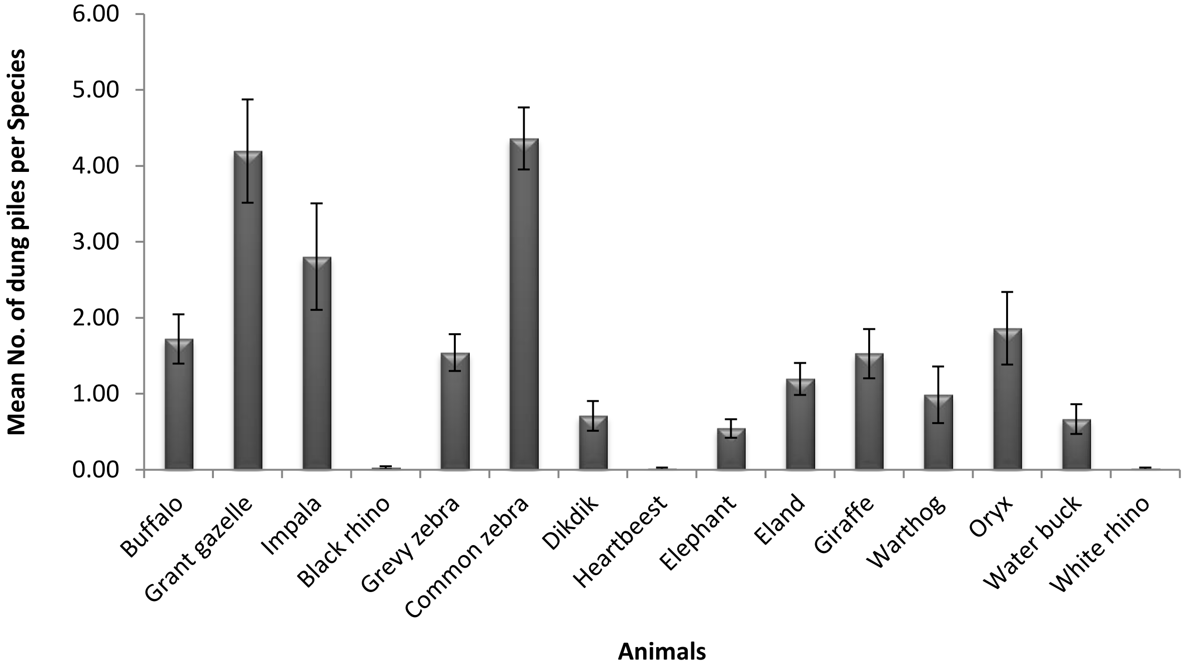

Figure 6: Number of dung piles of different animals counted in LWC

There was a significant difference in the number of dung piles in the three treatments ($F_{2,\ 1074} = 10.001$, $p < 0.0001$). Tukey test showed boma (360±2.04) had significantly higher mean number of dung piles than grazed (359±1.42) and control areas (359±0.98), (Table 6). Dry season (2.07±0.187) had significantly higher amount of dung ($F_{1,\ 1074} = 30.544$, $p < 0.0001$), than the wet season (0.94±0.064), while Dung density on mixed soils (1.90±0.17), was significantly higher ($F_{1,\ 1074}=18.063$, $p<0.0001$) than the black soils, (1.06±0.106).

In both dry and wet season, boma area had the highest number of dung piles (2.047±0.169), than grazed area (1.42±0.169) and least in control area (0.978±0.169); (Figure 7). However there was no significant interaction in number of dung piles between the treatments and the season, (p=0.094).

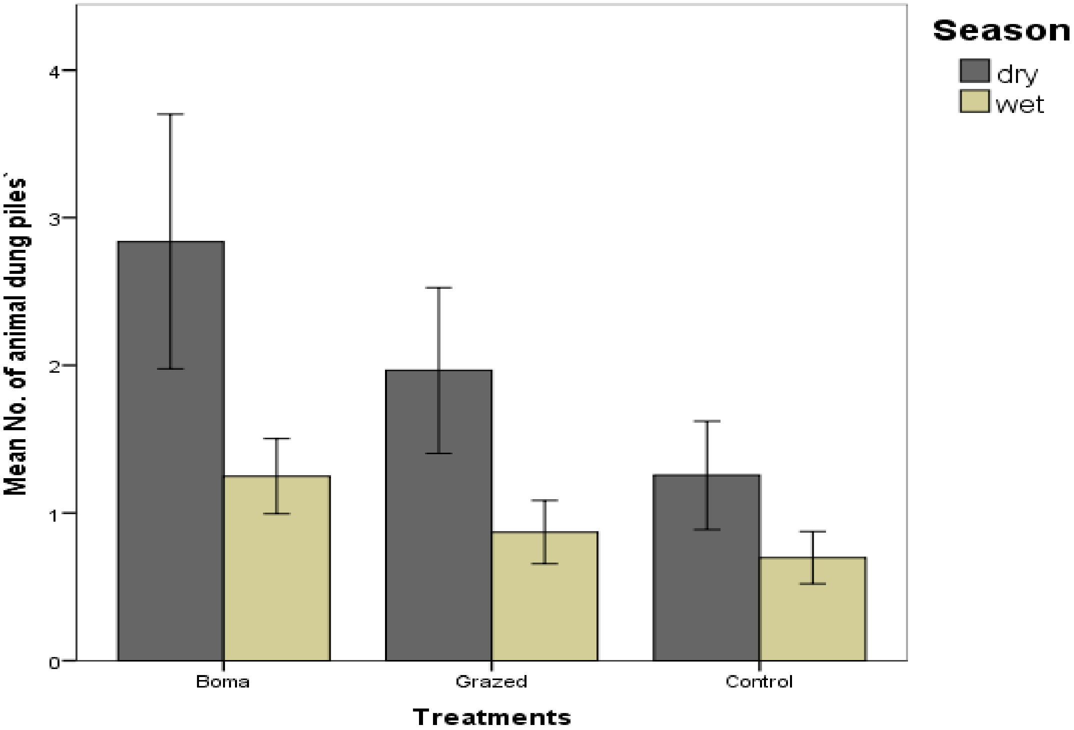

Figure 7: Amount of dung piles in three treatments during dry and wet season

Table 6: Tukey test showing difference in the number of dung piles among the three treatments

zone	N	Subset for alpha = 0.05	
		1	2
control	359	.98	
grazed	359	1.42	
boma	360		2.04
Sig.		.166	1.000

4.2 Grass quality

Boma area had the highest levels of Nitrogen (16386.36±1269.41Mg/Kg,) Phosphorous (2363.64±199.41Mg/Kg,) Potassium (18059.09±2303.56Mg/Kg), Calcium (4086.36±407.20Mg/Kg), Magnesium (1950.0±236.74Mg/Kg), (Figure 8), as well as Iron (1001.6±362.62 Mg/Kg), Manganese (175±80.6 Mg/Kg) and Zinc (51.97±19.81 Mg/Kg), (Figure 9), followed by grazed area and least in control area. Amount of Iron (1001.6±362.62 Mg/Kg), and Manganese (175±80.6 Mg/Kg) were highest in the boma area followed by control and least in grazed areas, while amount of Copper was highest in control (37.16±6.55 Mg/Kg), followed by grazed and least in boma area.

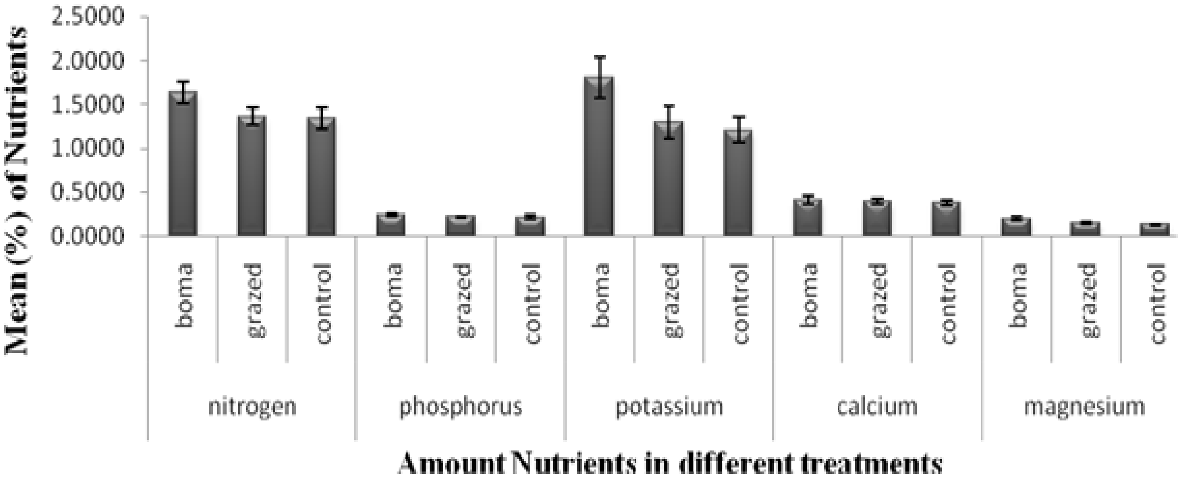

Figure 8: Amount of Macro nutrients (Mg/Kg) in the boma grazed and control treatments

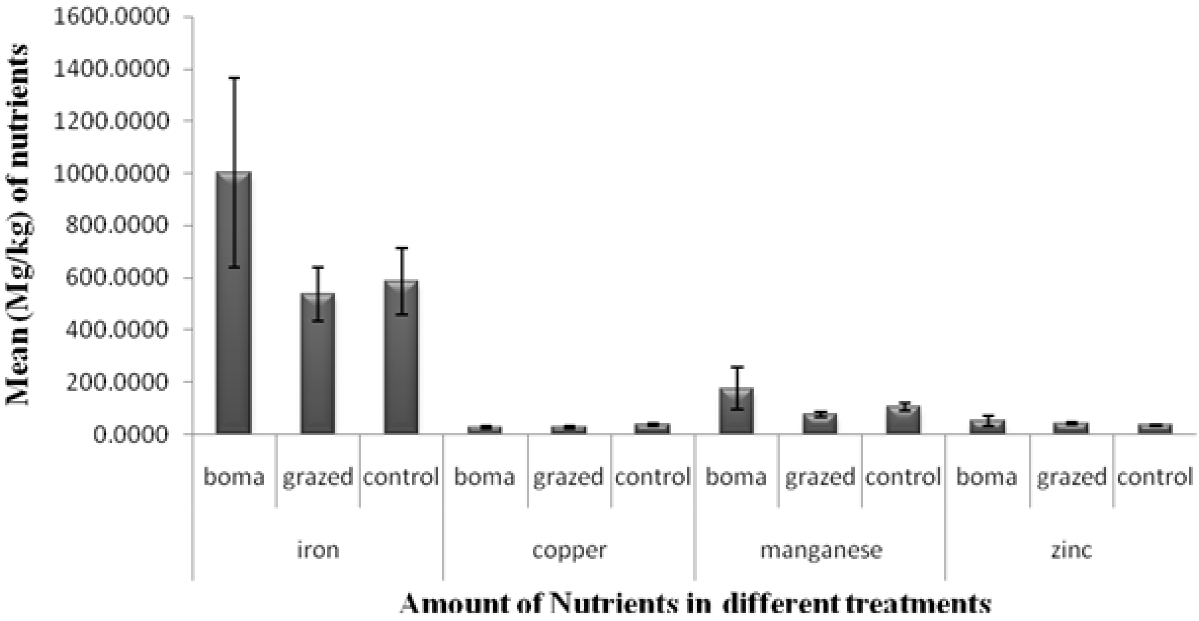

Figure 9: Amount of Micro nutrients (Mg/Kg) in the boma grazed and control treatments

In the three different treatments, there was no significant difference in Nitrogen, (*p*=0.149), Phosphorous, (*p*=0.655), Potassium, (*p*=0.063), Calcium, (p=0.798), Iron, (*p*=0.275), Copper, (*p*=0.349), Manganese, (*p*=0.296) and Zinc, (*p*=0.542), whereas, there was significant difference in Magnesium ($F_{2, 68}$ =4.505, *p*= 0.015); Sequential Tukey test showed that Magnesium was significantly higher in boma than in control whereas grazed area showed ambiguous results for magnesium, (Table 7).

Table 7: Tukey test showing difference in amount of magnesium in the three treatments

zone	N	Subset for alpha = 0.05	
		1	2
control	24	1283.3333	
grazed	24	1433.3333	1433.3333
boma	22		1950.0000
Sig.		.792	.071

Wet season had significantly highest amount of Nitrogen ($F_{1,\ 68}$ =78.415 $p<0.0001$), Phosphorous, ($F_{1,\ 68}$=17.460 $p<0.0001$), Potassium, ($F_{1,\ 68}$=149.611 $p<0.0001$), Calcium ($F_{1,\ 68}$ =24.290 $p<0.0001$), Magnesium ($F_{1,\ 68}$ =36.044 $p<0.0001$), (Figure 10), as well as Copper ($F_{1,\ 68}$ =79.045 $p<0.01$), Manganese ($F_{1,\ 68}$ =6.379 $p=0.041$) and Zinc ($F_{1,\ 68}$ =10.814 $p=0.002$), (Figure 11), as compared to the dry season, apart from Iron, where dry season had significantly highest amount as compared to wet season ($p=0.603$). However there was no significant difference in all amount of nutrients and the soil types, (P>0.05).

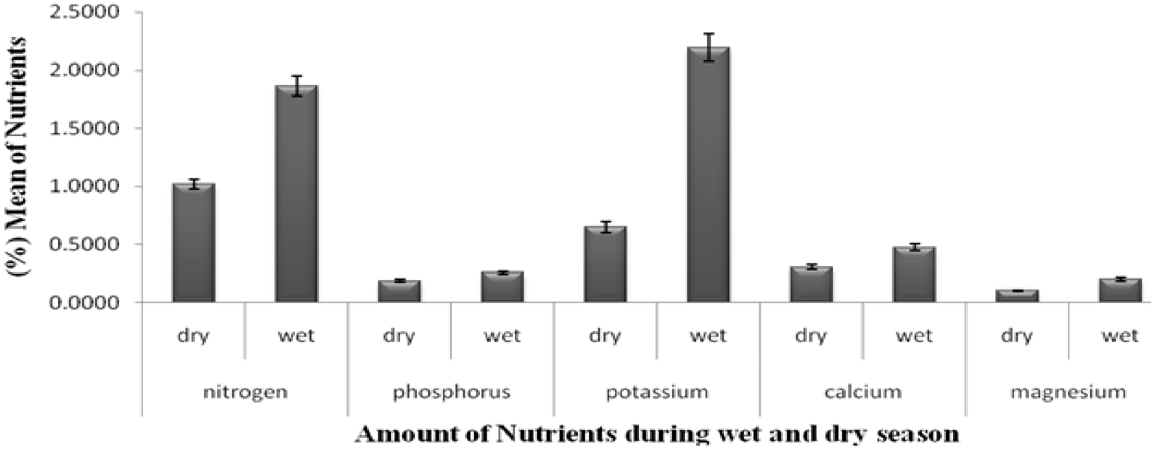

Figure 10: Amount of Macro nutrients (Mg/Kg) during wet and dry season in LWC

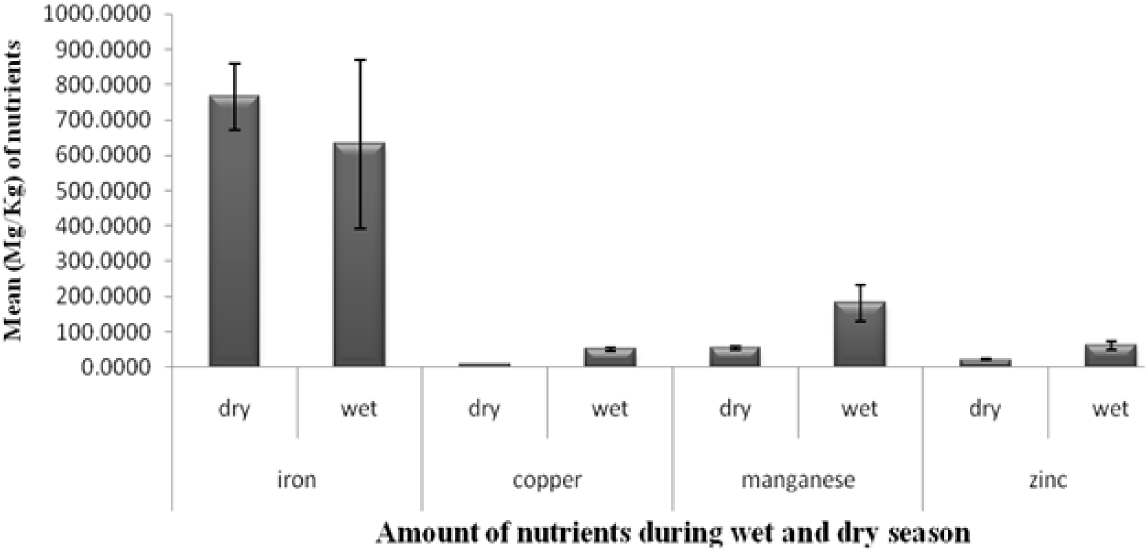

Figure 11: Amount of Micro nutrients (Mg/Kg) during wet and dry season in LWC

4.3 Grass diversity

Grass diversity was highest in control areas (0.45±0.22), moderate in the grazed areas (0.43±0.027) and lowest in the boma areas (0.28±0.024). There was a significant difference in grass diversity and the grazing treatments, ($F_{2,\ 65} = 14.437$, $p<0.0001$). Tukey test showed that control area had significantly higher diversity than grazed and boma area, (Table 8)

Table 8: Tukey test showing difference in mean diversity among different treatments

Zone	N	Subset	
		1	2
Boma	24	.2819	
grazed	24		.4316
control	24		.4464
Sig.		1.000	.900

Grass diversity was highest in boma sites designed in 2008, (0.439±0.029) followed by boma sites designed in the year 2009, (0.37±0.027) and least in boma sites designed in 2010 (0.354±0.027), and there was a significant difference in grass diversity and boma age ($F_{2,\ 65} = 3.747$, $p=0.029$). Tukey test for the boma age showed that 2008 bomas had significantly higher diversity than 2010 bomas while 2009 bomas showed ambiguous results for diversity, (Table 9).

Table 9: Tukey test showing different in mean diversity among different boma age

Year	N	Subset	
		1	2
2010	24	.3547	
2009	24	.3654	.3654
2008	24		.4397
Sig.		.949	.087

There was no significant difference in grass diversity among seasons (*P*=0.549) and soil types (*P*=0.216). However, wet season had the highest diversity (0.404±0.024) than the dry season, (0.369±0.0220), while mixed soils had the highest grass diversity (0.39±0.023) as compared to black soils (0.37±0.0245). Interaction between treatments and the boma age showed significant results ($F_{2, 65}$ =13.924; $p<0.0001$), (Figure 12), all other interaction between grass diversity and season as well as soil type showed no significant difference ($p>0.05$).

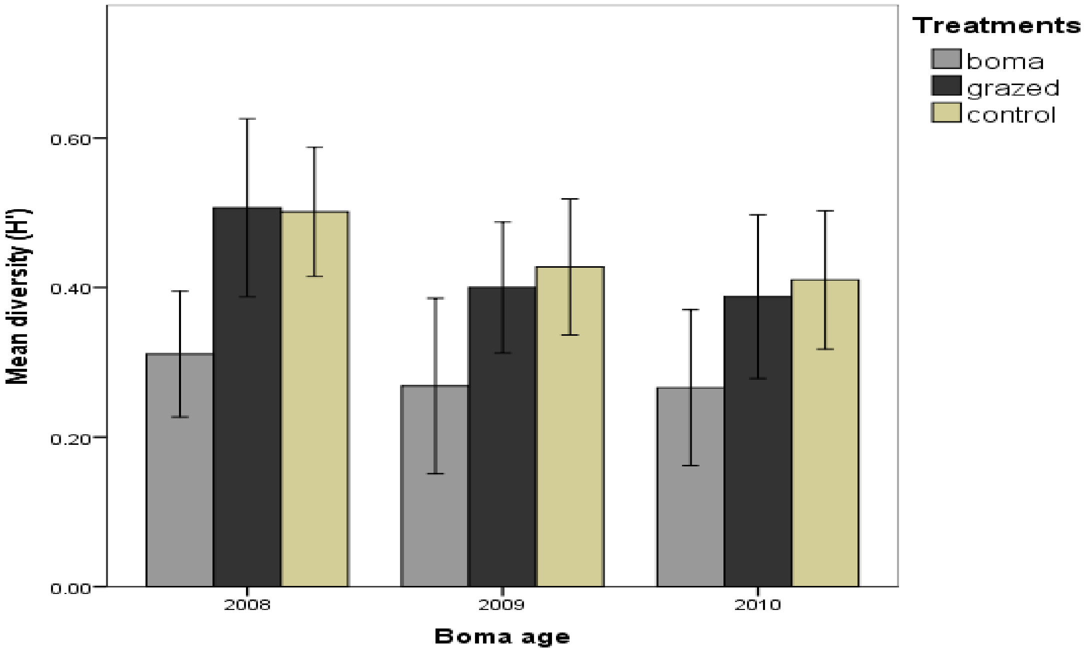

Figure 12: Mean grass diversity (H') in boma, grazed and control treatments in different boma ages

4.4 Grass biomass

Grass biomass was highest in control areas (202.570±10.855), moderate in the grazed areas (177.032±8.764) and lowest in the boma areas (103.354±5.0116). There was a significant difference in grass biomass and the grazing treatments, ($F_{2,\ 425}$ =46.696, $p<0.0001$).Tukey test showed that control area had significantly higher biomass than grazed and control area, (Table 10). Grass biomass was significantly higher ($F_{1,\ 425}$=107.172, $p<0.0001$) during the wet season than in dry season. The interaction between treatments and seasons was significant ($F_{2,\ 425}$= 27.040, $p<0.0001$), (Figure 13).

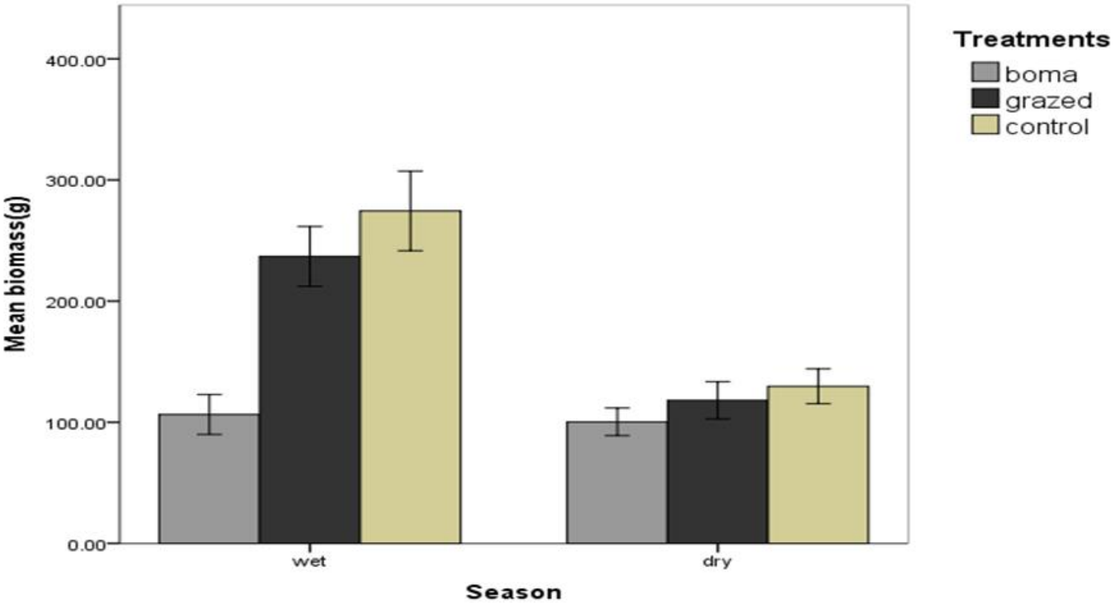

Figure 13: Mean grass biomass, in the boma, grazed and control areas during wet and dry season

Table 10: Tukey test showing the mean difference in biomass among the three treatments

zone	N	Subset for alpha = 0.05	
		1	2
boma	144	103.3549	
grazed	145		177.0316
control	143		202.5702
Sig.		1.000	.088

Mixed soils, (180.237±8.757) had significantly higher biomass ($F_{1,\ 425}$ =19.703, $p<0.0001$) than black soils (141.615±5.783), and showed significant interaction between treatments and soil types ($F_{2,\ 425}$ =10.137, $p<0.0001$), (Figure 14), while there was no significant interaction in the amount of biomass and the boma age (p=0.179),

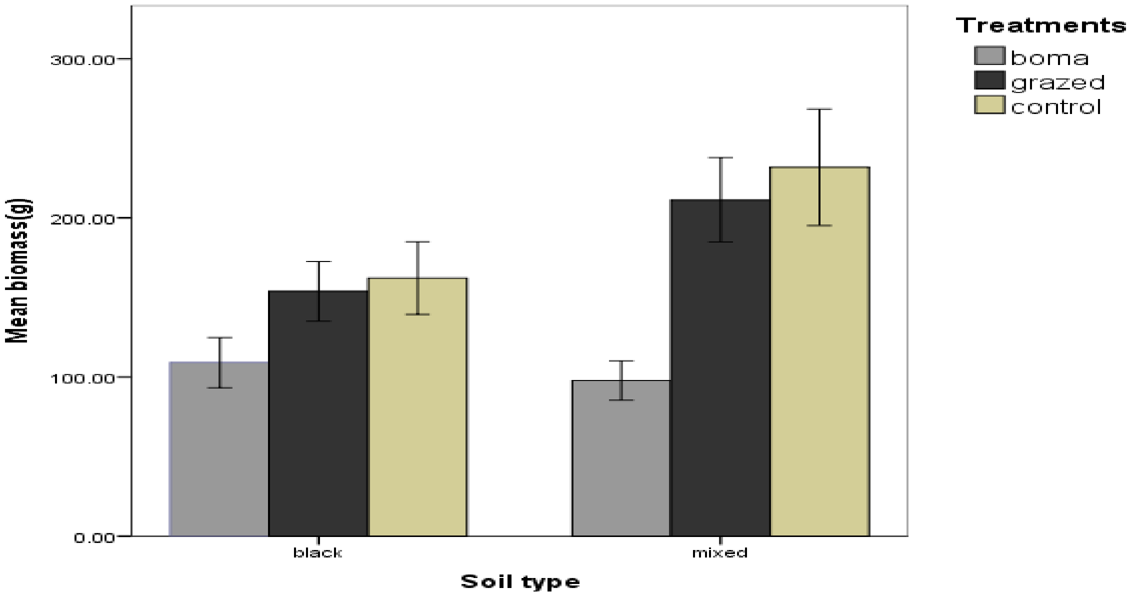

Figure 14: Grass biomass among different treatments in the mixed and black soil

CHAPTER FIVE

DISCUSSION

5.1 Habitat use by herbivores

5.1.1 Direct animal observation.

Both direct and indirect observation showed significant variations on how herbivores utilized different treatments that is, boma area, grazed and control area, as well as different activities in which animals engaged in, grazing was significantly higher in the boma area, while standing was significantly higher in the control area.

Boma area had a higher significant number of animals observed than other treatments; most notably, abandoned boma sites becomes ecosystem hot spots for variety of flora which attracts wild grazers this is as a result of livestock reducing grass cover through trampling and thus creating conditions that are beneficial to wild grazers by promoting growth of more nutritious forage plants through the removal of the residual unpalatable vegetation (Anderson and McCuistion, 2008; McCarthy, 2003).

Wet season had significantly higher number of animals as compared to dry season; this shows that, rainfall is an important factor in the regeneration of grass and other vegetation seeds which are trampled and buried in the soil by cattle; rainfall also brings about growth of soft and palatable grass species, as observed, *Pennisetum* species, which are most abundant are relatively palatable during the wet season and progressively becomes hard and fibrous during the dry season, and is thus likely to have been avoided by grazers during the dry season.

According to the boma age, bomas that were abandoned earlier in this case, 2008, had significantly higher number of animals observed than those lately abandoned, this implies that time is an important factor in the growth of new species as the response of boma sites may take several years before new species of grass start. According to (Blackmore *et al*. 1990; Reid and Ellis 1995; Augustine 2003a and Muchiru *et al*. 2009), after abandonment, a thick layer of livestock dung is left at the site and this later facilitates establishment of nutrient- rich plant communities that persist for decades to centuries. Other factors that would have contributed to higher number of animals are the diversity of grass species which were higher in old bomas than those recently abandoned.

Short closed grassland habitat had significantly higher number of herbivores compared to low open woodland and tall sparse shrub land. These areas are dominated by grasses and are characterized by vast open spaces, they are nutrient-rich from the growth and decay of deep, many-branched grass roots, and the rotted roots hold the soil together. These areas attract wild herbivores to graze on nutrient-rich grasses and rest in these open areas (Young et al. 1995; Augustine 2004; Muchiru *et al*. 2008; Veblen 2012).

5.1.2 Dung density

Boma area had significantly higher number of animal dung as compared to the grazed and control area, this was the same as to where most animals were observed, and is a clear indication that most herbivores were attracted to these areas due to reduced grass biomass and growth of soft palatable grass species.

Dry season on the other hand, had significantly higher number of dung piles compared to the wet season and this could lead to the assumption that boma areas provided other benefits to grazing animals other than availability of food, like the fact that they were open fields covered by bare grounds where by it was possible to keep an eye to the predators, also there was food availability everywhere and animals didn’t have to concentrate only on the boma sites. Other work (Veblen 2012) suggests that boma areas may serve as important wild herbivore foraging areas during the dry season, when grass is scarce in other areas.

Dung density was also significantly higher in the mixed soils than in the black soils. This might have been attributed by the fact that, mixed soils have better drainage and infiltration of water as compared to black cotton soils which are characterized by poor drainage and pronounced shrink–swell dynamics thus preventing occupancy by animals.

5.2 Grass quality

Abandoned bomas create nutrient-enriched patches within the landscape that support plant communities with mineral-rich grasses. Boma area showed highly significant amount of Magnesium as compared to grazed and control areas, and this is an essential macro nutrient that is required by animals, and wildlife can clearly benefit from the levels of these nutrient in boma grasses, which are sufficient to supply amounts recommended for lactation and pregnancy in wild ruminants (Robbins, 1993).

The high concentration of Magnesium in the boma area might have also been contributed by trampling and defecation thus increasing the nutrients in the soils; in addition cattle dung provides Phosphorous, Calcium and Magnesium in the soil. The practice of keeping cattle overnight in bomas creates fertilized patches within the landscape that provides high quality forage for wildlife, as abandoned bomas age and a grass layer develops, grasses are enriched.

Wet season had significantly higher amount of Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Copper, Manganese and Zinc as compared to the dry season, this would have resulted from dung containing high nutrients concentrations decomposing more rapidly and this is accomplished through leaching of nutrients by rainfall and water infiltration, this explains more as to why herbivores were mostly observed grazing during the wet season than the dry season. These findings suggest that glades provide an important source of nutrient-rich forage that is otherwise lacking in this relatively nutrient-poor ecosystem.

5.3 Grass diversity

Grass diversity was significantly higher in the control area than the grazed and boma area, this might have been attributed by the fact that, boma areas experienced the greatest trampling and grazing intensities and by the time of abandonment these areas are fully covered with dung thus the growth and development of new species either brought about by cattle dung that pass through digestive tracts or seed dispersed by adhering to the coats of animals would be buried due to trampling and thus would take time to regenerate in the boma area as compared to the other treatments. According to (Lauren M. and Kari E. 2015). Plant diversity losses were immediate especially occurring during boma use; On the other hand, livestock often consume and trample large amounts of plant material, and consequently increase the proportion of bare ground.

Results showed that there was significantly high grass diversity in bomas that were abandoned in the year 2008, than those abandoned in the year 2009 and recently 2010. This is a clear indication that, time is an important factor in the growth of vegetation and may also suggest that bomas through trampling reduced grass diversity which recovered after a period of time. According to (Morris *et al* 2008), grass species increases to a peak up to 20 years after a site is abandoned. Plant succession on these nutrient hotspots create a flush of grass that dominates the first twenty to sixty years post-abandonment, followed by a heavy cover of shrubs and trees.

The effect of rainfall and soil type on species diversity should, however, not be underestimated as rain enables new and existing seeds and grass butts to sprout and produce soft, green and abundant vegetation for plains game to feed on. Additionally, from the results although there was no significance difference in diversity among the season and soil types, it may be possible that rainfall was not sufficient to cause a significant alteration to grass diversity in all boma sites.

5.4 Grass biomass

Gras biomass was significantly higher in the control area than the boma and grazed areas, the reduction in biomass in the boma area was due to intensity of cattle grazing and trampling and from the findings boma area were mostly covered by bare ground and cattle dung by the time of abandonment. According to Frost and Launchbaugh, (2003), cattle have large rumens that are well adapted to ferment fibrous materials, thus they can manage fibrous herbaceous vegetation, such as dormant grasses, thus reducing the biomass.

Wet season had significantly higher biomass than the dry season; this shows rainfall play an important factor in the growth of new grass species, the tough and moribund grass that were un suitable for herbivores were smothered by effect of trampling and thus during rainy periods new soft palatable species suitable for herbivores emerges, from the findings, some of the grass species like the *pennisetum* species after undergoing trampling can recover especially after the rains. Cole (1995) found that plants with grass morphological features, like long and thin leaves, are most resistant to trampling on aboveground growth, although they have often reduced in height and in leaf length following trampling.

Mixed soils had significantly higher biomass than black cotton soils; this is attribute to the fact that mixed soils have different proportions of soil and generally are rich in nutrients, moisture and humus, than black cotton soils which are characterized by stressful shrink–swell dynamics. In addition, less palatable species may be more abundant on black cotton soils, dampening the response in these systems Goheen & Palmer (2010).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From this study, the following were the main conclusions

- The wide spread use of cattle bomas is based primarily on the need to protect cattle from theft and predation overnight, but it has a long term implications for nutrient redistribution within the landscape due to defecation and urination and subsequent effects on wildlife habitat. Nutrient enriched grassland patches persist on abandoned bomas thus strong selection of these patches by herbivores

- Boma recovery after abandonment requires considerable amount of time and rainfall before the growth of new grass species, this is due to intensive trampling and the level of cattle dung that covers the boma, thus diversity of grass is low on boma areas

- Thick and high moribund grass are not preferred by grazing wild animals and thus these areas are under utilized by wild animals due to increased fuel loads, through cattle grazing and trampling, moribund grass are reduced and this creates short grass lawns which are soft and palatable and attracts grazing animals.

6.2 Recommendations

- Wildlife Managers should consider the long-term implications for nutrient redistribution within the landscape and subsequent effects on wildlife habitat, ranch managers therefore can manipulate the long-term distribution and abundance of grazing animals on rangelands through careful consideration of boma placement and relocation rates.

- Land managers should implement grazing strategies that mitigate the effects of excessive livestock grazing by modifying the timing and duration of use. The timing of herbivory can have a significant impact on plant productivity and vigor, especially if livestock are repeatedly present during plant growth and reproductive stages. The duration of grazing should be brief to permit photosynthesis and plant recovery. If grazing is properly managed during these critical periods, plants are permitted to build their root systems and increase nutrient storage. Subsequently, plants become more robust, the likelihood of survival increases, and the overall forage production increases.

- In the case of endangered species, Lewa is a strong hold for the Grevy‘s zebras, rank grass and presence of livestock deter Grevy’s zebra from utilizing such areas. Thus it is recommended on properly managed and specialized livestock grazing systems that can maintain or improve habitat for wildlife especially the Grevy’s zebra. If vegetation is improved, then the numbers could be improved due to improved quality grassland that have a diversity of grasses including *cynadon* species which are highly preferred by lactating Grevy’s zebras

6.3 Way forward

- More study to be done to investigate other benefits of cattle boma to wild animals

REFERENCES

Altmann (1974). *Observational Study of Behavior: Sampling Methods* Vol. 49, No. 3/4 (1974), pp. 227-267

Anderson, E. W. and R. J. Scherzinger. (1975).Improving quality of winter forage for elk by Cattle grazing. *Journal of Range Management* 28(2): 120-125.

Anderson, A. and K. C. McCuistion. (2008). Evaluating strategies for ranching in the 21st century: successfully managing rangeland for wildlife and livestock. 30(2): 8-14.

Archibald, S. and Bond, W. J. (2004). Grazer movements: spatial and temporal responses to burning in a tall-grass African savanna. *International Journal of Wild land Fire* 13: 377-385.

Archibald, S., Bond, W.J., Stock, W.D. and Fairbanks, D.H.K. (2004). Shaping the landscape: fire grazing interactions in an African savanna. *Ecological Applications* 15: 96-109.

Atickem A, Williams S, Bekele A, Thirgood S. (2010) Livestock predation in the Bale Mountains, Ethiopia. *African Journal of Ecology* 48:1076–1082

Augustine (2003a). Long-term, livestock-mediated redistribution of nitrogen and phosphorous in an East African savanna. *Journal of Applied Ecology* 40:137–149

Augustine D J. (2004). Influence of cattle management on habitat selection by impala on central Kenyan rangeland. *Journal of Wildlife Management* 68:916–923

Blackmore AC, Mentis MT, Scholes RJ. (1990).The origin and extent of nutrient-enriched patches within a nutrient-poor savanna in South Africa. *Journal of Biogeography* 17:463–470

Bleich,V. C., J. G. Kie, E. R. Loft, T. R. Stephenson, M. W. Oehler, and A. L. Medina. (2005). Managing rangelands for wildlife. In: C. E. Braun (Ed.). Techniques for Wildlife Investigations and Management (pp. 873-897).

Beck, J. L., and D. L. Mitchell. (2000). Influences of livestock grazing on sage grouse habitat *Wildlife Society Bulletin* 28(4): 993-1002.

Bock, C. E., V. A. Saab, T. D. Rich, and D. S. Dobkin. (1993). Effects of livestock grazing on Neotropical migratory land birds in western North America. In: D. M. Finch, and P. W. Stangel (Eds.). *Status and management of neotropical migratory birds* (pp. 296-309). *United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report* RM-229.Fort Collins, Colorado.

Botha J.O., (1999). *A resource management plan for the Lewa Wildlife Conservancy in the Meru District of the central Kenyan highlands. Msc (Wildlife Management) thesis.* University of Pretoria, Pretoria.

Chaikina, N. A., and K. E. Ruckstuhl. (2006). The effect of cattle grazing on native ungulates: the good, the bad, and the ugly. Rangelands 28(3): 8-14.

Chris, T. and Stuart.T, (1994). *A field guide to the tracks and signs of southern and east African Wildlife.* Southern Publishers.

Cole, D.N. (1995). Experimental trampling of vegetation: Relationship between trampling intensity and vegetation response. *Journal of Applied Ecology* 32:203-214.

Davison, J. (1996). Livestock grazing in wild land fuel management programs. Rangelands 18(6): 242-245.

DiTomaso, J. M. (2000). Invasive weeds in rangelands: species, impacts, and management. Weed Science 48:255-265.

Dunham K M, Robertson E F, Swanepoel C M (2003) Population decline of tsessebe antelope (*Damaliscus lunatuslunatus*) on a mixed cattle and wildlife ranch in Zimbabwe. *Biological Conservation* 113:111–124

Edwards and Bogdan (1951). Important grassland plants in Kenya.

Fitch, L., and B. W. Adams. (1998). Can cows and fish co-exist? *Canadian Journal of Plant Science*78: 191-198.

Fleischner, T.L. (1994). Ecological costs of livestock grazing in western North America. *Conservation Biology* 8(3): 629-644.

Forest Resources Assessment Programme. (2001). Global Forest Fire Assessment 1999-2000.

Frost, R. A., and K. L. Launch Baugh. (2003). Prescription grazing for rangeland weed management: a new look at an old tool. Rangelands 25(6): 43-47.

Goheen J R, Palmer T M. (2010). Defensive plant-ants stabilize mega herbivore-driven landscape change in an African savanna. *Current Biology*. 20:1768–1772

Goheen J R, Palmer T M, Keesing F, Riginos C, Young T P. (2010) Large herbivores facilitate savanna tree establishment through diverse and indirect pathways. *Journal of Animal Ecology*; 79:372–382.

Grootenhuis J G (Ed) (1999). *25 Years of wildlife disease research in Kenya*, Nairobi. Kenya Agricultural Research Institute, Nairobi, Kenya

Gureja, N. and Owen-Smith, N. (2002).Comparative use of burned grassland by rare antelope species in a low veld ranch, South Africa. *South African Journal of Wildlife Research* 32:31-38.

Holechek, J. L., R. D. Pieper, and C. H. Herbel. (1998). *Range management principles and practices.* 3rdedition. Prentice Hall. 542pp.

Heitschmidt, R.K., M.M. Kothmann, and W.J. Rawlins. (1982b). Cow-calf response to stocking rates, grazing systems, and winter supplementation at the Texas Experimental Station. *J. Range Management.* 35:204-210.

Kaufman, J. B., and W. C. Krueger, (1984). Livestock impacts on riparian ecosystems and streamside management implications…a review. *Journal of Range Management* 37(5): 430-438.

Keppel, W. (2005).Animal impact: How trampling and disturbance benefit grassland ecosystems.

Knapp, P. A. (1996).Cheat grass (*Bromustectorum L.)* dominance in the Great Basin Desert: history, persistence, and influences to human activities. *Global Environmental Change* 6(1): 37 52.

Komarek, E.V., (1965). Fire Ecology: Grasslands and man. *Proceedings, Tall Timbers Fire EcologyConference***4***, 169-220.*

Lauren M. Porensky and kari E. Veblen (2015). Generation of Ecosystem Hotspots using short term cattle corrals in an African Savanna.

Lewa Wildlife Conservancy. (2007). Community livestock grazing programme on Lewa [online] Available from: http://www.lewa.org/grevys_zebra_at_lewa.php (cited 17 January 2009).

Linsen L. & Giesen, W., (1983). An ecological study of Lewa Downs, seasonally dry, central Kenyan grassland. University of Nijmegen, Nijmegen.

Low, B., chege, G., Kisio, E., Mwololo, M., Kirathe, J.,& Njonjo, D. (2005) *Lewa Wildlife Conservancy: Research & Monitoring Annual Report 2004.* Lewa Wildlife Conservancy, Isiolo, Kenya.

Loeser, M. R., T. D. Sisk, and T. E. Crews. (2001). Plant community responses to livestock grazing: an assessment of alternative management practices in semiarid grassland. In R. K. Vance, C. B. Ed minster, W.Covington, W. Wallace, and J. A. Blake (Eds.). *Ponderosa Pine Ecosystems Restoration and Conservation: Steps Toward Stewardship* (pp. 80-87). United State Department ofAgriculture, Forest Service, Rocky Mountain Research Station, Proceedings RMRS-P-22. Ogden, Utah.

Mac Arthur R.H. (1965). Patterns of species diversity. Biol. Rev, 40 510-533

Masters, R. A., and R. L. Sheley. (2001). Principles and practices for managing rangeland invasive plants. *Journal of Range Management* 54(5): 502-517.

McCarthy, J. J. (2003). Results from the use of a system of “rest rotational grazing” for livestock to improve wildlife habitat in Montana. *Journal of Mountain Ecology 7* (Supplement): 13-16.

Menke, J. and G.E. Bradford. (1992). Rangelands, Agriculture, Ecosystems and Environment.42:141-163.

Milchunas, D. G. (2006).Responses of plant communities to grazing in the southwestern United States. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-169. Fort Collins, Colorado.

Moe, S. R., Wegge, P. and Kapela, E. B. (1990).The influence of man-made fires on large wild herbivores in Lake Burungi in northern Tanzania. *African Journal of Ecology* 28: 35-43.

Morris *et al* (2008), Pastoralist livestock and settlements influence game bird diversity and abundance in a savannah ecosystem of Southern Kenya

Muchiru A N, Western D J, Reid R S (2008). The role of abandoned pastoral settlements in the dynamics of African large herbivore communities. *Journal of Arid Environments* 72:940–952

Muchiru A N, Western D, Reid R S (2009).The impact of abandoned pastoral settlements on plant and nutrient succession in an African savanna ecosystem. *Journal of Arid Environments* 73:322–331

Nader, G., Z. Henkin, E. Smith, R. Ingram, and N. Narvaez. (2007). Planned herbivory in the Management of wildfire fuels. *Rangelands* 29(5): 18-24.

Odadi W O, Abdulrazak A S, Karachi MM, Young T P (2011) African wild ungulates compete with or facilitate cattle depending on season. Science 333:1755–1757

Olff H, Ritchie M E (1998). Effects of herbivores on grassland plant diversity. Trends *in Ecology and Evolution*; 13:261–265.

Orodho, A. B., M. J. Trlica, and C. D. Bonham. (1990). Long-term heavy-grazing effects on soil and vegetation in the four corners region. *The Southwestern Naturalist* 35(1): 9-14.

Popolizio, C. A., H. Goetz, and P. L. Chapman. (1994). Short-term response of riparian vegetation to grazing treatments. *Journal of Range Management* 47(1): 48-53.

Pratt, D. J & Gwynne, M.D., (1977). *Rangeland management and ecology in East Africa*. Hodder and Stoughton, London.

Reid R S, Ellis J E (1995). Impacts of pastoralists on woodlands in South Turkana, Kenya: Livestock-mediated tree recruitment. *Ecological Applications* 5:978–992

Reynolds, T.D. and C.H. Trost. (1980).The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. *J. Range Management*. 33:122-125.

Riginos C. & Young TP. (2007). Positive and negative effects of grasses and wild and domestic herbivores on *Acacia* saplings. Oecologia; 153:985–995.

Riginos R, Porensky L M, Veblen K E, Odadi W O, Sensenig R L, Keesing F, Kimuyu D, Wilkerson M L. & Young T P. (2012). Lessons on the relationship between pastoralism and biodiversity from the Kenya Long-term Exclosure Experiment (KLEE) Pastoralism: Research, Policy and Practice.

Robbins, C.T. (1993) *Wildlife Feeding and Nutrition*. Academic Press, New York, NY.

Sandford, S. (2006).*Too many people, too few livestock: The crisis affecting pastoralists in the greater horn of Africa.*

Savory A. & Butterfield J (1999). *Holistic management: A new frame work for decision making*. 2nd ed. Tucson, A Z: Island press

Shannon, C.E. and Wiener, W. (1963). *The mathematical theory of communication,* University of Illinois Press, Urbana, USA.

Society for Range Management. (n.d).Biodiversity of rangelands, Available online at http://www.rangelands.org/pdf/Biodiversity_Issue_Paper_FA.pdf

Sutherland, W.J., (2000). *The Conservation Hand book Research, Management and Policy.* Cambridge University Press.

Taylor, N., J. E. Knight, and J. J. Short. (2004). Fall cattle grazing versus mowing to increase big game forage. *Wildlife Society Bulletin* 32(2): 449-455.

Tomor, B. M. and Owen-Smith, N. (2002). Comparative use of grass regrowth following burns by four ungulate species in Nylsvley Nature Reserve, South Africa. *African Journal of Ecology*40: 201-204.

Tobler M W, Cochard R. & Edwards PJ. (2003); The impact of cattle ranching on large-scale vegetation patterns in a coastal savannah in Tanzania. *Journal of Applied Ecology*; 40:430–444.

Trollope, W.S.W., (1983). *Control of Bush Encroachment with Fire in the Arid Savanna of Southeastern Africa.* PhD Thesis, University of Natal, Pietermaritzburg.

Trollope, W.S.W., (1989). Veld burning as a Management practice in Livestock Production. In: *Veld management in the Eastern Cape*, ed. J.E. Danckwerts and W.R. Teague, 67-73. Pretoria: Government Printer.

Trollope, W. S. W., (1990). Veld management with specific reference to game ranching in the grassland and savanna areas of South Africa. *Koedoe* **33**(2), 77-86.

Trollope, W.S.W. & Trollope, L. A., (1999). Report on the Assessment of Range Condition and the Fire Ecology of the Savanna Vegetation on the Lewa Wildlife Conservancy in Kenya – 1998.University of Fort Hare. Dept. of Livestock and Pasture Science.

Trollope, W.S.W., & Trollope, L. A., (2004).Prescribed burning in African grasslands and Savannas for wildlife management. *Arid lands Newsletter* **55**.

Vavra, M. (2005). Livestock grazing and wildlife: developing compatibilities. *Rangeland Ecology and Management* 58(2): 128-134.

Vavra, M., C. G. Parks, and M. J. Wisdom. (2007). Biodiversity, exotic plant species, and herbivory the good, the bad, and the ungulate. *Forest Ecology and Management* 246: 66-72.

Vázquez D P, Simberloff D. (2004); Indirect effects of an introduced ungulate on pollination and plant reproduction. *Ecological Monographs*. 74:281–308.

Veblen K E & Young T P. (2010) Contrasting effects of cattle and wildlife on the vegetation development of a savannah landscape mosaic. *Journal of Ecology*; 98:993–1001.

Veblen K E (2012). Savanna glade hotspots: plant community development and synergy with large herbivores. *Journal of Arid Environments* 78:119–127

Wallace, J. M., L. M. Wilson, and K. L. Launch Baugh.(2008). The effect of targeted grazing and biological control on yellow star thistle (Centaurea solstitialis) in canyon grasslands of Idaho. *Rangeland Ecology and Management* 61: 314-320.

Webb, R.H. and S.S. Stielstra. (1979). Sheep grazing effects on Mojave Desert vegetation and soils. *Environmental Management*. 3:517-529.

West, N. E. (1993). Biodiversity of rangelands. *J ournal of Range Management* 46(1): 2-13.

Young T P, Patridge N, Macrae A (1995) Long-term glades in acacia bush land and their edge effects in Laikipia, Kenya. *Ecological Applications* 5:97–108

APPENDIX 1

Botanical names of grass species found in Lewa Wildlife Conservancy that contributed to the species diversity for this study.

i. *Aristida kenyensis*
ii. *Brachiaria dictyoneum*
iii. *Brachiaria eruciformis*
iv. *Cenchrus ciliaris*
v. *Cynodon dactylon*
vi. *Digitaria abyssinica*
vii. *Digitaria milanjia*
viii. *Digitaria nuda*
ix. *Digitaria velutina*
x. *Eragrostis cilianensis*
xi. *Eragrostis superba*
xii. *Eriochloa nubica*
xiii. *Heteropogon contortus*
xiv. *Heterepogon melenocarpus*
xv. *Lintonia nutans*
xvi. *Microchloa kunthii*
xvii. *Panicum Poaeoides*
xviii. *Paspalum glumaceum*
xix. *Pennisetum maasaicum*
xx. *Pennisetum mezianum*
xxi. *Pennisetum stramenium*

xxii. Sedge- *Cyperus*
xxiii. *Sehima nervosum*
xxiv. *Setaria acromelaena*
xxv. *Setaria pumila*
xxvi. *Sorghum Purpureo sericeum*
xxvii. *Sporobolus pyramidalis*
xxviii. *Themeda triandra*