ECOLOGICAL FACTORS INFLUENCING LARGE HERBIVORE DISTRIBUTION IN RUMA NATIONAL PARK OF HOMABAY COUNTY, KENYA

BY

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ABSTRACT

Understanding ecological factors influencing large grazing herbivores distribution (LHD) in terrestrial ecosystems is a fundamental goal of ecology. However, herbivores are distributed in areas where they can maximize their energy gains within the natural constraints imposed by biotic and abiotic factors. Studies have shown that ecological factors variably influence LHD in savannah ecosystems. However, in Ruma National Park no research has been done to establish ecological factors that influence LHD in spite being a fragile fragmented ecosystem. The specific objectives were to: determine influence of grass biomass on LHD; assess relationship between grass species richness (GSR) and LHD; find out effect of altitude and water sources on LHD and determine the influence of mean monthly rainfall on LHD. This study adopted cross-sectional correlational, experimental and longitudinal research design. The study area was stratified into escarpment, riverine forest and wooded grassland using contours. Systematic sampling was done to get biomass sample plots by dividing the Park into 1km^2 grids, oriented transects south East to North west across the strata, purposely selected the first plot and got the next plot on 3km along the transect with 6, 12 and 18 plots respectively. Grass was clipped from 4 randomly selected quadrants in every 1km^2 in the 9 grids and air dried to constant weight for biomass estimation. GSR was visually counted from the subplots. Mean monthly rainfall emanated from Ruma weather stations for analysis. Contours were used for stratification and sample plot locations and altitudes were georeferenced using a GPS. Quantitative data were analyzed using least squares linear regression and multiple regressions. Results were presented in tables, scatter graphs and maps. Results show that mean grass biomass in Ruma National Park varied from 163g/m^2 to 1940g/m^2. The relationship (R^2=0.83, P=0.0001), indicated that 83% of the variation on LHD was accounted for by grass biomass. Positive associated (R^2=0.66, P=0.0001), demonstrated that 66% of the variation on LHD was explained by GSR with *Themeda triandra* being abundant. Mean monthly rainfall (R^2=0.51, P=0.001) explained 51% of the variation on LHD. Multiple regression (R^2=0.33, P=0.001) show that water sources and altitude explained 33% of the variation on the LHD with water sources (t=3.02) variation being higher than altitude (t=1.4). High rainfall had low LHD in the Park plains due to flooding. In conclusion the main ecological factors that best predict LHD are grass biomass and GSR. Therefore, there is need to conserve ecological factors such as grass biomass and GRS in Ruma National Park.

CHAPTER ONE

INTRODUCTION

1.1: Background to the study

Ecological factors influencing large herbivore distribution (LHD) are biotic and abiotic in nature. Biotic factors are the living components that shape an ecosystem whereas abiotic factors are non-living components of an organism's environment (Redfern *et al.*, 2003). Many landscape-scale models of large herbivore distribution focus primarily on the role of biotic factors such as forage quality and quantity (Redfern *et al.*, 2003). Methods for predicting species richness are increasingly being developed (Guisan & Zimmermann, 2000). These methods focus either on the prediction of vegetation distribution throughout an area (Gelfand *et al.*, 2006) or the computation of habitat suitability (HS) for certain animal species (Dettki *et al.*, 2003). Globally many landscape-scale models of herbivore distribution (HD) focus primarily on the role of biotic factors such as forage quality and quantity as opposed to the influence of the biotic factors on LHD thus failing to address the causes of environmental degradation that occur in Parks.

Animal welfare whether domestic or wild begin with the assessment of the primary production to ascertain availability and suitability. In Finland biomass assessment was done to show seasonal biomass changes and show what was present at a given time in different seasons (Colpaert *et al.*, 1995). Whereas in the Canadian University of Guelph, biomass assessment was carried out to verify the viability of commercial cultivation for bio-energy and bio-material applications since environmental impact of growing switch grass in Ontario was lacking (Carita, 2012). Evaluation of biomass in Finland and Ontario was entirely for the net worth of the rangeland and energy production respectively. Biomass is one of the ecological factors which is highly related to the herbivore distribution across the range and the densities of the large herbivore distributed in an area lead to environmental degradation and eventual extinction of the endemic rare and endangered species. There is need to understand the relationship between biomass as an ecological factor on the LHD.

Permanent grasslands including pastures occupy approximately 26% of the land surface of the Earth providing a large proportion of the diet for domestic and wild animal populations (FAO, 1996). Thus quality or quantity coupled with species diversity affect distribution of free ranging herbivores. To ensure correct management of such important resource, it is necessary to precisely monitor its production. Remote sensing provides an alternative mode of estimating grass biomass and vegetation community structure over very large areas at a reasonable cost (Mino *et al.*, 1998). Redfern *et al.*, (2003) predicted that herbivores in African savannah ecosystems must meet their nutritional requirements within the constraints of water availability, and found this to be the case for all water-dependent or semi water-dependent species in the Kruger National Park, South Africa. Sinclair (1985) found out that in the dry season in the Serengeti, zebra preferred areas with the tallest grass. Therefore, in arid or semi-arid landscape herbivores compromise closeness to water for forage availability (Bergstrom & Skarpe, 1999). Such a compromise is made possible by the degree of elasticity of their intrinsic constraints (Owen-Smith, 1993), which allow herbivores to increase their foraging distances when the benefits provided by distant forage outweigh the costs of travel (Brooks & Harris, 2008). This would only be possible, however, if the animals could walk to water when necessary (Owen-Smith, 1993). However, FAO (1996) focused on global area under grasslands, Redfern *et al.*, (2003) focused on the relationship between grass biomass and distance to water in Kruger National Park and Serengeti National Park respectively. None of these studies considered relationship of the water sources as an ecological factor to the

LHD. This study addressed the relationship of water sources to the LHD to better understand their relation since the study area is a National Park whose mandate is conservation for promoting tourism which depends on the LHD.

Herbivores locate themselves in areas where they can maximize their energy gains (Bailey *et al.*, 1996) within the natural constraints imposed by abiotic factors such as slope and distance to water but the negative relationship between wild grazer density and the organic matter digestibility of grass has not easily been explained, and merited further investigation. This appeared contrary to the suggestion that many species of wildlife preferred areas of lower biomass (Estes, 1997), since that indicated better food quality (Bergstrom & Skarpe, 1999). Sinclair (1974) found that, in the dry season in the Serengeti, buffalo expanded their diets to include lower quality grass components but maintained their minimum nutritional intake rate by selecting rare high quality grass. Zebra needed to eat considerable quantities of grass to fulfill their nutrient requirements (Estes, 1997).

In Athi-Kapiti plains Machakos, assessment of the effect of long-term biomass mowing and ungulate exclusion on grass species composition and soil nutrient status was done and significant changes noted in grass species (Berliner and Kioko, 1999). Distribution of free-grazing herbivores was a major issue facing rangelands managers (Taylor & Walker, 1978). The common theme was LHD in relation to nutrient extraction and ecosystem impact. In some circumstances, uneven grazing exacerbates deteriorative processes such as soil erosion (Holechek *et al.*, 1989). Thus understanding spatial-temporal dynamics of landscape use by free-grazing herbivores is critical for ecosystem management (Coughenour, 1991). Herbivores tend to select their diet mainly by grazing on certain grass species (Taylor & Walker, 1978). The studies by Taylor and Walker (1978), Berliner and Kioko (1999) were interested on the selection of the grass species by herbivores rather than relating the grass species to the LHD. Coughenour (1991) embarked on the spatial temporal dynamics of the free-grazing herbivores rather than the grass species as a determinant of LHD. Abundance of certain grass species is a factor that influences LHD in some parts of the park compared to others. Furthermore the Grass Species Richness (GSR) is an explanatory quality factor for herbivore habitat selection that needed to be assessed in relation to LHD and environmental conservation bearing in mind that Ruma National Park is presently an ecological island without outlets and inlets because of the electric perimeter fence erected to mitigate human wildlife conflicts.

Overall scarcity of forage, availability of water, competitive interactions with other wildlife or livestock and the effects of predation are some of the natural restrictions on LHD (Sinclair, 1985) but Redfern *et al.*, (2003) argued that a combination of both biotic and abiotic factors are particularly important in determining the distribution patterns of large herbivores in African savannah ecosystems. However, Bailey *et al.*, (1996) suggested that abiotic factors, such as slope and distance to water, are equally as important and can act as the primary determinants of large scale distribution patterns. Spatial dynamics in the landscape by free-ranging herbivores is integral to a successful ecosystem management but many landscape-scale models of HD focus primarily on the role of biotic factors such as forage quality and quantity (Redfern *et al.*, 2003). Large herbivores spend most time in areas where the available quantity and quality of forage is highest (Bailey *et al.*, 1996) which was in agreement with Estes (1997). However, the relationship of altitude and water sources on LHD in Ruma National Park was not well understood.

Previous work suggests that African herbivore distribution and community structure are primarily determined by rainfall and the nutrient status of the soil, via their effects on the quantity and quality of the primary production (Coe *et al.*, 1976). Coe *et al.*, (1976) proposed a model describing the variation in biomass of the ungulate communities based on annual rainfall, a good predictor of primary production across the globe (Lauenroth, 1979), and specifically in sub-Saharan Africa (Desmukh, 1984). The model explained a large proportion of the variance in ungulate biomass, but it has been criticized for the limited range of annual rainfall covered (100-700 mm) and the fact that it does not take into account the soil nutrient status (Bell, 1982) and other factors which influence the quantity and quality of plant resources, such as the grazing process itself (McNaughton & Georgiadis, 1986). Rainfall as an ecological factor was used modelling grass biomass production. This study on the relationship of the mean monthly rainfall on the LHD has not received any attention though being very important and unique for Ruma National by virtue of it being partly in the valley and partly on the escarpment which promotes flash floods to the Valley bottom and water logging.

Serengeti ecosystem was divided into two components: (1) open grasslands with low annual rainfall (600 mm) that support an extensive cover of short grasses; and (2) wooded grasslands in areas with higher rainfall (1000 mm) that support tall, highly lignified grasses (McNaughton, 1979). Rainfall was the most important factor influencing primary productivity of both grassland types (McNaughton, 1985). Most rainfall occurs from November to May, with occasional dry periods in January and February (Norton-Griffiths *et al.*, 1997). As a result, grass growth shows pronounced spatial and seasonal variation (McNaughton, 1985). Wildebeest exhibit seasonal shifts in habitat use, migrating from open grass- lands that are used during the wet season to wooded grasslands in higher-rainfall areas that are used during the dry season (Maddock, 1979). Rainfall forms an interface between migration from the open grasslands and the wooded grasslands whereas this study was interested in providing alternative LHD locations during the rainy season.

Although the general factors controlling the stable expansive grass and scattered trees were climate, fire and herbivory (Smith, 1999), different researchers differed in their approach on the ecosystem variables. For instance, Augustine and McNaughton (2006) focused on migratory habit of wild ungulates, while Aranibar *et al*., (2004), Caylor *et al*., (2005) and Wang *et al*., (2009) focused on rainfall and trees leaving the grasses which support the large number of herbivores in the trophic levels unattended. This created a knowledge gap that required urgent attention to show the relationship between the grass biomass and rainfall on the distribution of large herbivores. Despite the enormous scientific attention in this Ruma National Park owing to tsetse and its control, there was no study done on ecological factors like grass biomass, grass species richness, altitude, water and rainfall and their relationship to the distribution of the large herbivores.

Oba (2000) noted that land-cover change in the rangelands can be manifested in different ways, including bush encroachment, increased bare ground, reduced herbaceous biomass, changes in species diversity, and more profoundly, reduced crop productivity in cultivated areas. Ruma National Park, in the Lambwe Valley, is a high potential rangeland, surrounded by a community of cultivators (Republic of Kenya, 1984). Ecological stress is manifested by growth of bush cover, which is a common cause of herbaceous vegetation loss in dry savannahs, and is responsible for a decline in range condition (Oba, 2000). Bush cover becomes a problem when it exceeds 30% and induces a decline in range condition, and is symptomatic of rangelands where the production systems are under environmental stress (Wijngaarden, 1985). Studies done in the Lambwe Valley focused the efforts in the bush encroachments and the reduction in herbaceous biomass as opposed to the ecological factors influencing the LHD in Ruma National Park. The current study provides baseline information on ecological factors influencing the LHD which had been lacking besides basis for further research.

1.2: Statement of the problem

Many landscape-scale models of herbivore distribution focus primarily on the role of biotic factors such as forage quality and quantity. Yet, the abiotic factors that are also important in determining the number of the LHD in an ecosystem are not well understood. Moreover, the relative importance of biotic and abiotic factors has not been quantified, particularly in semi-arid fragmented ecosystems that are subjected to heavy human pressure such as Ruma National Park. In the past studies evaluation of biomass was entirely for the net worth of the rangeland bio-fuel energy and range productivity as opposed to influence on the LHD in a fragmented savannah ecosystem such as Ruma National Park

Large herbivores locate themselves in areas where they can maximize their energy gains in African savannah ecosystems. Previous studies have focused on the preference of the quality of grass by grazers to maximize their energy gains. Moreover, these studies focused on distribution and temporal dynamics of the grazing herbivores in relation to nutrient extraction and ecosystem impact. However, there is inadequate understanding of the influence of biomass and the GSR on LHD.

It was suggested that abiotic factors, such as slope and distance to water, are equally as important and can act as the primary determinants of large scale distribution patterns. However, the effect of altitude and water on LHD in Ruma National Park was not well understood. In addition, there was inadequate information on the influence of altitude and distance to water on LHD. Large herbivores exhibit seasonal shifts in habitat use, migrating from open grasslands that are used during the wet season to wooded grasslands in higher-rainfall areas that are used during the dry season and thus rainfall formed an interface between migration from the open grasslands and the wooded grasslands whereas this study was interested in the influence of mean monthly rainfall to LHD.

Despite many studies done in Ruma National Park owing to tsetse and its control, there is no study done on ecological factors like grass biomass, grass species richness, landscape and water and rainfall and their influence on LHD which are the hosts to the pests. Studies that have been carried out in the Lambwe valley have focused on the bush encroachments and the reduction in herbaceous biomass. However, no study has been done focusing on ecological factors influencing LHD in Ruma National Park. Therefore, the purpose of this study was to provide baseline information on ecological factors influencing LHD in Ruma National Park.

1.3: Objective of the study

The general objective of the study was to assess ecological factors influencing LHD in Ruma National Park.

Specific objectives are:

1. To determine the influence of grass biomass on LHD.
2. To assess the effect of grass species richness and LHD.
3. To find out the effect of altitude and water sources on LHD.
4. To determine the influence of mean monthly rainfall on LHD.

1.4: Research hypothesis

1. H_0: There is no significant influence of grass biomass on LHD
2. H_0: There is no significant effect of grass species richness on the LHD
3. H_0: There is no significant effect of altitude and water sources on LHD

4. H_0: There is no significant influence of mean monthly rainfall on LHD

1.5: Significance of the study

The study addressed the knowledge gaps from previous research, provided new knowledge and laid basis for further research. This study has shown the relationships between biomass and LHD, grass species richness and large herbivore distribution, altitude and water sources on the LHD and mean monthly rainfall on LHD which the studies by the researchers in the background of the study hadn't covered. No comprehensive research has been done on ecological factors influencing large herbivore distribution in the study area. Past studies (Allsopp, 1979; Parkinson, 1972) were based on observations without any statistical analysis whilst others are brief published and unpublished reports (Kones, 2005; Muriuki, 1995; Olubayo *et al.*, 1997). This study is important and vital in safeguarding the ecological integrity, basis for environmental degradation monitoring and tourism visitation planning through the acquired knowledge of LHD to enhance revenue generation for environmental conservation in Ruma National Park.

1.6: Scope and limitations of the study

This study was done in the 120km^2 of Ruma National Park. This refers to the area that is contained in the Legal Notice Number 77 (1966). The study was also limited to grass biomass, GSR, mean monthly rainfall, water sources and altitude and how they relate to the LHD in Ruma National Park. This study covers cross-sectional correlational, experimental and longitudinal research designs. The analysis is limited to linear and multiple regressions in conjunction to data collected in six months from January to June 2014.

CHAPTER TWO

LITERATURE REVIEW

2.1: Introduction

This chapter describes the relation of grass biomass on the large herbivore distribution, effect of GSR on the large herbivore distribution, effect of altitude and water sources large herbivore distribution, influence of rainfall on large herbivore distribution, gaps identified in the previous studies and the conceptual framework to this study.

2.2: Grass biomass and large herbivores distribution

Methods for predicting species distribution had been developed (Guisan & Zimmermann, 2000). These methods focus either on the prediction of vegetation distribution in space (Gelfand *et al.*, 2006) or the on habitat suitability (HS) for certain animal species (Dettki *et al.*, 2003; Hirzel *et al.*, 2002) and the co-relation to grazing herbivores distribution in an ecosystem. Almost all rangelands grazed continuously without any restriction on stocking rate lead to deterioration of the range (Holechek *et al.*, 1989). Thus selecting the proper stocking rate to a particular range site is the most important of all management decisions from the stand point of vegetation, livestock, wildlife and economic returns (Holechek *et al.*, 1989) and depends on the production of the range coupled with the average level of use that the principal range species can tolerate (Stoddart *et al.*, 1975). However relationship between the stocking rate and the range productivity was investigated but influence of biomass on herbivore distribution was not considered.

In an environment entirely free of constraints, herbivores locate themselves where they maximize their energy gain in the shortest possible time (Bergman *et al.*, 2001). In this regard Bailey *et al.*, (1996) suggested that large herbivores spend most time in areas where the quantity and quality of forage is highest. Animal welfare domestic or wild begins with the assessment of the primary produce to ascertain its availability and suitability.

Biomass assessment in the Canadian University of Guelph was carried out for bio-energy and bio-material applications to evaluate the energy use and environmental impacts of switch grass biomass production in Ontario through life cycle assessment (Carita, 2012). It has also been found out that there was need to reconstruct grass production to reduce the gap in knowledge of the past dynamics of typical steppe, allowing verification of model estimates of natural climate fluctuations in Northern China. This was also an important step towards understanding the response of different ecosystem components to future climate change in the typical steppe while delivering the baseline reference for a sound steppe management plan (Liang *et al.* 2003). Biomass was assessed for bio-energy and response to climate change as opposed to the biomass influence on the LHD in the rangelands.

Savannah's contrasting plant life form of trees, shrubs and grasses cover approximately an eighth of the global land surface (Smith, 1999), which translates to 25% of terrestrial biomes and thus second to tropical forests in their contribution to terrestrial primary production (Grace *et al.*, 2006; Sankaran *et al.*, 2004). They support a considerable proportion of the world's human population and a majority of their rangeland and livestock (Sankaran *et al.*, 2004), as well as a continuous layer of drought resistant herbaceous plant and scattered woody species (Porensky & Veblen, 2012). In Africa, savannahs cover about 600 million hectares of land, which translates to about 40% of the continent's area although the general factors controlling the stable expansive grass and scattered trees have been identified as climate, fire and herbivory (Smith, 1999). However, all these variables interact with a high degree of uncertainty due to land use changes (Cech *et al.*, 2010; Ludwig *et al.*, 2004). Most of the developed world has biomass assessment done in farms or range lands for livestock production (Sannier *et al*., 2002). Many methods have been in use but there is none that has been known to surpass another (Sannier *et al.*, 2002). Some of the developing countries including the African continent have joined the trend of establishing the net worth of biomass in their protected areas as a major factor though controlled by abiotic factors to determine the distribution of free ranging herbivores and also show productivity to calculate the stocking rates (Mordelet & Menaut, 1995). Biomass was assessed to show the area covered in relation to the global area and biomass for livestock production as opposed to the influence of biomass on the LHD in different ecosystems.

In Ghana, above-ground grass biomass, necromass and tree litter were measured monthly over a vegetation cycle to better discriminate the contribution of the different grass compartments and the above-ground grass biomass was found to be higher in the open than under canopies during the second part of the growing season (Mordelet & Menaut, 1995). The wellbeing of an ecosystem is producing enough biomass to satisfy the load exerted on it by the primary consumers and the ecosystem interdependence (Savadogo *et al*, 2007). In Burkina Faso, West Africa analysis of the herbaceous biomass was done and found out that the mean total biomass during the study period was reduced by the presence of livestock while it was not significantly affected by early prescribed fire or by selective cutting (Savadogo *et al*, 2007). Assessment of biomass was driven by the quest to understand and establish the carrying capacity as opposed to LHD.

In East Africa, an increase in bush cover by 10% reduces grazing by 7%, and grazing is eliminated completely by 90% bush cover (Wijingaarden, 1985). It was reported that in 1931, there was an estimated 500 elephants in the Lambwe valley (Wellde, 1989b). The large elephant population apparently interfered with development in the area and was perceived dangerous to the growing human population (Wellde, 1989b). In 1948, the elephants were driven to Transmara (Wellde, 1989b). Populations of lions (*Panthera leo*), cheetahs (*Acinonyx jubatus*) and black rhinoceros (*Diceros bicornis michaeli*) were present in the Valley as recently as 1936, and they were moved out of the area (Muthuri, 1993) but some have been re-introduced once more to Ruma National Park. In 1966 Lambwe Valley Game Reserve was created and the status of the Game reserve was upgraded in 1975 to the Lambwe National Park (Republic of Kenya, 1984) but was returned to Game Reserve status in 1976 and once again upgraded to National Park status with the name Ruma National Park in 1983 (Republic of Kenya, 1984). The same year, ostrich (*Struthio camelus*) zebra (*Equus burchelli*) and a herd of 28 Rothschild giraffe (*Giraffa carmelopardalis rothschildi*) were introduced into the park by the game department (Republic of Kenya, 1984).

Bush encroachment was seen as contributing to the slow growth in wildlife as thickets separate herds, and is unsuitable for grazing by the majority (Ayieko, 1976). Ayieko (1976) reported a population of 200 roan antelopes and by 1990 this figure had dropped to only 30 individuals anticipated to habitat changes and poaching (Littoroh, 1990). The roan populations reported to have been abundant before 1970 in the Maasai Mara, Shimba and Ithanga hills National Parks disappeared from 1974 and have gone locally extinct in the said parks leaving the only herd in Ruma National Park (Litoroh, 1990) which is now standing at 27 individuals in the north western part of the park (Kimanzi, 2012). The declining trend has made roan antelope as locally endemic and endangered species and still no data is available even from other areas where they existed to show the differences and similarities (Litoroh, 1990).

Although a wide variety of biomass production estimates and sampling techniques are available for inventory purposes, each technique displays inherent strengths and weaknesses in satisfying specific inventory objectives and constraints (Telfer, 1981). A wide variety of techniques have been developed for collecting biomass information, ranging from simple observations of plant presence to accurate quantification of biomass, production and utilization (Mannetje, 1978). The potential of land management units for biomass production, however, may be enhanced at seral stages of plant succession (Demarchi & Harcombe, 1982). Therefore, assessment of current carrying capacity for herbivore use, under prevailing management practices, requires biomass or production estimates of existing grass biomass in Ruma National Park and how it affects distribution to enhance environmental conservation.

2. 3: Grass species richness and large herbivores distribution

Grasslands occupy approximately 26% of the land surface of the Earth providing a large proportion of the diet for domestic and wild animal populations (FAO, 1996) species diversity affect distribution of free ranging herbivores. For management purposes production needs precise monitoring (Ikeda *et al.*, 1999). Remote sensing provides an alternative mode of estimating grass species structure over very large areas (Mino *et al.*, 1998). It was anticipated that the grass species diversity affected the free grazing herbivore but was not known whether negatively or positively as opposed to this study that was interested in the influence GSR on the LHD.

Understanding the patterns of variation in numbers and structure of communities and the consequences for species diversity has been a focal point in ecology for several decades (Hutchinson, 1959). Globally Africa has grassland communities of unique diversity: their species richness is at least twice that of ungulate communities in the other bio-geographic regions, even allowing for the Pleistocene extinctions (Sinclair, 1983). A striking feature of these communities is their spatial variability (McNaughton & Georgiadis, 1986). For instance, natural habitat for reedbucks is wet grasslands or reeds near water bodies (Wildlife Safari, 2010). Monitoring activities in Kruger National Park have shown that shrinking of the habitats and the preferred species caused subsequent reduction in the number of reedbucks (Kruger National Park, 2010). Reduction of the preferred GSR was associated with the reduction of a specific herbivore species in a National Park but didn't point out the fate of other herbivores in the Park or relate to the distribution of the herbivores as was the case for this study.

A baseline to assess the effect of long-term biomass grazing and ungulate exclusion on grass species composition and soil nutrient status was done on the Athi-Kapiti plains, Machakos Kenya and significant changes were noted in four of the seventeen grass species. (Berliner & Kioko, 1999). Distribution of free-grazing herbivores is a major issue facing animal and rangeland managers (Taylor& Walker, 1978). With big game-livestock interactions, game damage on private lands, threatened and endangered species, and non-point source water pollution (Holechek *et al.*, 1989). The common theme of these issues is animal distribution in relation to nutrient extraction and ecosystem impact. In some circumstances, uneven grazing exacerbates deteriorative processes such as soil erosion (Blackburn & Gaston, 1998). Thus understanding the spatial and temporal dynamics of grassland species use by free-grazing herbivores is critical for ecosystem management (Coughenour, 1991). The baseline carried out related to the condition of the range when there were herbivores and when they were excluded as opposed to this study that required finding out the influence of the GSR and the LHD.

According to the Kenya Wildlife Service (KWS), Ruma National Park was established with the objective of conserving this "fire-induced" grassland community, and to protect the threatened population of roan antelope (KWS, 1990b). The past vegetation composition was mainly rolling grassland with tracts of open woodland and thickets dominated by species of *Acacia seyal* and *Balanites aegyptiaca.* Open or sparsely wooded grasslands covered about 68% of the park while forest, woodlands and thickets cover the rest 32% (Republic of Kenya, 1994). There had been negative implications in terms of bush control, as fires alone increase the bush vigor and grass species stabilization (KWS, 1990b). Since the mechanism that regulate processes for improving fodder production for herbivores as well as conservation of species biodiversity is crucial (Augustine & McNaughton, 2006; Douglass *et al.*, 2011), decreasing environmental losses and increasing the primary production requires coordinated management within savannahs (Hudak , 2004). The research in the Park was concerned about the area covered by the different vegetation associations as oppose to the influence of the GSR on LHD in Ruma National Park.

Ungulate grazing reduces biomass accumulation with potential consequences decreasing the ecosystems' carbon fixing capacity (Wang *et al.*, 2009). Although ecological interactions and their dynamics have impacts on the general ecosystem functions (Hudak, 2004), grass species richness is influenced by changes in temperature, rainfall and CO_2 levels (Otieno *et al.*, 2010). Since the future temperature is predicted to rise due to global warming and affect savannahs, site-specific grass species management is urgently needed (Douglass *et al.*, 2011). In addition, any effort to manipulate fluxes under conditions of changing land use is based on an understanding of underlying mechanisms, sensitive to changes in ecosystem drivers such as grazing and climate to maintain sustainable grass species diversity levels to enhance ecological integrity (Chidumayo, 2001).

2.3: Effect of altitude and water sources on large herbivore distribution

While much work has been conducted globally on the separate effects of grazing and fire on grasslands guided by altitude and water availability, the interaction between fire and grazing in grassland species is not well- studied. In particular, fire is an important determinant of the pattern of large herbivore grazing activity, which is often spatially and temporally heterogeneous (Coppock & Det-ling, 1986; Shaw & Carter, 1990). Ungulates typically graze some areas heavily during some parts of the season (Willms *et al.*, 1988). This grazing pattern is caused by the apparent preference of the large herbivore for particular grass species. Selective use of habitats or plant species by large herbivores can influence plant population, species structure and ecosystem processes (Shaw & Carter, 1990). The relationship between fire and grasses guided by altitude and water availability in conjunction to seasonality was investigated as opposed to the influence of the altitude and water sources on the herbivore distribution.

Redfern *et al.*, (2003) predicted that herbivores in African savannah ecosystems must meet their nutritional requirements within the constraints of water availability, and found this to be the case for all water-dependent or semi water-dependent species in the Kruger National Park, South Africa. Grazers compromise closeness to water for forage availability (Bergstrom & Skarpe, 1999) due to elasticity of their intrinsic constraints (Owen-Smith, 1993), when the benefits provided by distant forage outweigh the costs of travel (Brooks & Harris, 2008). This is possible if the animals walk to water when necessary since altitude is also important in influencing LHD (Sinclair, 1985).

Theoretically, herbivores should locate themselves in areas where they can maximize their energy gains (Bailey *et al.*, 1996) within the natural constraints imposed by abiotic factors such as slope and distance to water but the negative relationship between wild grazer density and the organic matter digestibility of grass is not easily explained and merits further investigation (Estes, 1997). This might appear contrary to much of the literature, which suggests that many species of wildlife prefer areas of high grass species richness (Estes, 1997), since this often indicates better food quality (Bergstrom & Skarpe, 1999). Zebra need to eat considerable quantities of grass to fulfill their nutrient requirements (Estes, 1997). Indeed Sinclair, (1985) found that in the dry season in the Serengeti; zebra preferred areas with the tallest grass. Seasonality which regulates the water availability has been investigated in relation to the amount of food ingested by the herbivores as opposed to their distribution in an ecosystem.

Availability of surface water has significant effect on the likelihood of herbivores being present, even in the dry season, but abiotic factors, such as slope and distance to water, are equally important and act as the primary determinants of large scale distribution patterns (Bailey *et al.*, 1996). A combination of both biotic and abiotic factors is particularly important in determining the distribution patterns of large herbivores in African savannah ecosystems (Redfern *et al.*, 2003). The relative importance of these factors has not been quantified, particularly in arid ecosystems that are also subjected to heavy human pressure (Redfern *et al.*, 2003; Sinclair, 1985). Spatial dynamics of altitude by free-ranging herbivores is integral to a successful ecosystem management but many landscape-scale models of herbivore distributions focus primarily on the role of forage quality and quantity (Redfern *et al.*, 2003) while large herbivores spend most time in areas where the available quantity and quality of forage is highest (Bailey *et al.*, 1996). Many models focus primarily on the forage quality and quantity which is a product of the abiotic factor of altitude and water availability as opposed to the abiotic factors influencing the LHD in Parks

2.4: Monthly rainfall and large herbivores distribution.

Maintaining biodiversity in semi-natural grasslands is a major challenge for biodiversity conservation in Europe (European Environmental Agency, 2004). Diversity has frequently been assumed to follow a unimodal response to rainfall along grazing intensity (Grime, 1979; Huston, 1994). When plant diversity is reported simultaneously, only the species richness of vascular plants and rainfall associations is usually considered (Baur *et al.*, 2006). Associations of the plants and rainfall were investigated as opposed to the influence of rainfall on the LHD.

Previous work suggests that African herbivore distribution and community structure are primarily determined by rainfall and the nutrient status of the soil, via their effects on the primary production (Kruess & Tscharntke, 2002). Coe *et al* (1976) proposed a model describing the variation in biomass of the ungulate communities based on annual rainfall, a good predictor of primary production across the globe (Lauenroth, 1979), and specifically in sub-Saharan Africa (Desmukh, 1984). The model explained a large proportion of the variance in ungulate biomass, but it has been criticized for the small data set used, the limited range of annual rainfall covered (100-700 mm) and the fact that it does not take into account the soil nutrient status (Bell, 1982) and other factors which influence the quantity and quality of plant resources, such as the grazing process itself (McNaughton & Georgiadis, 1986). The influence of rainfall in increasing biomass production in both animals and plants was the major objective prompting the research as opposed to the influence of rainfall to the LHD done by this study.

In Namibia a real-time monitoring of vegetation biomass in Etosha National Park has been in place for fire risk assessment and estimates of biomass production associated to rainfall important in a wildlife reserve (Sannier *et al.*, 2002). Further production of grass was investigated on the gravel plains of the Central Namib Desert, during 10 rainfall seasons sampled from 1989-2003 to evaluate the rainfall-productivity relationship, to elucidate the relationship between temporal and spatial variability, and examine the spatial scale of patchiness (Henschel *et al*, 2005). Real time increment of biomass depending on the amount of rainfall was investigated as opposed to the rainfall amount influencing the LHD in protected areas.

In general terms, the Serengeti ecosystem was divided into two components: (1) open grasslands with low annual rainfall (600 mm) that support an extensive cover of short grasses; and (2) wooded grasslands in areas with higher rainfall (1000 mm) that support tall, highly lignified grasses (McNaughton 1985). Rainfall is the most important factor influencing primary productivity of both grassland types (Sinclair, 1975; McNaughton, 1985). Most rainfall occurs from November to May, with occasional dry periods in January and February (Norton-Griffiths *et al.*, 1997). As a result, grass growth shows pronounced spatial and seasonal variation (McNaughton, 1985). Wildebeest exhibit seasonal shifts in habitat use, migrating from open grasslands that are used during the wet season to wooded grasslands in higher-rainfall areas that are used during the dry season (Maddock, 1979). A number of factors influence the apparent preference by wildebeest for short grasses during the wet season. Short grasses on the Serengeti plains are more digestible, have higher concentrations of calcium and protein, and have a higher ratio of leaf to stem tissue than taller grasses in other areas (Kreulen, 1975). Rainfall patterns influence primary productivity of grasslands and the shifts of wildebeests from the plains to the forested areas whereas this study was concerned on the rainfall and the influence on the LHD in the savannah ecosystem.

Past records indicate that Lambwe valley was once part of the famous Mara-Serengeti ecosystem and witnessed a seasonal animal migration which was curtailed by settlements which caused fragmentation and isolation of the Park by constructing the perimeter fence (Wellde, *et al.*, 1989a). Ruma National Park represents an island surrounded by a sea of densely populated agro-pastoralism communities and appropriate management is required to maintain its function as an important natural habitat and its great socio-economic values (Schmidt, 1975). Rainfall is a very important factor in Ruma National Park on large herbivore distribution because the bigger part lies in the Lambwe Valley while the rest lie on Kanyamwa escarpment and rainfall results to flush floods that cause flooding and water logging in the plains.

2.5: Conceptual framework

Healthy distribution of herbivores in an ecosystem is determined by natural as well as anthropogenic factors in parks and reserves. However of greater influence is the natural biotic and abiotic factors on inter-relationships and dependency on energy levels. By virtue the Park is partly in the escarpment and partly in the Valley plains and wholly isolated from other dispersal areas by a perimeter electric fence in its boundaries. The independent variables were: grass biomass, grass species richness, altitude and water sources, and mean monthly rainfall whereas the dependent variable was large herbivore. The intervening variables were Soil, parent material, prevailing weather patterns, terrain, seasonality, anthropogenic activities, other herbivores, plants, micro – organisms and predation.

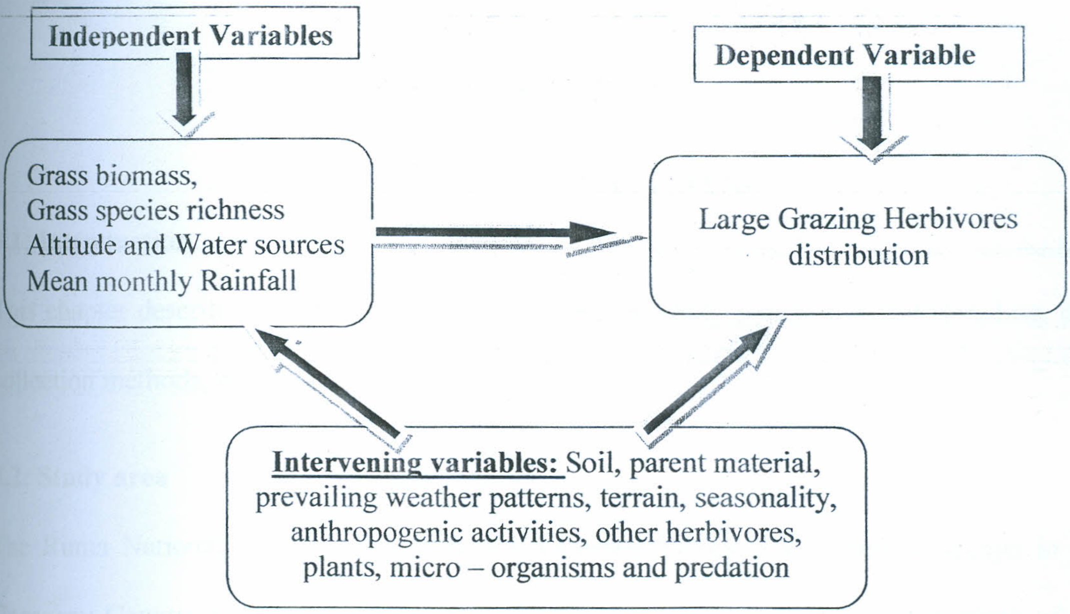


Figure 1: Conceptual framework

CHAPTER THREE

MATERIALS AND METHODS

3.1: Introduction

This chapter describes the study area, research design, study population and sampling, data collection methods, data analysis and presentation.

3.2: Study area

The Ruma National Park is situated in the Lambwe Valley, south-western Kenya in the Homabay County. It is located in present day Suba sub-county, about 72 km south of the equator, and lying within latitudes 34° 10' and 34° 20' East and longitudes 0° 30' and 0° 50' South (Bennun *et al.,* 2001) with a total land area of 120 km^2 in the valley (Legal Notice Number 77, 1966) have described this site. The terrain is mainly rolling grassland with tracts of open woodland and thickets. The landscape is dominated by species of *Acacia seyal* and *Balanites aegyptiaca.* Open or sparsely wooded grasslands cover about 68% of the park while forest, woodlands and thickets cover the rest 32%. About 1450 hectares of the grasslands in the park are unlikely to be seasonally flooded or wet since they are found in steep areas of the Kanyamwa escarpment in the South-East and Southern part of the park (Republic of Kenya, 1994). Bush encroachment, an important biophysical indicator of the habitat quality (Sserunkuuma, 1998), was clearly evident in the park. Those vegetation covers with a downward trend include grasslands, riverine forests, open woodlands and complete elimination of cultivation from the park but no one had tried to determine by how much, what is available or even the factors driving the process and the effect to the primary consumers (KWS, 2006).

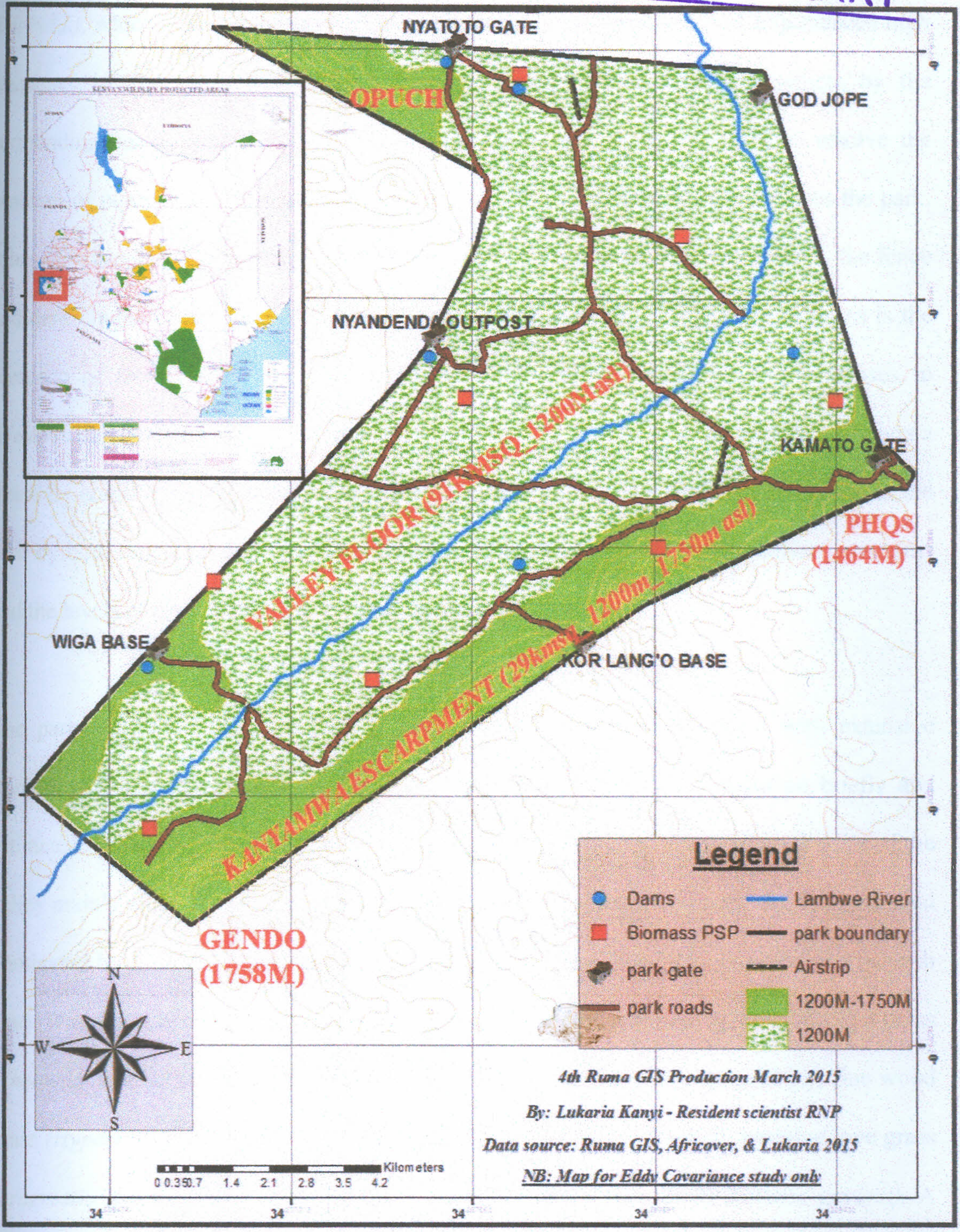


Figure 3.1: Study Area Ruma National Park (Source: RNP, 2013).

Ruma National Park was initially established as the Lambwe Valley Game Reserve in 1966 and acquired national park status in 1983 (KWS, 1990). It was mainly established to protect the locally endangered population of the endemic roan antelopes *(Hippotragus equinus* *langheldi),* which is not found anywhere else in Kenya. In the past, the park experienced high frequency of fire outbreaks, poaching incidences and human-wildlife conflicts by the surrounding community (KWS, 2006). A wire fence was erected in 1994 to resolve the problem of poaching and human-wildlife conflicts. The fence now totally encloses the park. It has now become completely isolated from its former surrounding environment by the fence and dense human settlement. Another historical problem of the park and its environs is the presence of tsetse flies *(Glossina pallidipes pallidipes)* that caused trypanosomiases in livestock and sleeping sickness in humans. The area was uninhabited until the 1930s when a tsetse fly eradication program was started (Waweru *et al.*, 1995). Continued habitation of the area by both man and livestock depended on the success of the tsetse fly control programs and the levels of tsetse densities (Waweru *et al.*, 1995).

The park vegetation is dominated by savannah grassland and woodland with extensive thickets or forest and bushes. Waweru *et al.,* (1995) described the vegetation briefly and estimated that about 20% of the park is an evergreen forest situated at the lowest point of the valley mainly along the Olambwe River. The rest of the habitat falls under wooded grassland dominated by *Balanites aegyptiaca, Acacia drepanalobium, Acacia seyal* woodland or bush land (Waweru *et al.*, 1995). The grass species recorded during the study were; Red oat grass *(Themeda triadra)* loudetia (*Loudetia kagerensis)*, star grass (*Setaria sphacelata),* fine wood grass *(Hyparrhenia filipendula),* African love grass (*Eragrostis curvula),* weeping love grass *(eragrostis superba),* star grass *(Cynodon dactylon)* and rhodes grass *(Chloris gayana).* A table was developed to show large herbivores and the plant species they feed on.

Table 3.1: Herbivores and the type of plants they feed on

No.	Herbivore	Mode of feeding	Species they feed on
1.	Giraffe *(Giraffa Camelopardalis rothschildi)*	Browser	Acacia pecies, *(Acacia drepanolobium, Acacia lahai)* Balanites *(Balanites aegyptiaca)*, Grewia species *(grewia bicolor, Grewia vilosa)*
2.	Buffalo (*Syncerus caffer)*	Grazer/ browser	*Themeda triadra, Setaria sphacelata, , Eragrostis curvula, Cynodon dactylon, Chloris gayana and herbs and shrubs of Acacia drepanolobium*
3.	Common Zebra *(Equus burchelli)*	Grazer	*Themeda triadra, Setaria sphacelata, , Eragrostis curvula, Cynodon dactylon, Chloris gayana Loudetia kagerensis, Hyparrhenia filipendula, eragrostis superba,*
4.	Roan Antelope (*Hippotragus equinus langheldi)*	Grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana Loudetia kagerensis*
5.	Impala(*Aepyceros melampus)*	Grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana*
6.	Topi (*Damaliscus lunatus)*	Grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana Loudetia kagerensis*
7.	Reedbuck(*Redunca redunca),*	Grazer	*Eragrostis curvula, Cynodon dactylon, Chloris gayana Loudetia kagerensis, Hyparrhenia filipendula eragrostis superba,*
8.	Lewel hertebeest *Alcelaphus buselaphus lelwel)*	Grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana*
9.	Oribi (*Ourebia ourebi)*	grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana*
10.	Black rhino	Browser	Acacia (*Acacia drepanolobium, Acacia polyacantha), Todialis aesciatica, Grewia vilisa,* Balanites *(Balanites aegyptiaca)*
11.	White rhino	Grazer	*Themeda triadra, Setaria sphacelata, Cynodon dactylon, Chloris gayana*

3.2.1: Topography and drainage

Ruma National Park is located along the Lambwe Valley and has been separated by two main mountain zones the Gwasi and Gembe hills to the west, and Kanyamwa escarpment to the east. Gwasi hills rise to 2,273m at Wiratha and separate the valley from shores of L. Victoria. Kanyamwa escarpment slopes gradually from 1,758m at Gendo in the south, to 1,464m at Kamgwagi (Ruma Park Headquarters) in the North. The valley floor lie about 75m above the level of L. Victoria (1,200m above sea level), but it is reported that after relatively recent stages of tectonic activities the valley submerged below the waters of the lake (Republic of Kenya, 1996). The park lies in the valley floor between Gwasi hills to the west, Kanyamwa escarpment to the east and Gembe and Ruri hills to the north. The park has altitude ranging from 1170-1750m above sea level. The Park is drained by Lambwe River, which flows across the park and into Lake Victoria. Lambwe is a seasonal river with a few permanent water pools along its course throughout the year. There are numerous water springs along the Kanyamwa escarpment from where a number of seasonal streams originate (KWS, 2006).

Omoto (1994) showed that most of the park valley bottom is covered by Pleistocene lacustrine sedimentary depositions overlain by alluvium clays washed from surrounding escarpment and hills of volcanic origin. Because the valley is surrounded by alkali rock formations, the ground waters are rich in sodium and many of the lower-lying sub-soils are consequently alkaline. All the water in the park is muddy and salty. Deep layers of fertile black cotton soil are also found in the valley. During the long rains the black cotton soil becomes waterlogged, which makes transportation almost impossible even with four wheel drive vehicles. The availability of water is mainly determined by rainfall and during severe dry season water is scarce to wildlife in the park.

Deep porous lacustrine deposits have since been overlaid with dark clays (oxisols), with extensive areas of poor drained black cotton soil extending over much of the valley floor including Ruma Park. Elsewhere there are fertile volcanic soils predominant along hillsides, although characterized by rocks. The region is classified as sub-humid to semi-arid with medium agricultural potential with annual rainfall ranging between 1,000-1,400mm and 60% reliability. The months of March/May experience long rains and short rains occur in August/

December. The area experience high temperatures throughout the year but range from 17.1^0C to 34.8^0C within Suba sub-county. The hot months are December and March with February being the hottest. Minimum temperatures vary from 17.1^0 C to 18^0 C (Republic of Kenya, 1996).

3.2.2: Gazettement/legal status

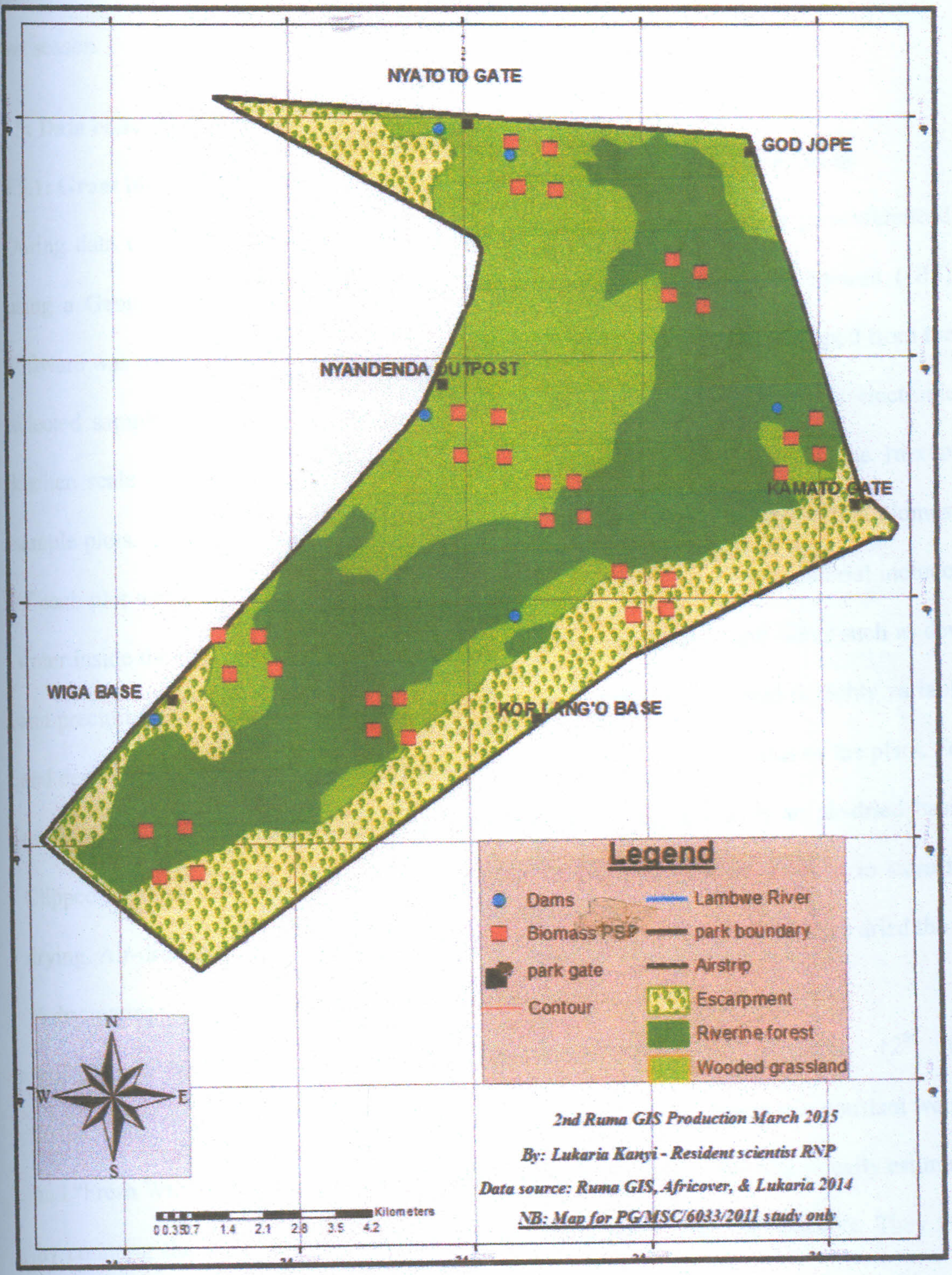
The Park was established as a Game Reserve in 1966 under the ownership of Homa Bay County Council through a legal notice number 77, (1966); which was later upgraded to national park status in 1983 (KWS, 2006).

3.3: Research design

This was a cross-sectional correlational, experimental and longitudinal research design. This research design was the most appropriate for the study as the activities were not to be repeated in similar period but deductions were to be made relying on the time period set for the research for the cross-sectional correlation design as in the water sources and altitude. Mean monthly rainfall and the accumulated large herbivore distribution in six months for the longitudinal research design. The sampling and the selection of sample plots, grass clipping and determination of the grass species richness is the experimental design. The unit of analysis was the number of individual large herbivores that visited the sample plots. This study relied on data collected within a specified six months period from January to June 2014 in Ruma National Park. The dry season was depicted by low mean monthly rainfall in the months of January, February, March and the wet season was depicted by high mean monthly rainfall in the months of April, May and June.

3.4: Study population and sampling

Ruma National Park is 120km^2. It was stratified into escarpment, riverine forest and the wooded grasslands depending on vegetation type and altitude. The escarpment consisted of the Kanyamwa escarpment between 1200m.a.s.l to 1758m.a.s.l at Gendo, the riverine forest consists of the riparian zone of Lambwe River and wooded grasslands comprise mainly of grasses and scattered shrubs and thickets at 1200m.a.s.l and below. Systematic sampling was done to get the plots by dividing Ruma National Park into 1km^2 grids, oriented 4 transects from south East to North west traversing the three strata and purposely selected the first plot from south East and got the next plot after every 3km along the transect. In the 4 transects 9 grids were selected with a 4km^2 plot and 36 subplots measuring 1x1km each. The 36 subplots plots were distributed as 6, 12 and 18 plots in the escarpment, riverine forest and wooded grassland respectively. Sample plots were randomly selected for grass clipping. To eradicate bias and minimize the sampling error, every subplot data was an average of 16 randomly selected sample plots. Grass was clipped from a total of 576 (1mx1m quadrants) that in average represented the analysis of data in the 36 sub plots of 1x1km. The grass clipped from randomly selected 16 (1m x1m) quadrants per subplot was sun dried to constant weight and the average grass weights from the quadrats was used to estimate biomass in every subplot (1kmx1km). Purposive selection of the large herbivores was done and 7 different species were selected to represent the large grazers' population. These were Roan antelope (*Hippotragus equinus langheldi)*, Reedbuck (*Redunca redunca),* Lelwel hartebeest *(Alcelaphus buscelaphus lelwel),* Topi (*Damaliscus lunatus)* Buffalo (*Syncerus caffer)*, Impala (*Aepyceros melampus)* and Oribi (*Ourebia ourebi)* (Appendix plates) because they were easily visible and could be distinguished. They were selected from a list made after the total census done in Ruma in 2011 and 2012 (Appendix Table 4.9). Using the locations of the subplots the established data base was queried with the input of the species and the number that was found in the subplots was recorded to denote distribution of the large herbivores; water sources were geo–referenced for spatial analysis. The grass biomass was estimated from the grass clipped in the sample quadrats whereas species richness was estimated visually by counting from the subplots.



2nd Ruma GIS Production March 2015

By: Lukaria Kanyi - Resident scientist RNP

Data source: Ruma GIS, Africover, & Lukaria 2014

NB: Map for PG/MSC/6033/2011 study only

Figure 3.2: Plots distribution in Ruma National Park.

Mean monthly rainfall for six months from January-June 2014 was used in the study with low precipitation period denoting the dry season and the high precipitation period denoting the wet season.

3.5: Data collection methods

3.5.1: Grass biomass and species richness, Rainfall, Altitude and Water sources

During data collection direction was navigated using a compass and plots geo-referenced using a Geographical positioning system (GPS). Geographical Information System (GIS) software was used to display the plots on a spatial map. Primarily grass was clipped from the selected sample plots placed in Kirk bags and weighed using Ashton Meyer's electronic kitchen scale with accuracy of 0.5g. Grasses were clipped and weighed in all the 1mx1m sample plots. Analyses were performed on the plot data to calculate the dry weight biomass of each plot using the clip-and-weigh method. The weight of clipped plant material includes water inside the plant (within and between cells) and water on leaves and stems such as dew and precipitation. Therefore, the weight of freshly harvested plant material is highly variable and depends on recent weather, atmospheric conditions, and the water status of the plant. For more meaningful interpretation of production, biomass is expressed on an air-dried basis. Clipped samples were weighed in the field, fresh weight recorded and brought to store for drying. Air-dried samples were used to calculate biomass. Once the samples were dried the

% dry matter = (Dry wt./Fresh wt.) *100

(https://www.google.co.ke/?gws_rd=ssl#q=grass+biomass+calculation formula, 12th July 2016). Where the "Dry Wt." is the weight of the sample after sun drying to a constant weight and "Fresh Wt." is the weight of the sample recorded in the field. GSR was visually estimated by counting the grass species numbers and recording them from the subplots. They were named using botanical expert knowledge and assigning them name using the binomial nomenclature where the generic and the specific names were given for each grass species found in the subplots. Contours were used for the Park zonation and a GPS was used to show location and altitude of the subplots and sample plots in the study area. GIS software was used to display the spatial layers in maps. Data on rainfall in mm collected from five rain gauge stations in the Park was added together and the mean monthly rainfall was calculated by dividing the total monthly rainfall by five stations and the mean monthly rainfall recorded in a table

3.5: Data analysis and result presentation

Air dried grass was used to calculate biomass in g/m^2 and the calculated biomass was presented in a table against the plots from which the grass was clipped. The number of the large herbivores were generated by querying the database with the input of the selected herbivores, the locations of the plots and presented in a column adjacent to the calculated grass biomass (Table 4.1) the data was put in a Minitab software for analysis using the linear squares regression with the large herbivores in the responsive column and the grass biomass in the explanatory column and the results presented in a regression scatter plot. Correlation of the biomass in relation to the large herbivores' distribution was done using regression scatter plot to show their correlation. GSR was determined visually by counting the number of species in every 10mx10m selected plot using standard methods and their number recorded in a table showing the corresponding number per plot. The number of large herbivores distributed in the plot got from the monitoring database was regressed against the grass species richness and the results presented in a regression scatter plot.

Altitude in m.a.s.l (meters above sea level) was recorded from a Geographical Positioning System (GPS) for all the plots and recorded against the plots and the stratification done using the contours. The water sources in the vicinity of the plot were counted and recorded against the number of the herbivores. The number of large herbivores distributed in the plots was regressed against the altitude and water source in a multiple regression where the large herbivores were the responsive variables while altitude and water sources were the explanatory variables acting upon the herbivores distribution. Mean monthly rainfall in millimeters from Ruma National Park rain gauge weather stations was used for the analysis.

3.6: Reliability and validity

Reliability is the extent to which results are consistent over time, accurate in representing the total population under study and can be reproduced again under a similar methodology (Joppe, 2000). This is the replicability or repeatability of results or observations. This also refers to the degree to which a measurement, given repeatedly, remains the same, the stability of a measurement over time and the similarity of measurements within a given time period (Kirk & Miller, 1986). In quantitative research Validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. In other words, does the research instrument allow you to hit "the bull's eye" of your research object? Researchers generally determine validity by asking a series of questions, and will often look for the answers in the research of others (Joppe, 2000). Reliability of the data collected was assured in estimating biomass because direct sampling, biomass clipping and weighing in the field using a digital weighing machine of known accuracy was done which can replicated by another research at different times or as specified by this research. The plots were also mapped as permanent sampling plots. The methods used in this research to measure are valid in other research activities the variables involved. Unusual results were validated through ground truthing. Standard ecological monitoring datasheets were used for data collection. Analysis and presentations were done using scientifically proven methods.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1: Introduction

This chapter contains results and discussions of the findings on the effects of the grass biomass on large herbivores distribution, effect of grass species richness (GSR) on of the large herbivores distribution, effect of altitude and water sources on large herbivores distribution and the Influence of mean monthly rainfall on large herbivores distribution in Ruma National Park.

4.2: Grass biomass and the large herbivores distribution

The number of large herbivores that had grazed in the subplots where the grass biomass was clipped during the study period was as shown in column five of against the mean biomass calculated for each sample plot recorded in column six of (Table 4.1). Biomass shown in the column six is an average of four subplots which was carried out to reduce bias with the standard deviation shown in column seven (Table 4.1). The number of large herbivores was highly distributed in areas where the grass biomass was relatively low. For ease of differentiating data from different parts of the park the bags were given unique initials. For this study T denoted transect, P denoted the plot, SP denoted subplot from where sample plots were generated and biomass clipped.

Table 4.1: Grass biomass and large herbivores distribution in the study sub plots

Transect	Plot	Subplot No.	Subplot	LHD	Mean Biomass g/m^2	Standard deviation
T1	P1	1.	SP1	30	850.3	0.6
		2.	SP2	35	613.1	0.5
		3.	SP3	39	443.8	0.5
		4.	SP4	40	504.1	0.3
	P2	5.	SP1	25	746.8	0.6
		6.	SP2	28	725.1	0.5
		7.	SP3	23	726.5	0.9
		8.	SP4	20	903.8	0.6
	P3	9.	SP1	35	461.8	0.7
		10.	SP2	31	566.5	0.7
		11.	SP3	33	391.4	0.8
		12.	SP4	35	479.4	0.9
T2	P4	13.	SP1	45	186.5	0.8
		14.	SP2	42	190.0	0.4
		15.	SP3	35	224.9	0.3
		16.	SP4	46	163.7	0.8
	P5	17.	SP1	8	1230.8	1.1
		18.	SP2	28	793.1	0.6
		19.	SP3	14	979.0	0.7
		20.	SP4	10	1066.7	1.8
	P6	21.	SP1	9	1224.3	1.3
		22.	SP2	12	1231.3	1.4
		23.	SP3	10	1241.1	1.1
		24.	SP4	33	852.6	0.6
T3	P7	25.	SP1	5	1939.5	1.2
		26.	SP2	7	1223.2	1.1
		27.	SP3	35	661.5	0.4
		28.	SP4	31	649.4	0.5
	P8	29.	SP1	35	667.2	0.7
		30.	SP2	25	736.0	0.9
		31.	SP3	35	613.8	0.6
		32.	SP4	33	553.2	0.6
T4	P9	33.	SP1	6	1366.2	0.7
		34.	SP2	22	905.2	0.4
		35.	SP3	8	1009.5	0.8
		36.	SP4	31	852.8	0.5

Grass biomass in Ruma National Park ranged from 164g/m^2 to 1940g/m^2 in the sample plots (Table 4.1). The data was subjected to linear squares regression analysis and the results in (Table 4.2) were produced.

Table 4.2: Regression analysis for the relationship between large herbivore distribution and biomass

The regression equation is

No. of Herbivores = 48.8 - 0.03 Biomass

Predictor	Coef	SE Coef	T	P
Constant	48.843	1.996	24.47	0.000
Biomass	-0.029289	0.002314	-12.66	0.0001

S = 5.198 R-Sq = 82.5% R-Sq (adj) = 82.0%

The results (Figure 4.1) show a strong (R-Sq. = 0.83, P=0.0001) negative relationship between large herbivores distribution and grass biomass which is statistically significant at 99% confidence levels thus rejecting the null hypothesis that there is no significant influence of the grass biomass on the LHD. A scatter plot was developed (Figure 4.1) from the linear regression analysis to show the relationship between the LHD and grass biomass in Ruma National Park.

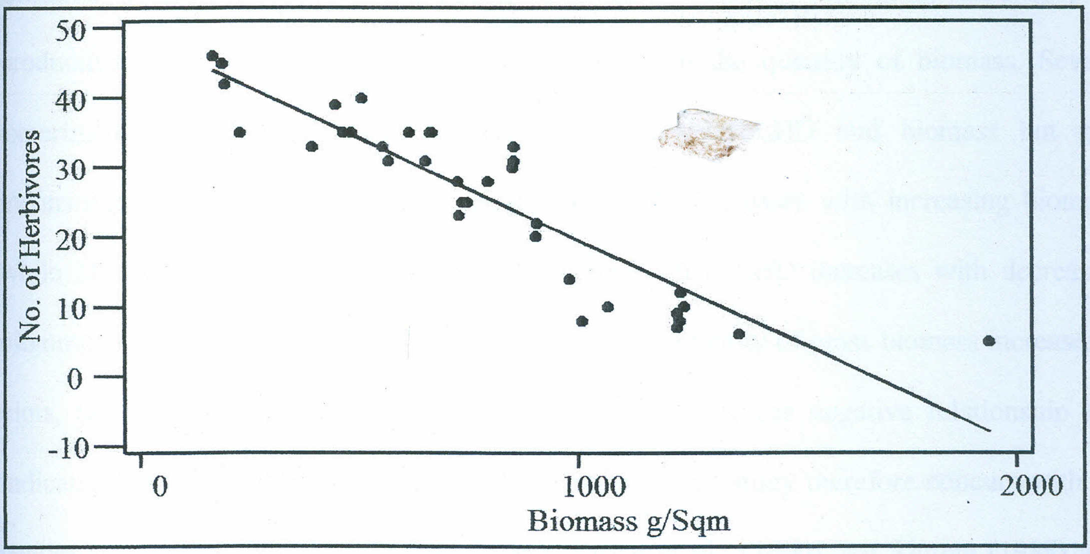


Figure 4.1: Relationship between grass biomass and large herbivores distribution.

Regression plot

No. of herbivores = 48.8 – 0.03 Biomass

S = 5.2 R-Sq = 83% R-Sq(adj) = 82% P = 0.0001

The scatter plot Figure 4.1, show that as the quantity of grass biomass increases in plots, the large herbivores distribution decreases. In parts of the Ruma National Park where the quantity of grass biomass was higher e.g. subplot 17, 20, 21, 22, 23, 25, 26, 33 and 35 whose biomass was beyond 1000g/m^2 had below 12 large herbivores recorded in the plots during the study period Table 4.1. The biomass consisted of dry and coarse grass that did not attract many large herbivores thus low distribution. Whereas in areas of the park with low quantity of grass biomass e.g. subplot 13, 14 and 16 had biomass ranging between 163 to 190 g/m^2 had the highest number of the grazers recorded during the study period (Table 4.1). The biomass the areas with higher distribution consisted of fresh grass that was preferred by many individuals of large herbivores. The least squares regression results of the relationship between mean grass biomass and the LHD (Figure 4.1).

Oksanen *et al.*, (1981) predicted that LHD should increase with an increase in plant productivity but productivity was not only pegged on the quantity of biomass. Several experimental studies examined the relationship between LHD and biomass but give inconsistent results. Reader (1992) indicates that LHD increases with increasing biomass, while McAuliffe (1986) and Ellison (1987) reported that LHD increases with decreasing biomass. The scatter plot (Figure 4.1) show that as the quantity of grass biomass increases in plots, the LHD decreases in the plots. This is shown by the negative relationship that indicates reduction of LHD as the biomass increases. This study therefore concurs with the studies by Ellison (1987), McAuliffe (1986), Taylor et al., (1990) and Tilman (1988) who shown that LHD increases with reduction in biomass.

This study also established that among the ecological factors studied, grass biomass was the most important ecological factor influencing the LHD as was in Bailey *et al.*, (1996) who suggested that large herbivores spend most time in areas where the quality of forage is highest. Braun (1973) and Kreulen (1975) found out that short grasses on the Serengeti plains were more digestible, have higher concentrations of calcium and protein, and have a higher ratio of leaf to stem tissue than taller grasses. The plains of Ruma National Park depict this scenario of short fresh grasses that attracted relatively higher LHD as compared to other parts of the Park.

Biomass is an important determinant of LHD (Harper, 1977) and concurs with the finding of this study where 83% of the influence on the LHD is controlled by biomass. Grime (1979) and Keddy (1990) predicted that HD should increase with increase in biomass. The basis of this prediction further indicates that LHD is more likely to interact and compete for resources at sites with higher biomass. In contrast, Taylor *et al.* (1990) predicted that LHD should not increase with an increase in biomass because the higher biomass consists of the most competitive plants and in most cases they are of poor quality. In Ruma National Park large herbivores are highly distributed in the plains which have relatively low biomass consisting fresh grasses. Taylor *et al,* (1990) argued that distribution reflects the ratio of resource demand to supply. This study found out that fresh grasses were in the plains where the biomass was relatively low thus a relatively LHD.

4.3: Grass species richness and the large herbivores distribution

Grass species richness (GSR) was estimated by counting the corresponding number of different grasses species found in the sub plot. The grass species richness was found to range from 2 to 8 grass species per subplot of 1km^2 (Table 4.3). These grass species were; Red oat grass *(Themeda triadra)* loudetia (*Loudetia kagerensis)*, star grass (*Setaria sphacelata)*, fine wood grass *(Hyparrhenia filipendula)*, African love grass (*Eragrostis curvula)*, weeping love grass *(eragrostis superba)*, star grass *(Cynodon dactylon)*, rhodes grass *(Chloris gayana)*. The number of the grass species found in the subplot was recorded against the number of the large herbivores found in the corresponding subplots (Table 4.3).

Table 4.3: Number of grass species and the corresponding number of large herbivores distributed in different subplots

Transect	Plot	Subplot No.	Subplot	Grazers	Grass species Richness
T1	P1	1.	SP1	30	3
		2.	SP2	35	4
		3.	SP3	39	4
		4.	SP4	40	5
	P2	5.	SP1	25	4
		6.	SP2	28	5
		7.	SP3	23	4
		8.	SP4	20	3
	P3	9.	SP1	35	6
		10.	SP2	31	4
		11.	SP3	33	5
		12.	SP4	35	5
T2	P4	13.	SP1	45	8
		14.	SP2	42	5
		15.	SP3	35	7
		16.	SP4	46	8
	P5	17.	SP1	8	2
		18.	SP2	28	4
		19.	SP3	14	4
		20.	SP4	10	2
	P6	21.	SP1	9	2
		22.	SP2	12	2
		23.	SP3	10	3
		24.	SP4	33	4
T3	P7	25.	SP1	5	2
		26.	SP2	7	3
		27.	SP3	35	4
		28.	SP4	31	4
	P8	29.	SP1	35	5
		30.	SP2	25	4

		31.	SP3	35	3
		32.	SP4	33	4
	P9	33.	SP1	6	2
		34.	SP2	22	3
		35.	SP3	8	2
		36.	SP4	31	3

The data in (Table 4.3) was put in Minitab software for analysis and Table 4.4 was developed to show the relationship between LHD and GSR

Table 4.4: Regression analysis: Large herbivores versus grass species richness

```
The regression equation is
No. of herbivores = 0.68 + 6.44 GSR

Predictor     Coef    SE Coef      T       P
Constant      0.685    3.332     0.21    0.838
GSR           6.4391    0.7879    8.17    0.0001

S = 7.216     R-Sq = 66.3%    R-Sq(adj) = 65.3%
Unusual Observations
Obs   GSR   Herbivores   Fit     SE Fit   Residual   St Resid
13    8.00    45.00     52.20     3.41     -7.20      -1.13 X
16    8.00    46.00     52.20     3.41     -6.20      -0.97 X
31    3.00    35.00     20.00     1.41     15.00       2.12R
```

NB:
R denotes an observation with a large standardized residual

X denotes an observation whose X value gives it large influence

A regression scatter plot was developed to show the relationship between the large herbivores and the GSR (Figure 4.2). The scatter plot (Figure 4.2) show the relationship of LHD and GSR using least squares regression analysis (R-Sq = 0.663, P = 0.0001). It indicates a positive relationship between GSR and LHD which is statistically significant at 99% confidence levels (Table 4.4) thus rejecting the null hypothesis that there is no significant effect of the GSR on the LHD. The findings (Figure 4.2) indicate that large herbivores are highly distributed in areas of Ruma National Park where the grass species richness is high.

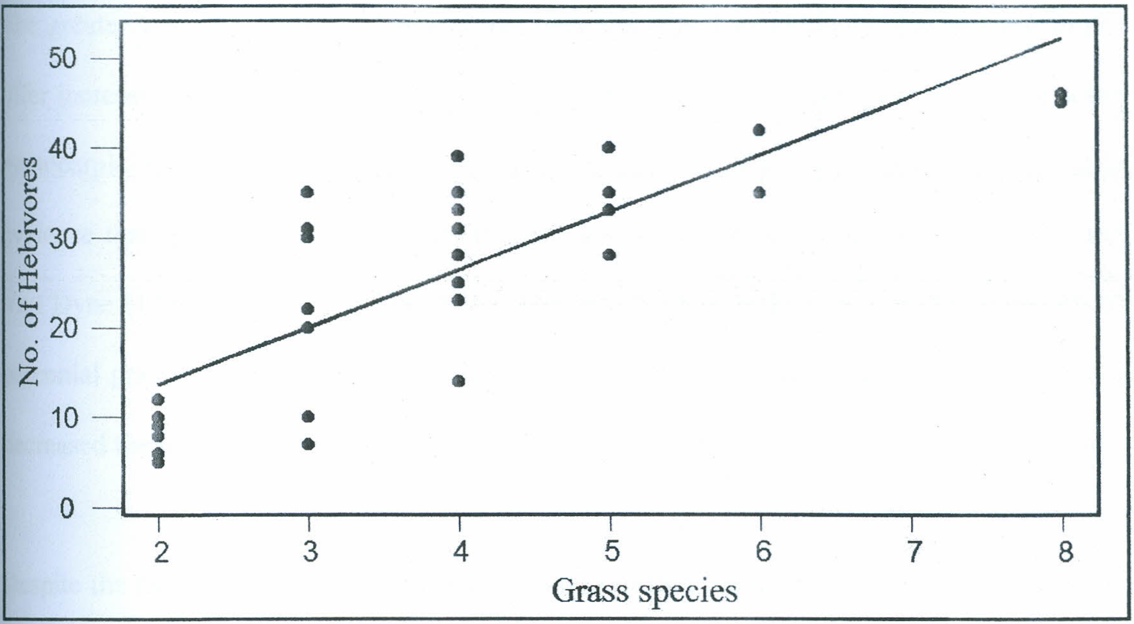


Figure 4.2: Relationship between large herbivores distribution and grass species richness

Regression plot

No. of Herbivores = 48.7 + 0.03 Grass species

S = 7.2 R-Sq = 66% R-Sq(adj) = 65% P = 0.0001

Apparently high biomass was associated with suppression of the less competitive grass species while those that were equally competitive were left and are of low quality thus low preference to the large herbivores. Consequently, the higher the GSR the more large herbivores are distributed. For specific grass species, tissue removal has been found to increase photosynthetic rates (Wallace *et al.*, 1984), increase allocation of current photosynthate to new shoots (Caldwell *et al.*, 1981), increase allocation of substrates from roots to shoots (Richards, 1984) making the large herbivores distribution maintain a diversity of the grass species. Thus high large herbivores distribution is associated with high GSR as shown by the findings of this study where the influence caused by the GSR on the large herbivores distribution is a substantial 66%.

The pattern is anticipated to the variations in GSR in different parts of Ruma National Park. The greater longevity of grazed plants has been presented as evidence that grazing might offer increased fitness on plants (Owen & Wiegert, 1982a). Although the life span of some monocarpic species can be lengthened by removing the flowering organs, there is little evidence that tissue removal increases the life span of perennial grass species. Wright and Van Dyne (1976) and West (1979) found that grazing had little effect on the longevity of perennial grass species, shrubs, and forbs but Canfield (1957), however found that grazing decreased the longevity of tall grass species but increased the longevity of short grass species.

Despite the fact that findings of this study found out that the distribution was influenced by GSR, there were three unusual observations in subplots 13, 16 and 3. Subplots 13 and 16 had 8 GSR and a very low standard residual value at -1.13 and 0.97 respectively (Table 4.4). This shows that the GSR has a large influence on LHD with both subplots recording 45 and 46 herbivores during the study period. This was contrary to subplot 31, high standard residue of 2.12, GSR was 3 and a substantial number of the 35 large herbivores distributed in the subplot as opposed to other observations like subplots 8, 23 and 26 which had a 3 GSR and a distribution of 8, 7 and 10 large herbivores distributed in the plots respectively. These unusual observations prompted a ground truthing. It was found out that subplot 31which had 3 GSR and an influx of 35 LHD had a large natural salt lick which attracted the herbivores than the graze thus the unusual observation. The other scenario where observations were the same on the number of GSR and had relatively low LHD of less than 10 had overgrown grass species of *Hypharrhenia fillipedulla* and *Eragrostis curvula* on the steep slopes of Kanyamwa escarpment with loose stone. These areas were rarely visited by the large herbivores, thus a low distribution

Monitoring activities in Kruger National Park, South Africa have shown that shrinking of the habitats and the preferred species caused subsequent reduction in the number of reedbucks (Kruger National Park, 2010). Canfield (1957) found that short grass species live longer on grazed ranges than on un-grazed ranges; this greater longevity is due to their release from competition with taller species. Indisputably, grasses have coevolved with large herbivores and have adapted to being grazed (Stebbins, 1981). Grass species from heavily grazed grasslands of the Serengeti ecosystem in Tanzania are examples of species that have long coevolved with large herbivores and are mutualistically associated with them (Wallace *et al.*, 1984) which in turn attract a higher distribution of herbivores as is the case in Ruma National Park.

4.4: Altitude and water sources on large herbivores distribution.

Park zonation was done using contours which joined areas of equal altitude. A GPS was used to record the locations and the altitude for every subplot. The altitude of in the plots ranged from 1172m.a.s.l to 1272m.a.s.l and the water sources ranged from 1 to 4 in the neighborhood of the subplot while the LHD ranged from 5 to 46 in the sample plots. This information was recorded against the number of the large herbivores that were distributed in the subplots during the study period (Table 4.5).

Table 4.5: The relationship between altitude and water sources and large herbivore distribution

Transect	Plot	Subplot No.	Subplot	Herbivore	Altitude	Water sources
T1	P1	1.	SP1	30	1207	1
		2.	SP2	35	1208	1
		3.	SP3	39	1206	1
		4.	SP4	40	1202	1
	P2	5.	SP1	25	1172	2
		6.	SP2	28	1173	2
		7.	SP3	23	1174	2
		8.	SP4	20	1174	2
	P3	9.	SP1	35	1192	4
		10.	SP2	31	1193	4
		11.	SP3	33	1192	4
		12.	SP4	35	1192	4
T2	P4	13.	SP1	45	1193	4
		14.	SP2	42	1192	4
		15.	SP3	35	1193	4
		16.	SP4	46	1192	4
	P5	17.	SP1	8	1191	1
		18.	SP2	28	1188	1
		19.	SP3	14	1193	1
		20.	SP4	10	1190	1
	P6	21.	SP1	9	1257	1
		22.	SP2	12	1263	1
		23.	SP3	10	1272	1
		24.	SP4	33	1215	1
T3	P7	25.	SP1	5	1206	1
		26.	SP2	7	1208	1
		27.	SP3	35	1210	1
		28.	SP4	31	1212	1
	P8	29.	SP1	35	1202	3
		30.	SP2	25	1203	3
		31.	SP3	35	1201	3
		32.	SP4	33	1204	3
	P9	33.	SP1	6	1224	2
		34.	SP2	22	1222	2
		35.	SP3	8	1223	2
		36.	SP4	31	1221	2

The data was put in Minitab for linear squares regression analysis to show the relationship between the altitude and the LHD. The results in the regression scatter plot Figure 4.3 show a weak (R-Sq = 0.15, P = 0.001) negative relationship between altitude and large herbivore distribution that 15% statistically significant at 99% was controlled by the altitude. The scatter plot demonstrates that as the altitude increases LHD numbers reduce. Ground trothing also found out that the escarpment was steep and rocky meaning that the large herbivores would spend more energy in meeting their daily requirements in such areas making them to avoid the escarpment (Figure 4.3).

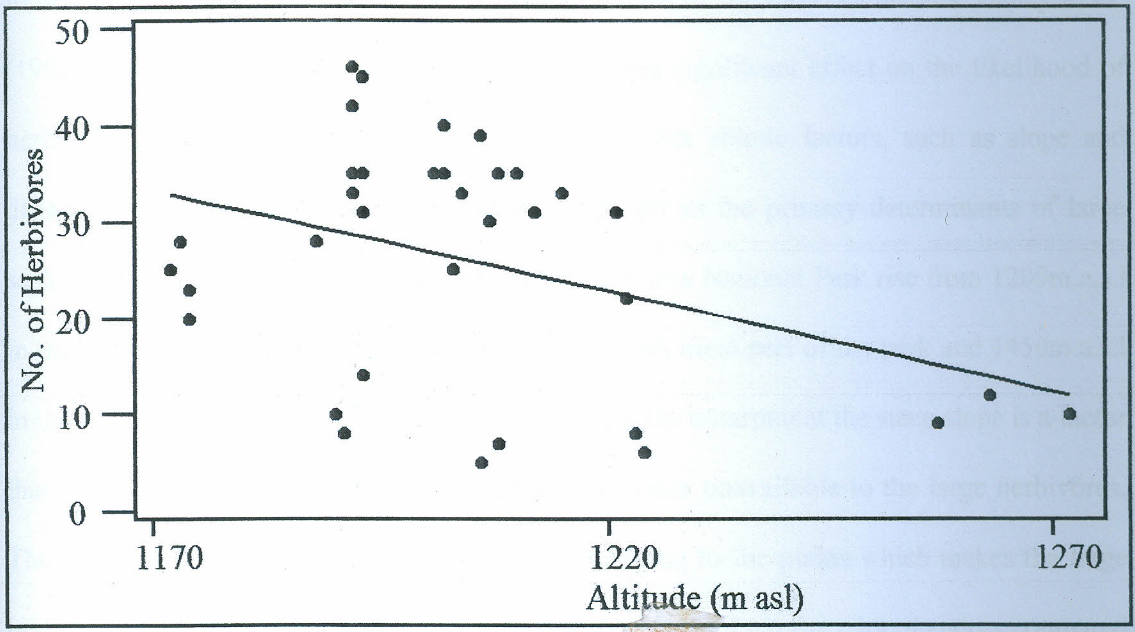


Figure 4.3: Relationship between large herbivores and altitude in meters above sea level.

Regression plot

No. of Herbivores = 277 – 0.2 Altitude

S = 11.4 R-Sq = 15% R-Sq(adj) = 13% P = 0.001

The large herbivore distribution was well manifested in lower altitude where there the slope was gentle making the large herbivores spend less energy in meeting their daily requirements. This made the large herbivores prefer the plains to the slopes. Many landscape-scale models of herbivore distributions focus primarily on the role of biotic factors such as forage quality and quantity (Redfern *et al.*, 2003). The results of (Figure 4.3) the least squares regression (R-Sq = 0.15, P = 0.0001) the relation between altitude and LHD show that 15% of the variation of can be accounted for by altitude.

Bergman *et al.*, (2001) and Bailey *et al.*, (1996) stated that herbivores often locate themselves in areas where they can maximize their energy gains within the natural constraints imposed by abiotic factors such as slope and distance to water. The escarpment is steep, hilly and the loose volcanic rocks thus attracting a low distribution of the large herbivores. Bailey *et al.* (1996) reported that availability of surface water has significant effect on the likelihood of herbivores being present, even in the dry season, but abiotic factors, such as slope and distance to water, are equally as important. They act as the primary determinants of large scale distribution patterns of the large herbivores. Ruma National Park rise from 1200m.a.s.l in the valley floor to1750m.a.s.l at Gendo to the south most part of the park and 1450m.a.s.l in the easterly part of the Park at Kamgwagi. Along the escarpment the steep slope is a factor that has made the streams very steep making the water unavailable to the large herbivores. The streams percolate into the ground before emerging to the plains which makes the large herbivores shift to the plains where accessing water does not require a lot of energy compared to the escarpment. Republic of Kenya (1996) reported that, the valley floor was about 75m above the level of L. Victoria (1,200m.a.s.l), but after relatively recent stages of tectonic activities the valley submerged below the waters of the lake. This study found out that large herbivores prefer the plains but due to flooding during heavy rains they relocate to higher grounds and soon revert back to the plains once flooding subsided.

Further a simple linear squares regression to find out the influence water sources was performed between the large herbivores and the water sources. The LHD in relation to water sources was represented by the regression plot in (Figure 4.4). The results Figure 4.4 show (R-Sq = 0.29, P = 0.0001) positive relationship between water sources and LHD which is statistically significance at 99% confidence levels. The scatter plot Figure 4.4 demonstrates that increase in the number of water sources was accompanied by an increase in the LHD. The results linear squares regression (R-Sq = 0.29) the relation between water sources and the LHD show that 29% of the variation of large herbivore distribution is accounted for by waters sources.

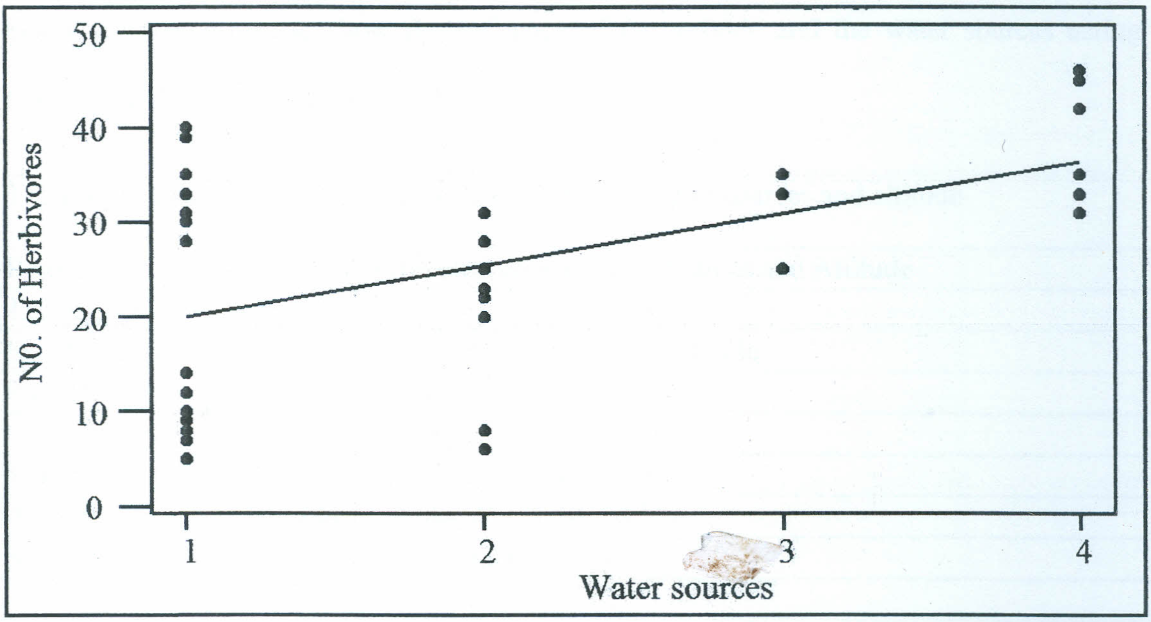


Figure 4.4: Relationship between large herbivore distribution and number of water sources.

Regression plot

No. of Herbivores = 14.5 – 5.5 Water sources

S = 10.4 R-Sq = 29% R-Sq(adj) = 27% P = 0.0001

Due to Ruma landscape there was need to find out the influence of the altitude and the water sources acting together on the large herbivores distribution. Water sources must be physically

$$\text{No. of Herbivores} = 159 + 4.66\ \text{Water sources} - 0.118\text{Altitude}$$

indicating that herbivore distribution was influenced more by water sources than altitude. Water sources had a positive linear relationship with herbivore distribution such that the more the number of the water sources the higher the herbivore distribution contrary to the influence by altitude which had a linear negative relationship with herbivore distribution showing that as the altitude increase herbivore distribution get low. This is attributed to the steep escarpment and volcanic loose rocks. The multiple regressions analysis described the effect of the two explanatory variables; water sources and altitude acting on the responsive variable; the large herbivores distribution shown that ($R\text{-sq} = 0.333$, $P = 0.001$) which is significant at 99% thus rejecting the null hypothesis that there is no significant effect of altitude and water sources on the LHD for 30% of the effect was accounted for by the water sources and the altitude both acting on the large herbivore distribution.

The results of the multiple regressions show that contribution of water sources was higher with 1538.8 Seq. SS and the altitude with 207.5 Seq. SS (Table 4.6). The contribution of each of the explanatory variables in the control of the responsive variable which was the large herbivore distribution could not be estimated because the measure of the water sources were counted in numbers and didn't have units whereas altitude was measured in m.a.s.l thus no comparison in such discrete quantities. To get the information that correlates the effect contributed by each altitude and water sources, the t ratios are used. In the regression analysis the t ratios were 3.02 for water sources and 1.40 for the altitude which confirmed that the water sources had more influence on the HD than altitude (Table 4.6).

This distribution was due to apparent preference of the large herbivore for water and terrain. It was, therefore, that in this landscape, herbivores were compromising closeness to water for forage availability (Bergstrom & Skarpe, 1999). Such a compromise is made possible by a degree of elasticity of their intrinsic constraints as in (Owen-Smith, 1993), which allow herbivores to increase their foraging distances when the benefits provided by distant forage outweigh the cost of travel (Bolker *et al.*; 2009). This was possible, however, because the animals could walk to water when necessary. The altitude facilitated refuge for the herbivores during the rainy season to evade the flooded areas but if no flooding was witnessed they would be in the plains. This concurs with the findings of this study that the water sources and the altitude act together in influencing the herbivores distribution in Ruma National Park.

4.5: Mean monthly rainfall and large herbivore distribution

The results for the months of January, February and March with rainfall amounts of 73.5mm, 25mm and 75.5mm respectively denoted the dry season and in the months of April, May and June with rainfalls 189mm, 183.3mm and 147.2 respectively denoted as the wet respectively table 4.8. The months of January, February and March denoted the dry season and the months of April, May and June denoted as the wet respectively (Table 4.7).

Table 4.7: Mean monthly rainfall and the large herbivores distribution

Month	Mean monthly rainfall	Cumulative Grazers counts
January	73.5	13722
February	25	15316
March	75.5	13437
April	189	5268
May	183.3	2732
June	147.2	1604

This data was put in the Minitab software for a regression analysis. The results (Table 4.8) show (R-Sq. = 0.51, P = 0.001) negative relationship between mean monthly rainfall and LHD which is statistically significant at 99% confidence levels thus rejecting the null hypothesis that there is no significant effect of mean monthly rainfall on the LHD. The scatter plot (Figure 4.5) demonstrates mean monthly rainfall (mm) increase is accompanied by a decrease in the LHD. Over 91 km^2 of Ruma National Park's 120km^2 is located on the floor of the Lambwe Valley at an altitude of 1200m.a.s.l.

Table 4.8: Regression analysis on the relationship between rainfall and the large herbivores distribution

The regression equation is				
No. of Herbivores = 14689 - 50Rainfall				
Predictor	Coef	SE Coef	T	P
Constant	14689	2874	5.11	0.007
Rainfall	-50.05	24.40	-2.05	0.001
S = 3824	R-Sq = 51.3%	R-Sq (adj) = 39.1%		

Large herbivores typically graze heavily in some areas during some parts of the season, whereas other areas receive little or no use (Andrew, 1988; Willms *et al*., 1988). With Kanyamwa escarpment to the east, Gwasi and Ruri hills to the west much of the flush floods are collected in the Park. The flooding makes the large herbivores to relocate to the escarpment which provides refuge for them. The flooding makes it difficult and challenging in traversing the Park; hence few or no sightings are made by the patrol teams.

Further a linear squares regression was performed between large herbivore distribution and mean monthly rainfall to find out influence of rainfall on the LHD. The LHD in relation to rainfall was represented by the regression scatter plot (Figure 4.5). In scatter plot, the negative relationship indicates that the herbivore distribution was high in the plains than in the escarpment during the high rainfall spell due to flooding in the plains. Higher rainfall corresponds to lower herbivore distribution in the plains. The results (Figure 4.5) show a 50-50 relationship between the herbivore distribution and the mean monthly rainfall because Ruma National Park partly lie in the valley and partly in the escarpment which controls the characteristic. It is also noted that Ruma National Park is completely fenced and there is no dispersal corridor for immigration or emigration. Therefore movement from the plains to the escarpment during the rainy and the dry season creates the situation. This is indicated by (R-Sq = 0.51; P = 0.001) that 51% of the relationship is attributed to the amount of rainfall (Figure 4.5).

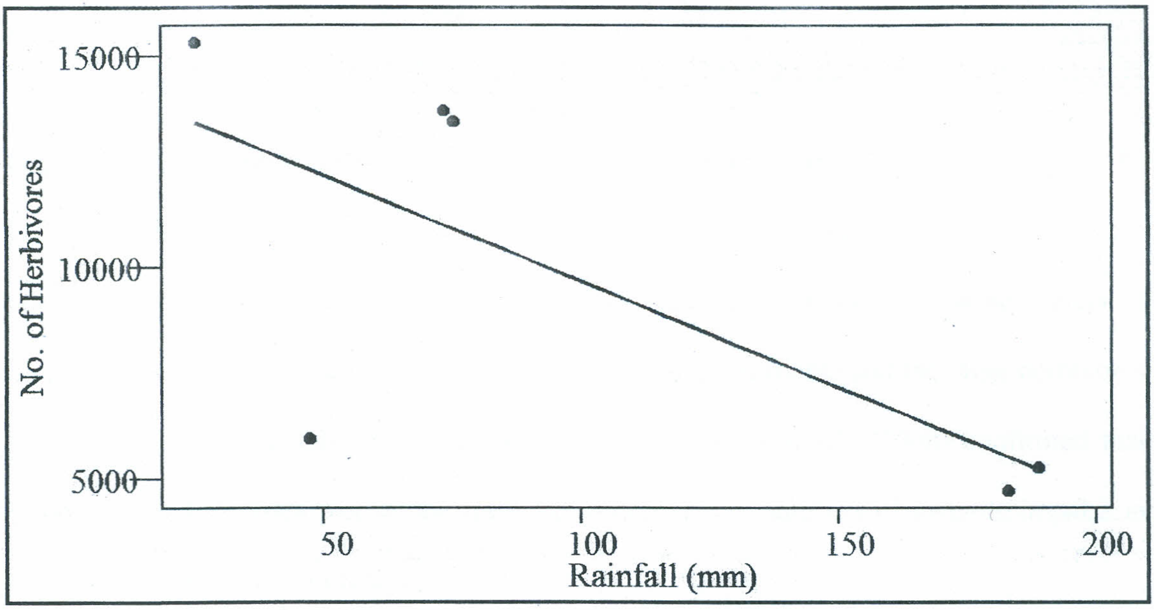


Figure 4.5: Relationship between large herbivore distribution and Rainfall.

Regression plot

No. Herbivores = 14689 - 50 Rainfall.

S = 3824 R-Sq = 51% R-Sq(adj) = 39% P = 0.001

The relationship between the LHD and mean monthly rainfall is linear. With Kanyamwa escarpment to the east and the Gwasi and Ruri hills to the west much of the flush floods are collected in the park. The flooding makes the LGH to relocate to the escarpment which provides refuge for them. The flooding makes it difficult and challenging in traversing the Park, hence few or no sightings.

Desmukh (1984) proposed a model describing the variation in biomass of the grass communities based on annual rainfall, a good predictor of primary production across the globe and specifically in sub-Saharan Africa. The model explained a large proportion of the variance in grass biomass, the limited range of annual rainfall which covered (100-700 mm) and the fact that it does not take into account the soil nutrient status (Bell, 1982) and other factors that influence the quantity and quality of plant resources, such as the grazing process itself (McNaughton &Georgiadis, 1986).

Higher mean monthly rainfall causes flooding because part of the Park lie entirely in the valley thus displacing large herbivores during high rainfall spells. During the rainy season the grasses soften and the ephemerals germinate giving the large herbivores a wide variety of biomass to select from. During this period water is readily available and the large herbivores move to the well-drained areas. A rigorous study by Ogutu *et al.,* (2008) confirmed that floods arising from high wet season rains led to decrease in numbers of juvenile impalas in Maasai Mara ecosystem in Kenya.

Herbivores respond to both cumulative past rainfall and seasonal fluctuations in mean monthly rainfall through changes in movements, reproduction and survival (Ogutu *et al.*, 2008; Owen-Smith & Mills, 2006). For example, during the 1997 drought and 1997-1998 El Niño floods, there were mass deaths of ungulates attributed to anthrax outbreak in Serengeti (Ogutu *et al.*, 2008) facilitated by the rainfall as the pre-disposing factor for the bacterial spores to grow and get distributed. Understanding intensity and frequency of such droughts and floods in a region aid formulation of management plans and policies. They promote mobility and flexible access to resources by wildlife through maintaining open dispersal and migratory routes (Ogutu *et al.*, 2008).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1: Introduction

This chapter contains the summary of the findings of the study, the conclusion, recommendations and areas for further research.

5.2: Summary

Biomass in Ruma National Park ranged from 163g/m^2 to 1940g/m^2. The effect of grass biomass (R-Sq = 0.83, P = 0.0001) on the large herbivores distribution indicate that about 83% of the variation is accounted for by quantity of biomass. The relationship between grass biomass and the large herbivores distribution indicate that large herbivore distribution increased with decrease of grass biomass. The effect of GSR on the large herbivore distribution (R-Sq = 0.66, P = 0.0001) indicated that about 66% of the variation of the LHD is accounted for by GSR. The effect of water sources and altitude (R-Sq = 0.333, P = 0.001) indicate that about 33% of the variation of the large herbivore distribution is jointly influenced by the water sources and the altitude. The effect of rainfall on large herbivore distribution (R-Sq = 0.51, P = 0.001) indicate that 51% of the variation of large herbivore distribution is accounted for by the amount of rainfall.

This study identified several patterns of LHD and their resource selection across seasons of the study period. While there were some differences in resource requirements, it is clear that forage value was important for all the large herbivore distribution. According to this study grass biomass is low in the plains due relatively higher distribution of large herbivores in the plains of Ruma National Park. The results demonstrate that as the quantity of grass biomass increases in the Park, the number of the large herbivore distribution decreases. It was found out that short grasses on the plains have a higher leaf to stem ratio tissues than taller grasses in other areas of the park and control 83% of the variation of large herbivore distribution in Ruma National Park.

5.3: Conclusion

This study established that grass biomass was the most important ecological factor influencing the large herbivore distribution at 83%. The GSR is the second most important ecological factor whose influence is 66% and has positive linear relationship to the large herbivore distribution. The water sources and the altitude jointly influence large herbivore distribution at 33% in Ruma National Park. This study found out that the rainfall effect at 51% of rainfall on large herbivore distribution had a negative linear relationship due to the fact that the flush flood prone plains lie in the Lambwe Valley bottom of Kanyamwa escarpment, Isuria and the Gwasi hills.

In contrast, LHD do not increase with an increase in biomass because the higher biomass consists of the most competitive grasses and are of poor quality. In Ruma National Park large herbivores are highly distributed in the plains which have relatively low biomass consisting fresh grasses. Distribution reflects the ratio of resource demand to supply and that this ratio could be equally high at sites with low or high biomass depending on the resource demanded by the large herbivores. This study found out that fresh grasses are realized in the plains where the biomass was relatively low with high distribution of the large herbivores.

Rainfall is a very important factor when it is relatively high because the Park get flooded thus displacing the large herbivore to the escarpment but soon reverts to the plains once the flooding recedes. This knowledge is instrumental to the management in guiding the management in locating of herbivore monitoring trails and hiking routes to attract visitors even when there flooding to maximize on the conservation revenue collection. The altitude and water source are as important but water sources have a greater influence on the LHD in Ruma Nation Park.

The large herbivores are found distributed in large numbers in the plains where biomass is relatively low but consisting of varied grass species and relatively gentle slope. This is a positive characteristic to capitalize on to promote tourism and revenue generation through placing access roads where the visitors can find most of the wildlife in Ruma National Park. These increases return visits and the visitors becoming an indirect product sales people enabling others to visit. Nevertheless, this positive aspect of high distribution of wildlife in the plains would eventually cause environmental degradation due to overcrowding and over utilization of the primary production. The open plains and access roads built will call for high security machinery coupled with research because wildlife are exposed to threats like poaching on endangered species like the white rhino (*Ceratotherium simum*) which have so far been introduced to the park.

5.4: Recommendations

From the present study and its findings the following recommendations are made:-

1. Further re-introduction of large herbivores that existed in Ruma National Park for hierarchical grazing to reduce the grass biomass in areas it is high to improve the ecological integrity by promoting grass species establishment.
2. Categorization of the large herbivores in low land and higher altitude species to understand the existence of site specific and territorial species to improve the management techniques and strategies for environmental conservation.

3. Since the park lie in the valley monitoring is challenged by flooding. There is need to customize on the findings of this study and make hiking trails in the escarpment which can be used by the tourist and the patrol teams when the wildlife move from the plains to the escarpment to maximize on conservation revenue collection.
4. Access routes for tourism purposes should be constructed in the plains to enable the visitors maximize in seeing wildlife in the park to promote repeated visitation and maximize on the conservation revenue generated during the dry season.

Areas for further research

1. There is need to employ remote sensing method using transmitters to collect data on distribution during day and night.
2. This study was limited to the number of grass species in the subplots rather than the ecological factors that prompt such a scenario like edaphic factors. There is need to study other factors contributing to a high GSR in the plains.
3. There is need to carry out subsequent studies to understand the intensity and frequency of droughts and floods to aid in formulation of management plans and policies that promote mobility and flexible access to resources by wildlife through maintaining open dispersal and migratory routes between the escarpment and the plains through the riverine forest since the park was once part of the Mara-Serengeti ecosystem but now a fragmented savannah ecosystem with an electric perimeter fence the restrict emigrations and immigrations of wildlife.

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