An Analysis of the Factors Influencing Wildlife Population in Some Selected Counties in Kenyan Rangelands

Winifred Wanjiku Kamochu

Kenya Institute for Public Policy
Research and Analysis

KIPPRA Discussion Paper No. 198
2017

KIPPRA in Brief

The Kenya Institute for Public Policy Research and Analysis (KIPPRA) is an autonomous institute whose primary mission is to conduct public policy research leading to policy advice. KIPPRA's mission is to produce consistently high-quality analysis of key issues of public policy and to contribute to the achievement of national long-term development objectives by positively influencing the decision-making process. These goals are met through effective dissemination of recommendations resulting from analysis and by training policy analysts in the public sector. KIPPRA therefore produces a body of well-researched and documented information on public policy, and in the process assists in formulating long-term strategic perspectives. KIPPRA serves as a centralized source from which the Government and the private sector may obtain information and advice on public policy issues.

Published 2017

Bishops Garden Towers, Bishops Road
PO Box 56445-00200 Nairobi, Kenya
tel: +254 20 2719933/4; fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org

ISBN 9966 058 85 0

The Discussion Paper Series disseminates results and reflections from ongoing research activities of the Institute's programmes. The papers are internally refereed and are disseminated to inform and invoke debate on policy issues. Opinions expressed in the papers are entirely those of the authors and do not necessarily reflect the views of the Institute.

This paper is produced under the KIPPRA Young Professionals (YPs) programme. The programme targets young scholars from the public and private sector, who undertake an intensive one-year course on public policy research and analysis, and during which they write a research paper on a selected public policy issue, with supervision from senior researchers at the Institute.

KIPPRA acknowledges generous support from the Government of Kenya, African Capacity Building Foundation (ACBF), and the Think Tank Initiative of IDRC.

Abstract

This study seeks to analyze some of the factors that influence wildlife population within the Kenyan rangelands. Wildlife have continued to decline within the rangelands, catching the attention of the government because of the strategic positioning of wildlife-based tourism in the achievement of the Vision 2030. Wildlife-based tourism accounts for more than 75 per cent of the total earnings in the tourism sector. Continued decline has far reaching economic and ecological consequences on the individual and the nation as a whole, including loss of income, employment and foreign exchange not forgetting ecological imbalances that come with elimination of a species from an ecosystem. This study used panel data obtained from various sources including Department of Resource Survey and Remote Sensing (DRSRS - wildlife and livestock), among others. The fixed effect model was adopted for analytical purposes. The analysis established that increased population and level of urbanization are associated with wildlife declines. On the other hand, increasing acreage under protected areas was associated with increased numbers of wildlife within the rangelands. Additionally, livestock was found to be compatible with wildlife. This study therefore recommends establishment of zones within the rangelands that will allocate specific land uses for settlement, zoning of areas for urban areas and allocation of land for wildlife uses. It also recommends livestock keeping alongside wildlife as the main form of land use. The study also recommends supporting protected areas through finances, and legislation to make them more effective in wildlife protection.

Abbreviations and Acronyms

ASALs	Arid and Semi-Arid Lands
CITES	Convention on International Trade in Endangered Species
DRSRS	Department of Resource Survey and Remote Sensing
GIS	Geographic Information Systems
IUCN	International Union of Conservation of Nature
KFS	Kenya Forestry Service
KNBS	Kenya Bureau of Statistics
KWCA	Kenya Wildlife Conservancies Association
KWS	Kenya Wildlife Service
KWTA	Kenya Water Towers Authority
LAPSSET	Lamu Port-South Sudan-Ethiopia-Transport
NEC	National Environment Council
NEMA	National Environmental Management Authority
NMK	National Museums of Kenya
SDGs	Sustainable Development Goals
WWF	World Wildlife Fund

Table of Contents

List of Figures

List of Tables

List of Appendices

1. Introduction

1.1 Background Information

Wildlife refers to animals and plants living in their natural habitats and have not been domesticated by humans. For the purposes of this study, wildlife refers to animals. Wildlife counts have been going down worldwide (Lusweti, 2011). The global living planet index report has put the decline since 1970 to be 52 per cent. The poorest countries and the tropics are the most affected, recording a decline of 58 per cent and 56 per cent, respectively (WWF Global, 2014). Cheetah, common chimpanzee, the mountain gorilla, the lion and the rhinos are some of the species that are listed in the International Union of Conservation of Nature (IUCN) red list of endangered species. The trends of wildlife population in Africa are indicative of a mixture of outcomes with some species experiencing declines while others are becoming steady. For instance, the Wild Nature Institute has indicated that the giraffe population trends are on a decline with the continent loosing 30 per cent in the recent past, while the wildebeests in Tanzania have reduced by 88 per cent in the last 20 years (Wild Nature Institute, 2014). The grevy's zebra and the rhino population have become steady in Kenya due to concerted conservation efforts.

1.2 Wildlife in the Kenyan Rangelands

The rangelands of Kenya occupy about 80 per cent of total land area (Nelson, 2012). Rangeland is a kind of land, not a land use (Bidwell and Glasgow, 2007) characterized by low rainfall, savannah vegetation which is usually grass, and sparsely distributed shrubs and woody plants. It has varied climatic conditions, which are extreme ranging from hot to cold deserts including the tundra. The soils in these areas are also highly varied in type from mollisols in the grasslands to sandy soils in the deserts. The topography is diverse making different geological regions around the world (Solomon et al., 1993; Chapin et al., 1995; Roselle et al., 2009 and Blench and Sommer, 1999). Their complexity gives them different identities around the globe including the prairies, pampas, grasslands, woodlands, savannahs, hot and cold deserts, arid lands, etc (Roselle et al., 2009; Chapin et al., 1995).

Different authors have given various extents of the rangelands. In relation to the total land surface, rangelands occupy 47 per cent of total area (Roselle et al., 2009; Bidwell and Glasgow, 2007). When looking at the world land area and you exclude the Antarctica, they occupy between 18 and 23 per cent of total world land area (Blench and Sommer, 1999) and more than half (51% or 68.5 million km^2) of the terrestrial land surface, (Solomon et al., 1993; Lean et al., 1990; Prentice et al.,

1992 in Chapin et al., 1995.). When considering agricultural lands, it is estimated that globally 69 per cent of land under agricultural use is in the rangelands (FAO Stats 2009 in Niamir-fuller et al., 2012).

Different ecological zones in the rangelands are used for various economic activities. Traditionally, rangelands were considered mainly for livestock and wildlife sustenance (Roselle et al., 2009). This has, however, changed with time and apart from being home to pastoral communities who rely on the grassland for their livestock, rangelands are also rich in biodiversity and are especially known for hosting the large mammals (Blench & Sommer, 1999) which are important for touristic purposes. Depending on the level of development or policies a country pursues, rangelands are used for numerous economic activities including but not limited to ranching, livestock rearing, farming both large and small scale which can either be rain-fed or irrigated and wildlife conservation (Blench and Sommer, 1999).

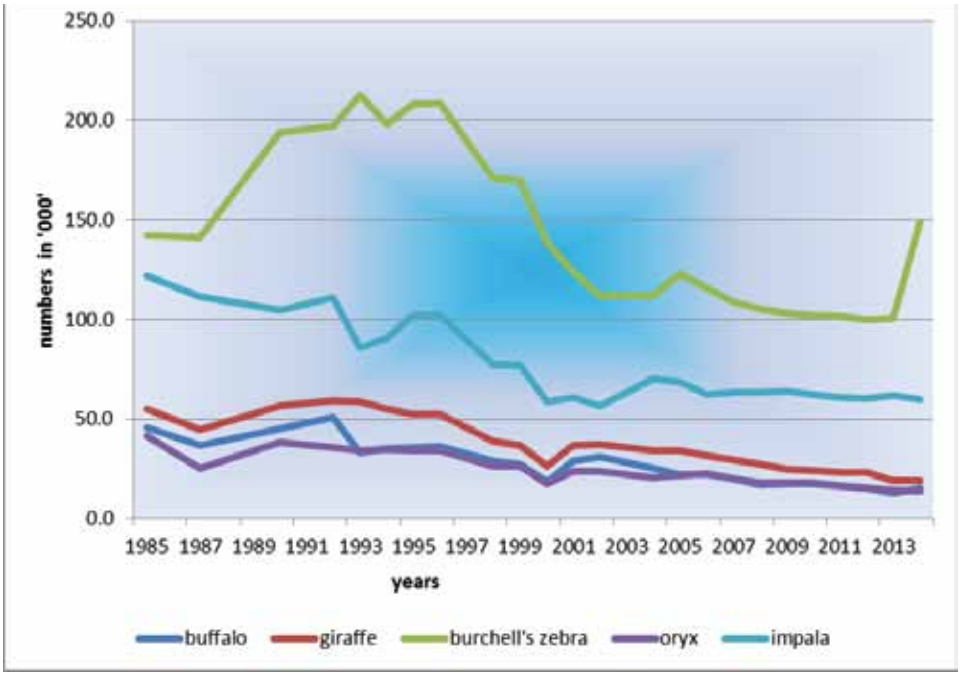
Worldwide, rangelands are considered as some of the "last great wildlands" hosting wildlife outside protected areas that have no formal legal protection. It also supports millions of people, many who are considered to be poor pastoralist (Niamir-fuller et al., 2012). The situation in the rangelands is, however, changing. With population increase more and more people in the semi-arid region are moving in to the drier parts of the rangelands and converting them into farming lands. This, in turn, has placed pressure on the pastoralist as land for grazing reduces. This impacts the forage, which means that the wildlife that thrive in these lands will be affected as their habitat continuously becomes converted into human habited landscapes (Blench and Sommer, 1999).

In Kenya, rangelands are an important ecosystem for wildlife management as they hold 90 per cent of wildlife and 88 per cent of protected areas (Osano, Leeuw and Said, 2012). Kenya is rich in biodiversity, hosting a total of 1,847 species, 76 amphibians, 1,103 birds, 407 mammals, and 261 reptiles. This wildlife is the main attraction for the tourists accounting for 90 per cent of safari tourism and 75 per cent of the total tourism income (KWS, 2013; Okello and Mwinzi, 2001). Despite this important role, wildlife in Kenya has been declining with the country losing about half of its wildlife to various threats. Currently, there are 138 endangered and threatened species, of which 16 are listed as critically endangered. Different periods in the Kenyan history have recorded different decline rates of wildlife numbers. An analysis of data from KNBS on the wildlife declines in the Kenyan rangelands shows wildlife losses in the 1970s and 1980s to be the most severe at 48 percent. These declines reduced to 23 and 11 per cent in the 1990s and 2000s, respectively (Government of Kenya, 2015). The differentiated decline rates are associated with various institutional and legislative reforms that the government

undertook during those periods. In fact some of the species that experienced heavy declines in the 1980s and 1990s such as the elephant (72%) and gerenuk (68%), actually recorded increases in the following decade of 2 and 3 per cent, respectively, due to policy and institutional reforms that were undertaken by the government.

While these improvements are commendable, a review of the last five years shows a 16 per cent decline of wildlife in the rangelands (KNBS, 2014; 2015; 2016). Some of the species that continue to decline include the Grevy Zebra, which has undergone 85 per cent decline in the last 35 years, the large carnivores, the antelopes, the primates and the giraffes (Musyoki et al., 2012). Kenyan rangelands have experienced 40 per cent (about 412,000) animal declines (Conniff, 2009) an average rate of 2.5 per cent per annum (Government of Kenya, 2007). If this trend continues the tourism sector competitiveness may go down affecting the overall economic growth (Government of Kenya, 2007). Furthermore the ecological integrity will affect the overall ability of the environment to support livelihoods dependent on wildlife.

Figure 1.1: Trends in wildlife populations in Kenya tangelands from 1985 to 2012



Data source: KNBS (Various), Statistical Abstracts

Species reduction and fluctuations is a factor of many combinations of natural and human influences (birth and death rates, changes in resources, temperature and rainfall, predation, disease, pollution, alien species, over-exploitation). Overall, the major causes of these losses are habitat loss, degradation and climate change (Woodley et al., 2015). Habitat loss is the main threat accounting for 85 percent of all species decline described in the IUCN's Red List (Joppa, 2012).

Kenya employs a variety of international and regional instruments to reduce the rate of wildlife decline. It is a signatory to international agreements such as the Convenction on International Trade in Endangered species (CITEs) and Convection on Biodiversity, among others. Locally, it has established the Centre for biodiversity, the National Biodiversity Action Plan 2010 and most recently the Wildlife Management and Conservation Act 2013. It has also established numerous protected areas. However, despite these positive moves, wildlife is still experiencing threats that lead to their decline.

In addition, Kenyan rangelands continue to receive high numbers of immigrants from the high potential areas seeking for new agricultural lands. In some arid counties, people are taking to agriculture as a form of land utilization as employment opportunities continue to shrink in urban areas (Duraiappah et al., 2013 and Government of Kenya, 2011).

Furthermore, the economic and educational landscape in the ASAL districts in Kenya has led to a changing lifestyle and is encouraging growth of urban areas. According to the Vision 2030 development strategy for northern Kenya and other dry areas, the numbers of urban centres, though unplanned, are increasing and the already existing ones are continually expanding. The increased numbers are mostly as a result of creation of new smaller administrative units by the national government in a bid to bring services closer to the people. They thus attract new settlers from within and outside these old districts. People prefer to settle in these areas because of the availability of water and services such as schools and power.

With a population growth rate of 2.7 per cent per annum (World Bank, 2013) and planned increase of irrigable lands in the ASALs continued wildlife decline is inevitable. This study helps understand the factors that determine wildlife population in the rangelands with the aim of coming up with effective strategy to combat declines while at the same time supporting those efforts that promote increase.

1. 3 Legal and Institutional Mechanisms and Reforms Aimed at Reducing Wildlife Declines

The Constitution of Kenya places the responsibility of environmental protection and by extension wildlife with the State. The role of protection of wild animals lies with the national government and county governments. The National Government plays it role through formulation of policy, legislative framework and funding through the Ministry of Environment. The mandate of the Ministry is to protect, manage and conserve the environment and natural resources for the social economic development. Specifically, the Directorate of Natural Resources in the Ministry deals with forest and wildlife conservation. The county governments are in charge of reserves that were initially under the county councils. Other key institutions involved in the protection of wildlife include Kenya Wildlife Services (KWS), Kenya Forest Services (KFS), National Museums of Kenya (NMK), National Environmental Management Authority (NEMA), National Environmental Council (NEC), and Kenya Water Towers Authority (KWTA).

In a bid to protect wildlife and reverse their declines, the government has undertaken various strategies and reforms. The first legal strategy was in form of gazetted regulations of 1898. These regulations mainly gave guidelines on hunting, and they also provided for the establishment of game reserves which were mainly under the councils. The government then established the Game Department in 1907 which had more of the same functions with the regulators. The Department was put in charge of wildlife management and hunting control in the country. In addition, the Department was given the responsibility of dealing with problem animals outside the protected areas. The role of the parks management was given to a committee. The situation remained the same until 1945 when Ordinance No. 9 came to be and established a Board of Trustees to administer national parks.

With self-rule, the government took over the management of the wildlife and in 1975 there was a policy on wildlife management in place. In the same year, the Wildlife Management Act Cap 376 of 1975 was passed by Parliament. The Act called for the involvement of all the stakeholders in wildlife management. In 1976, the Game Department and National Park Trustees were merged to form the Wildlife Conservation Management department. Within the same period, the President banned all forms of hunting and trading in wildlife. To make the ban effective, Parliament enacted regulations that enabled the government to recall all the licenses that had been issued to businesses that dealt with wildlife trophies.

The government went further and purchased all their stocks. The Game Department had a clean bill of health from the start and it was assumed that these measures would make its work even better. However, due to financial constraints

resulting from government under-funding to the Department, it was unable to execute its mandate effectively. In fact, it is during its tenure that sharp wildlife declines were experienced, with the rhinos and elephants bearing the brunt of poaching. In 1989, the Wildlife Management Act was amended to replace the Wildlife Management department with the Kenya Wildlife Services (KWS) in the early 1990s. Up to date, KWS is in charge of wildlife conservation and protection in Kenya, with measurable success in some areas. Consequently, the government has continued with reforms in legislation and institutions that deal with wildlife. However, the government has in the past been criticized for dishonesty in dealing with wildlife issues by attempting to centralize powers to KWS contrary to earlier policies and international conventions that have continued to call for decentralization and community involvement. The 2007 Wildlife and Management Bill offers a good example of such a bill that sought to control wildlife tourism in private and communal protected areas including the conservancies. The Act has tried to address most of the issues affecting the wildlife sector. It has, for example, taken cognizance of the conservancies and given them a definition. Largely, it has dwelt on wildlife protection through reduced poaching, hunting, problem animal control, compensation for wildlife injury, death or crop damage etc. While this is commendable, the success of the Act is yet to be seen. The Act has failed to address the underlying issue that leads to declines, which is habitat degradation and elimination that is affecting more than 60 per cent of wildlife found in private and communal or trust land as it only provides for the establishment of private and communal-protected areas without giving guidelines on the sustainability or modalities of change of use. Thus owners remain prone to profit maximization that can lead to land use change (Government of Kenya, 2012; Kipngetich, 2012; Fred, 2012).

As it is now, the management and conservation of wildlife is governed by the Wildlife Management and Conservation Act 2013 which delegates most of the enforcement to the Kenya Wildlife Service. This is the only Act that expressly deals with wildlife in Kenya but, like many other natural resources, wildlife covers various habitats which have different management and protection bodies, thus the protection is extended to other institutions that deal with other natural resources. In fact, the number of Acts that touch on wildlife, wildlife habitat conservation or protection in one way or another including multilateral agreements are more than 70. Some of the multilateral environmental agreements relevant to wildlife protection include the Convention on Biodiversity, which seeks to safeguard ecosystems in order to reduce biodiversity loss by 2020, and the African Convention on the Conservation of Nature and Natural Resources of 1969 and revised in 2003. The convention sought to safeguard all wildlife and their habitats by incorporating land use planning. Other actors in wildlife protection and conservation are the non-

governmental and private institutions and organizations who have mostly played the role of lobby and funding in the sector (Mwenja and Eves, 2009). In addition, the government has adopted the United Nations' Sustainable Development Goals (SDGs). Goal 15 aims at protection and restoration of terrestrial ecosystem in order to halt and reverse wildlife declines. The governments are specifically required to "Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species" (United Nations, 2015). Likewise, the country's blueprint on development, the Vision 2030, gives guidelines on wildlife protection and proposes securing migratory corridors to reverse declines (Government of Kenya, 2007).

1.4 Research Problem

The Government of Kenya has in the past enacted various legislative and institutional reforms to reverse wildlife declines. Some of the legislative reforms include banning of wildlife hunting and trophy trades, review of the past wildlife policies, and enactment of the National Wildlife Management and Conservation Act 2013. It has also carried out systematic institutional reforms from the Game Department in 1907 to the current Kenya Wildlife Service. Despite these efforts, the last 30 years have seen wildlife numbers shrink by between 35 per cent and 50 per cent due to human encroachment into wildlife habitats. Currently, there are 138 endangered and threatened species in Kenya (KWS, 2013). The threat to wildlife populations is a serious one for Kenya mostly because the declines are occurring both within and outside the government-protected areas (Western, Russell, and Cuthill, 2009). The Amboseli National Park and Maasai Mara National Reserves are some of the protected areas that continue to experience general declines of wildlife associated with increased population and encroachments in their habitats (NEMA, 2014). Consequently, the government is struggling to meet its obligation under the Vision 2030 goals on wildlife protection that required all wildlife and their habitats be fully protected by 2012.

Wildlife is crucial for the balancing of the ecosystem services (Blench and Sommer, 1999; Chapin et al., 1995.) and wealth creation through the tourism sector. In Kenya, wildlife is pivotal to the growth and preservation of the tourism sector as it accounts for 90 per cent of safari tourism and 75 per cent of the total tourism earnings (Okelo and Mwinzi, 2001). By 2014, tourism accounted for 3.5 per cent of total employment and about 9 per cent of formal employment (KIPPRA, 2016) and a leading foreign income earner. Differentiation of the wildlife safari product has been placed among the trajectory in the tourism sector that is expected to deliver the annual 10 per cent growth rate anticipated in the Vision 2030. Continued loss

of wildlife will not only affect sustained growth in the tourism industry; but also have far-reaching economic consequences on economic development. Resultant loss of jobs will mean increased poverty levels, high dependency rate and the consequences. This will further slow down economic growth, which means jobs will not be created fast enough to accommodate the growing population. The end result will be a vicious cycle of poverty. It is against this background that this study seeks to examine the factors that affect wildlife populations in the rangelands, which hold 90 per cent of wildlife and 80 per cent of the protected areas (Osano, Leeuw and Said, 2012) and answer the question as to what factors influence wildlife population within the Kenyan rangelands?

1.5 Objectives

This study is an attempt to establish and explain the factors that affect wildlife population in the Kenyan rangelands and to give policy recommendations on the same.

Specific objectives

(i) To determine the factors that affect wildlife populations.

(ii) To give policy recommendations based on the outcome of the objective one.

1.6 Justification

Regarding wildlife conservation, the Vision 2030 aims to fully protect all wildlife and their habitats to prevent wildlife loss and extinction of threatened species by the year 2030. Wildlife in Kenya's rangelands is steadily declining at an average rate of 2.5 per cent per year. Studies on the decline of wildlife have mostly focused on declines within the protected areas without regard to the existing patterns of land use practices outside the protected areas where most wildlife is found. Rangelands are important ecosystem for wildlife management as they hold 90 per cent of wildlife and 80 per cent of protected areas. Understanding the drivers and pressure that results in decreased wildlife populations in the rangelands is important to policy makers as it enables them to implement effective strategies to halt the declines by mitigating the negative impacts. Over 90 per cent of developments such as the Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) corridor, the Standard Gauge Railway line, and the Konza City Technopolis are within rangelands. There is also continued pressure on arable land, leading people to encroach into the arid lands and further compromising the predicament of wildlife. To achieve the 10 per cent annual growth envisioned in the Vision 2030, the government intends to expand the tourism sector which largely depends on

wildlife. In fact, the future of the tourism industry depends on the current status of wildlife. Evaluation of the factors that affect the declines will help in drawing specific interventions that will allow policy makers to target the declines more effectively. The findings can also enrich the Land Use Planning Bill 2014 and the Wildlife Management and Conservation Act regulations may need review.

Kenya has adopted the Sustainable Development Goals. Goal 15 has a focus on reversing land degradation and halting biodiversity loss by 2020 by urgently protecting and preventing extinction of threatened species. The outcome of this study has the potential to offer significant solutions that will slow down loss of wildlife.

A review of the literature has also established that there is a new form of land use that is emerging in the rangeland; that is, conservancies which has not been well explored. These will be explored to come up with comprehensive recommendations that can help slow down wildlife declines.

2. Literature Review

2.1 Theoretical Literature Review

There are as many theories explaining causes of wildlife decline. Hoffman (2004) gives an overview of a few theories that help to explain wildlife declines as a result of human natural environment interactions. Man relies on the natural environment for his sustenance and sometimes to the detriment of the natural environment. The theories that Hoffman uses are the neo-malthusian theories and treadmill theory of production. The neo-malthusian theory emphasizes that population growth leads to demand for more land for food production and infrastructure development that leads to depletion of the resources. The need to increase food production means that wildlife will be displaced in favour of agricultural production, which can lead to species decline (Czech, Krausman, and Devers, 2000 in Hoffman, 2004). The neo-malthusian theory was later modified by the treadmill of production theory that argues that growth is necessary to keep jobs and revenue but this will happen at the detriment of the environment in the end. Economic interests override environmental concerns with continued degradation of the environment.

Another theory that is used to explain wildlife numbers or richness in an area is the theory of Island Biogeography. This theory was established by McAurthur and Wilson in 1967. It contends that the number of species in an area that is isolated is determined by the size and proximity of that area to the origin home of the species. Urbanization, and road network or pipeline passing in wildlife habitat can create islands and consequently isolation leading to their reduction. This theory is also used to explain fragmentation. Habitat fragmentation is the contraction of the animals' required range for survival by either human activities or the natural phenomena. Climate variations and the resultant consequences such as fire, flooding, and drought constitute the natural phenomena while land conversion for agricultural activities and building houses for settlement and infrastructure development constitute the anthropogenic causes of fragmentation. The consequence of fragmentation is shrinking habitats for animals and increased edge effects. There is then ensuing competition for forage and separation from other species and inaccessible breeding and migratory corridors. There is also increased interaction with humans, all which make habitat fragmentation one of the major causes of fauna decline.

The economic growth theory on the other hand, implies that production uses environmental resources for the welfare of human beings. This can lead to degradation of the environment or natural resources, thus reducing future supply and increasing costs. This has an implication on wildlife declines.

The Boserupian theory sees population growth as the principal force driving societies to find new lands for agriculture production. This is the current scenario in the Kenyan arid lands where people have continued to encroach as they seek for more arable land for cultivation, therefore displacing wildlife (Markham, 2001).

Other works have underscored the mentioned theories on the causes of wildlife declines; Swanson (1995) underscored the role of people in wildlife declines to include lack of proper and effective institutions and policies and pursuing of economic activities that do not take into account the needs of other species. Overgrazing and agricultural pricing (Hanley et al., 2007) hunting, habitat destruction and climate change also affect wildlife populations negatively (Eppink, 2007). Declining-population paradigm was advanced by Caughley (1994) who explains population declines as a process. To Caughley, declines are determined by the ability of the animal to adapt to environmental changes that are anthropogenic in nature. To summarize, species reduction and fluctuations is a factor of many combinations of natural and human influences such as birth and death rates, changes in resources, temperature and rainfall, predation, disease, pollution, alien species, over-exploitation and, overall, the major causes of these losses are habitat loss, degradation and climate change (Woodley et al., 2015).

2.2 Empirical Literature Review

Wildlife has been a subject of studies by different authors worldwide, touching on various aspects from the ecological to the biological. Ogada and Keesing (2010) used linear regression and correlation analysis to study changes in population of raptors and scavenging birds in Laikipia County between the year 2001 and 2003 using rainfall as the explained variable and found that both species declined by 68 per cent and 70 per cent, respectively during the study period. The study in Laikipia focused on changes in population of birds but was not able to give the actual causes of declines that were observed.

Groom and Western (2013) looked at the impact of land sub-division on wildlife and pasture conditions using Merueshi and Mbirikani ranches as their area of study. They used general linear regression model on which they applied sequential analysis of variance (ANOVA) and found that sub-division of land and permanent settlements reduces wildlife numbers and livestock movement. It also slows the recovery of forage after the dry periods and greatly reduces the biomass.

Kiringe and Okello (2007) identified trading in bush meat, poaching, human encroachment into the protected areas and dispersal and migratory wildlife areas and the resultant human wildlife conflicts as some of the factors that negatively affect wildlife protected areas in Kenya.

Mundia and Murayama (2009) analysis of long-term land cover changes in the Maasai Mara ecosystem indicated that wildlife was rapidly declining as grassland continuously became converted into agricultural land. The study utilized multispectral remote sensed data which was analyzed using GIS and reviews of the existing knowledge to come to its conclusion that a mixture of factors come into play to effect wildlife declines and they include land use policy in place, tourism facilities development, and increased competition between livestock and wildlife.

Nyamasyo and Kihima (2014) looked at the effect of land use change in the Kimama wetland on wild ungulates and found that encroachment into the ecosystem led to the rising cases of human wildlife conflicts. There was also increased habitat destruction and degradation and displacement of wildlife by livestock and consequently reduction of the wildlife. Invasive species were also found around the wetland. The study used a combination of methods to come into these conclusions including, Pearson correlation coefficient statistics analysis, GIS and ERDAS and descriptive statistics.

Using "a flexible multivariate semi-parametric generalized linear mixed model with a negative binomial error distribution and a log link function", Ogutu, Piepho, and Said (2011) analyzed trends in wildlife and livestock in the Mara region between 1977 and 2009 and found that most wildlife populations had declined. There was competition between wildlife and livestock in the region mostly due to anthropogenic effects. A follow up of the same study by Ogutu et al (2014) widened the scope of the analysis but with similar methodology to include population pressures, governance and government policy on wildlife. The conclusions were similar that anthropogenic factors affects wildlife populations in Kajiado County. The (2014) study showed that most of the land that was initially utilized by wildlife has been converted into agricultural land and settlement areas, effectively reducing the wildlife habitats and their numbers in these farmed areas.

Okello et al (2015) studied the impact of 2007-2009 droughts on large mammals in the Kenya Tanzania boarder using geographical information systems (GIS) to analyze the data and found that wildlife declined because of the drought but were able to recover once it rained. However, the recovery rate was not similar for all species as some are more sensitive to environmental changes.

Using log linear models, Ottichilo et al. (2000) studied the trend of the non-migratory herbivores and livestock in the Maasai Mara region between 1977 and 1997. He also sought to establish whether there were any differences in the population trends of these animals in relation to their habitat, either within or outside the protected areas. The study revealed that most wildlife resided outside the protected areas and the declines were at 68 per cent in both instances.

Coggan (2006) study using Darwin Scout Programme wildlife monitoring and threat monitoring, GIS and SPSS found that poaching and retribution killings, proximity to the roads and rivers affect wildlife trends and presence and concluded that large ranges are required to maintain viable wildlife populations.

Waithaka (2004) reviewed the ecological and socio-economic problems associated with tourism, land use changes and breakdown of traditional governance structures in Maasai Mara ecosystem. The study identified agriculture, poaching, increased human wildlife conflicts, elitism, and sedentary settlement as the major threats to the Mara ecosystem. Overcrowded tourist facility and overuse of some part of the ecosystem impacted negatively on the ecology by disturbing animals and damaging vegetation.

Using GIS, Syombua (2013) did a spatial analysis of land use changes in Taita Taveta District. The study established that wildlife and livestock habitats were decreasing in favour of rain-fed and irrigated agriculture.

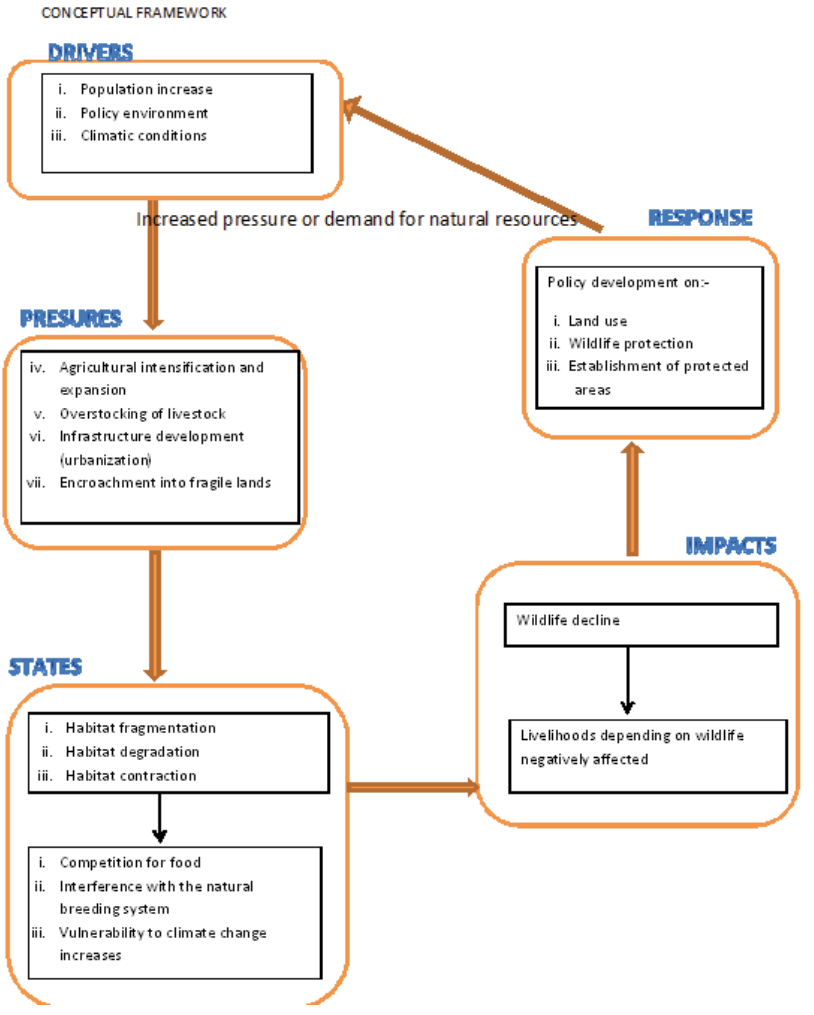
2.3 Overview of the Literature

Overall, there are numerous causes of wildlife decline. Most of the studies on wildlife in Kenya, however, have focused on the trends without looking into the actual causes of the declines. The main area of focus has mainly been the Maasai Mara ecosystem, only which is quite small considering the extent of rangeland that habours wildlife in Kenya. The review has further established that the focus has been on the factors that have negative impacts, leaving out the positive factors that help with increased numbers. This is important as policy environment in the wildlife sector is continually changing and shifting in favour of community-based conservancies which are changing the rangeland landscape in favour of wildlife. In addition, most of these studies are biased towards the impact of agriculture and livestock on wildlife. This study intends to add a new variable that has not been widely explored in the Kenyan context; that is the role of urbanization in determining wildlife populations. Overall, this study will focus on analysing some of the factors that affect wildlife population, whether positive or negative, with an intention to enrich policies in wildlife protection.

3. Methodology

3.1 Conceptual framework

Figure 3.1: Conceptual framework



Source: Modified from Kristensen (2004)

According to the literature reviewed wildlife population is determined by numerous factors either directly or indirectly. The process follows a chain of events from the main drivers to the resultant impact. Since man relies on the natural environment for sustenance, an increase in population exerts pressure on the natural

environment as demand for food and land for settlement increases. To acquire these goods and services from the environment there results in land conversion as more land is cleared to pave way for settlement, which can either be rural or urban setting settlement. As more land is required for food production there is usually encroachment into the fragile lands, thus contracting the range available for wildlife and consequently their declines. Since wildlife supports livelihoods, and the government then responds by creating a friendly policy environment to remedy the situation. Other factors that drive wildlife population include the policy environment, which will determine the development path a country will pursue either to the detriment or enhancement of the wildlife habitats. Climatic conditions are also known to affect wildlife declines, for example during drought a lot of wildlife succumbs to starvation. The interactions between all these variables are illustrated in Figure 3.1.

It is conceptualized that depending on the nature of human activity, the numbers will either increase or decrease. Both overstocking and urbanization have a negative effect on the wildlife as they affect their habitat. Overstocking means that there is competition with wildlife for grass pasture and range degradation which will mean less fodder for the wildlife. Urbanization and infrastructure development cause fragmentation of habitats and hinder movement to the breeding ground and safety nets during drought. Human-related factors also affect natural factors (rainfall, temperatures, etc) accelerating their intensity, For example, deforestation has the ability to negatively affect the climatic conditions of a region, with consequences being reduced total rainfall resulting into drought which will then mean there will be no forage for the wildlife resulting to death and therefore reduced numbers. Government interventions have an impact on these outcomes through investment and policy measures that they pursue. Protected areas have been fronted as a remedy to wildlife declines. The more land we convert into protected areas, the better we are able to preserve habitat for wildlife and increase their numbers. It is therefore conceptualized that wildlife declines are a function of human population, urbanization, rainfall, livestock and area under protection.

3.2 Analytical Framework

Panel data can be analyzed using pooled OLS, fixed effects model, and random effects model. The fixed effects model is based on the assumption that time-invariant individual characteristics should be controlled for because they can bias the dependent or independent variables. The fixed effects model eliminates all time-invariant differences between entities to facilitate estimation of the net effect of time-varying variables. The fixed effect model is given as:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \mu_{it}$$

Where:

α_i denotes a constant

β_1 is a vector of coefficients

X_{it} is a vector of independent variables

μ_{it} is an error term

i and *t* denote an entity and time, respectively

The random effects model, on the other hand, is based on the assumption that the variation across entities is random and uncorrelated with the independent and dependent variables. Thus, the model is given as:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \mu_{it} + \varepsilon_{it}$$

Where:

μ_{it} is the between entity error (random effects) term

ε_{it} is within entity error term

Other terms are defined as in the previous equation.

The fixed effects model has the advantage of controlling for all time-invariant differences across entities, thereby preventing the coefficients of independent variables from being biased due to omitted time-invariant characteristics. The random effects model, on the other hand, has the advantage of facilitating estimation of the effect of time-varying variables. This study adopted the fixed effects due to its simplicity and aforementioned advantages.

3.3 Model and Model Specification

There are three techniques used to analyze panel data, fixed effect and random effects models and pooled regression. This study uses the fixed effects model. The model is able to control for variables that are omitted. The disadvantage of the model is that it cannot be used to investigate time-invariant causes of the dependent variables.

The equation for the fixed effects model takes this form:

$$Y_{it} = \beta_1 X_{it} + \ldots\ldots + \beta_k X_{kt}\, \alpha_i + \mu_{it}$$

Where:

α_i ($i = 1 \ldots. n$) is the unknown intercept for each entity (*n* entity-specific intercepts).

Y_{it} is the dependent variable (DV) where i = entity and t = time

X_{kt} represents one independent variable (IV)

β_1 is the coefficient for that IV

μ_{it} is the error term (Williams, 2015)

Based on data availability and literature reviewed, this study makes use of the following variables, livestock, urbanization, population, protected areas, and rainfall. The model is thus specified as follow:

$$W_{it} = \alpha + \beta_1 L_{it} + \beta_4 U_{it} + \beta_5 PA_{it} + \beta_6 R_{it} + \varepsilon\iota\tau$$

Where:

W_{it} is wildlife numbers in the county

α is constant

$\beta_1 L_{it}$ is the number of livestock in the county

$\beta_4 U_{it}$ is the level of urbanization expressed as the percentage of the people living in the urban areas

$\beta_5 PA_{it}$ is the acreage under the protected areas

$\beta_6 R_{it}$ is the total rainfall received in an area

$\varepsilon\iota\tau$ is the error term to represent the variables that have not been taken care of.

3.4 Data Types and Data Sources

This study uses panel data for the period between 2000 and 2012 that was obtained from various government departments. The wildlife and livestock data was obtained from the Department of Resource Survey and Remote Sensing, population data were obtained from the Kenya National Bureau of Statistics and development plans and data on protected areas was obtained from the Kenya Wildlife Conservancies Association (KWCA) and 2014 United Nations List of Protected Areas of Kenya (data based on the WDPA October release). Data on rainfall was available from KIPPRA. The data was organized in panels of six counties which included Kajiado, Narok, Laikipia, Taita Taveta, Samburu and Isiolo. For the purpose of analysis, wildlife numbers constituted an aggregation of data on the Burchellas Zebra, Giraffe, Grants Gazelle, Buffalo and Eland.

3.5 Variable Description and Measurements

Table 3.5: Variable description

Variable name	Description	measurement	Expected sign
Wildlife	No. of wild animals in a county	Absolute numbers	Explained variable
Urban population	No. of people living in the urban areas	Percentage of people living in the urban area in a county	-ve
Livestock	Proxied by the number of sheep and goats in each county	Absolute numbers	-ve
Rainfall	Precipitation	Total rainfall per county	+ve
Protected areas	National parks and reserves, animal sanctuaries, private and community conservancies and ranches which have wildlife in them including forest conservancies	Area in km^2 aggregated per county	+ve

3.6 Estimation Strategy

The summary statistics of the variables used in the study were estimated to describe the asymptotic characteristics of the data. This involved calculating the mean, standard deviation, and minimum and maximum values of the variables. The correlation matrix was then estimated to determine the strength and direction of the correlations between the variables, and to detect the presence of multicollinearity. However, multicollinearity was further tested formally using the variance inflation factor (VIF) method.

The presence of heteroschedasticity was tested using the Wald test for group-wise heteroskedasticity. Heteroscedasticity was corrected for using robust standard errors. The regression model was first estimated using pooled OLS. This was followed by estimation using the fixed effects and random effects model. The three models were estimated to compare the results for consistency of the parameters in terms of the statistical significance, size of the coefficients and direction of the relationships. The Breusch-Pagan Lagrange multiplier test for random effects was used to choose between the pooled OLS and the random effects model. Additionally, the Huasman specification test was used to choose between the fixed effect and random effects model.

4. Results and Discussions

4.1 Results for Regression Models

To analyse panel data, the three techniques that were mentioned above were utilized and pooled OLS, fixed effect and random effects were run. The results of the analysis are as indicated in Appendix 1 . According to Park (2011), if individual effect *ui* (cross-sectional or time-specific effect) does not exist (*ui* = 0), ordinary least squares (OLS) produces efficient and consistent parameter estimates and vice versa. This eliminated the use of OLS and consequently explored the use of fixed and random effects models. The results of the two models are also as in the Appendix. The Hausman test was then carried out and the results are as appended. The fixed effect model was then found to be the most appropriate and the test for heteroskedasticity was then carried out. Heteroskedasticity was then corrected for by adding robustness while running the fixed effect model.

Table 4.1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Absolute wildlife numbers	78	36,032.59	25,544.45	5415	97,367
Livestock	78	73,0437.9	487,781.5	120,844	1,839,890
Population (number of people residing in a county)	78	387,685.7	234,151.3	104,401	976,627
Percentage of urban population in each county	78	23.07111	10.83259	6.293675	43.52869
Protected areas acreage (pa)	78	40,633.76	77,892.85	2,160.4	212,529.7
Total rainfalls (Tr)	78	533	253.5989	75.9	1,080.4

Table 4.1 shows the minimum and the maximum number of wildlife, livestock, population, level of urbanization and acreage under protected areas in all the counties under study. The maximum and the minimum rainfall is consistent with the expectation of the precipitation expected within the rangelands.

An analysis of the correlation (Appendix 1) indicated that there was some level of correlation between the variables and this necessitated running of the variance inflation factor (VIF). Since the mean VIF was found to be 2.95; that is, less than 10 (Appendix 2). Multicollinearity was not a problem and therefore the analysis could continue. Next, Heteroscedasticity Modified Wald test for group-wise heteroskedasticity in a fixed effect regression model was run. The results indicated that some level of hetroskedasticity existed (Appendix 3) and this was corrected for using robust standard errors. The regression analysis results are

shown in Appendix 4, 5 and 6 for pooled OLS, fixed effects model and random effects model, respectively. The Hausman specification test was then carried out and the results are shown in Appendix 8.

Table 4.2: Fixed effects model with robust standard error statistics

Variable	Coefficient (Standard errors in brackets)	t- statistics
Log of livestock	0.284* (0.084909)	3.34
Urbanpop	-0.009* (0.0031947)	2.69
Log of total rainfall	-0.012 (.0293099)	0.41
Log of protected area	0.120* (.0334615)	3.58
Log of population	-0.930** (.199764)	4.66
Constant	5.539** (.6458599)	8.58
	* p<0.05; ** p<0.01	

4.2 Discussion of Results

There was negative correlation between wildlife and urbanization because, as the number of people in urban areas increase, the number of wildlife decreases. This can be explained from the fact that most urban areas tend to encroach into wildlife areas and some of them are situated at the migration corridors, as is the case of Nairobi National Park and Kitengela, respectively. The natural vegetation is usually replaced by the built environment which displaces the wildlife by eliminating their habitat. A negative correlation between protected areas and urbanization indicates or asserts to the notion that, indeed, vegetation is cleared to pave built environment which in turn affects the rainfall received in an area. It is well known that forests are able to create micro-climates. There was also no relationship between the acreage under the protected areas and rainfall. A correlation between protected areas and livestock was negative. This could be explained by the fact that most protected areas exclude livestock grazing within. Overall, there was presence of multicollineality between variables and this necessitated the running of the VI test to establish if the multicolineality effects that were present were significant. The results are shown in Appendix Table 2.

The results indicate that livestock density, urbanization and protected areas are statistically significant at 5 per cent significance level while population is highly significant at 1 per cent significance level.

There is a negative relationship between population and wildlife, which is statistically significant at 1 per cent significance level. An increase in population by 1 per cent results into a decrease in wildlife by 0.93 per cent. This is in line with the theory that increased populations means that more land is required to grow food and to settle, which leads to encroachment into wildlife habitats. This is also associated with increased human wildlife contacts and consequently conflicts. Poaching, hunting, revenge killing also come into play. This finding is also in line with Brashares (2004), Norton-griffiths et al (2009), Joppa (2012), Ogutu et al (2010), and Parks and Harcourt (2002).

The coefficient of urban population was negative and statistically significant at 5 per cent significance level as shown in Table 4.2. This means that a 1 per cent increase in urban population leads to a decrease in wildlife population/numbers by 0.009 per cent. Urbanization affects wildlife both directly and indirectly; directly when buildings replace natural environment and indirectly as clearing of land can lead to modified climate. These findings are in tandem with those of Riley et al (2003, 2006) and Ewing et al (2005).

A protected area is a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (IUCN, 2008). The Wildlife Management Act 2013 adopts this definition of the protected area and so does this study. The coefficient of protected area was also positive and statistically significant at 5 per cent significance level. This result means that an increase in protected area by 1 per cent increases wildlife by 0.12 per cent. This is in line with other studies that looked at the protected areas and their role in conservation (Western et al., 2009 and Burner et al., 2001).

Livestock came out to be statistically significant but the sign was contrary to the expectation. Livestock had a positive relationship with wildlife. The relationship was statistically significant at 5 per cent significance level. Thus, an increase in livestock by 1 per cent is associated with a 0.28 per cent increase in wildlife. This is contrary to the literature which shows that with increased livestock density there is decreased wildlife densities (Ogutu et al., 2010). However Galliziolli (1979) in his paper on the effects of grazing on wildlife argues that it is not the presence of livestock that is a threat to wildlife population but overgrazing. Thus, if it is controlled then they can both mutually coexist. This can also mean that the area under study was not overstocked/grazed.

5. Conclusion and Recommendations

The objective of this study was to determine the factors that affect wildlife population in Kenyan rangelands. A fixed effect model was used to assess the effects of population, livestock, rainfall, level of urbanization and presence of protected areas on wildlife. It has been established that population increase and increased urbanization negatively impact on wildlife numbers within the Kenyan rangelands. However, increasing land under protected areas leads to increased number of wildlife. As long as there is no overstocking, then wildlife and livestock can coexist.

5.1 Policy Recommendations

Population

Based on history, population will continue to increase and the best way to address the issue of population increase affecting the wildlife is through re-orientation of where the increased numbers of people are being accommodated to prevent continued encroachment into the wildlife lands. This then proposes development of zones where people can settle and put up structures and other economic activities to stem unplanned conversion of rangelands into settlements.

Urbanization

To address the issue of urban sprawl towards wildlife areas, there is need to establish urban growth boundaries beyond which no cluster urban developments will be allowed.

Protected areas.

Currently, there are protected areas managed by the government and which support wildlife. However, there are other protected areas that are privately-owned and also those that are communally-owned. For the government-owned, there is need to legislate to safeguard against degradation. Their management strategy should also extend to land outside protected areas and not covered by the government but has wildlife. This calls for massive collaboration with the community and private land owners. The modality of collaboration should also be legislated to make it implementable. The community should also be aware of the same to safeguard against unrealistic expectations. There is also need to develop and support structures that are working and supporting private- and communally-owned protected areas. The government should also take advantage of devolution to implement land zoning and assign land for wildlife use through county governments.

Livestock

There is need for the government to support livestock production as one of the major economic activity in the rangeland as it seems compatible with wildlife. This can be done by offering farmers better prices for livestock produce and subsidized drugs and other services that relate to livestock keeping.

References

Bidwell, T. G. and Glasgow, S. J. (1997), The National Rangeland Judging Contest Judging Rangeland for Livestock and Wildlife Values, 6063(405).

Blench, R. and Sommer, F. (1999), Understanding Rangeland Biodiversity, (September), 1–51.

Brashares J.S., Arcese P. and Sam M.K. (2001), Human Demography and Reserve Size Predict Wildlife Extinction in West Africa, Proc. R. Soc, London Ser. B268: 2473–78.

Chapin, F. S., Diaz, S., Howden, M., Smith, M. S., Benning, T., Bryant, F. and Rodriguez, R. (1995), Rangelands in a Changing Climate: Impacts, Adaptations and Mitigation.

Coggan, L. (2006), Assessing Wildlife Distribution and Population Trends in the Greater Mara Ecosystem, Kenya: The Synergistic Effects of Landscapes and Threats. Masters Thesis, University of Kent.

Conniff, R. Conniff (2009), The Growing Specter of Africa without Wildlife", in *Environmental 360 Magazine*, August 2009.

Duraiappah, K., Naeem, S., Agardy, T. Ash, N.H. and David Cooper H.D. (2013), "No Title No Title." Ecosystems and Human Well-Being: A Framework for Assessment 12(16): 81–87.

Ewing, R., J. Kostyack, D. Chen, B. Stein and M. Ernst (2005), Endangered by Sprawl: How Runaway Development Threatens America's Wildlife. National Wildlife Federation, Smart Growth America, and Nature Serve. Washington, D.C., January 2005.

Government of Kenya (2011), Vision 2030 Development Strategy for Northern Kenya and other Arid Lands.

Government of Kenya (2013), Kenya wildlife and Management Act.

Groom and Western (2013), Impact of Land Sub-division and Sedentarization on Wildlife in Kenya's Southern Rangelands Forum, 66(1), 1–9. http://doi. org/10.2111/REM-D-11-00021.1.

Hoffman (2004), "Social and Environmental Influences on Endangered Species: A Cross National study", *Sociological Perspectives*, Vol 47, No.1: 79-107.

http://www.safaricomfoundation.org/fileadmin/template/main/downloads/

Joppa, L. (2012), "Population Change in and Around Protected Areas", *Journal of Ecological Anthropology*, 58 Vol. 15 No. 1: 2011-2012.

Kenya Wildlife Service - KWS (2013), "Endangered Species" Accessed through http://www.kws.go.ke on 20-09- 2015

Kipngetich, J. (2012), Laying the Foundation for Conservation of Kenya's Natural Resources in the 21st Century, 29(1), 30–38.

Kristensen, P. (2004). The DPSIR Framework.

Lusweti, A. (2011), "Biodiversity Conservation in Kenya", in Trade Notes: Institute of Economic Affairs, Issue No. 32.

MacArthur, R. H. and E. O. Wilson, (1967), *The Theory of Island Biogeography*. Princeton, NJ: Princeton University Press.

Mundia, C. N. and Murayama, Y. (2009), Analysis of Land Use/Cover Changes and Animal Population Dynamics in a Wildlife Sanctuary in East Africa, 952–970. http://doi.org/10.3390/rs1040952.

Mwenja, I. and H.E. Eves (2009), BEAN Bush Meat Fact Sheet: Kenya Wildlife Policy, Game Ranching and Bush Meat Field Assessment. Bush Meat-Free Eastern Africa Network, www.bushmeatnetwork.org.

National Environmental Monitoring Authority - NEMA, (2014), State of Environment Report. Nairobi: National Environmental Monitoring Authority.

Nelson (2012), An Analysis of International Law, National Legislation, Judgements, and Institutions as they Interrelate with Territories and Areas Conserved by Indigenous Peoples and Local Community, 1–41.

Niamir-Fuller, M., Kerven, C., Reid, R. and Milner-Gulland, E. (2012), Co-existence of Wildlife and Pastoralism on Extensive Rangelands: Competition or Compatibility?, 1–14.

Nyamasyo, S. K. and Kihima, B. O. (2014), Changing Land Use Patterns and Their Impacts on Wild Ungulates in Kimana Wetland Ecosystem, Kenya.

Ogutu, J. O., Owen-Smith, N., Piepho, H.-P. and Said, M. Y. (2011), "Continuing Wildlife Population Declines and Range Contraction in the Mara Region of Kenya During 1977–2009", *Journal of Zoology*, 285: 99–109.

Okello, M. (2007), Threats and their Relative Severity to Wildlife Protected Areas of Kenya, 5(2), 49–62,

Okello, M. and Mwinzi, A. (2001), "Relative Importance of Conservation Areas in Kenya Based on Diverse Tourist Attractions", *Journal of Tourism Studies*, 12 (1): 39-49.

Okello, M. M., Kenana, L., Muteti, D., Warinwa, F., Warui, J., Sitati, N. W. and Mwita, M. (2015), The Status of Key Large Mammals in the Kenya–Tanzania Borderland: A Comparative Analysis and Conservation Implications, 7(4), 267–276.

Osano, Leeuw and Said (2012), Wildlife PES Schemes and Pastoral Livelihoods in Arid and Semi-Arid Lands (ASALs) in Kenya.

Ottichilo, W. K., Leeuw, J. De, Skidmore, A. K., Herbert, H., Prins, T. and Said, M. Y. (2000), Population Trends of Large Non-migratory Wild Herbivores and Livestock in the Masai Mara, 202–216.

Parks S. A. and Harcourt A.H. (2002), "Reserve Size, Local Human Density, and Mammalian Extinctions in U.S. Protected Areas", *Conservation Biology*, 16: 800–8.

Syombua, J. (2013), "Land Use and Land Cover Changes and their Implications for Human-Wildlife Conflicts in the Semi-arid Rangelands of Southern Kenya", *Journal of Geography and Regional Planning*, Vol. 6(5): 193-199.

United Nations (2015), Transforming our World: The 2030 Agenda for Sustainable Development.

Waithaka, J. (2004), "Maasai Mara—an ecosystem under siege: An African Case Study on the Societal Dimension of Rangeland Conservation", *African Journal of Range and Forage Science*, 21:2, 79-88.

Western, D., Russell, S. and Cuthill, I. (2009), The Status of Wildlife in Protected Areas Compared to Non-Protected Areas of Kenya, 4(7).

Woodley, S., MacKinnon, K., McCanny, S., Pither, R., Prior, K. Salafsky, N. and Lindenmayer, D. (2015), "Managing Protected Areas for Biological Diversity and Ecosystem Functions", in G. L. Worboys, M. Lockwood, A. Kothari, S. Feary and I. Pulsford (eds), *Protected Area Governance and Management*. Canberra: ANU Press.

World Bank (2013), World Bank Database accessed through, http://data.worldbank.org/ on 20-09-2015.

WWF Global (2014), *Living Planet Report 2014*. Retrieved from http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/

Appendices

Appendix Table 1: Correlation matrix

	Log wildlife	Population log	Urban population	Protected areas log	Total rainfall logs	Logs of livestock
Log wildlife	1.0000					
Urban population	-0.2797* 0.0131	-0.4072* 0.0002	1.0000			
Protected areas log	-0.0235 0.8380	-0.0184 0.8731	-0.1265 0.2696	1.0000		
Total rainfall logs	0.7520* 0.0000	0.7091* 0.0000	-0.1647 0.1495	0.1106 0.3349	1.0000	
Logs of livestock	0.4519* 0.0000	0.5244* 0.0000	-0.0099 0.9316	-0.6977* 0.0000	0.2946* 0.0088	1.0000

Appendix Table 2: Multicollinearity test results

Variable	VIF	1/VIF
Logs of livestock	4.24	0.235916
Protected areas log	2.95	0.338755
Total rainfall logs	2.19	0.457160
Urban population	1.37	0.727838
Mean VIF	2.95	

Appendix Table 3: Hetroskedasticity test result

Ho: sigma (i) ^ 2 = sigma ^2 or all i

chi2 (6) =93.13

prob > chi2 = 0.0000

Appendix Table 4: Pooled OLS results

Logwildlife	
Urbanpop	0.000
	(0.16)
trlog	0.504
	(3.88)**
palog	- 0.028
	(0.80)
poplog	0.836
	(6.26)**
_cons	- 1.428
	(2.36)*
R2	0.74
N	78
* p < 0.05; ** p < 0.01	

Appendix Table 5: Fixed effects model

Logwildlife		
	loglivestock	0.284 (7.52)**
	Urbanpop	- 0.009 (4.19)**
	trlog	- 0.012 (0.32)
	palog	0.120 (3.82)**
	poplog	- 0.930 (6.10)**
	_cons	5.539 (7.95)**
	R2	0.59
	N	78
* p < 0.05; ** p < 0.01		

Appendix Table 6: Random effects model

Logwildlife		
	loglivestock	0.017 (0.27)
	Urbanpop	0.000 (0.09)
	trlog	0.505 (3.86)**
	palog	- 0.016 (0.26)
	poplog	0.809 (4.80)**
	_cons	- 1.549 (2.04)*
	N	78
* p < 0.05; ** p < 0.01		

Appendix Table 7: Breush and Lagrangian tests results

	Var	Sd = sqrt (Var)
Logwild-e	.147133	.383592
e	.0025507	.0505048
μ	0	0

Test: Var = 0

chibar2 (01) = 0.00

prob > chibar2 = 1.0000

Appendix Table 8: Hausman specification tests results

Variables	b fixed	(B) random	(b-B) Difference
Poplog	-0.9300396	0.8087971	-1.738837
Urban pop	-0.0085979	-0.0002251	-0.008823
palog	0.1197058	-0.0155833	0.135289
trlog	-0.012054	0.5053779	-0.5174319
loglivestock	0.2836504	0.0166769	0.2669735
TEST: Ho: difference in coeficent not systematic CHI2 (5) = (b -B) '[(v_b-v_B) ^(-1)] (b-B) = 344.67 Prob > chi2 = 0.0000 (v_b-v_B is not positive definite)			