POPULATION ECOLOGY OF MAASAI GIRAFFE (*GIRAFFA CAMELOPARDALIS TIPPELSKIRCHI*) IN RELATION TO CLIMATE VARIABILITY IN SOUTHERN KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

I dedicate this thesis to my mother Victoria, wife Immaculate and daughters Emilly, Catherine, Lilian, Sarah, Elizabeth, Anne-Marion and Joyce who gave me moral support and enjured my absence from the family for long periods of time during the entire PhD study period at the School of Biological Sciences, University of Nairobi.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ANP	Amboseli National Park
ASALs	Arid and Semi-arid Lands
CBD	Convention on Biological Diversity
DRSRS	Department of Resource Survey and Remote Sensing
ENSO	El Nino Southern Oscillation
FAO	Food and Agricultural Organization of the United Nations
GIS	Geographic Information System
GMOs	Genetically Modified Organisms
ICT	Information Communication Technology
ILRI	International Livestock Research Institute
IPCC	International Panel on Climate Change
IUCN	International Union for conservation of Nature
IUCN-SSC	International Union for Conservation of Nature - Species Special Committee
KD	Kernel Density
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
KWS –AWF	Kenya Wildlife Service-African Wildlife Foundation
MCP	Minimum Convex Polygon
MEMR	Ministry of Environment and Mineral Resource
NNP	Nairobi National Park
TANAPA	Tanzania National Parks
TAWIRI	Tanzania Wildlife Research Institute
TENP	Tsavo East National Park
TWNP	Tsavo West National Park
UNFCCC	United Nations Framework Convention on Climate Change
UNEP-WCMC	United Nations Environment Program-World Climate Monitoring Center
WCMD	Wildlife Conservation and Management Department
WWF	World Wide Fund for Nature

Definition of technical terms

Biodiversity refers to the variety of life on earth that includes diversity in ecosystems, species, genes and the ecological processes that support them (CBD, 1992).

Conservation is the management of human use of the biosphere to yield sustainable benefits to present generations while maintaining its potential to meet the needs and aspirations of future generations. Conservation therefore embraces preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment. (IUCN, UNEP & WWF, 1991).

Climate Is the average state of the atmosphere for a given time scale of hour, day, month, season, year or decade in a given geographical region (Houghton, 2002).

Climate Change Is a variation in atmospheric conditions attributed directly or indirectly to human activities which, in addition to natural climate variability, is observed over comparable time periods (UNFCCC, 1992).

Climate Variability – Are variations in the mean state and other statistics of climate variables on all temporal and spatial scales beyond that of individual weather events. The variations may occur in variables such as temperature, precipitation, storms, sea surface and sea levels.

Climate Change and **Climate Variability** can be used interchangeably as variability refers to ‘all temporal and spatial scales’ for any climate change can be a variability if it takes long enough in terms of temporal scale.

Weather Is the state of the atmospheric conditions at a single instant of time for a single occurrence.

Rainfall as it applies to weather conditions can be defined as the amount of precipitation of any type, primarily in liquid form and measured by a rain gauge <u>OR</u> the quantity of water usually expressed in millimeters or inches that is precipitated in liquid form in a specified area and time scale.

Temperature is a measure of the degree of hotness or coldness of an object or substance usually expressed in degrees Celsius (^{0}C) or Fahrenheit (^{0}F).

ABSTRACT

Wildlife populations and their habitats are facing serious threats from global changes in climate and human development activities. Large herbivores with slow reproductive rates, bulk food requirements, wide foraging ranges and high potential value are highly vulnerable to those changes. Their responses to environmental pressures and human-induced landscape changes are however, not well understood. The purpose of this study was to generate essential data and information to support sustainable conservation and management of Maasai giraffes in the changing landscape of southern Kenya.

Giraffe population characteristics were investigated through observations and counts of giraffes along belt transects established in Nairobi, Amboseli and Tsavo West National Parks. The primary data were used to analyze giraffe population structure and changes in its spatial and temporal distribution.

Primary data were collected on mean annual rainfall amounts and temperature ranges. Similarly, secondary data on the above variables for the past 30 years were reviewed to determine the long term rainfall and temperature variability in the three study sites. Data was collected on the distribution of water sources in the three study sites. Data was also collected on giraffes' habitat use and occupancy and the number of plant species eaten by giraffes during the wet and dry seasons.

Giraffe home range sizes were determined using both 95% and 50% Minimum Convex Polygon (MCP) and Kernel Density (KD) methods. Data on human impacts on giraffe and its habitats was collected and assessed to determine the magnitude of the impacts.

One-way ANOVA was used to test if there were significant differences in the mean number of giraffes of different age-classes in the different habitats. When tests were performed on groups of adult males, there was no significant difference in the mean number of giraffes in this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). When a similar test was performed on groups of adult females, there was still no significant difference in the mean number of giraffes in this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). However, a test performed on groups of sub-adult males, showed a significant difference in this age-class ($F_{3, 18} = 3.16$, $p < 0.05$). Independent samples test using Levene's F test for equality of variances showed no significant difference in the mean number of giraffes during the wet and dry seasons in the three study sites ($F_{1, 4} = 12.22$, $p > 0.05$). Chi-square tests showed no significant difference in giraffe numbers in the different habitat types ($X^2_{0,\ 05,\ 4} = 9.49$, $p > 0.05$). A two-sample Mann-Whitney (U) signed rank test showed no significant difference ($p > 0.05$) between the wet and dry season giraffe home range sizes in the three study sites ($U_{0.05,\ 5,\ 5} = 2$, $p > 0.05$).

This study concluded that the number of giraffes had increased over time inside protected areas as compared to that outside protected areas. The study recommended that a concise study be carried out on how Maasai giraffe population trends and distribution are related to the current land use changes and infrastructure development in Southern Kenya.

Key Words: Climate, Conservation, Food, Giraffe, Human interaction, Water,

CHAPTER ONE

INTRODUCTION

1.1 Background

Giraffe (*Giraffa camelopardalis* Linneaus 1758) is an even toed mammal, the tallest of all extant land living animal species and largest ruminant. Giraffes are noted for their extremely long necks and legs and prominent horns (ossicones). Giraffes are 5-6m (16-20ft) tall and males weigh about 1,200kg while females weigh about 830kg. The giraffe's long neck allows it to reach for foliage unavailable to most other herbivores except for elephants. Being browsers, giraffes inhabit various habitats of savanna, grasslands and open woodlands. They feed on more than 20 plant species (Parker, 2004) as they traverse large areas of their home range where they encounter and use a wide variety of vegetation types than other browsers. Giraffes have been found to prefer leguminous plants of the genus *Acacia* (Leuthold & Leuthold, 1972; Field & Ross, 1976; Kok & Opperman, 1980).

Giraffe ecology and population dynamics can be influenced by both extrinsic and intrinsic factors. Extrinsic factors include precipitation, human disturbance, habitat disturbance and competition for resources and mates, while intrinsic factors are the allele effect, stress and other density dependent processes. Population dynamics in giraffe can also be influenced by poaching, habitat fragmentation, predation, forage and shift in fecundity (Dagg & Foster, 1972). Studying and understanding the complex ecological processes in giraffe habitats is important in the study of ecology and population dynamics of Maasai giraffes in Southern Kenya. Giraffe population dynamics can be studied through tracking of known individuals or herds, ground counts and aerial surveys.

Population dynamics in any given species is primarily influenced by natality, mortality and animal movement in and out of an area. These factors can cause either increase or decrease in numbers of the species (Obari, 2009). A corner stone of most ecological studies is an estimate of the abundance of a particular population of a species. However, some of the available techniques employed in estimating species populations do provide accurate estimates of population size.

The Maasai giraffe (*Giraffa camelopardalis tippelskirchi*) which is also known as the Kilimanjaro giraffe or the southern race of giraffe inhabits the southern parts of Kenya and northern Tanzania (Plate 1.1). This species is one of the three subspecies of giraffe found in Kenya. The other two subspecies are the Rothschild's giraffe (*Giraffa camelopardalis rothschildi*), also known as the Uganda giraffe or the western race of giraffe and the Reticulated giraffe (*Giraffa camelopardalis reticulata*), also known as the Somali giraffe or the northern race of giraffe.

Plate 1.1: Herd of Maasai giraffes in Maasai Mara National Reserve, Kenya.

Giraffe numbers are thought to have declined by 30% in the last ten years across the African continent bringing down their numbers to less than 100,000 individuals (Fennessy, 2009). Giraffes occur widely in Eastern and Southern Africa south of the Sahara desert (Kingdom 2003) and a very small population of the giraffe subspecies *Giraffa camelopardalis perelta* remains in Niger (Le Pendu & Ciofolo, 2002). However, the distribution of all giraffe sub-species in the African continent is now much more reduced and fragmented (Kingdom, 2003).

All the giraffe subspecies now have a greatly restricted range and occupy tracts of land where there is an expanding human population. Being large herbivores, giraffes range widely and traverse large areas. Understanding giraffe ecology and population dynamics in relation to climate variability in Southern Kenya is therefore critical to the conservation and management of the Maasai giraffe subspecies.

Over the last two decades, giraffe translocations have resulted in giraffe range expansions in some areas although not beyond the species historical range. While changes in giraffe population structure and distribution are easy to understand through studies, factors influencing its dynamics are not clearly known. The majority of giraffe population dynamics studies focus on current ranges of the species and their relation to conservation and management (Berry, 1978; Ciofolo, 1995). But numerous short term studies of giraffe population dynamics have been undertaken throughout their current ranges (Foster, 1966; Dagg & Foster, 1972; Berry 1973; Leuthold, 1979; Pellew, 1984; Van der Jeugd & Prins, 2000; Fennessy, 2004).

Climate change in Africa is expected to lead to higher occurrences of severe droughts in semi-arid ecosystems. For example, a severe drought associated with El Nino-Southern Oscillation (ENSO) phenomenon was recorded in 1991-92 in southern Africa. Climate change directly affects ecosystems through seasonal increases in air temperatures and changes in precipitation, thus causing severe droughts and fires (IPCC, 2007). With climate change, there will be shifts in biodiversity ranges and the distribution of many species will change. Such changes affect the availability, accessibility and quality of resources upon which people and wildlife rely on. These have implications on protection and management of wildlife and its habitats, protected areas and forests (Gandiwa & Zisadza, 2010).

Climate change has rendered giraffe more vulnerable to ecological disasters. For example, the ability to adapt to climate variability is influenced by local characteristics like topography, existing biodiversity and presence of invasive species, successional changes in ecosystem state and landscape fragmentation. Understanding the range of natural variability and ecosystem response plays a key role for the future management of ecosystems (Gandiwa & Zisadza, 2010). Other serious impacts of climate change on ecosystems include change in nutrient concentration in plants and river systems, surface water availability, river flow regimes and differences in phenology of plants (Gandiwa & Zisadza, 2010).

Climate change is also likely to affect wildlife behaviour, that is, non-migratory animal species like giraffe may be forced to develop migratory tendencies in search of food and water with great difficulty of adapting to the new lifestyles. Climate change may bring about increased incidents of pests and wildlife disease outbreaks. There will also be increased incidents of human/wildlife conflicts as it occured in Amboseli and Tsavo West National Parks, Kenya during the 2009/2010 severe drought (KWS, 2010). There will be disruption of both plant and animal species life cycles whereby interdependent species may lose synchronization of their activities (UNFCCC, 1992).

Populations of many wildlife species, including giraffe have declined substantially both inside and outside protected areas in Africa. The decline has been caused by recurrent droughts, growing human population and settlement, expansion of large scale farming and other land use changes (Ogutu, 2011), Persistent patterns of wildlife declines have been reported in areas experiencing major land use changes and other anthropogenic activities as experienced in Maasai Mara, Athi-Kapiti plains (Ottichilo, 2000), Amboseli (Western & Maitumo, 2004) and Laikipia (Georgiardis, 2009). The main cause of wildlife population declines is due to expanding human population in adjoining ranches and livestock incursions into protected areas. Over the past decade, giraffe numbers in Africa have suffered at least 30% decline in population due to habitat loss, fragmentation and encroachment, severe poaching and increasing human population (Fennessy, 2009).

Giraffe is not listed under the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) species Red List as there is no sufficient evidence of international trade in it and its derivatives. Apart from Rothschild's giraffe which has been listed as endangered, Maasai and Reticulated giraffe subspecies are considered by IUCN as a Lower Risk/Conservation Dependent (LR/CD) subspecies and thus require more conservation efforts to ensure their future survival. Giraffe is therefore considered as a species of least concern. But giraffes now face serious threats as a result of poaching (for meat, skin and tail brushes), habitat loss and limited genetic variability among the isolated populations.

Historical knowledge of a species population dynamics provides a background for its conservation and management. Limited data on giraffe ecology and population dynamics has restricted appropriate conservation and management efforts for the species nine subspecies across the African continent. Limited research and associated difficulties in monitoring of giraffes hinder our understanding of their population structures and life history (Fennessy, 2009). Although understanding a species population structure is beneficial, a broad knowledge of the historical and current factors, coupled with intrinsic and extrinsic factors can provide information for appropriate conservation of the species (Fennessy, 2009).

Changes in herbivore numbers are directly proportional to the dynamics of vegetation, but herbivore population size is considered to remain constant despite dramatic changes in vegetation density. However, this can only be true for situations with human intervention like provision of water to herbivores when the natural resources are scarce. In natural systems, deterioration of vegetation is likely to lead to decrease in herbivore population sizes (Ogutu, 2011).

Long term ungulate counts in the African continent have been conducted in Kruger, Serengeti, Ngorongoro, Maasai Mara, Nairobi and Lake Nakuru National Parks. These counts provide species population trends for individual parks. Complex ecological interactions such as rainfall-ungulate and predator-prey oscillations make it difficult to distinguish human induced oscillations from those due to ecological changes (Western, 1975). Despite lack of systematic monitoring, there has been a large number of individual wildlife censuses conducted in eastern and southern Africa since the 1960’s. Caro and Scolt (2007) showed that it is possible to statistically combine such disparate counts and methodologies to determine wildlife population trends in a given area.

Significant decline in wildlife numbers has been observed in Tsavo East, Tsavo West and Meru National Parks, Kenya. When linear regression models were used to interpret wildlife population trends, Maasai Mara National Reserve and Nairobi National Park showed a negative but non-significant downward trend (Ottichilo, 2000). However, studies in Maasai Mara showed that non-migratory wildlife species, which included giraffe, declined by 58% between 1977 and 1997 with no significant difference in decline inside and outside the reserve (Ottichilo, 2000). Similar analyses for Lake Nakuru and Amboseli National Parks showed non-significant increases. Wildlife populations declined by 63% in Tsavo East and Tsavo West National Parks between 1977 and 1997 and by 78% in Meru National Park between 1977 and 2000 (Ottichilo, 2000).

Giraffes’ survey in the Tsavo-Mkomazi ecosystem showed that the ecosystem supported about 2055 giraffes in the year 2011 (KWS-TAWIRI, 2011). The giraffe population in the Tsavo-Mkomazi ecosystem was seen to have increased from 1148 animals in 1999 to 2055 animals in the year 2011 representing an increase of 55% (n=907). However, compared to the number of giraffes in the year 2008, a population decline of about 19% (n=395) was recorded in three years. The highest decline of about 50% (n=254) and 45% (n=242) was recorded in northern Tsavo East National Park and Chyulu Hills National Park respectively (KWS-TAWIRI, 2011).

Although it is not possible to relate the national wildlife trends to rainfall, the oscillations correspond to drought cycles recorded in Southern Kenya where a majority of the wildlife is found. Wildlife population fluctuations due to drought and rainfall fluxes have been shown in Amboseli, the two Tsavo National Parks and Maasai Mara National Reserve (Ottichilo, 2000). Ungulate population fluxes are expected, given the close correlation between large herbivore biomass and rainfall across a wide range of savannah ecosystems in Eastern and Southern Africa (Western, 1989).

Long term population data of resident ungulates in Maasai Mara showed declines in numbers of respective species like Wildebeest (81%), Buffalo (82%), Eland (76%), Topi (73%), and Coke's hartebeest (66%) over a 20 year period of 1977-1997. For example, decline in Wildebeest numbers from 119,000 to 22,000 individuals was attributed to human encroachment through wheat farming, subsistence poaching, vegetation changes and drought (Ottichilo, 2000).

1.2 Problem Statement

Like all other large herbivores, Maasai giraffe population has been declining over time in Kenya. The causes of the decline are not well understood, but it has been hypothesized that the causes of decline include habitat loss, habitat fragmentation and habitat constriction, human disturbance (poaching, habitat encroachment and destruction, predation by mega-carnivores such as lions, hyenas, wild dogs and leopards). The negative impacts of climate variability, especially cyclic droughts and their effects on food and water supply as well as disease epidemics have also been identified as important causes of giraffe population decline. The relative contribution of these causes of population decline has not been assessed and this study sought to contribute to this knowledge deficit. Few studies have so far related the population ecology of giraffes to climate variability and human activities in the savanna regions of Africa. This study sought to generate data on giraffe population dynamics, movement and the impacts of human activities and climatic factors in the savanna region of Southern Kenya.

1.3 Justification for the Study

Giraffes have been declining in Kenya over the past few decades. However, the reasons for this decline have not been fully investigated, quantified or documented. This study has been necessitated by six main reasons which include i) limited information on decline in giraffe numbers over time, ii) disruption of gene flow due to loss of wild animals dispersal areas, iii) habitat fragmentation, iv) giraffe population isolation, v) giraffes confinement in national parks and private ranches and vi) stochastic events like the effects of climate variability.

When compared with other mega-faunal species, savannah giraffes have been the subject of very few systematic studies. For example, investigations have been concentrated on in-situ ecology of

Maasai giraffe (e.g. Dagg & Foster, 1982; Pellew, 1984; Young & Isbell, 1991; Fennessy, 2004; Cameron & du Toit, 2007; Fennessy, 2009). Other in-situ studies are those on giraffe behaviour (e.g. Ginnett & Demment, 1999; Le Pendu & Ciofolo, 2000; Van der Jeugd & Prins, 2000; Cameron & du Toit, 2005) and ex-situ (e.g. Horwich & Kitchen, 1983; Kristal & Nooman, 1979). There have also been physiology studies in-situ (e.g. Pellew, 1984; Mitchel and van Sittert, 2010; Van Schalkwyk & Skinner, 2004) and ex-situ (Kearmey, 2005). Studies on giraffe distribution, demography and until recently, taxonomy have been largely neglected by researchers (Brown & Brenneman, 2007).

No studies have specifically been done on the effect of climate variability on Maasai giraffe population size, densities and trends over time in Southern Kenya. The Maasai giraffe population in Southern Kenya is under growing pressure from changing resource distribution and increasing impacts of human activities. This study seeks to understand how large herbivores, specifically Maasai giraffes, are responding to changes in local environmental and ecological conditions as well as human-induced pressures in Southern Kenya.

1.4 Research questions

1. What is the current size and age structure of the Masai giraffe population and how has it changed over time in the study area?
2. How have key climatic elements, particularly rainfall and temperature changed over time in the study area?
3. Which factors influence local habitat use by Maasai giraffes in the study area?
4. What are the home range sizes of resident giraffes and which factors influence their movements in the study area?
5. How have the human activities impacted on giraffes and their habitats in Southern Kenya?

1.5 Research objectives

1.5.1 Broad objective

The broad objective of this study was to generate essential data and information to support sustainable conservation and management of Maasai giraffe (*Giraffa camelopardalis tippelskirchi*) in relation to climate variability in Amboseli, Athi-Kapiti plains and Tsavo ecosystems.

1.5.2 Specific objectives

i) To determine the size, age structure and trends in the Maasai giraffe (*G.c.tippelskirchi*) population over time in Southern Kenya.

ii) To determine trends in climatic conditions, particularly rainfall and temperature and their effects on availability of food and water to Maasai giraffes in Southern Kenya.

iii) To determine factors that influence local habitat use by Maasai giraffes in the study area.

iv) To determine home range sizes and movement patterns of Maasai giraffes in the study area.

v) To determine human impacts on giraffes and their habitats in Southern Kenya rangelands.

1.6 Research hypotheses

It has been hypothesized that the:

1. Maasai giraffe population has been declining due to impacts of climate variability in Southern Kenya.
2. Patterns of giraffe habitat use and movement by giraffes have changed due to climate variability in Southern Kenya.
3. Changes in the Maasai giraffe population and habitat use can be attributed to climate related changes in forage and surface water resources as well as human activities.

1.7 Scope, limitations and assumptions of the study

This study focused on Maasai giraffe population in three sites: Amboseli, Nairobi and Tsavo West National Parks. Giraffes living outside these protected areas in Southern Kenya were not studied except when they moved into the parks. The study was also limited by the available resources, especially funds and field equipment. Giraffes studied were not marked but morphological features were used to identify individuals, their sex and relative age. The giraffes were assumed to be resident in the study sites at least during the whole period of the study and that there was no drastic shift in climatic conditions from the long term pattern in Southern Kenya.

1.8 Outline of the thesis

This thesis consists of nine chapters. Chapter one introduces the study by providing the background information, problem statement, justification for the study, research questions, research objectives, research hypotheses; the scope, limitations and assumptions of this study as well as this thesis outline.

Chapter two provides the literature review by exploring ecological and economic significance of wildlife in Africa, climate change and its evidence in Kenya, potential impact of climate variability on wildlife, Maasai giraffe population trends in Southern Kenya, giraffe social organization and interactions, climate variability in Southern Kenya, landscape changes and their impacts on biodiversity, human-wildlife-livestock interactions and knowledge gaps.

Chapter three deals with topics on the study area which cover the location and size, land tenure and use, socio-economic trends, Amboseli ecosystem, Athi-Kapiti plains ecosystem, Tsavo West/Chyulu hills ecosystem, trends in large herbivore populations and trends in pastoralism and human-wildlife conflicts. Under materials and general methods, this chapter deals with the study design, data collection, assessment of giraffe population trends in the study area, assessment of giraffe habitat occupancy and use in the three study sites, assessment of giraffe movement and dispersal in Southern Kenya.

Chapter four covers topics on: climate variability and its effects on giraffe population in Southern Kenya. The chapter provides information on introduction, scope of the study, research objectives. Materials and methods; collection of climate data, analysis of rainfall and temperature data in the three study sites. The results section covers; analysis of rainfall and temperature variations in the study area where it covers; rainfall and temperature patterns in Amboseli, Nairobi and Tsavo West National Parks. It also covers the relationship between rainfall and giraffe population in ANP, NNP and TWNP and the overall trends in giraffe population and climate in Southern Kenya. The discussion and conclusion sections deal with; trends in climate variables in Southern Kenya, relationship between rainfall and giraffe population in the three protected areas, trends in giraffe population in the region and conclusion.

Chapter five deals with the giraffe population structure and movement patterns in Southern Kenya, where it covers; the introduction, scope of the study, research objectives, materials and methods which cover; giraffe population sex ratio and age structure, seasonal movement patterns of resident giraffes, conservation status of movement corridors and ecological conditions of dispersal areas. The discussion and conclusion sections deal with; factors influencing giraffe population structure, factors affecting giraffe movements in Southern Kenya, conservation status of giraffe migration corridors, ecological and human impacts on giraffe dispersal areas and conclusion.

Chapter six of deals with giraffe home ranges and habitat use in Southern Kenya. It coveres the introduction, scope of the study, research objectives, methods of determining giraffe home range sizes, seasonal variability of the home ranges, assessment of giraffe habitat use, results which cover; giraffe home range sizes, dry and wet home ranges, giraffe habitats and their use, discussion and conclusions on factors influencing giraffe home ranges, effects of seasonal changes on giraffe home ranges and conservation status of giraffe habitats and conclusion.

Chapter Seven deals with giraffe forage and water resources in Southern Kenya and covers; introduction, scope of the study and research objectives, materials and methods and results. The results cover; assessment of relative abundance of the giraffe food plants, assessment of seasonal availability of giraffe food plants in the three study sites, relative abundance of giraffe food plants, seasonal patterns of availability of giraffe food plants, distribution of surface water sources, seasonal patterns of distribution of surface water sources and assessment of availability of surface water resources in the three study sites. The discussion and conclusion sections cover; factors influencing food access by giraffes, effects of seasonal patterns of food availability, factors influencing water availability and access by giraffes, consequences of climate variability on giraffe and its food resources.

Chapter Eight covers the topic on: human impacts on giraffes and its habitats in Southern Kenya. The chapter gives the introduction, scope of the study and research objectives, materials and methods. The results section deals with; the assessment of land use changes in the three study sites, assessment of human activities in wildlife dispersal areas, assessment of human-giraffe interactions, assessment of human-livestock-giraffe interactions in the study area and trends in land use changes. The discussion and conclusion sections deal with; trends in settlements development, trends in tourism development, and effects of land use changes, impacts of settlements and tourism development and impacts of infrastructure development.

Chapter Nine provides the general discussion, conclusions and recommendations made. The general discussion deals with; trends in giraffe population size and structure, influence of climate variability on food and water availability for giraffes, factors influencing local habitat use by giraffes, human impacts on giraffes and their habitats in Southern Kenya and conclusions. The chapter gives recommendations for i) further study and ii) management actions. The last part of this thesis consists of the list of literature review and citation references and appendices on the study.

1.9 Chapter summary

The objective of this study was to generate essential data and information to support sustainable conservation and management of Maasai giraffes in relation to climate variability in Southern Kenya. Giraffe population have been declining in Kenya over the past few decades and the reasons for this decline have not been fully investigated, quantified or documented. The study was necessitated by six main reasons which included; limited information on decline in giraffe numbers over time, disruption of gene flow due to loss of their dispersal areas, habitat fragmentation, giraffe population isolation, giraffes' confinement in national parks and private ranches and stochastic events like the effects of climate variability in Southern Kenya.

It had been hypothesized that the causes of giraffe population decline included habitat loss, habitat fragmentation and constriction, human disturbance (poaching, habitat encroachment and destruction), predation by mega-carnivores such as lions, hyenas, wild dogs and leopards. The negative impacts of climate variability, especially cyclic droughts and their effects on giraffe food and water supply as well as disease epidemics had also been identified as important causes of giraffe population decline in Southern Kenya.

The study focused on Maasai giraffe population ecology in the three sites of Amboseli, Nairobi and Tsavo West National Parks. Some of the limitations of the study were that giraffes living outside these protected areas in Southern Kenya were not studied except when they moved into the national parks. The study was also limited by the available resources, especially funds and field equipment. Giraffes studied were not marked but morphological features were used to identify individuals, their sex and relative age. The giraffes were assumed to be resident in the study sites for the whole period of the study and that there was no drastic shift in climatic conditions from the long term pattern in Southern Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.1 Ecological and economic significance of wildlife in Africa

Wildlife has both direct and indirect values. Direct values include consumptive use value of non-market products of firewood and game meat. It also includes productive use value as commercial value of timber and fish products. Indirect values of wildlife include non-consumptive use value of scientific research, aesthetic value and bird watching. Wildlife also has the option value of maintaining options available for the future. For example, the existence values of wildlife are the ethical feelings of the existence of wildlife by the people.

Wildlife values differ with the interests of the stakeholders involved. Financial profitability, economic yield and environmental sustainability are of high value for high level decision makers and communities living in close proximity to wildlife (Bojo, 1996). The importance of wildlife therefore consists of economic, nutritional, ecological and socio-cultural significance. Wildlife also poses negative values to man with very high economic consequences. These values include livestock depredation, crop damage and invasive pests. The greatest value of wildlife lies in the future opportunities brought to mankind to adapt itself to local and global changes (World Resource Institute (WRI), 1994).

The ecological value of biodiversity is demonstrated by the capacity of the ecosystem to absorb pollutants, maintain soil fertility and micro-climates, purify water and provide other ecological services as wildlife interacts continuously with all the components of the entire ecosystem (World Resource Institute (WRI), 1994). The ecological value of wildlife in natural habitats is that it has a direct effect on the physiognomy of habitats. For example, the ecological role the elephant plays in the African savannas is well studied such that when it disappears from its original distribution range, ecosystems are bound to change.

Open habitats become subject to bush encroachment and eventually turn to closed forests/woodland. Such changes can cause disappearance of some species as well as allowing some forest wildlife species to thrive. Wildlife plays an important role in seed dispersal. For example, migratory bird species can disperse seeds over long distances just like bats and monkeys can disperse fruit-bearing plant species of trees through their droppings (Stuart-Hill & Davis, 1992).

In Africa, elephants disseminate many seeds of trees over long distances, both in dry savanna and moist forest ecosystems. For example, in the Tai forest of Cote d'Ivore, 30% of woody vegetation is disseminated by elephants (Alexandre, 1978). In the Weza National Park of Cameroon, elephants are responsible for the occurance and growth of *Balanites aegyptiaca* trees in the flood plains of the Logone River. The disappearance of elephants can lead to a drastic decrease of trees which they feed on as observed in the forests of Tai National Park, Cote d'Ivore, Lope Boouvre, Gabon and Aberdares, Kenya (Alexandre, 1978).

Wildlife has a pollination role on certain plants as done by some taxa of insects, birds and bats. Some wildlife species can also have detrimental ecological impacts on habitats. For example, in the savanna ecosystems where animal communities are dominated by a few large species like hippopotamus, buffalo, wildebeest and elephants, habitats are adversely affected when their carrying capacities are surpassed (Cumming, 1982). In some cases, the destruction of habitats by elephants can threaten the survival of sympatric wildlife species. For example, in the Weza National Park, Cameroon, the destruction of the *Acacia seyal* tree species by elephants near watering points during the dry seasons endangered the survival of giraffes, which rely on this tree species for forage (Ben-Shahar, 1999).

Other negative ecological impacts on habitats caused by large herbivores, such as hippopotamus and buffalo are injuries and deaths to humans who form part of the ecosystem interaction processes. There is also the effect of change in landscape to 'modified ecosystems' where both people and wildlife play a major role that has a major impact on ecosystems in the long run. Both overgrazing and overbrowsing of vegetation by wildlife occurs sporadically in some habitats, thus degrading them. This can cause population crashes in some large herbivore species. For example, the elephant population crash in the Tsavo East National Park, Kenya was due to the elephant surpassing its carrying capacity after its habitat had been adversely affected by severe droughts (Leuthold & Leuthold, 1978).

Wildlife can be used to assess the quality of the environment. Some species can be an indication of the health status of an ecosystem. For example, the presence of some birds of prey in an area can highlight environmental problems like poisoning, pollution and disease. Some aquatic species like the Otters (*Lutra maculicolis*) and Trout (*Salmo trutta*) are the best indicators of good quality water in a given ecosystem (Ben-Shahar, 1999).

In most African countries with wildlife, the wildlife industry forms a major part of the informal activities which are neither officially registered nor described in many instances. Some of these wildlife values can not be quantified in terms of the aesthetic, educational, ecological or ethical values. The economic value of wildlife can be put into two broad categories namely: Consumptive use value where a number of activities where the wildlife resource is exploited by consuming either live or dead animal materials and Non-consumptive use value of wildlife where the activities give value to wildlife without removing the resource.

Both consumptive and non-consumptive uses of wildlife generate revenue that contributes to the Gross National Product (GNP) to the economies of many African countries. The wildlife sector contributes a lot to the GNP of most African countries (Chardonnet, 1998). For example, in 1989, the wildlife GNP for Zimbabwe was in the tune of USD 131.7 million, while that of the Central African Republic (CAR) was USD 30 million. In Cote d 'Ivore, the informal wildlife sector reaches 99.5% of the wildlife GNP, while in Zimbabwe, the official wildlife sector reaches 94.7% of the total wildlife GNP (Chardonnet, 1998). Wildlife is a source of hard currency to the economies of Kenya and Tanzania where wildlife related tourism activities rank second and first respectively in terms of foreign exchange earnings (Chardonnet, 1998).

Countries in the eastern and southern parts of Africa earn substantial income through wildlife tourism. In Kenya, tourism is becoming a leading foreign exchange earner and a larger portion of this tourism is wildlife based (Sindiga, 1995). For example, in 1994 the tourism industry generated USD 484 million to Kenyas' economy and represented about 35% of the total foreign exchange earned in the country that year. Tourist visits rose from 826,200 visitors in 1993 to 863,400 in 1994 and most of them visited national parks and reserves to view wildlife.

In South Africa, 90% of the 1,052,000 tourists who visited that country in 1995 visited national parks and earned the country R13 billion. In Tanzania, wildlife tourism generates income of about USD 570 million per year (Chardonnet, 2002). National Parks in the Great Lakes Region, such as the Virunga National Park in the Democratic Republic of Congo (DRC) and the Volcanos National Park of Ruanda earn massive incomes through ‘Gorrila tourism’. In the DRC, the number of visitors to protected areas increased from 5,000 in 1972 to 25,000 in 1990 with one third of them visiting Virunga National Park. In Ruanda, the income generated by the Volcanos National Park in 1986 amounted to USD 10 million which represented one third of that country’s foreign exchange earnings (Sournia, 1998).

The economic value of wildlife is different in West and Central African countries where protected areas are not so much visited. For example, Senegal’s Djoudj National Park which is considered to be one of the best ornithological sanctuaries in West Africa, only receives about 1,500 tourists per year.The Pendjari National Park of Benin recorded only 2,000 visitors in the 1991/92 season (Sournia, 1998). It is also important to note that less than 500 tourists visit the Bouba Njida National Park of Cameroon per year. In North Africa, Tunisia receives about 4.8 million visitors each year and national parks receive about 100,000 visitors of which only 6% are foreigners.

In Africa, wildlife ranching by the private sector contributes a lot to wildlife conservation as demonstrated in South Africa where there is presently more wildlife than in a century ago. Globally, income generated from wildlife ranches is made of hunting (80%), eco-tourism (10%) and wild animal sales (10%). Wildlife sales reflect the true economic value of large mammals as dictated by the market value. For example, in 1991, 8292 animals were sold for R62.9 million in 48 sales in South Africa (Chardonnet, 2002). In Namibia, wildlife utilization which combines tourism, hunting and cropping offer more favourable returns on communal land, while trophy hunting is beneficial on private farms. The wildlife industry is therefore more beneficial to the people as compared to agricultural farming in the semi-arid and arid areas of Namibia.

In Zimbabwe, the Bojo survey demonstrated that wildlife enterprises in the large scale commercial ranches were more significantly profitable than cattle ranching (Bojo, 1996). In the semi-arid regions of Zimbabwe with unreliable rainfall, wildlife alone provides more profit than either cattle or mixed wildlife and cattle ranching (Jori, 1998). Investiments on wildlife ranching are much cheaper than cattle ranching because the infrastructure and management inputs are cheaper and wildlife ranching creates more jobs and income to the people than does cattle ranching (Chardonnet, 2002).

2.2 Climate change and its evidence in Kenya

Kenya has in the recent past seen increased evidence of climate change, such as rising temperatures and change in rainfall patterns. The country has also experienced extensive climate related impacts through increased frequency of droughts and floods. Current data on climate elements demonstrates that the climate of Kenya is changing at an unprecedented rate due to human activities that are causing desertification (Ogallo, 1988). This has been experienced in the marginal areas of Southern Kenya.

Evidence of climate change is based on statistical analysis of past trends in observed changes in climate elements of temperature, rainfall, sea level rise and receding mountain glacier coverage. Since the 1960’s, Kenya has experienced increasing temperature trends in different parts of the country as rainfall patterns indicate increased irregularity and variability with neutral to slightly decreasing trends in annual rainfall amounts. It has been observed that there is a general increase in rainfall events during the months of September to February, suggesting that the short rains of the months of October to December extend to the normally hot and dry months of January to February over most areas (Ogallo, 1988).

Sea level rises in the coastal regions of Kenya have been recorded and follow global trends. In addition to this, there is evidence of depletion of glaciers in Mt. Kenya which attests to rising temperatures in mountain regions (Ogallo, 1988). Data on temperature and rainfall from the Kenya Meteorological Department for the last 50 years as well as the annual state of the environment (SoE) reports give evidence of climate change in Kenya. There is therefore evidence of variable and unpredictable climate patterns, particularly rainfall (Mutai & Ward, 2000).

Severe fluctuations in rainfall amounts and temperatures can have devastating effect on the fauna and flora in a given ecosystem. Severe droughts at such times could lead to vegetation die-offs and consequent reduction in forage available to giraffes resulting in high mortalities of ungulates (Ogutu, 2007). For example, in the Mara-Serengeti savanna ecosystem, rising temperatures and declining rainfall throughout the 1990s and early 2000s, combined with prolonged and strong ENSO episodes caused habitat desiccation and reduced primary productivity (Ogutu, 2008). Such occurrences adversely affect local plant and animal communities resulting in higher mortalities of ungulates when there is shortage in forage.

Rainfall variability directly influences vegetation characteristics like forage composition, quality and quantity that define the movement and distribution of large herbivores. For example, Okello and Kiringe, 2011 found out that Amboseli National Park had a dry season metabolic biomass density of wildlife of 2,357.68 kg/km^2 as compared to that of the wet season of 693.71 kg/km^2. These figures tell us that over 70% of the large mammals, including giraffe concentrate in the park during the dry season when forage is abundant and moved out of the park during the wet season in search of forage. Also the nature of vegetation and distribution of forage and water resources influence giraffe movements and distribution in the Amboseli ecosystem (Okello and Kiringe, 2011).

Warming over the Eastern Africa landmass exacerbates evaporation and crop water deficit. The rising temperatures and declining rainfall may lead to progressive habitat desication and reduction in vegetation production in southern Kenya. For example, the long rains in central Kenya have declined by more than 100mm per annum since the mid-1970s, a decline that is probably linked to the warming of the Indian Ocean and is likely to continue (IPCC, 1999).

A warming of more than 1^{0}C may increase drying impacts especially in lowland areas. Long term climate change modeling data has shown projected changes in the amounts of rainfall received during the long rain months (March-April-May-June) in the Maasai Mara, Amboseli and Tsavo ecosystems. The observed projected precipitation changes from 1975 – 2050 show substantial rainfall decline in the Maasai Mara and Amboseli ecosystems but with no significant changes in the Tsavo ecosystem (Table 2.1). The rising temperatures in the three ecosystems are likely to intensify the impacts of drying change, thus impacting negatively on the primary productivity in these ecosystems (IPCC 1999).

Table 2.1: Projected changes in rainfall and temperature in Maasai Mara, Amboseli and Tsavo ecosystems during 1975-2050.

Ecosystem	Rainfall (mm) Decline	Temperature (^{0}C) Increase
Maasai Mara	-100	1.1
Amboseli	-50	0.9
Tsavo	±50	0.7

Source: (IPCC 1999).

2.3 Potential impacts of climate variability on wildlife

Impacts of climate variability on biodiversity have been evident from cyclic droughts and lack of forage and water for giraffe and other large herbivore wildlife species in savanna ecosystems. Modelled climate change impacts show that climate variability has already caused changes to the distribution of many plants and animals, leading to severe range contractions and extinction of some species (Ogutu, 2007). Some changes on terrestrial species include phenolgy in terms of leaf unfolding, flowering dates, migration and timing of reproduction, species distribution and plant communities' structure. There will also been populations' fragmentation and isolation when their habitats are fragmented due to climate change.

In the past 50 years, only two *El Nino* Southern Oscillation (ENSO) were recorded with higher standards of 3.0 in 1983 and 2.3 in 1998. With such high recordings, Fredrikson, Danielson and Swenson (2007) reported significant environmental impacts on forests, grasslands and wildlife populations in Borneo following the ENSO of 1997 – 1998. They noted that there was a significant increase in competition for forage for wildlife species, increased faunal death rates and decrease of up to 80% in overall species population range.

As regards climate change effects on biodiversity, it was noted that the prolonged drought of 1992 – 1996 reduced rainfall in the Rift Valley lake systems of Kenya by almost half per year (Ngaira, 2006). Rainfall reductions and near high heat records were observed in the Mara-

Serengeti ecosystem as well as the rest of equatorial East Africa between 1993 and 1997 (Ogutu, 2007), which affected giraffes and other large herbivore species.

In some ecosystems, vegetation may disappear as a result of drought and increase the probability of extinction of herbivore species that depend on grasses. Soil drying or desiccation has rapid effects on primary productivity, reducing biomass by 10-30% and will further cause changes in litter fall and nutrient cycling (Badgley & Behrensmeyer, 2008). Projected droughts with increased frequency of severity or reduction in precipitation would reduce forage for giraffes in its ranges, reduced water volumes in rivers, which would lead to wildlife deaths, increased human-wildlife conflicts and increased rates of species extinction due to habitat loss (Badgley & Behrensmeyer, 2008).

Human activities like cultivation, urban development and ecosystem fragmentation will have great impact on giraffe ranges. Human activities which cause climate change are those that influence radiation transfer in the atmosphere and radiation absorption on the earth’s surface. Other human activities like use of combustion fuels and deforestation contribute to localized climate change that affects the general biodiversity and large herbivores in particular.

Climate change may affect the living patterns of vectors that cause disease which in turn cause the spread of diseases among human beings and wild herbivore species like giraffe. Rising temperatures may, for example, cause rinderpest and anthrax diseases outbreaks the will cause death to giraffes and other wild herbivores. Climate change will also cause flooding conditions and air pollution that may cause morbidity and eventual deaths to both people and wild herbivores like giraffe.

There is a likelihood of projected global change in climate that will directly affect biodiversity through changes in temperature and precipitation. This will lead to indirect increase in the frequency of such disturbances like droughts and storms that will impact negatively on the large herbivores in the savanna ecosystems. Human activities exert additional pressure on biodiversity that accelerates climate-mediated biodiversity loss through human land use changes, deforestation, logging, soil and water pollution, water over-abstraction, wildlife habitats fragmentation and spread of invasive animal and plant species.

Climate change can cause shifts in species geographical range due to changes in temperatures and humidity. Species ability to respond to climate change will depend to their ability to 'track' shifting climate by colonizing new territory or changing their physiologies and adapting to changes (Thuiller, 2007). Climate change has made wildlife species like giraffe more vulnerable to ecological disasters. For example, the ability of species to adapt to climate change and variability is influenced by local characteristics like topography and micro-refugia, existing biodiversity, presence of invasive species, successional ecosystem state and landscape fragmentation. Therefore, understanding the range of natural variability and ecosystem response to these is important for the future management of ecosystems that support biodiversity (Gandiwa & Zisadza, 2010).

Climate change in Africa is expected to lead to higher occurrences of severe droughts in semi-arid and arid ecosystems. For example, a severe drought associated with *El Nino* Southern Oscillation (ENSO) phenomenon was recorded in 1991-92 in Southern Africa. Climate change directly affects ecosystems through seasonal increases in air temperatures and changes in precipitation, thus, causing severe droughts and fires (IPCC, 2007). With climate change, there will be shifts in biodiversity ranges and the distribution of many species will change. Such changes affect the availability, accessibility and quality of resources upon which people and wildlife depend on. These have implications on protection and management of wildlife, habitats, protected areas and forests (Gandiwa & Zisadza, 2010).

Other serious impacts of climate change on ecosystems include change in nutrient concentration in plants and river systems, surface water availability, river flow regimes and differences in phenology of plants. There will also be increased incidents of human/wildlife conflicts as were in the cases of Amboseli and Tsavo National Parks, Kenya during the 2009/2010 severe drought (KWS, 2010). Climate change will bring about change in wildlife behaviour, that is, non-migratory animal species may be forced to develop migratory tendencies in search of food and water with great difficulty of adapting to the new lifestyles. Climate change may also bring about increased incidents of pests and wildlife disease outbreaks. There will be disruption of both plant and animal species life cycles whereby interdependent species may lose synchronization of their activities (UNFCCC, 1992).

Change in climate triggers change in biodiversity by favouring invasive species proliferation against native fauna and flora. A combination of climate change, species invasions and reduced areas of natural habitat may promote biotic homogenization in biodiversity hotspots leading to unpredictable interactions among plants, animals and micro-organisms. Human economic activities like trade enhance dispersal of species and other micro-organisms. Other ecological disruptions caused by climate change will be increased carbon dioxide in the atmosphere. There will also be habitat destruction and fragmentation due to human land use changes and pollution as has been witnessed in some parts of Southern Kenya.

The impact of climate change or variability on wildlife has been noteable locally, regionally and globally. Climate change is expected to become one of the major drivers of extinction of species due to changes in the breeding times of species and shifts in distributions caused by the variation in temperature and precipitation regimes. It has been estimated that about 20-30% of plant and animal species will be at risk of extinction due to global warming and that a significant proportion of endemic species may become extinct by the year 2050 as a consequence (UNFCCC, 1992).

Mean annual temperatures have risen steadily over recent decades and an even higher increase is predicted in the years to come. This will be more pronounced in sub-saharan Africa where current climate models project a minimum temperature rise of 3-4^0C across the African continent by the end of this century. This will be approximately 1.5 times the global average increase. Climate change affects different ecosystems in different ways depending on the complexity and original characteristics of the ecosystem, geographical location and presence of factors that may regulate the extent of the changes (UNFCCC, 1992).

Climate change is attributed directly or indirectly to human activities, which, in addition to natural climate variability, is observed over comparable time periods. Climate has variability on all time and space scales and will always be changing. At any time scale there are variations in climate variables such as temperature, precipitation, severe storms, sea surface temperatures and sea levels (UNFCCC, 1992).

Climate change in Africa is expected to lead to higher occurrences of severe droughts in semi-arid and arid ecosystems. For example, a severe drought associated with El Nino-Southern Oscillation phenomenon was recorded in 1991-92 in Southern Africa. Rainfall reductions and near record heat were observed in the Mara-Serengeti ecosystem as well as the rest of equatorial East Africa between 1993 and 1997 (Ogutu, 2007). These stochastic events have serious impacts on the fauna and flora of savannah ecosystems of East Africa as they cause massive deaths to wildlife species due to starvation after vegetation die offs during severe droughts.

Climate change is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which in addition to the natural variability observed over comparable time periods (UNFCCC, 1992). ‘Adverse-effects-of-climate-change’ are changes in the physical environment or biota resulting from climate changes which have significant deleterious effects on the composition, resilience or productivity of natural or managed ecosystems or on the operations of socio-economic systems or on human health and welfare (UNFCCC, 1992).

Altered climate regimes directly affect wildlife behaviour, migration, foraging, growth and reproduction. Climate change could disturb the dynamic equilibrium of terrestrial ecosystems by affecting their productivity, biomass production, hydrological balance and trophic interactions (Surasinghe, 2010). Climate change also intensifies natural disasters and shifts in natural disturbance regimes. Such processes impose physiological and environmental stress on terrestrial ecosystems, thus affecting their resistance and resilience. Terrestrial biota readily responds to temperature where both flora and fauna alter their distributions towards more favourable climatic conditions. Some climatic factors that determine processes like periodism are fixed while others drive weather pattern changes (Surasinghe, 2010).

Rising temperatures favour biological activities of wildlife pathogens that can cause disease to certain wildlife species. Climate change can disrupt species interactions, mutual associations and other ecosystem functions. Climate change predisposes native wildlife species to extinction and alters the functions and structure of ecosystems. It can also cause impacts on species by accelerating disease distribution patterns and severity as species are stressed by increased temperatures. There is therefore likelihood as a result of climate change for tick borne diseases like East Coast Fever (ECF) and others to increase in some areas of Sub-Saharan Africa (Surasinghe, 2010).

Climate change has some positive effects in that it causes the drying up and elination of some invasive species, particularly during drought periods. Increased temperatures may also kill disease parthogens that may not survive the high temperatures, thus reducing the chances of such parthogens causing disease to wild herbivore species like giraffes. During flood time, such parthogens are swept down the seas where they die off and reduce their chances of causing disease to wild herbivore species like giraffe. Climate change may cause death of invasive animal species, thus reducing competition for food and water resources with wildlife.

2.4 Giraffe populations trends in Kenya

In Kenya, the Maasai giraffe population estimates stood at 7,609 giraffes in the year 2010, (KWS-TANAPA, 2010). The Amboseli ecosystem with an area of 8797 Km^2 had 2289 giraffes, Magadi/Namanga ecosystem with an area of 5513km^2 had 815 giraffes, Tsavo ecosystem with an area of 40,000 km^2 had 2500 giraffes, Maasai Mara ecosystem with an area of 1500 km^2 had 1691 giraffes and the Athi-Kapiti plains ecosystem had 314 giraffes, thus giving a national total of 7609 giraffes. There are isolated populations of Maasai giraffe in Shimba Hills National Reserve, Hell’s Gate National Park and Naivasha basin, whose numbers are yet to be established (Fig.2.1).

The population estimate of Rothschild's giraffe was 410 and that of Reticulated giraffe was 2,741 animals. Maasai giraffes therefore contributed about 75% of Kenya's entire giraffe population (KWS-TANAPA, 2010). Within the same year, aerial counts by KWS in October, 2010 and the National Giraffe Stakeholders 2011 Workshop review on giraffe numbers and distribution in Kenya, the numbers of the three giraffe subspecies in Kenya showed considerable variations. In this survey, Maasai giraffe numbers were estimated at 5,603 giraffes with Amboseli ecosystem hosting about 1,053 giraffes, Magadi/Namanga ecosystem (192), Maasai Mara ecosystem (1691), Nairobi National Park and Athi-Kapiti Plains ecosystem (414), Naivasha/Hells Gate dispersal areas (623) and Tsavo ecosystem (1630) giraffes. Rothschild's giraffe population was estimated at 446 while that of reticulated giraffe was 4,101 giraffes.

Rothschild giraffe population in Kenya has declined drastically since the species displacement from its traditional ranges of Soy and Endebess as a result of human settlement and cultivation. Other causes were to due poaching of giraffes for meat in Nasalot National Reserve and other areas outside protected areas and the death of the giraffes in Mwea National Reserve due to the out break of Anthrax disease. The population of reticulated giraffes has declined over time due to poaching for meat and skin by communities in Northern Kenya, who usually resort to killing giraffes as a source of proteins during the cyclic and prolonged droughts prevalent in the region.

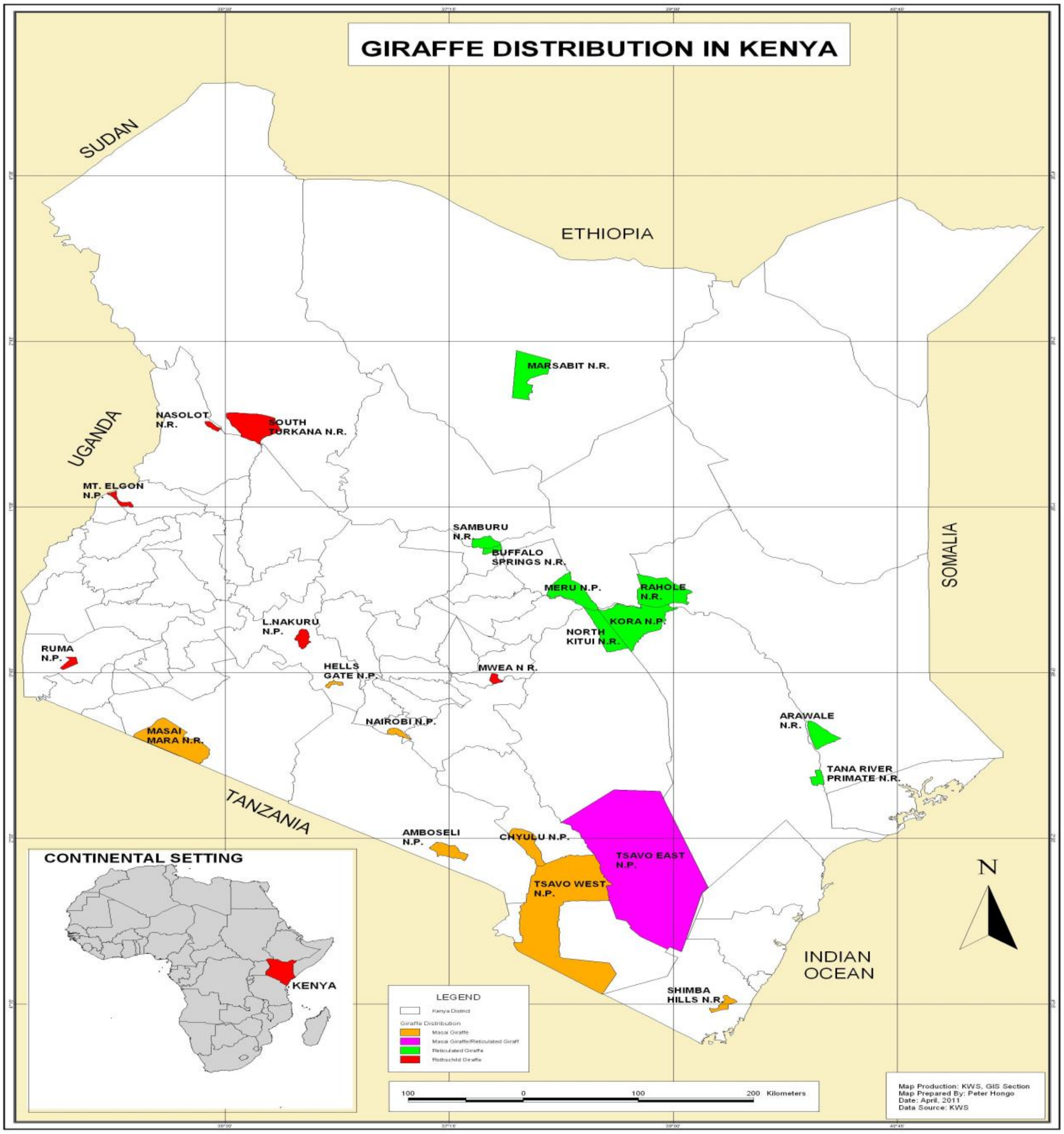


Figure 2.1: Distribution of Rothschild giraffe (Red), Maasai giraffe (Orange), Reticulated giraffe (Green) and the interface between Reticulated and Maasai giraffes in Tsavo East National Park (Pink) in Kenya's protected areas.

Source: KWS GIS Lab

Maasai giraffes occur in larger numbers within their range in Kenya. Currently, Maasai giraffe population is thought to be declining due to threats from poaching for meat and hides, habitat loss, fragmentation and constriction, loss of migration corridors and predation by lion, hyena and wild dogs. According to Kenya Wildlife Service large mammal aerial counts report of 2010, Maasai giraffe population was estimated at 7609 animals (KWS, 2010).

In the year 2010, Maasai giraffe population estimates were as follows: Amboseli ecosystem (2289) giraffes, Magadi/Namanga (815) giraffes, Tsavo (2500) giraffes, Maasai Mara (1691) giraffes and Athi-Kapiti Plains had a population of 314 giraffes, thus, giving a total of 7609 of Maasai giraffe subspecies in Kenya. The other two giraffe subspecies population estimates were Rothschild giraffe (410) and reticulated giraffe (2741). Maasai giraffe therefore contributed about 75% of Kenya's entire giraffe population (KWS-TANAPA, 2010).

According to the KWS-AWF 2008 total aerial count of elephants and other large mammal species in the Tsavo ecosystem, Tsavo-Mkomazi ecosystem hosted 50% of the Maasai giraffe population with the rest of the giraffe population found outside protected areas of Taita Hills. In that count, Tsavo West National Park alone had a total of 675 giraffes (KWS-AWF, 2008). Maasai giraffes have relatively stable populations compared to Rothschild's giraffe (*Giraffa camelopardalis rothschildi*) and Reticulated giraffe (*Giraffa camelopardalis reticulata*) subspecies, though their numbers had also been affected in the recent years (Fennesy, 2009).

2.5 Giraffe social organization and interactions

Mammalian groupings show complex biological systems characterised by individual social dynamics that result in non-random relationships among individuals. In mammals, social preferences are defined as patterns of interaction or association in which specific individuals associate with one another. Although social preferences have been measured with proximity, nearest neighbours and preferred association and interaction by partners in ungulates are frequently of the same individuals. When social preferences are consistently maintained over time, then they become relationships (Horwich & Kitchen, 1983).

Social relations in giraffes are loose and shifting, except for the mother-young bond where group type distribution is similar to the expected distribution on the assumption of a non-selective association. Giraffes do not show preferential association between particular sexes and age-classes nor between individuals (mother-young expected). Absence of socio-spatial segregation in giraffes is confirmed by the high degree of overlap of group or individual home ranges that are independent of sex and age (Le Pendu & Ciofolo, 1999).

Group composition in giraffes is unstable as evidenced by individuals usually observed with only about half of their partners of the previous day. The loose associations in giraffes have been observed by many authors (Foster, 1966; Dagg & Foster, 1976; Berry, 1978; Leuthold, 1979; Pellew, 1984; Pratt & Anderson, 1985). Observations in Serengeti National Park, Tanzania, showed the composition of a herd of giraffes containing an adult female remained unchanged for two consecutive days (Pellew, 1984).

Mammals can also show symmetric relationships when both individuals direct similar behaviours towards one another and show mutual attraction. Social relationships in giraffes can be distinguished from simple aggression on the basis of interactions between individuals. Several life history variables have been successfully used to explain social relationships of adult female ungulates (Pellew, 1984).

In giraffes, mother-offspring relationships are frequently maintained up to adulthood and such preferences may encompass other matri-lineal relationships. For example, in Red deer, mother-daughter and sister-sister pairs associate more than other female pairs. Peers may also be preferred partners of adult ruminants ((Horwich, van Dyke & Cogswell, 1983). Despite pervasive presence of social relationships within mammals, studies on giraffe have concluded that they associate randomly, forming only loose social bonds (Coe, 1967; Dagg & Foster, 1976; Estes, 1991; Kingdom, 1997) that are temporary and occur mainly between young animals (Le Pendu & Ciofolo, 2000).

Frequent changes in group membership are well documented aspects of giraffe social behaviour (Foster, 1966; Leuthold & Leuthold, 1978; Pellew, 1984; Pratt & Anderson, 1982, 1985). Most authors have analyzed giraffe data based on age-class structure rather than by individuals (e.g, Le Pendu & Ciofolo, 2000). The only strong bond among giraffes is between a mother and her dependent young (Langman, 1977), but long term observations of giraffe populations suggest that social relationships may be maintained for a long time, particularly by mother-daughter relationship.

In the wild, female giraffes form a stable group of individuals within an area (Van der Jeugd & Prins, 2000), that can be divided into geographically distinct sub-groups, despite absence of physical barriers (Pratt & Anderson, 1982), suggesting that females frequently encounter the same group of other females. In giraffes, social groups have also been observed in nursery groups with consistent membership of females and their offspring (Pratt & Anderson, 1985) where calves frequently interact and associate with other calves perhaps forming peer bonds (Langman, 1977; Pratt & Anderson, 1979, 1982).

In giraffes, interactions are usually distributed among the different sexes and age-classes. Young males exhibit all types of interactions with peers interacting more frequently than other age-classes. Non-sexual (agonistic) interactions are more common among males. Leuthold (1979) observed high frequencies of necking among sub-adult male giraffes. This behaviour is also common among adult males (Pratt & Anderson, 1985). Sub-adult and adult males usually initiated sexual interactions with sub-adult female giraffes more than adult females. Pratt and Anderson (1985) also found out that adult males tested urine of sub-adult females more frequently than that of older females.

Sexual interactions occurring between young males are usually acts of mounting attempts and necking. Contact interaction is more common among groups or individuals of all age-classes. Contact interaction is also high among juveniles as peer bonding is developed at such ages and plays an important role in the socialization of young individuals (Pratt & Anderson, 1985).

2.6 Climate variability in Southern Kenya

Most parts of Southern Kenya receive rainfall from the south-west monsoon winds during the long rains of March – May (FAO, 1994). The rainfall is mainly of convectional nature, hence localised. The rainfall spatial and temporal distributions as well as the intensity are highly variable. The long rains fall during the months of April and May while the short rains fall during the months of October to November, but the start, duration and stop dates of these seasons are highly variable.

Inter-annual variability of rainfall in East Africa results from complex interactions of forced and free atmospheric variations (Ogallo, 1988, Mutai & Ward, 2000). A close relationship between large scale climatic signals and annual rainfall has already been established. Atmospheric general circulation model shows that the Indian Ocean sea surface temperature (SST) exerts great influence on the short rains in Southern Kenya than influences of local relief. A warmer Indian Ocean is associated with wet conditions in most of East Africa. One of the objectives of this study was to establish the rainfall and temperature patterns in Southern Kenya and their potential effects on Maasai giraffe population in the region.

Kenya’s climatic conditions vary from humid tropical climate along the coast to arid areas inland, while the mean temperatures and rainfall vary with elevation. Kenya experiences a bimodal seasonal pattern of rainfall since it lies astride the equator. The long rain season starts around the month of March and runs through to the month of June with the peak centred on the months of March to May. The short rains run from September and taper off in the months of November and December.

There are large regional differences in rainfall variability. The long rains (March – May) are less variable, so the inter-annual variability is related primarily to the short rains. These are also linked to large-scale as opposed to local atmospheric and oceanic factors. Rainfall fluctuations show strong links to ENSO phenomenon, with rainfall tending to be above average during the ENSO years (Nicholson, 1996).

Understanding long term climatic variability is basic to the conservation and management of biodiversity. Analysis of temporal variation in the local rainfall, temperature and normalized difference vegetation index (NDVI) using hemispheric ENSO showed variations in the ecosystems of Southern Kenya and Northern Tanzania, particularly in the Mara-Serengeti ecosystem (Ogutu, 2008). Local rainfall showed striking temporal variability and an even 5 year quasi-periodicity in the ecosystem. Severe droughts were a recurrent feature in the savanna ecosystem but severe droughts were relatively infrequent. The timing of floods and droughts coincided with strong episodes in the activities of the ENSO phenomenon. Above average rainfall often accompanied cold ENSO episodes and below average rainfall accompanied by warm ENSO events (Ogutu, 2008).

Both minimum and maximum temperatures were below normal during cold ENSO events. Rising temperatures and declining rainfall throughout the 1990's and early 2000's, with unprecedented prolonged and strong ENSO episodes enhanced habitat dessication and reduction in primary productivity in the ecosystem. This increased the delibitating effects of adverse weather on local plant and animal communities resulting in high ungulate mortalities (Ogutu et al., 2008). The predictions of climate variability were the *El Nino* phenomena, Global tropics SST (10^0S-10^0N, 0-360^0) and South Indian SST (0-15^0S, 45-60^0E) and the Southern Oscillation Index (SOI) (Ogallo, 1988). These climate variations have been experienced in Southern Kenya.

2.7 Landscape changes and their impacts on biodiversity

The use of land to produce goods and services has been in practice around the world for a long time of settled agriculture (Esikuri, 1991). Expansion and intensification of agriculture has become the most signicant activity that is altering the global environment. Although landscape transformation for agricultural production has historic, economic, political and social justification, recent trends and rates of conversion of natural habitats to croplands have been drivers of species extinction (Esikuri, 1991).

Landscape characteristics like vegetation cover are modified by land use changes that impact negatively on biodiversity. This at the same time degrades wildlife habitats causing local extinction of some wildlife species. The impact of human activities on wildlife habitats will vary depending on the spatial and temporal scales considered and the persistence of such activities in the landscape. Human alterations of the landscape tend to have high degrees of persistence and consistency that hinder ecosystems resilience as long as these areas are under continuous use by man. Human activities in savanna ecosystems override the natural ecosystem changes brought about by climate variability of the past decades (Ojima et al., 1994).

Interactive effects of climate variability and land use change have had devastating effects on biodiversity and the livelihoods of people in the Southern Kenya rangelands (Western et al., 2009). The spatial scale and connectivity that underpins the inherent cultural and biological diversity is increasingly getting fragmented and constrained by land use changes and climate variability. Landscapes are becoming increasingly isolated with constraints on the movement of species and system flows threatening biodiversity and human livelihoods (Western et al., 2009).

Most protected areas are faced with unprecedented challenges like increasing human populations, land use changes and infrastructure development. Likewise, there is increasing pressure outside protected areas due to growing pressure from neighbouring communities that demand for pasture and water for their livestock from protected areas. Land use changes in southern Kenya rangeland ecosystems like changing land tenure systems, rapid and un-controlled infrastructure development and human settlement are leading to the decline in wildlife migration corridors and dispersal areas. These changing scenarios have accelerated incidents of human/wildlife conflicts and poaching of wildlife in southern Kenya rangelands. Due to these emerging challenges, the management of protected areas need to move first and effectively respond to these challenges.

Land in Southern Kenya is occupied by nomadic Maasai pastoralists, who have now been forced by environmental conditions, government land policies and immigration by non-pastoralists from other parts of Kenya to settle and lead sendentary lifestyles. The changing land use patterns have affected wildlife habitats and their ranges. Changes in land use like farming will affect giraffe habitats and at the same time prevent large wild herbivore migrations through what can be referred to as ‘compression effect’ (Dublin & Hamilton, 1987). Increasing human land use activities in savanna ecosystems brings man into direct conflict with wildlife, thus intensifying human-wildlife conflicts.

2.8 Human-Wildlife-Livestock Interactions

Increasing human population densities, encroachment through settlements and activities in giraffe habitats have made human-wildlife conflicts more frequent in the last few decades (FAO, 1994). Most wild animal species get locally extinct where large scale commercial plantations are established. Human-wildlife conflicts will be experienced along the edges of the remaining natural habitats. Conflicts are usually common in areas where wildlife and human populations co-exist and share limited resources. Climate variability indirectly increases the intensity and frequency of such conflicts when it modifies environments and their productivity by favouring some species that cause problems to humans. Human-wildlife conflicts become more intense where livestock and agriculture are important to rural communities’ livelihoods. Severe droughts cause a decrease in natural resource productivity and are associated with considerable increase in human-wildlife conflicts (KWS, 2010).

With the current human population growth rates, climate change trends, increasing demand for resources and the growing demand for access to land will hasten human-wildlife conflicts. Most giraffe traditional dispersal and migration areas are now occupied by humans, thus preventing giraffes from peaceful use of these habitats. Under changing climatic conditions, wild animals move to these areas and human-wildlife conflicts escalate. The consequence of this is that wild animals usually get killed.

Human beings encroach into giraffe habitats in search of resources like fodder and water and in the process escalating the conflicts between the two. In times of increasing pressure on limited resources, the capacity of local communities to co-exist with wild animal species, including giraffes reduces substantially (Dickman, 2008). Losses of livestock due to lion and other carnivore attacks are usually higher than other factors including natural mortality of livestock.

Warmer temperatures reduce plant and vegetation productivity in semi-arid environments making wildlife and livestock compete for forage and water resources. For example, in Northern Kenya, longer and more frequent droughts have ravaged pastoralist livestock in the recent past. This increases pressure on the limited resources available for both people and wildlife. This situation has led to lower tolerance for damages caused by wildlife, thus higher rates of retaliatory killings of certain wildlife species by pastoralist communities.

2.9 Knowledge gaps

Several gaps were identified during this study. These gaps need to be addressed to generate more data and information that will assist in sustainable conservation and management of Maasai giraffes in Southern Kenya rangelands. The following gaps were identified:

a) Need to have robust models to predict habitat changes in savanna ecosystems of southern Kenya. For example, how will these habitats fragment or constrict in future as a result of climate variability/change?'

b) No research conducted on 'The interactions between habitat fragmentation and climate variability on wild ungulate populations' dynamics in Southern Kenya rangelands'. Studies in Maasai Mara ecosystem have shown that habitat fragmentation can decrease the spatial scale over which herbivores access forage, thus decreasing their populations. These studies showed that wildlife are less able to locate productive forage patches whose access has been reduced (Ottichilo, 2000). Similar studies need to be done in southern Kenya rangelands for comparative purposes.

c) Lack of long term monitoring of Maasai giraffe population trends in Southern Kenya rangelands and ecosystem viability. The information generated from such monitoring will assist in the forecasting, planning and management of wild herbivore populations in Southern Kenya rangelands.

d) There is inadequate data on the effect of climate variability on Maasai giraffe population dynamics in Southern Kenya rangelands. For example, there is a strong relationship between wild herbivores species abundance and rainfall amounts due to global warming that may markedly alter the abundance and diversity of wild herbivores (Ogutu, 2008).

e) There is need for research on the ‘Effect of climate variability on the nutrient concentration in giraffe food plants’. Nutrient quality in herbivore foods is important due to the fact that plants lack some essential dietry components which can only be obtained by careful selection of diet food plant species by an herbivore to obtain a balanced diet (Stephens & Krebs, 1986). For example, in the Serengeti-Mara ecosystem, the nutrient content of forage had been found to be important to seasonal movements of migratory grazer species as well as influencing the spatial distribution of the resident grazers (McNaughton, 1990). Requirements for minerals by lactating female giraffes and their young or those in their late stages of gestatation periods influence their movements to areas where forage has high content of calcium, magnesium, sodium and phosphorus.

2.10 Chapter summary

The literature review in this chapter focuses on the ecological and economic significance of wildlife in Africa where it has outlined the ecological roles wildlife plays in maintaining functional ecosystems in Africa. Wildlife was seen to play an important economic role by contributing to the GDP of many African countries in terms of foreign exchange earnings from tourism and wildlife ranching. This was demonstrated by how wildlife boosted the GDPs of South Africa, Zimbabwe, Tanzania, Kenya, Ruanda, Democratic Republic of Congo, Cameroon and Senegal.

Variations in climate have been experienced in Southern Kenya which has experienced long periods of cyclic droughts and altered rainfall patterns. The variations seem to follow a particular pattern. For example, the *La Nina* events of severe droughts occur after evey 5 years while the *El Nino* events of very high rainfall occur afte every 10 years. Climate variability had affected forage and water availability for giraffes by causing their shortage during the severe drought periods.

Human land use changes and tenure systems have caused landscape changes and their impacts on giraffe ranging patterns have been evident in Southern Kenya. Human-giraffe-livestock interactions have led to increased cases of human-wildlife conflicts. The conflicts have escalated as human beings and their livestock compete for forage and water resources with giraffes.

CHAPTER THREE

STUDY AREA, MATERIALS AND GENERAL METHODS

3.1 Study Area

3.1.1 Location and size

This study was carried out in Amboseli, Athi-Kapiti plains and Tsavo ecosystems located in Southern Kenya. Studies on giraffe population ecology and population dynamics were specifically conducted in the study sites of Amboseli National Park (392 km^2), Nairobi National Park (117 km^2) and Tsavo West /Chyulu Hills National Parks (11,000km^2), (Figure 3.1).

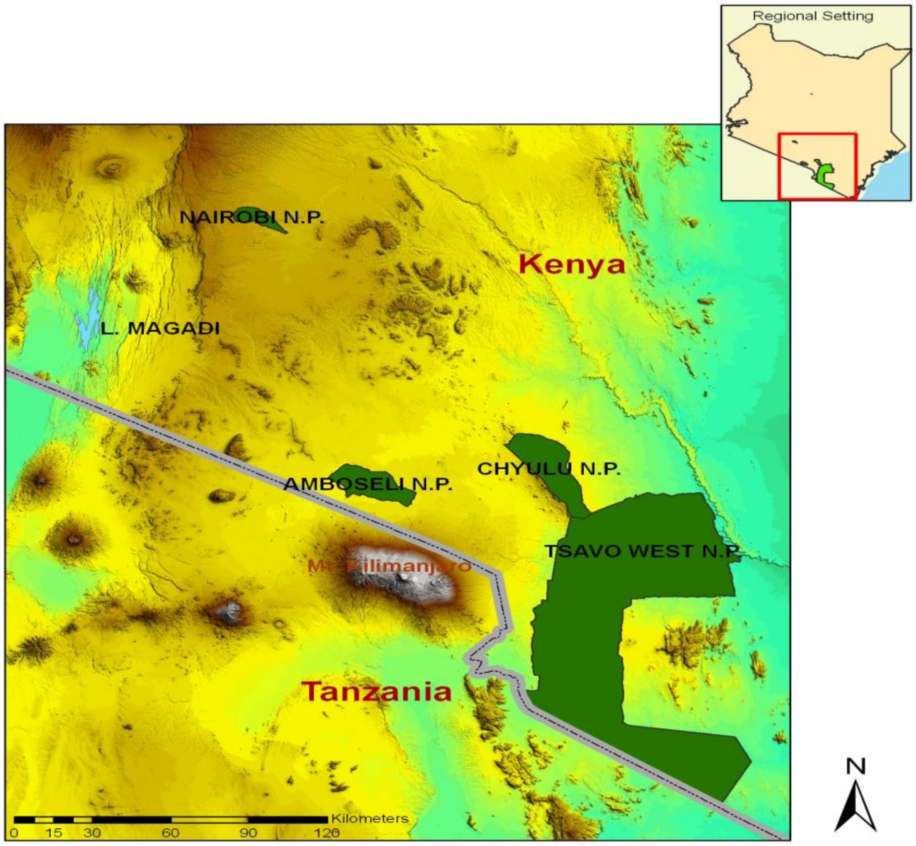


Figure 3.1: The study area covered Amboseli, Nairobi and Tsavo West National Parks in Southern Kenya

Source: KWS GIS Lab

3.1.2 Land tenure and use

Many areas with abundant wildlife resources such as Samburu, Trans-Mara, Kajiado, Taita-Taveta and Kwale districts are undergoing rapid land tenure and land use transformations. State and Trust lands which had been adjucated as Group and individual ranches are being sub-divided and sold or developed for other economic ventures. People in these areas have leased their lands for development loans to grow wheat, maize and horticultural crops through irrigation. These land use changes and developments have intensified conflict between people and wildlife.

Loss of land and displacement of settled communities from their traditional sources of livelihoods due to designation of certain areas as national parks and reserves have forced people to resort to alternative land use practices to support their family livelihoods. The current land use policies make sustainable land use and wildlife conservation incompartible. The changing land use systems in Kajiado district have had a great impact on the fragile ecosystem where changes from pastoralism to agro-pastoralism introduced use of fertilizers, growing of GMO crops and over-abstraction of water for irrigation purposes.

Land use changes have inherent consequences like pastoral communities abandoning their tradition practices of livestock herding, changing their lifestyles, encroachment into wildlife habitats, loss of wildlife migration corridors, reduced production and supply of beef and general environmental degradation as the new land use practices degrade fragile ecosystems that are not suitable for the new land use practices.

3.1.3 Social and economic trends

The entire economic system of rageland production in Kenya has undergone radical change since the mid 1970's. With human population increasing by 3% per year, cultivation in ASALs has increased by 8% and stabilizing livestock numbers while at the same time wildlife conservation declining by 3% (GOK, 1996). As land use and tenure systems changed in the rangelands, there was transition from the traditional pastoralism to agro-pastoralism as a socio-economic means of survival.

The economy of communities in the Southern Kenya is pastoralism but rain-fed agriculture done by the immigrant non-pastoralist communities of the Kikuyu, Kamba and Chagga people is practiced in high agricultural potential areas on the slopes of Mt. Kilimanjaro and Chyulu hills. Irrigated cropping is taking place along the river valleys and swampy areas within the Amboseli ecosystem. The main areas with irrigated agriculture are along the Nol- Turesh River in Kimana area, Ngong hills, Mt. Kilimanjaro slopes and Namanga hill.

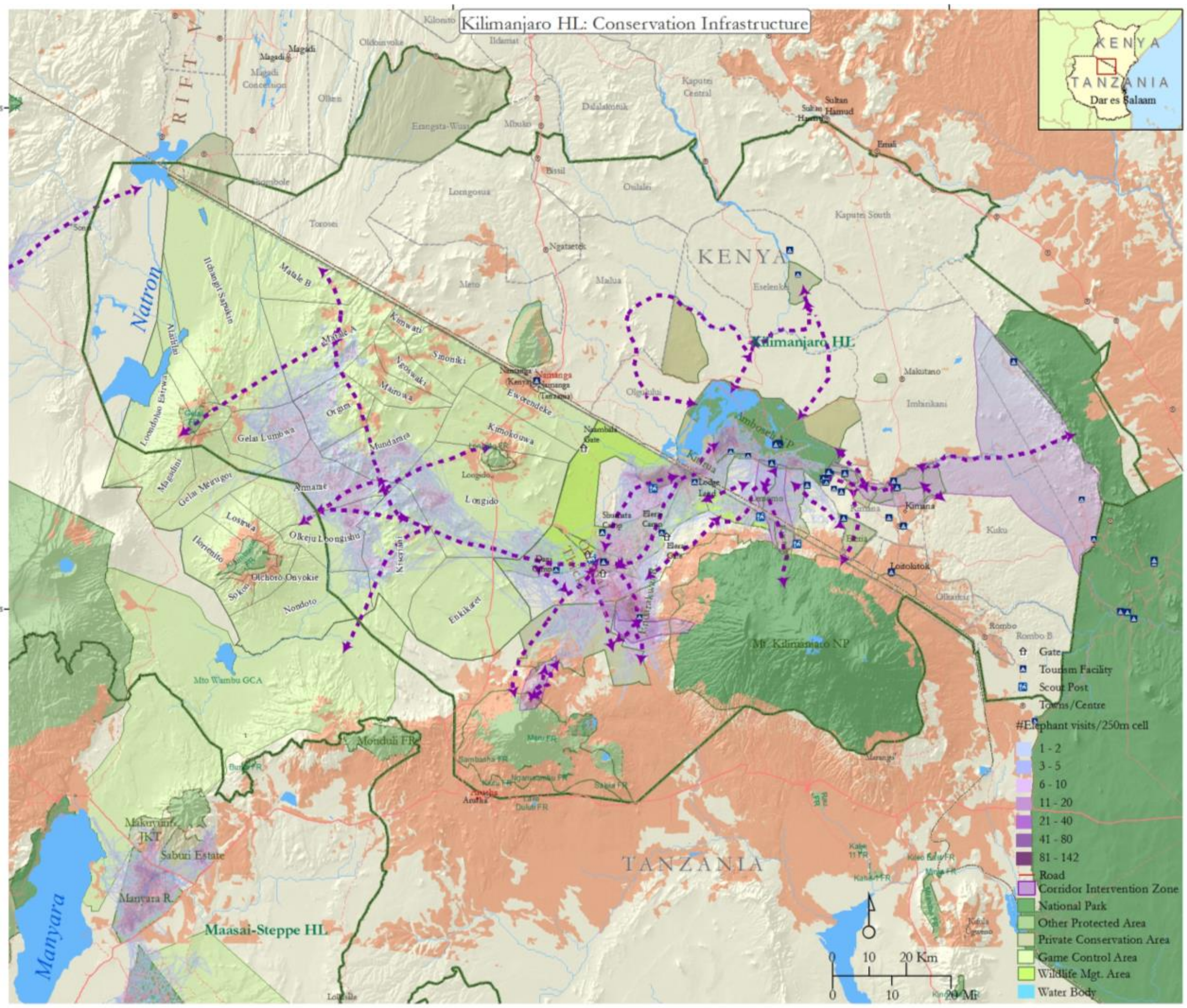
Other socio-economic activities include tourism based on hotel industry, culture, curio shops, balloon safaris, camping and wage employment. Ranching, mining and associated activities have been taken up by people to improve their earnings. With improved road transport system, people are engaging in business of transport, trade and agri-business of buying and selling of agricultural products of tomatoes, onions, beans and maize to up market towns of Nairobi and Mombasa. Because of the proximity of Nairobi City, ranchers supply meat to the Kenya Meat Commission factory in Athi River town which then distributes meat to Nairobi City where most of it is consumed.

3.1.4 Amboseli ecosystem

The ecological extent of the Amboseli ecosystem is delineated by the extent of animal movements. This ecosystem covers an area of 8,797 km^2 with the protected area of Amboseli National Park comprising of 392 km^2. The park is located 35^0 05’ E and 37^0 025’E and 2^0 24’S and 2^0 30’S. The Amboseli basin lies between 1100 – 1200m above sea level. It covers an area of $392Km^2$ of the larger 8797 Km^2. Amboseli ecosystem stretches between Mt. Kilimanjaro, Chyulu Hills, Tsavo West National Park western boundary and the Kenya-Tanzania border. Amboseli ecosystem consists of the Amboseli National Park and the six Group Ranches of Olgulului/Ololarashi, Kimana/Tikondo, Imbirikani, Eselengei, Kuku and Rombo.

Amboseli National Park is almost surrounded by Olgulului/Ololorashi Group Ranch which is a major wildlife dispersal area. The national park is a dry season grazing area for wildlife which disperses to adjacent ranches during the wet seasons for forage and water resources. The entire ecosystem is threatened by loss of wildlife migration corridors and dispersal areas, critical for survival of the ungulate populations (Personal observation).

Increasing human population, settlements, agriculture and livestock production in adjacent Group ranches pose as great threats to wildlife conservation in Amboseli ecosystem. Infrastructure development along the park boundary has fragmented wildlife habitats, reduced dispersal areas and curtailed animal movements. Changes in land tenure and use have compromised the integrity of Amboseli ecosystem as the inherent activities carried out are incompatible with giraffe conservation (Figure 3.2).



Elephant observations from 21 elephants fitted with GPS radio-collar. Sep 2005-Aug 2008
A. Kikoti, WEC

AFRICAN WILDLIFE FOUNDATION®

Sources:
KERCP, AWF, KWS, TAWIRI,Tracks4Africa, FAO-Africacover, NASA-SRTM

AWF Spatial Analysis Lab - Jan-12

Figure 3.2: Amboseli-West Kilimanjaro ecosystem and wildlife movement routes.

Source: AWF Special Analysis Lab.

3.1.5 Athi-Kapiti Plains ecosystem

The Athi-Kapiti plains ecosystem consists of Nairobi National Park, Kitengela and Kaputei dispersal areas and Machakos ranches that are widely utilized by various wildlife species including giraffe. Nairobi National Park is situated 10km south of Nairobi City. It lies between latitudes $2^{0}18'$ and $2^{0}20'$S and longitudes $36^{0}23'$ and $36^{0}28'$E. The national park is bordered by Wilson Airport to the North, Mombasa road to the east, Langata road to the west and Kitengela dispersal area to the south and covers a gazetted area of $117km^{2}$. It has a mean altitude of 1780m above sea level. The park has a large supply of water sources comprising of man-made dams and streams and acts as a dry season refuge for wildlife (Obari, 2009).

Nairobi National Park is unique as it is the only protected area located close to a capital city in the world. This savanna ecosystem comprises of different vegetation types dominated by open grasslands with scattered Acacia tree bushes. The western part of the national park has highland dry forest vegetation with the permanent Mbagathi River vegetated by riverine forest vegetation forming the southern boundary of the park. To the south of the park are the Athi-Kapiti plains and the Kitengela wildlife dispersal areas which are important wildlife range areas during the wet seasons of the year (Imbahale et al., 2007).

The Athi-Kapiti plains ecosystem that is located south of Nairobi City is occupied by the traditional Maasai pastoralists who depend on livestock keeping. The plains host large herds of both wildlife and livestock and serve as critical wet season wildlife dispersal areas from Nairobi National Park. These plains extend to the larger Machakos ranches to the east and linked to Amboseli ecosystem to the south by the gently sloping Emarti valley. This ecosystem has experienced rapid land use changes that have resulted in huge urbanization and the expansion of the townships of Athi River and Kitengela (Imbahale et al., 2007), (Figure 3.3).

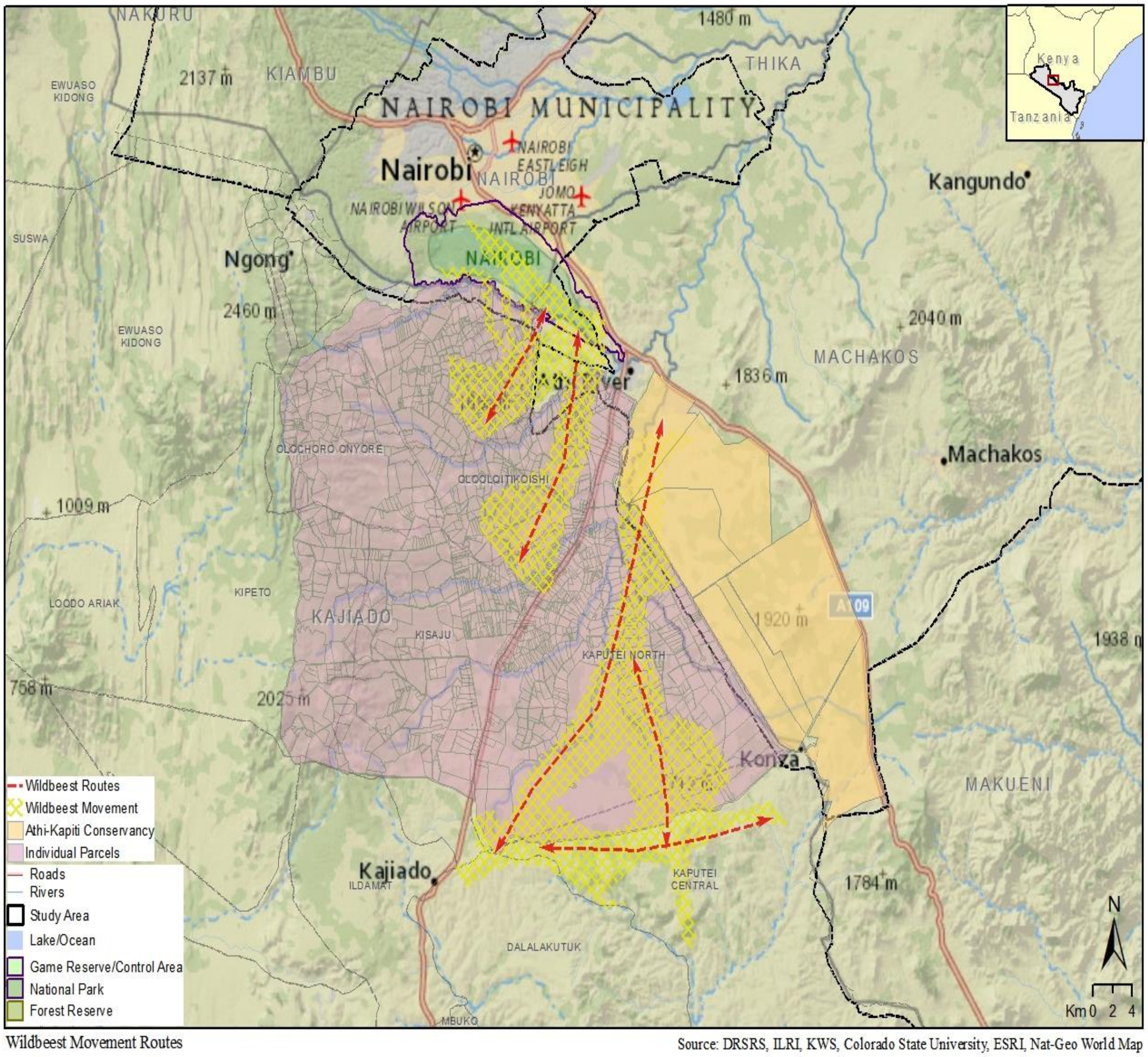


Figure 3.3: Athi-Kapiti plains ecosystem and wildlife movement routes.
Source: DRSRS, ILRI, KWS, Colorado University, ESRI, Nat-Geo World Map.

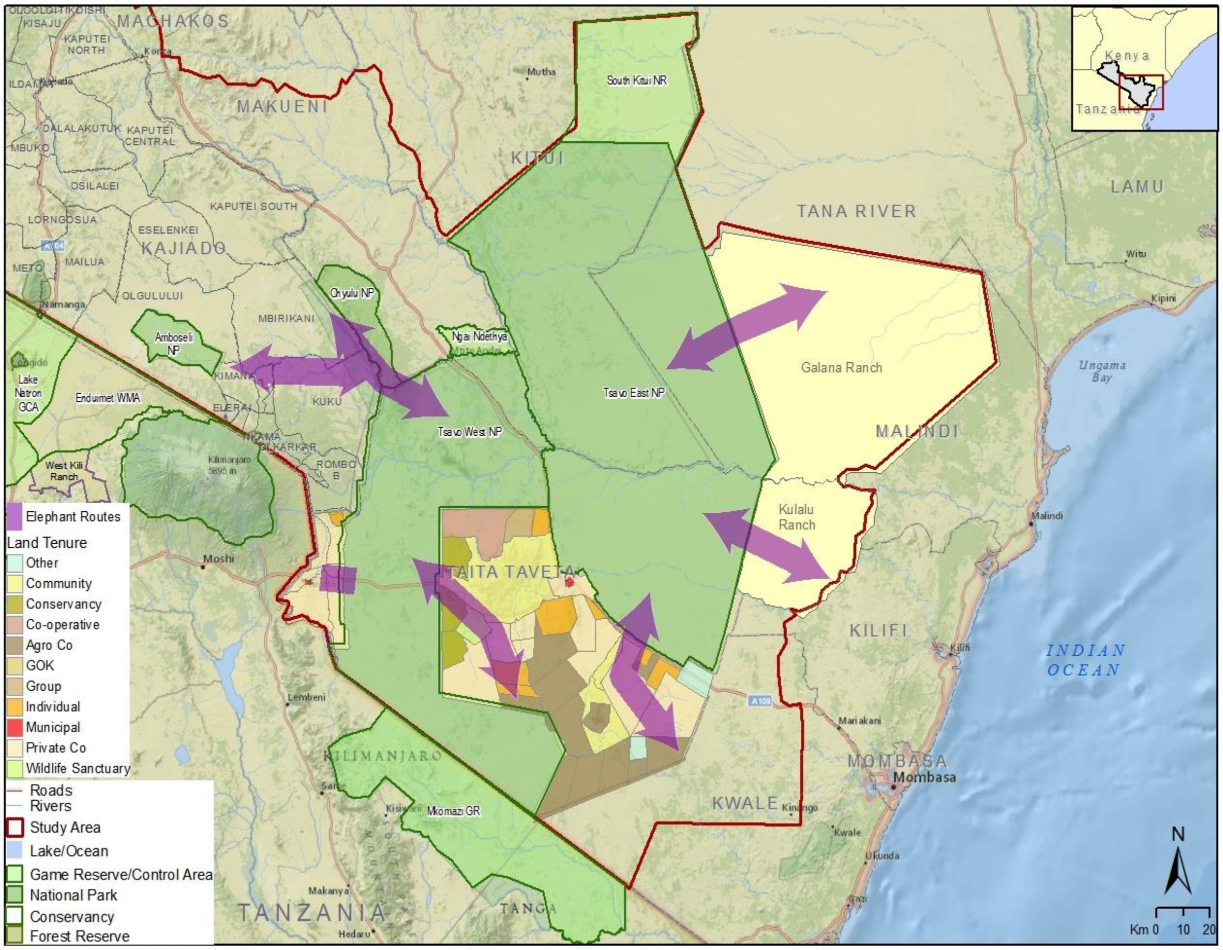
3.1.6 Tsavo West-Chyulu Hills Ecosystem

Tsavo ecosystem is located in south-eastern Kenya and covers an area of about 40,000km^2. It consists of the largest conservation area of Tsavo East, Tsavo West and Chyulu Hills National Parks. The three national parks in the Tsavo conservation Area (TCA) comprise of 45% of the total area of Tsavo ecosystem. 55% of the ecosystem is a non-protected area with 40%

comprising of cattle ranches while the remainder (15%) is devoted to cultivation of agricultural crops.

Large areas of Tsavo ecosystem are important for migratory wildlife species such as elephants which migrate from Tsavo West National Park to Mkomazi Game Reserve in Tanzania. Because of its extent, Tsavo ecosystem hosts the largest population of elephants in Kenya and other endangered wildlife species like the black rhino, Grevys' zebra and Hirola (Hunter's hartebeest). The vegetation of Tsavo ecosystem consists of remnants of the formally extensive Commiphora - Acacia woodlands that have been highly modified by elephants. The tree and shrub densities are low near rivers with patches of riverine forest or fringe trees along water courses (Leuthold, 1978).

Tsavo West National Park covers an area of 9,065 Km^2 with Chyulu Hills National Park lying adjacent to it. It lies equidistant between Nairobi and Mombasa cities along the Nairobi-Mombasa Highway and located along latitude 2^{0}9167'S and longitude 37^{0}9167'E. The park lies in a vast savannah ecosystem dotted with rocky hills produced by the recent volcanic eruptions associated with the formation of Mt. Kilimanjaro. Its altitude ranges from 150m – 1821m above sea level (Leuthold, 1978), (Fig. 3.4).



Elephant Movement Routes

Source: DRSRS, KWS,AWF, ESRI, Nat-Geo World Map

Figure 3.4: Extent of Amboseli – Tsavo-Chyulu hills ecosystem and elephant migration routes.

Source: DRSRS, KWS, AWF, ESRI, Nat-Geo World Map.

3.1.7 Trends in large herbivore populations

The noteable large wild herbivore species in the study area are the elephant, giraffe, buffalo, zebra, wildebeest and Eland. Cattle as a domestic stock were considered among the large herbivores because of the ecological role they play in the ecosystem. Trends in large wild herbivore populations appear more stable than those of the domestic stock. The large herbivores comprise about 22% of the total biomass in the larger Kajiado county of Amboseli ecosystem. In Kajiado County, cattle numbers rose from 410,000 in 1976 to 690,000 in 1983 after their numbers recovered from the 1974/76 drought (Croze, 2007). However, wild herbivores were not uniformly distributed in the ecosystem. In the period 1974-76, large wild herbivores accounted for only 37% of the total biomass in the Athi-Kapiti plains ecosystem, 29% in the Amboseli ecosystem and 8% in the central hills of Machakos and Kiboko area of Makueni County (Table 3.1).

Table 3.1: Percentage change in the number of cattle and wildlife in Kajiado County during the period between 1970 and 1990.

Species	**1970's**	**1990's**	**% Change**
Buffalo	35000	30187	-15
Cammel	557485	651254	+18
Cattle	3319749	2911496	-12
Eland	25000	19123	-26
Elephant	39000	14923	-6.2
Giraffe	62000	50000	-20
Greater Kudu	233	45	-81
Wildebeest	224000	173354	-23
Zebra	148060	150000	-59

Source: Peden (1984)

In the years 2000 and 2002 counts, elephants were concentrated in Amboseli National Park and Kimana Wildlife Sanctuary. Elephants were found outside the national park in Olugulului/ Ololorashi Group Ranch in the *Acacia xanthophloea* woodlands. Buffalo distribution was influenced by the location of water points with about 70% of the buffoloes found in Amboseli National Park. Large expanses of grasslands in the Amboseli swamps attract buffaloes to these locations. Buffaloes were also restricted to swamps in Kimana Sanctuary away from human cultivated areas.

Giraffes were uniformly distributed in the ecosystem due to availability of their preferred browse where they also fed on succulent twigs and buds in water scarce environments. Eland distribution was rather uneven and they were mostly found on the slopes of Chyulu hills far away from human settlements. Elands were also found along the slopes of Mt. Kilimanjaro albeit in small numbers (Table 3.2).

Table 3.2: Estimated large herbivore numbers in Kajiado County including Amboseli National Park in the 1990's.

ECOSYSTEM	KAJIADO ECOZONE		AMBOSELI ECOZONE	
Estimate/Species	Number (000's)	% biomass	Number (000's)	% biomass
Wildebeest	43	22	11	15
Zebra	22	18	4	10
Eland	7	10	4	15
Giraffe	8	25	3	27
Other wildlife	-	25	-	33
Total	80	100	22	100

Source: Croze (1978), Peden (1984)

According to the 2011 KWS total aerial census of elephants and other large mammals in Tsavo-Mkomazi and Amboseli-Longido ecosystems, the number of elephants increased from 6,399 in 1988 to 12,573 in the year 2011 giving a gross increase of 96% in 13 years. Elephant numbers in Tsavo-Mkomazi ecosystem decreased by 2% in 3 years (2008-2011) through natural mortality as a result of droughts and disease outbreaks (Estes, 1991). The buffalo population fluctuated during the period 1988-2011. Buffalo population increased in Tsavo West National Park by 25.1% during the period 2002-2011 (Table 3.3).

Table 3.3: Annual number of large wild herbivores in Tsavo-Mkomazi ecosystem (1988-2011)

Year	Elephant	Buffalo	Giraffe	Zebra
1988	5363	5860	-	-
1989	6037	10038	-	-
1991	6763	10206	-	-
1994	7371	11798	-	-
1999	8068	5949	1148	-
2002	9284	7347	1284	-
2005	10397	9371	1584	-
2008	11691	6514	2450	8276
2011	12573	7402	2055	6726

Source: KWS database

The Tsavo ecosystem supported about 2,055 giraffes in the year 2011. Prior to the year 1999, giraffe data for the whole ecosystem were not available. Giraffe population increased from 1,148 animals in 1999 to 2055 animals in the year 2011 representing an increase of 55% (n=907). However, compared to their numbers in the year 2008, giraffe population declined by 19% (n=395). The highest decline in giraffe numbers of about 60% (n=254) and 45% (n=242) were recorded in Tsavo East and Chyulu Hills National Parks respectively. During the four previous counts, Tsavo West National Park recorded the highest number of giraffes whereas South Kitui National Reserve recorded the least number of giraffes. Large groups of giraffes were recorded in Chyulu West, southern part of Tsavo West National Park and northern part of Mkomazi National Park.

In the year 2011, large herds of cattle were found in Chyulu West around Njukini area that borders Chyulu Hills National Park. The Taita ranches and the southern tip of TWNP and Mkomazi National Park had large herds of cattle. Cattle were also many in TENP, particularly that part south of the Thiba River and areas bordering the Galana ranch. The invasion of cattle and herders could have increased competition with the wild grazing herbivores, such as Zebra, but there were no ecosystem – wide data for these equids prior to the year 2008

3.1.8 Trends in pastoralism and human wildlife conflict

Interactions between pastoralists and wildlife occur at various levels. The nature and intensity of interactions change in response to changes in land use patterns. In higher rainfall areas, there is intensified livestock production with smaller herds in small tracts of land making pastoralists move from pure pastoralism to agro-pastoralism. This makes pastoralists include opportunities from wildlife into their livelihood strategies through community based natural resource management initiatives.

While adopting agro-pastoralism in wildlife occupied areas, human/wildlife conflicts are bound to occur. There is therefore predation of livestock by carnivores, damage to crops and infrastructure by elephants, buffaloes and zebras. Some of the causes of human/wildlife conflicts include: loss and damage of agricultural crops, damage to forest plantations by wildlife, human injuries and deaths, livestock depredation, competition for forage and water with livestock, disease reservoirs and transmission and poaching for wildlife trophies and bush meat trade by local people.

3.2 Materials and general methods

3.2.1 Study design

The study area was identified as that part of Southern Kenya where Maasai giraffes are found both in and outside protected areas. Topographical maps for Amboseli, Athi-Kapiti plains and Tsavo ecosystems were obtained and specific study sites of Amboseli, Nairobi and Tsavo West National Parks delineated. Giraffe habitat type maps were delineated in each of the three study sites to depict six broad vegetation categories of forest, woodland, shrub, bush/shrub, swamp and grassland that were sampled to collect data on giraffe frequency of habitat use and occupancy (Pratt & Gwynne, 1977).

The specific study sites were identified as the gazzeted protected areas of Amboseli, Nairobi and Tsavo West National Parks. Both topographical and J-peg maps for the three study sites were obtained and six habitat types were delineated for the purpose of the study. Each of the habitat types in the study sites was regularly sampled and data on the frequency of giraffe use and occupancy collected. Food plants eaten by giraffes were recorded and those unidentified plants were collected for identification to produce a check list of food plants browsed upon by giraffes in the three study sites.

Vegetation sampling was carried out in the three study sites to determine the relative abundance of giraffe forage using the point centred quarter (PCQ) method for vegetation sampling. The various giraffe habitats in the three study sites were assessed to determine impacts of human activities on them.

3.2.2 Data collection

Giraffe herds or individuals were located in the study sites by visual means and by use of a pair of binoculars. Once spotted, their GPS coordinates relative to the position of the observation vehicle were recorded to determine giraffe locations and distribution in the three study sites. Giraffe numbers were determined through both total and aerial count methods along belt transects and recoinnances flights along grid lines respectively. Giraffe sexes were determined through focal animal sampling where they were sexed.

Their age-class structures were determined as adult male (AM), adult female (AF), sub-adult male (SAM), sub-adult female (SAF) and young (Y). Data was collected on the above parameters and recorded in specially designed data sheets for data compilation and analysis. Secondary data on trends in giraffe numbers in the study area were obtained through the review of data sets from the DRSRS and KWS databases, publications and journals.

Data sets collected on various parameters during the study were analyzed using existing statistical packages and GIS programs and software. All statistical analyses were done at 95% limits of confidence.

Data were collected in the three study sites on Maasai giraffe numbers, temporal and spatial distribution. Data was also collected on individual giraffe sexes and age structures that were determined through visual means and by use of a pair of binoculars. Each of the three study sites was regularly visited to collect data on the above parameters. Total ground count method along belt transects was used to determine giraffe numbers in Amboseli and Nairobi National Parks, while both total ground and aerial count methods were used to determine giraffe numbers in Tsavo West National Park.

Belt transects were used to count giraffes. Giraffes spotted far off from the belt transects were observed and counted using a pair of binoculars. Giraffe numbers for the respective study sites were then recorded in specially designed data sheets and their cumulative totals determined.

Trends in Maasai giraffe populations were also determined from both primary and secondary data. Data from past large mammal counts in Amboseli, Athi-Kapiti plains and Tsavo ecosystems from other Kenya Wildlife Service researchers were reviewed to determine giraffe population trends over time. Giraffe spatial and temporal distribution in the study sites were determined by recording their location coordinates using a hand held GPS. The GPS coordinates were later used to plot giraffe spatial and temporal distribution in Amboseli, Nairobi and Tsavo West National Parks.

Data was collected on the frequency of giraffes' use and occupacy of the six delineated habitat types in the three study sites. Data was also collected on the number of plant species eaten by giraffes during the wet and dry seasons. During vegetation sampling using the point centered quarter (PCQ) method, data was collected on habitat type, point number, quadrant number, tree species, point-plant distance, tree height, percentange canopy cover and diameter at breast height (dbh).

Data collected on the above parameters was later used to calculate the frequency(F), relative frequency (RF), density (D), dominance (Dom), relative dominance (Rel.Dom.) and importance value index (IVI) of giraffe food plants in Amboseli, Nairobi and Tsavo West National Parks. The summation of the importance value index (IVI) of giraffe food plants in the respective study sites was used to determine the relative abundance of giraffe forage in the three study sites.

Data on human interactions with giraffe and its habitats were collected by assessing the gravity of impact of human activities on giraffes and their habitats in the study area. Regular visits were made to randomly selected areas that had experienced serious impacts due to human activities to collect data on the impacts. Secondary data was also collected from KWS data bases and Occurance Books (OBs) on human/wildlife conflicts experienced in respective study sites. Additional information was obtained from the offices of the local administrators in the Ministries of Agriculture and Livestock Development, District Officers and the Kenya Forest Service (KFS).

Data sets on giraffe numbers were analyzed using existing statistical packages, especially STATISTICA 6.0 (Stasoft, 2001) and Statistical Package for Social Scientists (SPSS 17.1). The data sets were also analyzed using descriptive statistics. Two hypotheses were posed before analysis of the data sets. The Null (Ho) hypothesis of there being no correlation between giraffe numbers and annual rainfall amounts and the Alternative (Ha) hypothesis of there being a correlation between the giraffe numbers and rainfall were posed. No data transformation was carried out on the data sets as the relationship between the two variables was found to be linear. No logarithmic or arcsine transformation on the data sets was carried out since the data sets needed not have been freely distributed (Zar, 1996). All statistical tests were performed at 95% (0.05) level of significance.

3.2.3 Assessment of giraffe population trends in the study area

Total annual counts of giraffe numbers in Amboseli, Nairobi and Tsavo West National Parks were conducted and obtained totals tabulated. Giraffe numbers for thirteen (2000 – 2012) years in each of the three study sites were then explored and their trends determined through calculation of the giraffe population changes between successive years. Percentages of successive years' population increase or decrease were also calculated for Amboseli, Nairobi and Tsavo West National Parks. Descriptive statistics were used to analyze giraffe population trends in each of the three study sites.

3.2.4 Assessment of giraffe habitat occupancy and use in the three study sites

In ANP, giraffes were located in the southern, northern and eastern parts of the park. However, few giraffes were encountered in the western part of the park which consists mainly of the dry and seasonal Lake Amboseli. Giraffes were also located in the less swampy central parts of the park where they foraged on the available thick and thin bush vegetation. Giraffes were found in all parts of the national park during both the wet and dry seasons of the year. This is an indication that giraffes utilize the available forage in the national park throughout the year. Although giraffes movd out of the national park to the surrounding community group ranches, they nonetheless came back to the national park after short periods of absence. Resident giraffe populations stayed in the national park throughout the year and utilized habitats with their preferred forage in the park.

Giraffes showed an even spatial distribution pattern in Nairobi National Park. The giraffes were well distributed in all habitat types, but their presence was low in forest and grassland habitats. Forest habitats were avoided by giraffes due to difficulty in manoeuvering them and absence of preferred food plants. Giraffes utilized the forest edges that are hemmed by *Rhus natalensis* vegetation type, a preferred food plant by giraffes. Single males were located in forest glades utilizing the forest edges and water pans found in the glades. The expansive Athi plains to the south-east of the national park were less utilized by giraffes, thus their absence in this area which is characterised by vast expanses of grassland vegetation.

Giraffes were mainly located in the central, southern and south-eastern parts of the park. The southern parts of the park are mainly covered by woodland vegetation along the Mbagathi River while the central and south-eastern parts of the park have a mixture of both thick and thin bush habitats that influenced giraffe distribution. Since the national park is almost closed up by fencing, giraffes utilized the same habitats during both the wet and dry seasons of the year. Giraffes in the park concentrated feeding mainly in the southern woodlands along the Mbagathi River and the riverine vegetation along the rivers that cris-cross the national park.

Giraffes showed an un-even spatial distribution pattern in Tsavo West National Park. Giraffes were mainly located along the riverine vegetation of the perennial Tsavo River and the Mzima springs *Acacia xanthophloea* woodland vegetation. Giraffes were concentrated in the northern and western parts of Tsavo West National Park. Giraffes were also located in the far southern parts of the park near Lake Jipe along the Kenya-Tanzania border. The central parts of the park had either very few or no giraffes. This was mainly due to dominance of the dry thin bush habitats that lack in foliage of preferred giraffe food plants and water sources.

The spatial and temporal giraffe distribution patterns in Tsavo West National Park were similar. Giraffes were spatially distributed in the same areas during both the dry and wet seasons, particularly in the northern parts of the park. During both the wet and dry seasons, giraffes were located in both the thick and thin bush habitats, but they tended to move to the Tsavo River during the dry seasons where they concentrated feeding on riverine vegetation along the Tsavo River.

3.2.5 Assessment of giraffe movement and dispersal

Wildlife migration corridors and dispersal areas were assessed and categorized as blocked, degraded and not threatened (mainly in protected areas). The Amboseli-Tsavo ecosystem, the connection between ANP and TWNP through Kuku and Mbirikani Group ranches as well as the wildlife species access to Chyulu Hills National Park were assessed through ground truthing and found to be blocked. The last remaining link running down the northern face of Mt. Kilimanjaro to ANP as well as the corridor between the montane forest and lowlands was assessed and found to have been severed. Swamps critical to wildlife and livestock in Kimana, Kuku and Mbirikani Group ranches were assessed and found to have all been lost to cultivation for agricultural crops.

Wildlife migration corridors and dispersal areas in the Athi-Kapiti plains ecosystem were assessed through ground truthing and found to have been severely affected by human activities due to rapid land use changes experienced in the area. Increased and expanding infrastructure development had adversely affected the Nairobi-Kitengela-Athi-Kapiti plains wildlife movement corridor/routes to the east. The southern Nairobi-Kaputei-Isinya-Magadi wildlife movement routes had equally been affected by the changing human land use activities and tenure systems.

Through both aerial surveys and ground thruthing, it was found in the Tsavo ecosystem, that those wildlife movement corridors not threatened by human activities were found inside the national parks and these includd the Thiba river crossing, Yatta plateau gaps and the Ngulia to

Yatta plateau links. The blocked corridors included the southern parts of Tsavo West National Park to Rukinga and Taita hills that had been blocked by fences and small scale farming. Other corridors are the Maktau to Kasigau that had been affected by heavy human settlement, fences and small scale farming.

The Komboyo to Chyulu hills corridor was assessed through ground truthing and found to have mainly been affected by human encroachment. The Chyulu hills-Amboseli corridor had been affected by land sub-divisions, agriculture, fences and infrastructure development while the Tsavo West National Park – Lake Jipe wildlife corridor had been affected by high density human settlements and agriculture. The Tsavo East to Galana ranch degraded corridor was mainly due to livestock encroachment for grazing purposes.

Plate 3.1: Giraffes in Amboseli-Tsavo West ecosystem migration corridor

3.2.6 Chapter summary

Land use and tenure systems have been changing in the last decade in Southern Kenya. It has been observed that the resident pastoral Maasai community has changed from pastoralism way of life to that of agro-pastoralism. They have also settled to sedentary type of life and built permanent houses where they are engaged in farming, business and pastoralism. The changes in land use and tenure systems have impacted negatively on giraffe ranging patterns in Southern Kenya.

Trends in Maasai giraffe populations were determined by analyzing both primary and secondary data. Data from past large mammal counts in Amboseli, Athi-Kapiti plains and Tsavo ecosystems from the Department of Resource Surveys and Remote Sensing (DRSRS) and Kenya Wildlife Service (KWS) data bases were reviewed to determine giraffe population trends over time. Giraffe population in Amboseli, Nairobi and Tsavo West National Parks had showed annual variations for a period of 13 years (2000 – 2012). Giraffe numbers had either increased or decreased during certain years in the three study sites.

Generally, giraffes showed uniform use of all habitats during both the dry and wet season in the three study sites. In ANP, giraffes utilized the available forage in the national park throughout the year. Giraffes showed an even spatial distribution pattern in Nairobi National Park while they showed an un-even spatial distribution pattern in Tsavo West National Park where they were mainly located foraging along the riverine vegetation of the perennial Tsavo River and the Mzima springs *Acacia xanthophloea* woodland vegetation.

Giraffe migration corridors and dispersal areas had been assessed and categorized as either blocked, degraded and not threatened (mainly in protected areas). The Amboseli-Tsavo ecosystem, the connection between ANP and TWNP through Kuku and Mbirikani Group ranches as well as the giraffe access routes to Chyulu Hills National Park were assessed and found to be blocked. The last remaining link running down the northern face of Mt. Kilimanjaro to ANP as well as the corridor between the montane forest and lowlands were assessed and found to have been completely cut off by human settlement and cultivation.

CHAPTER FOUR

CLIMATE VARIABILITY AND ITS EFFECTS ON GIRAFFE POPULATION TRENDS IN SOUTHERN KENYA

4.1 Introduction

Climatic elements, particularly, rainfall and temperature have been varying in southern Kenya over time. In the past 30 years, mean annual rainfall amounts and temperature ranges have shown variations in time and intensity. There have been reduced rainfall amounts and increased prevalence of cyclic droughts that have affected general primary productivity which wild herbivores like giraffes depend on in the region. Rainfall has become increasingly unpredictable in terms of time and distribution. The usually predictable long and short rain seasons have become increasingly unpredictable and fall at unexpected times.

There have been instances of very heavy and intense rainfall during the short rain periods more than during the long rain periods. Such rains end up causing floods that have been detrimental to wildlife during *El Nino* periods (Ogutu, 2007). There have therefore been cyclic and prolonged dry periods experienced in southern Kenya rangelands with serious effects on the grazer wildlife species. For example the 2009/2010 drought experienced in the Tsavo and Amboseli ecosystems caused deaths to the grazer wildlife species when they lacked grass to feed on as the vegetation had dried up as a result of prolonged droughts.

There have been variations in the mean maximum and mean minimum temperatures recorded in Amboseli, Athi-Kapiti plains and Tsavo ecosystems over time. This led to increase in temperatures that caused dessicating effects on vegetation and high intensity heat that was intolerable to the large herbivores, particularly the giraffes in the study area (Plate 4.1). Generally, rainfall and temperature variability cause fluctuations in availability of both forage and water to the wild herbivore species including the giraffes. This study sought to understand climate variability and how it affected giraffes and availability of its forage and water in the study area.

Plate 4.1: Maasai giraffes in Amboseli National Park during the dry season

4.2 Scope of the study

This chapter deals with climate variability in southern Kenya. The study looked at climatic elements, particularly rainfall and temperature variability over a period of 30 years (1982-2012). The specific objectives of the study are outlined in section 4.3. Procedure of climate data collection is covered in the materials and methods section. The study yielded results and analyzed the collected data using the available analytical tools. It has therefore analyzed results on the relationship between rainfall and giraffe numbers and trends in giraffe population in Southern Kenya.

4.3 Research objectives

i) To establish patterns of climate variability and its effects on giraffe population in Amboseli, Nairobi and Tsavo West National Parks.

ii) To determine the relationship between rainfall patterns and giraffe population trends in Amboseli, Nairobi and Tsavo West National Parks.

4.4 Materials and methods

4.4.1 Collection of climate data

Climate data on rainfall and temperature was collected from the weather stations in Amboseli Baboon Research station, Wilson Airport and Voi town that are found in Amboseli, Athi-Kapiti plains and Tsavo ecosystems respectively. Recorded daily, monthly and mean annual rainfall amounts were compiled for each of the three study sites of ANP, NNP and TWNP for a period of two (2011 and 2012) years. Both mean annual maximum and mean annual minimum temperature data was collected in the weather stations located in the three study sites. Secondary data on the mean annual rainfall amounts and temperatures recorded in Amboseli, Nairobi and Voi weather stations for the past 28 years were obtained from the Meteorology Department of Kenya and reviewed to determine the long term rainfall and temperature variability in the three study sites.

Data on the mean annual rainfall amounts and giraffe numbers for the past 13 (2000 – 2012) years were compiled for each of the three study sites. The mean annual rainfall amounts were then correlated with annual giraffe numbers to determine the relationship between rainfall amounts and giraffe numbers in Amboseli, Nairobi and Tsavo West National Parks. Both mean annual maximum and minimum temperatures were correlated with mean annual rainfall amounts to determine annual climate variations in the three study sites.

4.4.2 Analysis of rainfall and temperature data in the three study sites

Historical data over a period of 30 years were analyzed to provide insight about the rainfall trends in the study area. The trend analysis showed gradual decline in annual rainfall for the period between 1982 and 2012. However, statistical analysis of the deviations from the mean rainfall amounts received in Amboseli, Nairobi and Tsavo West National Parks were not significant ($p>0.05$). This meant that the annual amount of rainfall in the study area has not significantly decreased during the last 30 years, but there have been considerable inter-annual variations over time.

Rainfall and temperature variables showed marked annual variations over the 30 year period in Amboseli ecosystem. For example, the highest mean annual rainfall of above 400mm was received in the years 1989 (460mm), 1998 (450mm) and 2010 (450mm) while the lowest mean annual rainfall of less than 200mm was recorded in the years 1984 (100mm), 1992 (150mm), 2003 (150mm), 2007 (150mm) and 2009 (160mm). These were generally considered as the dry years with drought occurring almost after every 10 years, thus exhibiting a 10 year drought cycle with droughts occurring during the years of 1984, 1992, 2003 and 2009 (Figure 4.1).

The mean maximum temperatures in Amboseli ranged between 30^{o}C and 45^{o}C. The mean maximum temperatures were highest during the drought years of 1984, 1992 and 2003. The mean minimum temperatures were constant and averaged 15^{o}C with the difference between the mean maximum and mean minimum temperature being 20^{o}C. Such extreme temperature variations caused stress to both animals and plants in Amboseli ecosystem (Fig. 4.2 and Fig. 4.7).

There was a clear annual variation in rainfall amounts in Amboseli National Park. Analysis of annual rainfall amounts for the past 30 (1982-2012) years showed that Amboseli ecosystem had recorded both very high and very low rainfall amounts during certain years. This follows a pattern where certain years had received very low rainfall (dry years) while some years received very high rainfall (wet years). The Amboseli ecosystem experienced prolonged droughts during the dry years, but at the same time received heavy rainfall that was associated with flooding during certain years.

Rainfall data has been maintained in Amboseli National Park since 1972 with the long term data series being a composite of measurements at three different meteorological stations within 5km of each other. Ecosystem stress on elephants in Amboseli was expressed by use of Dry Season Intensity (DSI) index (Fig. 4.1). This index was used to estimate the severity of the long dry seasons in a given year. These were the number of dry months with less than 20mm of rain expressed as a fraction of the total annual rainfall for a particular year (Lindslay, 1994). The DSI was also used as a proxy measure of the extent of plant biomass decline through consumption by herbivores (length of the dry season) relative to the plant biomass growth or production (Croze, 2010).

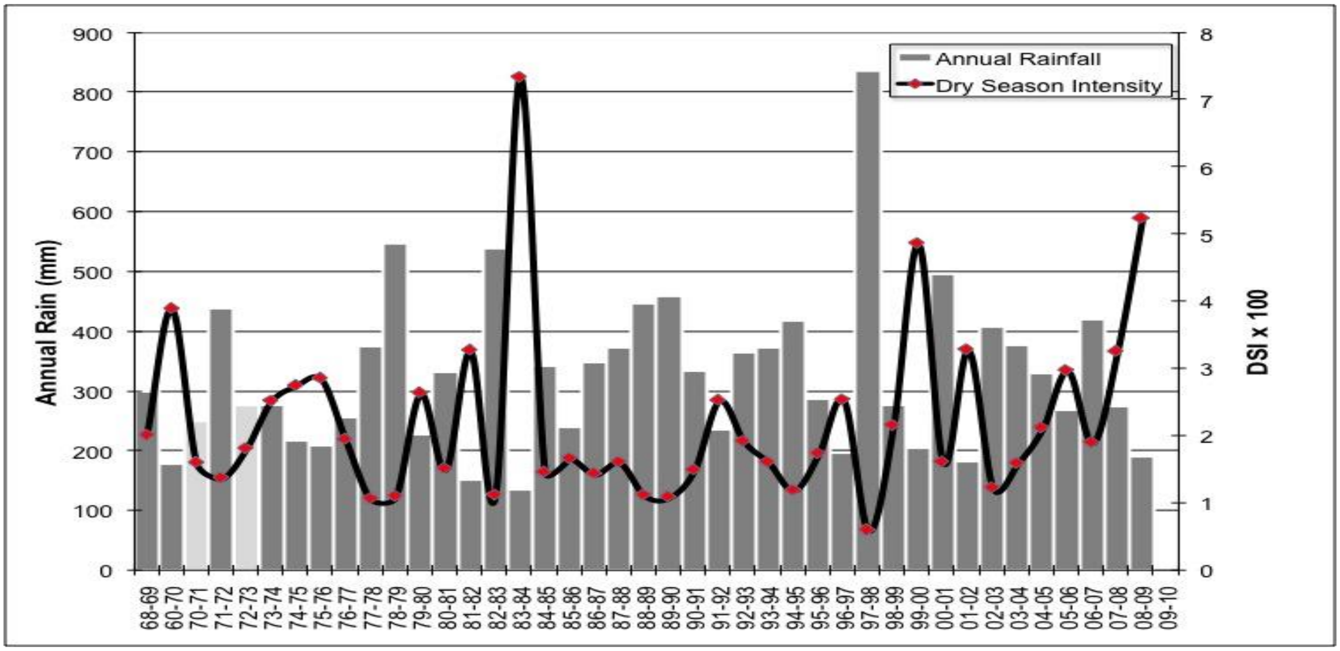


Figure 4.1: Mean annual rainfall (bars) and dry season intensity index (line) in Amboseli National Park for the period 1968-2010.
Source: Amboseli Baboon Research Project.

4.5 RESULTS

4.5.1 Long term rainfall patterns in the study area

As shown in Figure 4.1, the peaks of the dry season intensity (DSI) index in Amboseli generally coincided with periods of low rainfall. Low DSI coincided with groups of years with above average rainfall. High DSI values coincided with low availability of forage for giraffes in ANP.

The Amboseli ecosystem had low rainfall amounts in the years 1982, 1984, 1986, 1992, 1997, 2000, 2002, 2011 and 2012. These were the years when the ecosystem had experienced severe droughts that impacted negatively on giraffe in the ecosystem. Very low annual rainfall amount of 110mm was recorded in 1984 when the ecosystem experienced the worst drought. Some herbivore wildlife species, such as zebra and wildebeest died of starvation as a result of the severe drought that affected mostly the grazers. But, the years of 1983, 1989, 1990, 1995, 1998 and 2004 recorded above average rainfall amounts. The highest mean annual rainfall amount of 850mm and mean annual deviation from the long term average coincided with the *El Nino* year of 1998 and the ecosystem experienced serious flooding when the entire Amboseli basin was submerged for most of the time and affected life forms in the Amboseli basin (Fig. 4.2a).

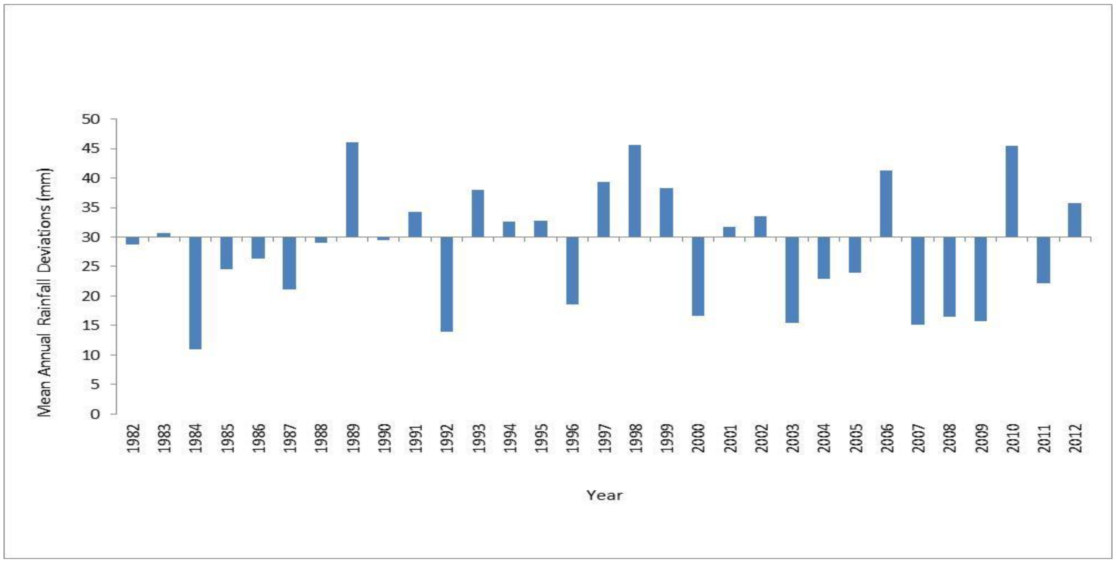


Figure 4.2a: Mean annual rainfall deviations from the long term mean in Amboseli National Park over a period of 30 years (1982 – 2012).

The annual rainfall amounts received in Nairobi National Park varied from one year to the other. The park received a mean annual rainfall amount of 700mm and a maximum mean annual rainfall amount of 1500 mm. Below average (< 700mm) annual rainfall amounts were received in the years 1984, 1996, 2000 and 2007 (Dry years). Very high (>1000mm) annual rainfall amounts were received in the years 1982, 1988, 1995, 1998, 2001 and 2004 (Wet years). The greatest increase in rainfall occurred during the *El Nino* year of 1998 while the minimum deviations from the long term average coincided with the *La Nina* years. (Fig. 4.2b).

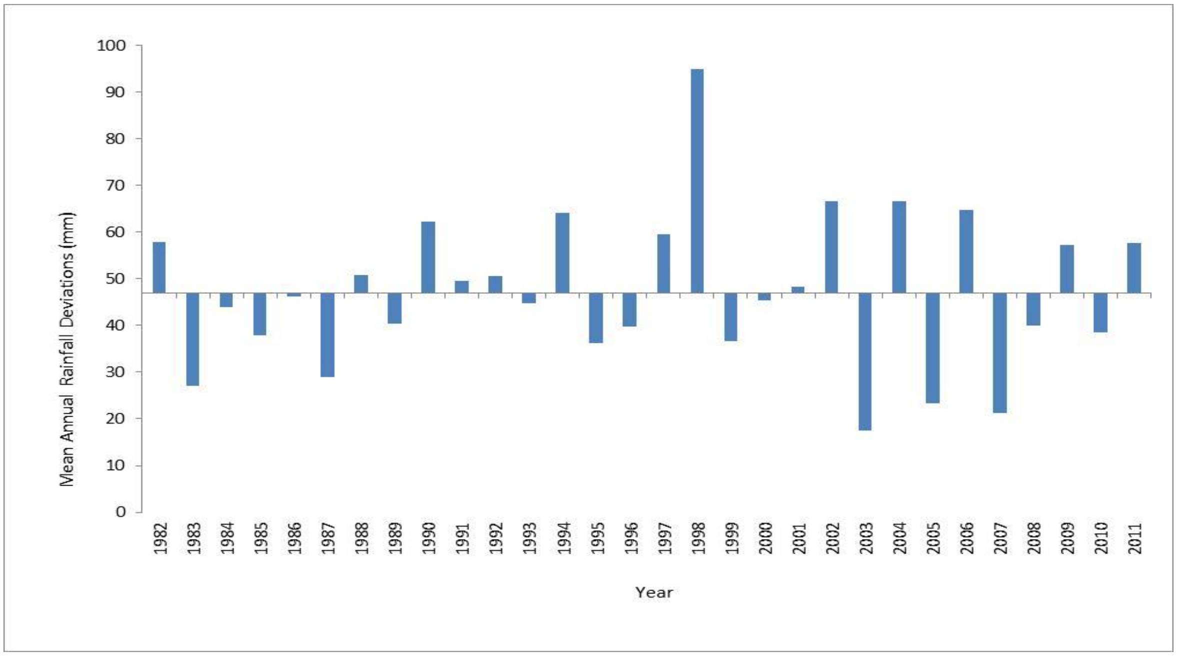


Figure 4.2b: Mean annual rainfall deviations from the long term mean in Nairobi National Park (1982 – 2011).

Tsavo ecosystem receives bimodal rainfall which is highly irregular in time and space. The mean annual rainfall is about 500mm. The long rains fall in the months of March-May and are highest in the Taita Hills and Mt. Kilimanjaro area. The short rains fall in the months of November-December and are highest in the northern and eastern parts extending to the Tsavo National Parks. The months of June through to October are relatively cool and dry with desiccating winds that cause major nutritional stress to herbivore wildlife species.

The annual rainfall amounts received in Tsavo West National Park also varied from one year to the other as indicated by the analysis of rainfall data of 13 (2000 – 2012) year period. Being located in a semi-arid ecological zone, the ecosystem received average annual rainfall of 500mm. The Tsavo West National Park recorded below average (< 500 mm) rainfall amounts in the years 2000, 2005, 2007, 2008, 2009 and 2011 (Dry years). The park recorded above average (> 500 mm) rainfall amounts in the years 2001, 2003, 2004 and 2012 (Wet years). The ecosystem received high rainfall amounts in the years 2002 (849mm), 2006 (1091mm) and 2010 (839mm) that were regarded as very wet years. The year 2006 was categorized as the *El Nino* year when the park received very high rainfall amount of >1000 mm, the highest rainfall ever recorded in the ecosystem in the past 30 years. This rainfall was accompanied by devastating floods that claimed both human and animal lives (Fig. 4.2c).

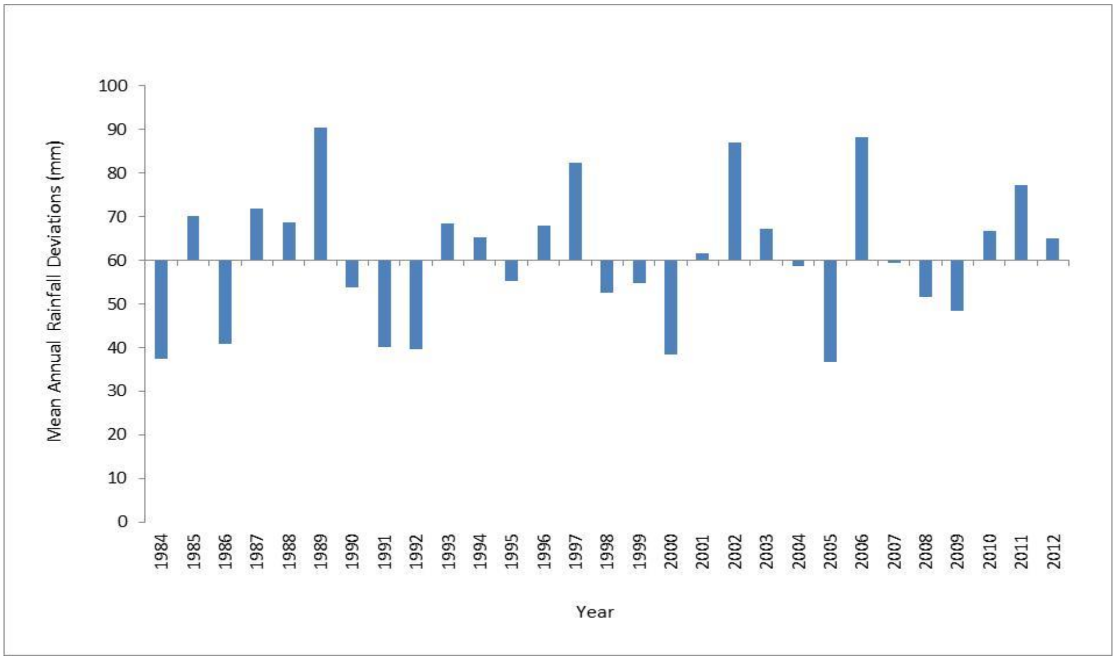


Figure 4.2c: Mean annual rainfall deviations from the long term mean in Tsavo West National Park (1982 – 2012).

4.5.2 Rainfall and temperature variation in the study area

Historical data over a period of 30 years were analyzed to provide insight about the rainfall trends in the study area. The trend analysis showed gradual decline in annual rainfall for the period between 1982 and 2012. However, statistical analysis of the deviations from the mean annual rainfall amounts received in Amboseli, Nairobi and Tsavo West National Parks were not significant ($p > 0.05$). This meant that the annual amount of rainfall in the study area has not significantly decreased during the last 30 years, but there have been considerable inter-annual variations over time.

The 3 year running mean rainfall amounts and least squares regression line superimposed revealed no cyclic signals with these limited data sets. However, it clearly showed year to year fluctuations to be much higher in Amboseli and Tsavo West National Parks than in Nairobi

National Park with the 3 year moving averages lying above the actual rainfall amounts during the drier years (Fig. 4.5, Fig 4.7 and Fig. 4.9).

4.5.2.1 Rainfall and temperature patterns in Amboseli National Park

The graphical presentation of the mean annual rainfall variations using the three year moving averages in Amboseli National Park showed higher rainfall variations with sharper peaks as compared to those shown by plots of the real annual rainfall amounts recorded (Figure 4.1). The inter-annual rainfall variations deviated by a mean of 28.3mm with a standard deviation of 10.0 over the 30 year period (N=30, SD: 10.0, mean: 28.3±SD). The year to year fluctuations were much more pronounced with the rainfall deviating by a mean of 33.5mm with a standard deviation (SD) of 6.64 for above average rainfall years (N= 19, SD: 6.64, mean: 33.5±SD). However, the year to year fluctuations were less pronounced with rainfall deviating by a mean of 18.81mm with a standard deviation (SD) of 4.43 for below average rainfall years (N=14, SD: 4.43, mean: 18.81±SD) (Fig. 4.3a).

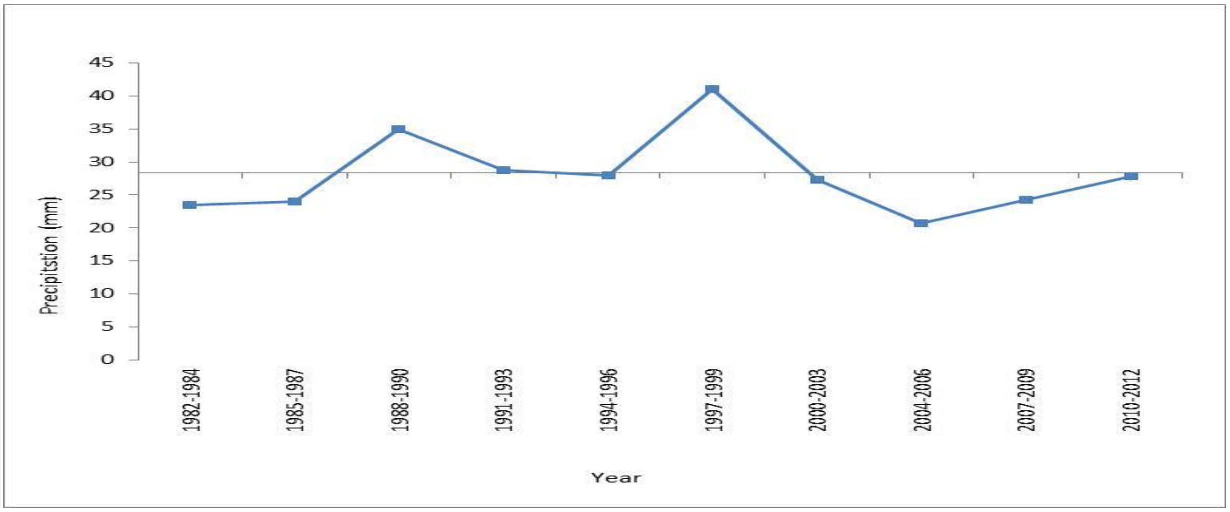


Figure 4.3a: Three year moving averages of mean rainfall deviations in Amboseli National Park (1982-2012).

Amboseli ecosystem receives bimodal rainfall as it receives both the long and short rains. The long rains occur during the months of March-May while the short rains occur during the months of October- January. However this pattern has changed in the recent past as the ecosystem has witnessed long spells of dry periods with rainfall being received only once in a year. Sometimes short rains in Amboseli occur in the months of November and December, but can sometimes start in early October. Being in a semi-arid ecosystem, Amboseli National Park receives an average of 300mm of rainfall per annum. The ecosystem lies on the rain shadow of Mt. Kilimanjaro and thus has poor rainfall regimes. Relief rainfall is received from Mt. Kilimanjaro, Chyulu hills and Namanga hill.

Temperatures range between 30-35^{0}C with temperatures being low during the months of May-July. The rest of the months experience high temperatures that are characteristic of the semi-arid conditions. The ecosystem has suffered devastating effects of prolonged cyclic droughts with severe woodland vegetation die off. Amboseli National Park recorded the highest mean annual rainfall of 840mm during the El Nino year of 1997-1998 while the lowest mean monthly rainfall of 11mm was recorded during the severe drought years of 1984 (Fig. 4.3b and Appendix 10).

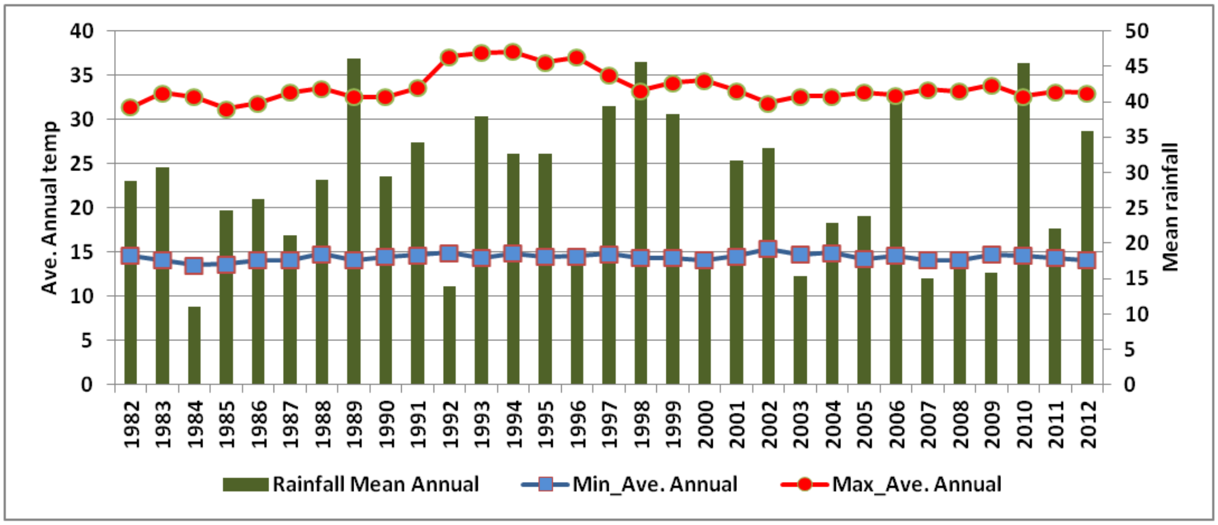


Figure 4.3b: Mean annual rainfall and temperature variations in Amboseli National Park.

4.5.2.2 Rainfall and temperature patterns in Nairobi National Park

The graphical presentation of the mean annual rainfall variations using the three year moving averages in Nairobi National Park showed lower rainfall variations with less sharp peaks as compared to those shown by plots of the real annual rainfall amounts recorded (Figure 4.4). The inter-annual rainfall variations deviated by a mean of 60.86mm with a standard deviation of 15.44 over the 30 year period (N=30, SD: 15.44, mean: 60.86±SD). The year to year fluctuations were much less pronounced with the rainfall deviating by a mean of 73.21mm with a standard deviation (SD) of 10.53 for above average rainfall years (N= 15, SD: 10.53, mean: 73.21±SD). The year to year fluctuations were also less pronounced with rainfall deviating by a mean of 47.63mm with a standard deviation (SD) of 2.16 for below average rainfall years (N=14, SD: 2.16, mean: 47.63±SD) (Fig. 4.4a).

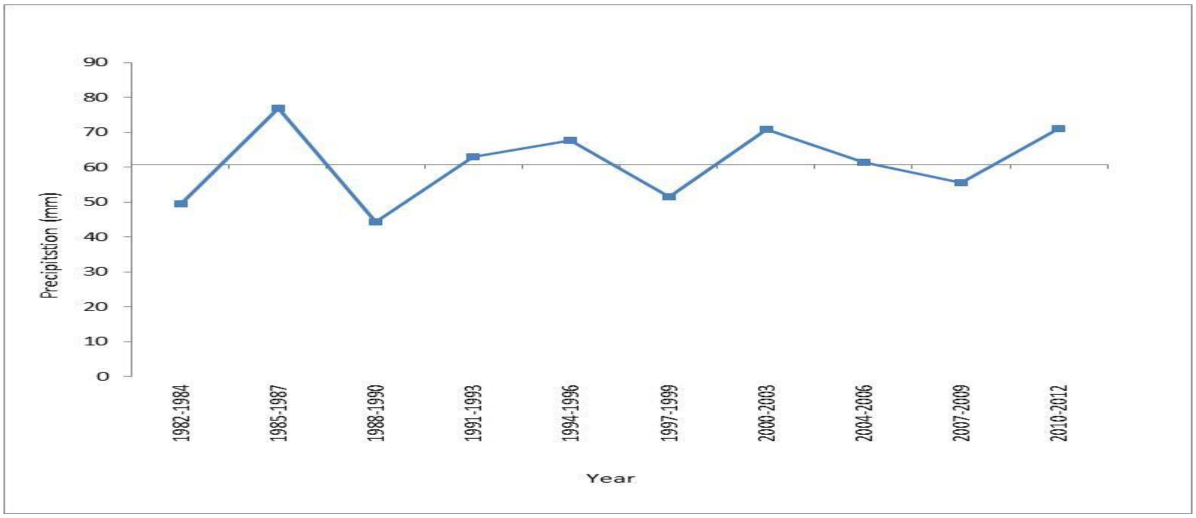


Figure 4.4a: Three year moving averages of mean rainfall deviations in Nairobi National Park (1982 – 2012).

Nairobi National Park receives bimodal type of rainfall with the long rains falling during the months of March-June and the short rains falling during the months of October- December. The average annual rainfall received is 500mm with a mean annual temperature of 19.6^0 C. However, the mean annual rainfall amounts vary with the western forested area (Langata gate) receiving a mean annual rainfall of 911mm and the eastern part (East gate) receiving 726mm of rainfall. The area has a sub-humid climate with seasonal wet and dry periods, hence exhibiting temperature variations with minimum temperatures of 12.3^{0}C and maximum temperatures of 25^{0}C.

There were marked mean annual rainfall variations in the Athi-Kapiti plains ecosystem. High rainfall amounts above 700mm were received during the years of 1985, 1987, 1989, 1997, 2002, 2006 and 2011. Low precipitation of mean annual rainfall of less than 500mm was however received during the years of 1984, 1986, 1991, 1992, 2000, 2005 and 2009. These were considered as the dry years that showed a cyclic drought period of 5 years interval (Figure 4.4).

The mean maximum temperatures averaged 25^{o}C while the mean minimum temperatures averaged 10^{o}C. The difference between the mean maximum and mean minimum temperatures was 15^{o} C. However, the difference in mean maximum and mean minimum temperatures caused less stress to both animals and plants in the Athi-Kapiti plains ecosystem as compared to the stress caused by temperature variations to biodiversity in Amboseli ecosystem (Fig. 4.4b and Appendix 11).

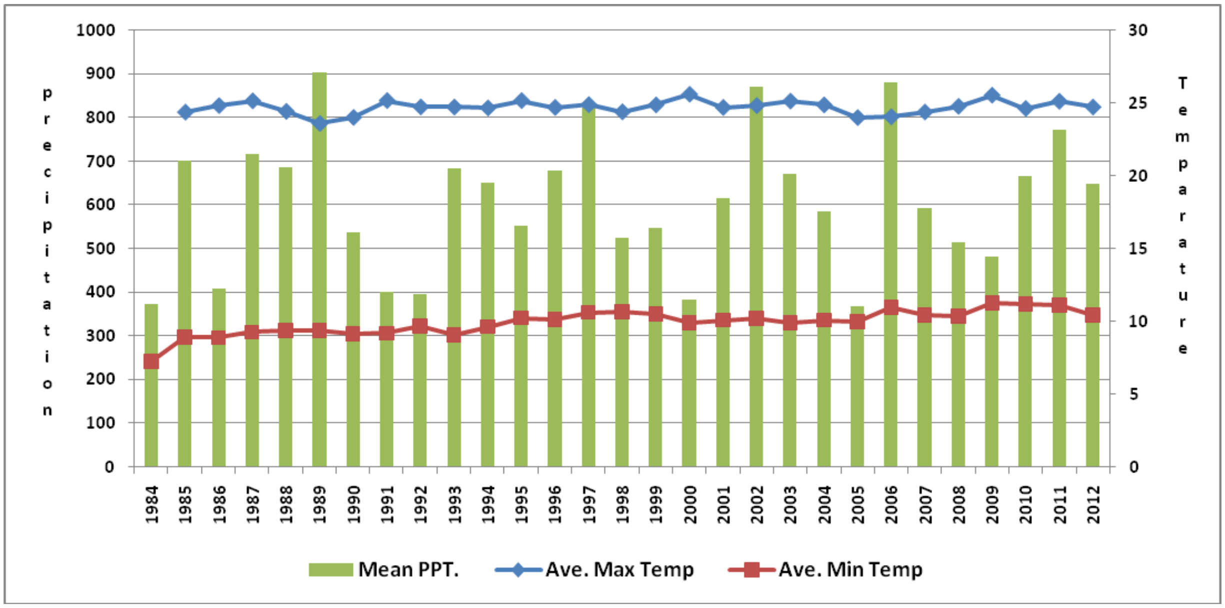


Figure 4.4b: Rainfall and temperature patterns in Nairobi National Park.

4.5.2.3 Rainfall and temperature patterns in Tsavo West National Park

The graphical presentation of the mean annual rainfall variations using the three year moving averages in Tsavo West National Park showed higher rainfall variations with more sharp peaks as compared to those shown by plots of the real annual rainfall amounts recorded (Figure 4.5).

The inter-annual rainfall variations deviated by a mean of 47.31mm with a standard deviation of 16.53 over the 30 year period (N=30, SD: 16.53, mean: 47.31±SD). The year to year fluctuations were more pronounced with the rainfall deviating by a mean of 60.79mm with a standard deviation (SD) of 12.29 for above average rainfall years (N= 14, SD: 12.29, mean: 60.79±SD). The year to year fluctuations were also more pronounced with rainfall deviating by a mean of 35.50mm with a standard deviation (SD) of 8.79 for below average rainfall years (N=16, SD: 8.79, mean: 35.50±SD) (Fig. 4.5a).

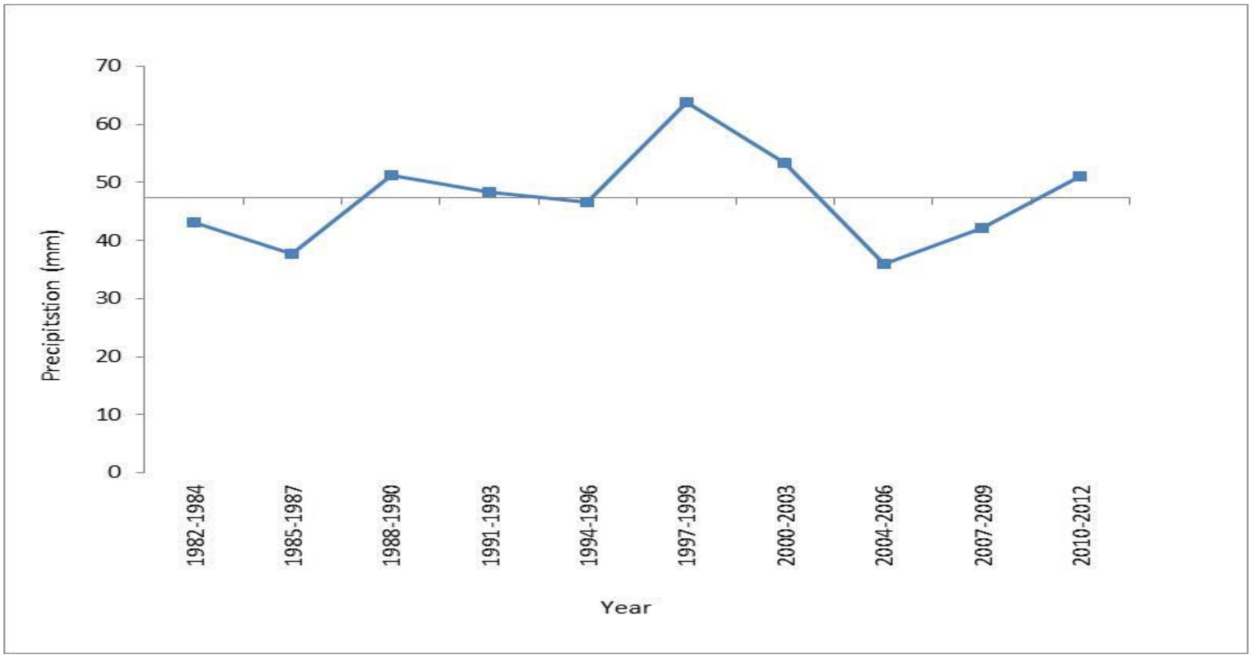


Figure 4.5a: Three year moving averages of mean rainfall deviations in Tsavo West National Park (1982 – 2012).

Tsavo West National Park weather is that of very hot conditions with temperatures reaching 40^0C during the dry season of January-February. It has two rainfall maximas with the long rains falling from October to December. Rains are more intense in the south-western part of the park that receives high annual rainfall of 700mm, while the north-eastern part of the park receives less annual rainfall of 200mm. The highest monthly rainfall amount of 140mm was recorded during the month of December while the lowest rainfall amount of near 0mm was recorded in the dry but humid month of July, 2003.

The highest temperature of 28^0C was recorded during the wet month of March while the lowest temperature of 23^0 C was recorded during the dry but humid month of July, 2003. The dessicating winds during such times cause periods of nutritional stress to herbivores in Tsavo West National Park.

Annual rainfall amounts received in Tsavo West National Park varies between 250 and 500mm. The rains received follow a bimodal pattern falling in the months of March-May and November-December but with highly irregular spatial and temporal distribution. During the March-May rain season, the highest rainfall is received in the areas that lie between Taita hills and Mt. Kilimanjaro. During the November-December rain season, the highest rainfall amounts are recorded in the northern and eastern parts of Tsavo West National Park. The two rain seasons are usually separated by two dry seasons which are relatively cool and dry.

There was also a marked variation in mean annual precipitation in Tsavo ecosystem as evidenced by mean annual rainfall variations. For example, the highest mean annual rainfall of above 600mm was recorded during the years of 1982, 1990, 1994, 1997, 1998, 2002, 2004, 2006, 2009 and 2011. The lowest mean annual rainfall of less than 300mm was recorded in the years 1983, 1987, 2003, 2005 and 2007 The mean maximum temperatures averaged 30^oC while the mean minimum temperatures averaged 20^oC in Tsavo ecosystem. The difference between the mean maximum and mean minimum temperatures was 10^oC (Fig. 4.5b and Appendix 12).

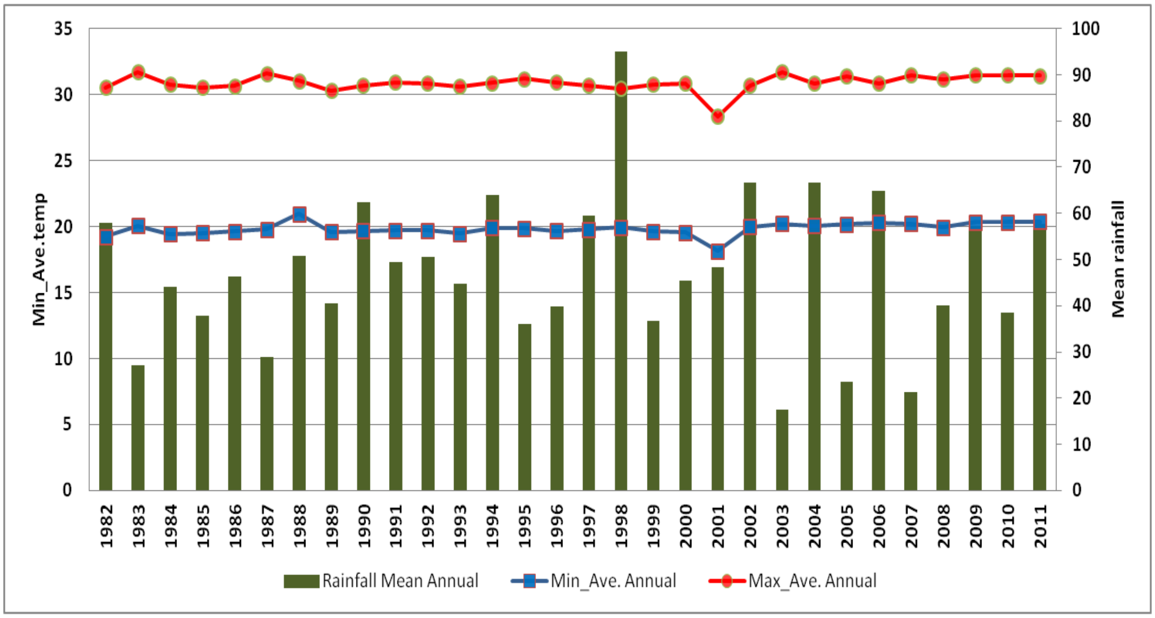


Figure 4.5b: Mean annual rainfall and temperature variations in Tsavo ecosystem (1982-2011).

4.5.3 Relationship between rainfall and giraffe population in Amboseli National Park

Giraffe numbers had a gradual decline from the year 2003 through to the year 2007. In the year 2008, giraffe numbers in Amboseli National Park increased slightly but declined in the year 2009. However, there was a steady increase in giraffe numbers from the year 2010 through to the year 2012. Giraffe numbers and annual rainfall amounts showed a negative relationship where giraffe numbers decreased with increase in rainfall amounts (Fig. 4.6a).

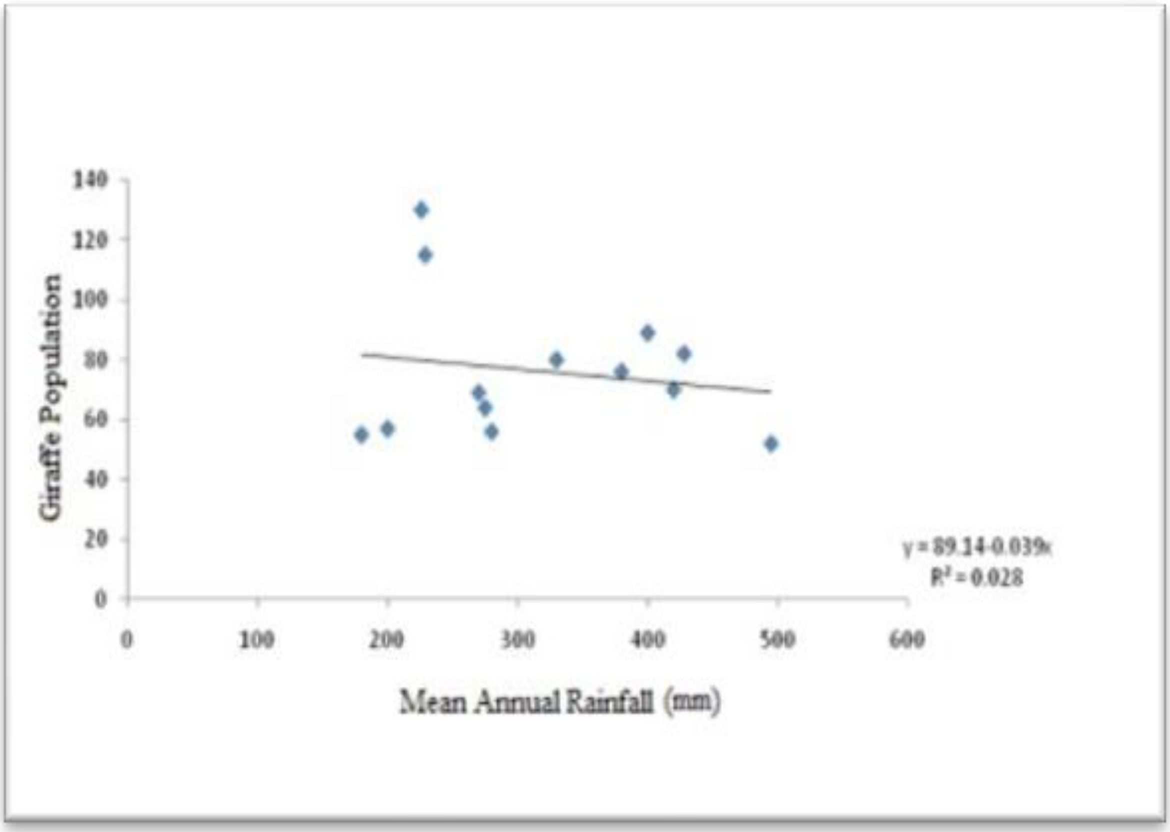


Figure 4.6a: Annual giraffe population with mean annual rainfall amounts in Amboseli National Park.

4.5.4 Relationship between rainfall and giraffe population in Nairobi National Park

Giraffe numbers in Nairobi National Park increased gradually from 90 animals in the year 2001 to 100 animals in the year 2003 and then decreased slightly to 75 animals in the year 2005. From the year 2005, giraffe numbers increased from 70 to 80 animals in the year 2007. Giraffe numbers increased to 100 animals in the year 2008. The numbers dropped from 100 animals in the year 2010 to 90 animals in the year 2011. In the year 2012 there was a sharp increase in giraffe numbers from 100 animals in the year 2011 to 200 animals in the year 2012. This sharp increase was associated with giraffe movement into Nairobi National Park following their displacement from the Kitengela dispersal areas due to land use changes and persecution by humans.

The correlation of giraffe numbers with annual rainfall amounts in Nairobi National Park also showed a negative relationship. The direction of the relationship is negative and that there was a relationship between the two variables where giraffe numbers decreased with increase in rainfall amounts. This was also a case of negative correlation where giraffe numbers decreased with increase in annual rainfall amounts in Nairobi National Park (Fig. 4.6b).

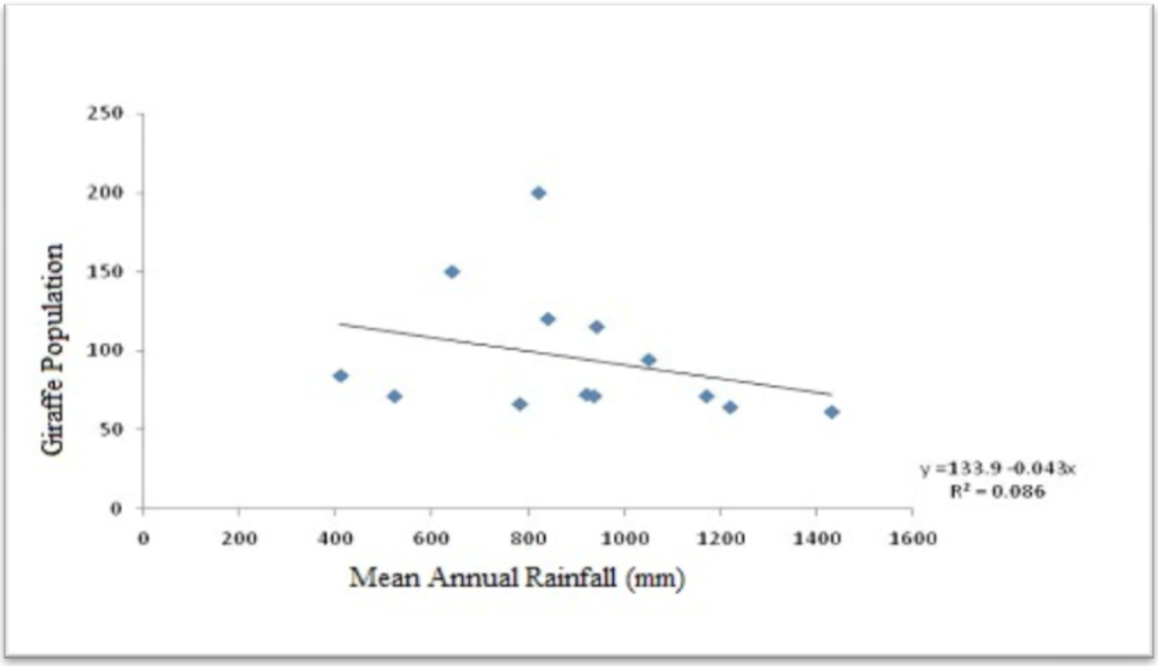


Figure 4.6b: Annual giraffe population with mean annual rainfall amounts in Nairobi National Park.

4.5.5 Relationship between rainfall and giraffe population in Tsavo West National Park

There were variations in giraffe numbers where they increased and decreased over time. The variations in giraffe numbers followed a particular pattern where they increased and decreased after every two years. The correlation of giraffe numbers and annual rainfall amounts showed a positive correlation. This showed that there was a relationship between giraffe numbers and the mean annual rainfall amounts. This was a positive correlation where giraffe numbers increased with increase in annual rainfall amounts (Fig. 4.6c).

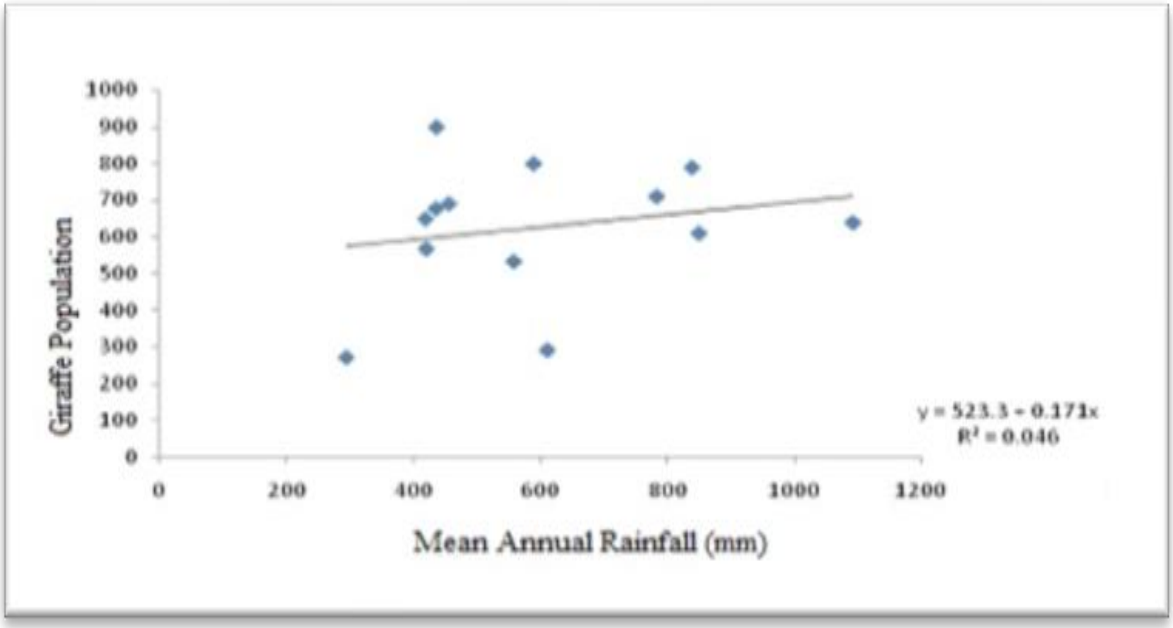


Figure 4.6c: Annual giraffe population with Mean annual rainfall amounts in Tsavo West National Park.

4.6 Overall trends in giraffe population and climate in Southern Kenya

Giraffe numbers (n) in Amboseli National Park showed annual variations. In the year 2000, the giraffe population declined by 8.8 % (n=5) from 57 to 52 in the year 2001. The highest increase in giraffe population of 61.8% (n=34) was in the year 2003 while the highest decline of 26.1% (n=18) occurred in the year 2007. The giraffe population showed a marked increase of 25% (n=14) in the year 2008 but declined slightly by 8.6% (n=6) in the year 2009. In the years 2010, 2011 and 2012, the giraffe population showed successive increases of 28.1% (n=18), 40.2% (n=33) and 13% (n=15) respectively (Fig. 4.7a and Appendix 4).

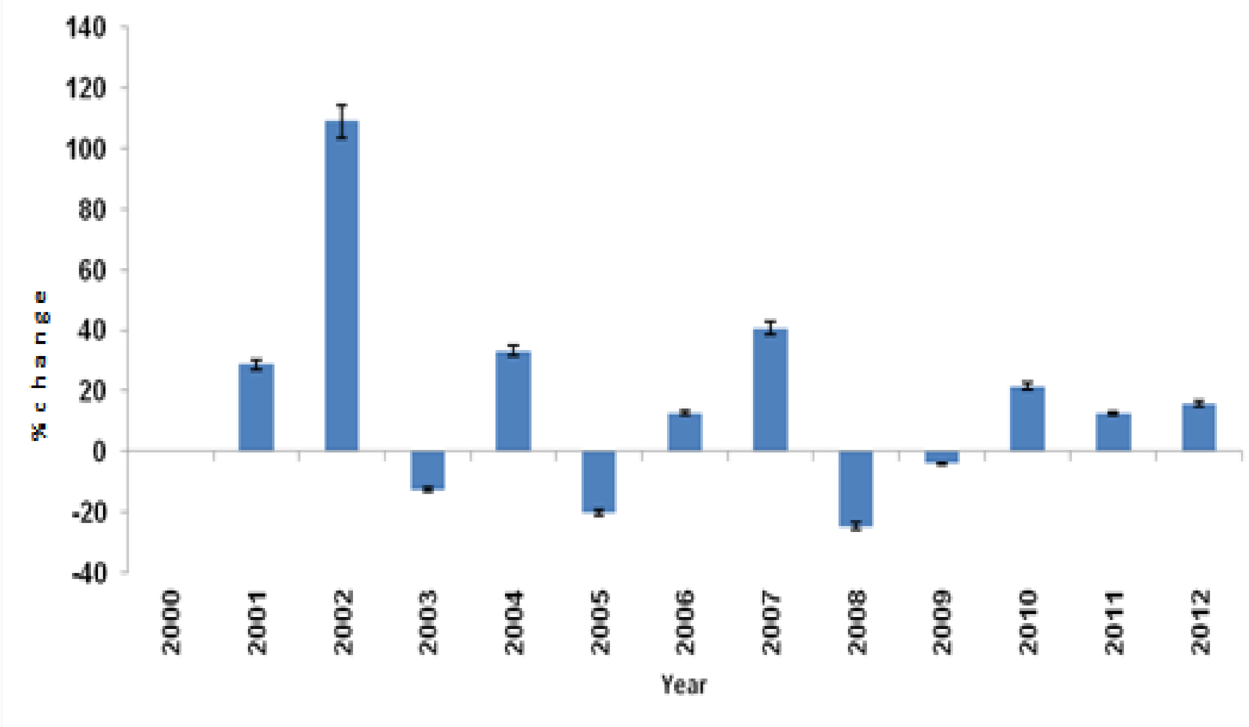


Figure 4.7a: Annual giraffe population changes in Amboseli National Park (2000-2012).

Giraffe numbers (n) in Nairobi National Park also varied from one year to the other. The numbers showed both increases and decreases. Giraffe numbers declined by 14.1% (n=10) between the year 2000 and 2001. Giraffe numbers showed increases of 4.9%, 10.9% and 1.4% in the years 2002, 2003 and 2004 respectively. Small declines in giraffe population of 8.3% (n=6) and 4.3% (n=5) occurred in the years 2005 and 2010 respectively. Giraffe numbers showed gradual increases of 7.6% (n=5) and 18.3% (n=13) during the years 2006 and 2007. However, the highest decline of 41.7% (n=35) in giraffe numbers in Nairobi National Park occurred in the year 2009 while the highest increase of 112.8% (n=106) occurred in the year 2012. Nairobi National Park hosted a cumulative total of 1,239 giraffes between the year 2000 and 2012. Over the same period of time, giraffe numbers in Nairobi National Park increased by 116 animals (Fig. 4.7b and Appendix 5).

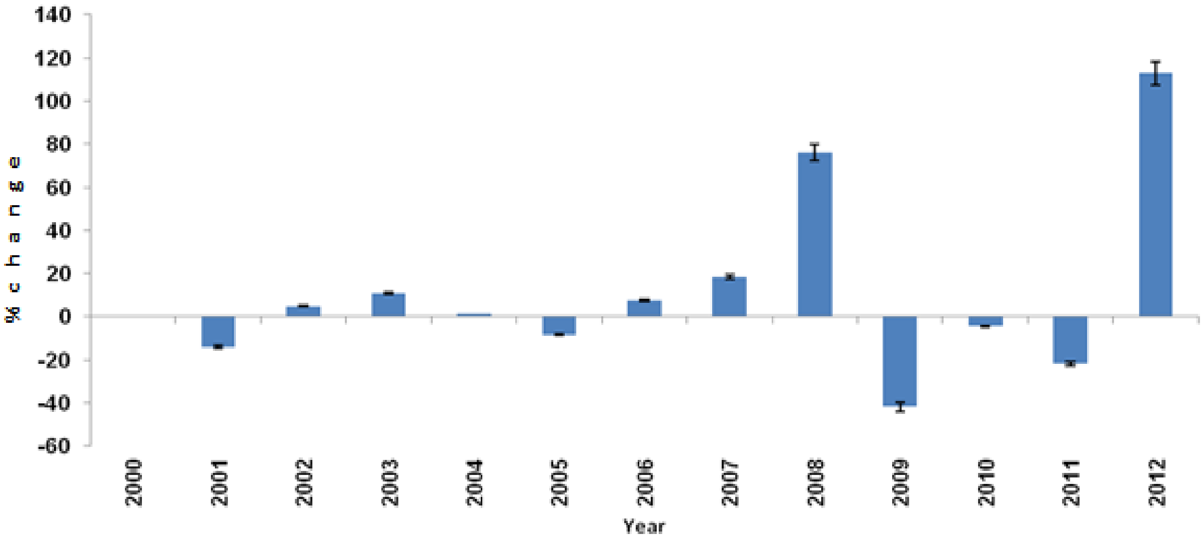


Figure 4.7b: Annual giraffe population changes in Nairobi National Park (2000-2012).

Giraffe numbers (n) fluctuated from one year to the other in Tsavo West National Park. The annual giraffe population trends increased with increase in annual rainfall amounts. There were oscillations in giraffe numbers where they increased and decreased over time. The oscillations in giraffe numbers seemed to have followed a specific pattern where they increased and decreased after every two years.

The giraffe numbers increased by 28.6% (n=65) in the year 2001 and 109% (n=319) in the year 2002, but showed a slight decrease of 12.6% (n=77) in the year 2003. Giraffe numbers showed an increase of 33.1% (n=177) in the year 2004 but decreased by 20.1% (n=143) in the year 2005. Giraffe numbers showed consecutive increases of 12.7% (n=72) and 40.6% (n=260) in the years 2006 and 2007, but showed declines of 24% (n=222) and 4.1% (n=28) in the years 2008 and 2009 respectively. Giraffe numbers also increased by 21.5% (n=144), 12.5% (n=99) and 15.5% (n=109) in the years 2010, 2011 and 2012 respectively. The highest increase in giraffe numbers in Tsavo West National Park was 109% (n=319) in the year 2002 while the highest decline was 24.7% (n=222) in the year 2008 (Fig. 4.7c and Appendix 6).

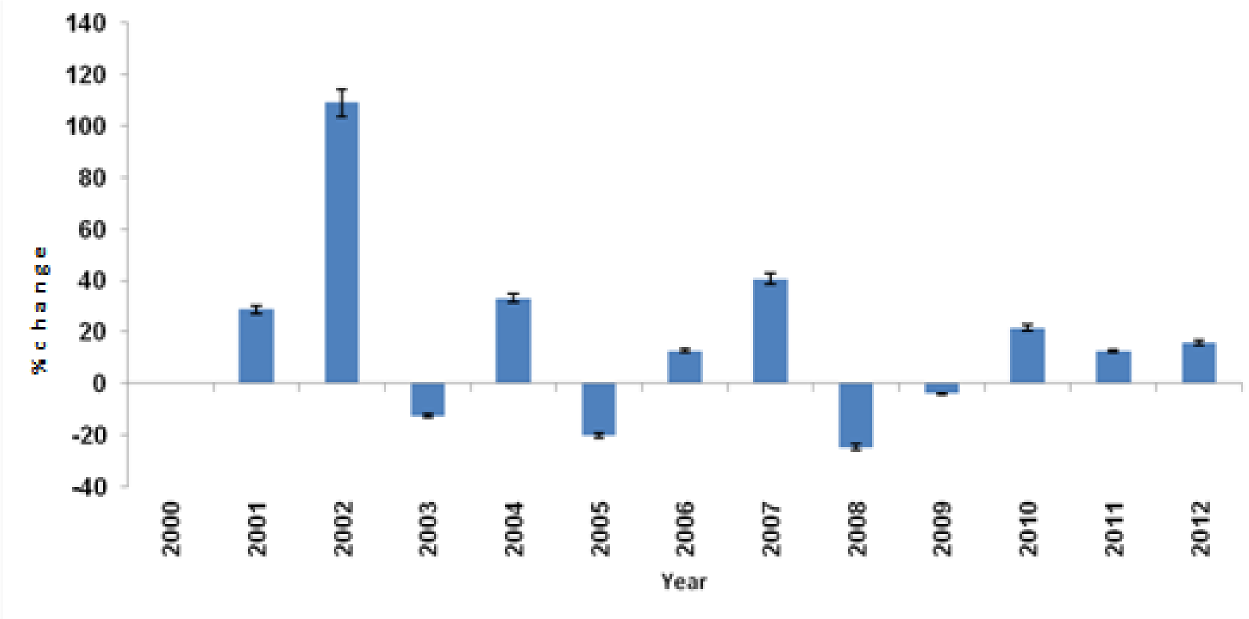


Figure 4.7c: Annual giraffe population changes in Tsavo West National Park (2000-2012).

4.7 Discussion and Conclusion

4.7.1 Trends in climate variables in Southern Kenya

Precipitation in the savanna ecosystems of Amboseli, Nairobi and Tsavo has declined over time. The effects of climate change on biodiversity of Southern Kenya have been felt since the beginning of this centutry. Cyclic and prolonged droughts have been occuring over time. These have been marked by increase in diurnal temperatures. The 2009-2010 severe drought affected biodiversity in Southern Kenya. Herbivore wildlife species were more affected as they lacked forage to feed on. As a result of this, grazer wildlife species like wildebeest and Zebra died in Amboseli National Park. Hippos and other grazer wildlife species were equally affected in Tsavo West National Park. However, this drought did not have serious effects on wildlife in Nairobi National Park, but Maasai pastoralists' livestock were decimated in the adjacent Kitengela dispersal areas.

The climate of Amboseli basin is dominated by a combination of the migrating Inter-Tropical Convergence Zone (ITCZ) that seasonally moves north and south of the equator and trade winds originating from the Indian Ocean. The diverse topography and the high mountains break up classical circulation patterns with the moisture bearing winds from the Indian Ocean that are strongly influenced by local topography that result in a highly variable local climate (Griffiths, 1972). Temperatures in Amboseli basin vary both with altitude and season with mean monthly temperatures ranging from 34^0C in February- March to as low as 12^0 C in July (Altmann et al, 2002).

The climate of Amboseli basin is influenced by the high Mt. Kilimanjaro and Mt. Longido in Tanzania and Chyulu and Namanga hills in Kenya. The highest temperature in Amboseli-Magadi ecosystem of 40^0 C was recorded in the Magadi area while the lowest temperature of 10^0 C was recorded in Loitokitok on the north-eastern slopes of Mt. Kilimanjaro (Altmann, et al., 2002).

Bimodal rainfall is received in Amboseli ecosystem with the long rains falling between March and May while the short rains fall between October and December. Loitokitok town which is located on the slopes of Mt. Kilimanjaro receives a mean annual rainfall of 1250mm while Magadi and Lake Amboseli that are located on the lower elevations receive a mean annual rainfall of 500mm. Rainfall received in the slopes of Mt. Kilimanjaro manifests differently in that it is higher during the short rains period of October to December than during the long rains period of March to May. Heavy rains are mainly of convectional type with influence of the Ngong hills, Chyulu hills and Nguruman escarpment (Altmann, et al. 2002).

Generally, the weather of NNP has been stable with about halve of the years receiving above average annual rainfall amounts. The amount of rainfall received over the years seemed adequate for primary productivity to provide forage that sustained most of the herbivore wildlife species. NNP experienced prolonged droughts in the years 1984, 2000 and 2007 (Dry years). However, these droughts did not have adverse effects on the herbivore wildlife species as most of them remained in the park to feed on the accumulated forage at the time. Very high annual rainfall amounts were received in the years 1998, 2001 and 2004 (Wet years).

Severe droughts can cause decline in herbivore species numbers. For example, species in the Mara–Serengeti ecosystem had declined by about 58% in the year 2000 due to drought related effects on vegetation (Ottichilo, 2000). The 2009 drought in Amboseli ecosystem reduced Wildebeest and Zebra populations by 70-95% (KWS, 2010).

The effects of climate changes and fluctuations on savanna ecosystems were felt in the 1991-92 drought that decimated populations of large herbivore species of elephant, buffalo, hippo and giraffe (Surasinghe, 2010). Browser wildlife species like giraffe and elephant were not seriously affected by the 1991-1992 and 2009-2010 severe droughts experienced in Amboseli and Tsavo West National Parks as it did on the grazer wildlife species.

4.7.2 Relationship between rainfall and giraffe population in the three protected areas

The effects of rainfall variability and fluctuations on savanna ecosystems that were felt in the 1991-1992 drought decimated populations of large herbivore species of elephant, buffalo, hippo and giraffe (Surasinghe, 2010). This study found out that giraffe populations were not severely affected by the droughts experienced in the study area over the years.

There were marked temperature variations in the study area over time. These variations were manifested in both the maximum and minimum temperature ranges in Amboseli, Athi-Kapiti plains and Tsavo ecosystems. It was noted that there had been a general increase in the mean minimum temperatures recorded in the three ecosystems over time. There had been a general rise in temperatures and increased rainfall variability in Amboseli, Nairobi and Tsavo West National Parks.

Extreme maximum and minimum day and night temperatures had been experienced particularly in Amboseli and Tsavo ecosystems. These were marked by increase in diurnal temperatures (Altmann et al. 2002). Increased temperatures associated with the prevalence of cyclic and prolonged droughts accelerated evaporation rates in the study area. Strong winds blowing across the landscapes, particularly in Tsavo West National Park tended to creat dessicating effects on the vegetation types thus causing them shed their leaves and denying giraffes foliage that was necessary for their nutrition.

The high evapouration rates as a result of high temperatures particularly in the Amboseli basin caused the fast drying up of the expansive and open Lake Amboseli, thus its seasonality. This effect was equally felt in Tsavo ecosystem that led to fast drying up of scouped dams and water pans, thus, depriving giraffes of water that was necessary for their survival. Generally, the high evapouration rates created water stressed situations for wildlife in the study area.

4.7.3 Trends in giraffe population in the region

Giraffe population trends in Amboseli, Nairobi and Tsavo National Parks showed annual variations with populations that either increased or decreased due to natality and mortality of individuals within the populations. The increase or decrease in giraffe numbers in the study sites was also attributed to immigration and migration of giraffes in and out of the three study sites. This study has shown that other factors such as human disturbances, habitat fragmentation, and predation can influence Maasai giraffe population dynamics in Southern Kenya. The study also observed marked fluctuations in giraffe populations in and outside protected areas due to poaching, habitat loss and fragmentation, shortage of forage and shift in fecundity.

In Tsavo West National Park, for example, decline in giraffe populations was attributed to changes in ecosystem state. Leuthold and Leuthold (1978) showed that reduction in woody vegetation in Tsavo West National Park led to long term decline in giraffe population. Morrison et al., 1992, noted that no single factor has been a greater cause of decline in wildlife populations than the loss of habitat. This study has shown that loss of wildlife dispersal areas in the ecosystems can contribute to decline in wildlife populations. This may also be attributed to reduced reproductive rates, increased mortality rates and increased competition for forage between wildlife and livestock (Obari, 2009).

Other studies have shown that many wildlife species have declined both in and outside protected areas in Africa. These declines have primarily been caused by shrinking wildlife range due to expansion of large scale farming and other land use changes (Ogutu, 2011). The primary cause of wildlife population decline seems to be due to expanding human population and livestock encroachment into protected areas. Although past wildlife species counts have shown substantial declines in the pastoral areas of Athi-Kapiti plains (Ottichilo, 2000), Amboseli basin (Western &

Maitumo,2004), Laikipia District (Georgiardis, 2009), this study has shown a general increase in giraffe numbers inside protected areas of Amboseli, Nairobi, Tsavo West and Chyulu Hills National Parks. This may be attributed to giraffes moving into these secure protected areas after being displaced from their traditional ranging lands by human activities and poaching. Herbivore population dynamics are also known to be emergent outcomes of movements and the spatial and temporal distributions of forage in the landscape (Dagg, 1970).

Quantification of wildlife species and factors governing populations and ecosystem viability are important for forecasting planning and management of wildlife populations. Fluctuations in wildlife numbers due to cyclic droughts and rainfall fluxes have been experienced in Maasai Mara National Reserve, Amboseli, Nairobi and Tsavo West National Parks. Ungulate population fluxes in the three study sites were expected, given the large herbivore biomass correlation with rainfall (Ogutu, 2011).

The interaction between livestock and wildlife influences wildlife populations in and outside protected areas. For example, livestock populations in Amboseli increased sharply from the 1940s to the 1960s due to availability of water and veterinary services (Western, 1973). Wildlife numbers started increasing in Amboseli basin with the establishment of Amboseli National Park in the 1970s. Backed by increased community conservation initiatives, zebra, elephant and buffalo numbers increased while wildebeest numbers decreased as a result of severe droughts of the 1970s and 1980s. Some of these species numbers recovered thereafter when substantial amounts of rainfall were received.

However, most browser species like impala, eland and giraffe declined due to loss of habitat as a result of increased human cultivation and other associated activities. Giraffe and eland numbers declined in Amboseli and Chyulu Hills National Parks due to persistent poaching for bush meat. Giraffe numbers have also been declining in Amboseli basin due to the high concentration of elephants and ecological separation of pastoral and wildlife ecology across the park boundary (Western & Gichohi, 1999). However, this study has observed an increase in elephant and giraffe numbers in Amboseli National Park but a decrease in numbers of other browser species like the Gerenuk.

4.8 Conclusion

Climate variability will affect the functioning of ecosystems in Southern Kenya. By influencing primary productivity especially the availability of forage, climate variability will also influence giraffe population dynamics and movement in southern Kenya. With climate variability, the interactions between herbivores and plants are likely to change and that herbivore pressures on plants may increase. This will lead to shortage of forage due to overbrowsing of the already scarce forage occasioned by frequent droughts by giraffes.

Altered climate regimes directly affect giraffe behaviour, migration, foraging, growth and reproduction. Climate change could distabilize Maasai giraffe population dynamics in southern Kenya. In response to these effects, giraffes have adjusted their foraging strategies in order to adapt to the prevailing environmental conditions brought about by local climate variability. Giraffes have been forced by climatic variations to seek for habitats with available forage and water. With continued scarcity of forage, giraffes have split into smaller groups and moved to different habitats to seek forage. This created giraffe herds' segregation that may be detrimental to their reproductive success and security.

Drought during the dry seasons has forced giraffes to move for long distances in search of forage and water. High ambient temperatures have also forced giraffes to change their foraging behaviours to feed at night when temperatures are cool and tolerable. During the day, giraffes resorted to early morning and late afternoon feeding, while they sought for shade from the mid afternoon intense heat. Cyclic droughts and shortage of forage and water for giraffes were attributed to the effects of rainfall and temperature variability in the study area.

4.9 Chapter summary

This chapter has provided information on the climate variability and its effects on giraffe population in southern Kenya. The chapter highlights the results of the analysis of climatic data (rainfall and temperature), giraffe population trends and the relationship between the two. Rainfall and temperature data for a period of 30 years (1982-2012) were analyzed for Amboseli, Nairobi and Tsavo West National Parks in Southern Kenya. The long term rainfall and temperature data indicated considerable annual variation. The highest annual rainfall in all the three study sites was associated with the *El Nino* phenomenon while the lowest annual rainfall was associated with *La Nina* events in East Africa. There was a marked decline in annual rainfall and moderate increase in temperature during the 30 year period in Southern Kenya. Droughts and flooding were cyclic following a 5 year cycle.

The three national parks studied in Southern Kenya supported a total of 1130 Maasai giraffes with Amboseli, Nairobi and Tsavo West National Parks supporting 130, 200 and 800 giraffes respectively. This number fluctuated due to reproduction and movement of giraffes into and out of the study sites. Predation and poaching especially outside the protected areas also contributed to changes in the numbers of giraffes inhabiting each national park. The giraffe population showed an overall increase of about 8-12 percent. But the increases were highest in Nairobi National Park because of immigration of giraffes from the surrounding rangelands which was rapidly being converted into farmland and settlements.

There was an overall positive but non-significant relationship between annual rainfall and giraffe population trends in the three study sites. The giraffe population showed a negative but modest relationship with annual rainfall in Amboseli. Thus, giraffe numbers in the park decreased with increasing amounts of rainfall. In NNP the population of giraffes showed a negative but non-significant relationship with annual rainfall. In TWNP there was modest positive correlation between giraffe population and annual rainfall. The giraffe population appeared to increase or decrease after every two years in TWNP. The overall trend showed the giraffe population declining with increasing rainfall in Amboseli and Nairobi National Parks, but increasing with annual rainfall in Tsavo West National Park. The observed patterns of giraffe population trend can be primarily attributed to variations in climate and their effects on food and water availability.

CHAPTER FIVE

GIRAFFE POPULATION STRUCTURE AND MOVEMENT PATTERNS IN SOUTHERN KENYA

5.1 Introduction

Population age structure is the distribution of the age-classes among individuals in a population. All mammalian species have age-class structures of adult, sub-adult and young individuals (Obari, 2009). These three age-classes can be used to structure giraffe populations where adults consist of those individuals aged more than 5 years while sub-adults are those individuals aged 1-5 years and young/juveniles are those individuals aged less than one year (Foster, 1966). Limited standardization in the classification of giraffe age-classes exist (Dagg and Foster, 1972; Berry, 1973; Leuthold, 1979; Pratt and Anderson, 1982; Young and Isbell, 1991; Le Pendu & Ciofolo, 2000; Van der Jeugd and Prins, 2000; Fennessy, 2004). Validated height-age estimates have also been used to structure giraffe populations (Dagg and Foster, 1982).

Fecundity in animal populations correlates with availability of its food. Atle (2000) suggested that Deer populations limited by food availability showed low fecundity, increased calf mortality and increased age of attaining maturity and old age among groups. He also observed that there was increase in differential mortality of males. Dagg and Foster (1972) described the Nairobi National Park giraffe population structure as stable and normal. Juveniles were observed in Namibia to have become self reliant after attaining the age of one year and behaved like adults or sub-adults (Fennessy, 2004). So giraffes can be classified as sub-adults on attaining the age of one year. Sub-adults can be classified as adults on attaining 5 years of age. These correlate with sexual maturity and social presence (Hall-Martin & Janson, 1975; Dagg and Foster, 1982).

Most mammalian species have an expected sex ratio of 1:1. Consequently, giraffe sub-populations like in any other animal species are expected to have adult male to adult female sex ratio of 1:1. However, giraffe populations in the wild may have sex ratios departing from the expected 1:1 male to female sex ratio. In most giraffe populations, males and females are usually present in the same numbers giving a male to female sex ratio of 1:1 as observed in Nairobi

National Park (Foster, 1966). But sex ratios may vary in some giraffe populations as a result of sexual segregation while feeding in different secure habitats.

Large wild herbivore species exhibit movements in response to climate variability. At times of drought when there is shortage of forage, giraffes move for long distances in search of forage and water. These movements could be local within habitats in the same ecosystem or long distance movements from one ecosystem to the other. Giraffes move with other migratory wildlife species like elephants following specific movement routes referred to as migration corridors in search of forage. The effects of climate variability on wild herbivore species have been felt in the Southern Kenya where wild herbivore species exhibit seasonal movements from one habitat to the other or from one ecosystem to other in search of forage and water. Variations in climatic elements can force giraffes break into smaller herds and take different directions in search of forage. This alters giraffe structures to an extent that their group composition changes completely.

5.2 Scope of the study

The study was confined to Amboseli, Athi-Kapiti plains and Tsavo ecosystems that are located in Southern Kenya. The study looked at giraffe population age structures. It also looked at giraffe social structure and herd compositions. The study involved structuring giraffe sub-populations into the three main classes of adult, sub-adult and youg individuals.

Giraffe movement patterns in Southern Kenya were also looked into. Their movement patterns in the traditional movement routes and migration corridors were assessed as to whether they were still accessible for their movements from one ecosystem to the other.

5.3 Research objectives

i) To determine giraffe population age structure and sex ratio in Southern Kenya
ii) To determine giraffe movement patterns in Southern Kenya
iii) To map out giraffe movement corridors and dispersal areas in Southern Kenya

5.4 Materials and methods

5.4.1 Assessment of giraffe age structure and sex ratio

Data was collected on giraffe population age structures and sex ratios. Spotted individual giraffes or their herds were sexed and their relative ages determined. Giraffe age structures were determined using the following criteria: Adults >5 years, sub-adults 1-5 years and young/juveniles < 1 year (Fennessy, 2004). The various giraffe age-classes were determined based on their body size and height relative to that of adult giraffes.

The size of the ossicones (horns) of individual giraffes was also used to estimate giraffe relative ages. Giraffes were structured as adult male (AM), adult female (AF), sub-adult male (SAM), sub-adult female (SAF) and young (Y). Giraffe operational sex ratios were then determined by calculating the ratio of adult males to that of adult females in Amboseli, Nairobi and Tsavo West National Parks to get the respective study sites giraffe sex ratios.

One-way ANOVA method was used to compare whether there were significant differences in the means of the different giraffe age- classes in different habitats in Amboseli, Nairobi and Tsavo West National Parks. Both group statistics and independent sample tests were used to analyze the data sets. Chi-squared tests were performed on giraffe population operational sex ratios to test for significant differences between the observed and expected giraffe population sex ratios in the three study sites. All statistical tests were performed at 95% level of significance.

One-way ANOVA method was used to compare whether there were significant differences in the means of different giraffe age-classes in different habitats. When tests were performed on groups of adult males (AM), there was no significant difference in the means of this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). When tests were performed on groups of adult females (AF), there was also no significant difference in the means of this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). However, tests performed on groups of sub-adult males (SAM), showed a significant difference in the means between groups of this age-class ($F_{3, 18} = 3.16$, $p < 0.05$).

5.4.2 Assessment of giraffe movement patterns

The conservation connectivity framework (CCF) process was used in mapping out wildlife movement corridors and dispersal areas. This process brought together different data sets of both sample and total wildlife counts and that of high resolution satellite telemetry collected in Amboseli, Athi-Kapiti plains and Tsavo ecosystems. Total and sample, telemetry and ground count data were used to map out both wildlife migration corridors and dispersal areas. Geographical Information System (GIS) was used for mapping and modeling of giraffe movement patterns in the study area.

5.4.3 Mapping of movement corridors and dispersal areas

Data for mapping of wildlife migration corridors and dispersal areas was assembled from known current and historical wildlife movement patterns from literature of Lamprey's work in Tarangire National Park, Tanzania (Lamprey, 1963) as well as information from the Department of Resource Survey and Remote Sensing (DRSRS). The data obtained helped in verifying connections and highlight important linkages that may not be captured with other types of data. Data from existing maps were used to identify barriers like fences and other obstructions in Athi-Kapiti plains and Kitengela dispersal areas. Africover 2008 maps were used to identify the distribution of agricultural fields and other forms of land use in the various ecosystems in Southern Kenya.

Data on wildlife species abundance and distribution was compiled from sample and total counts using both aerial and ground counts from ecosystems across Southern Kenya. Data was also obtained from the DRSRS 73 dry and wet season sample counts of large herbivores conducted from the year 1970-2011 in Athi-Kapiti plains, Kajiado, Taita-Taveta and Tsavo- Galana ecosystems using Systematic Reconnaissance Flights (SRF) methodology (Griffiths-Norton, 1978). During the reconnaissance flights, a high winged twin-engine Partineva 68 aircraft flying at 400ft (122m) above ground level with strip widths calibrated at 282m and 304m was used. The sampling resolutions for respective sampling blocks were allocated as follows: Athi-Kapiti plains (2.5 x 5km transect interval), Kajiado, Taita-Taveta and Tsavo-Galana (5 x 5km interval) and Amboseli, Nguruman, Shompole/ Magadi (2 x 2km transect interval).

5.5 Results

5.5.1 Giraffe population sex ratio and age structure

This study found out that the giraffe populations in Amboseli, Nairobi and Tsavo National Parks had relative age structures of adults, sub-adults and young within the sub-populations. In nature, all mammalian species populations have a relative age structure of adult, sub-adult and young individuals. This study also showed that giraffe sub-populations in the three study sites had all the five age-class structures of adult male, adult female, sub-adult male, sub-adult female and young.

Assessment of giraffe population operational sex ratios showed that the three study sites of Amboseli National Park ($X^2 = 37.42$), Nairobi National Park ($X^2 = 27.14$) and Tsavo West National Park ($X^2 = 4.40$) had giraffe operational sex ratios of 1:2. The overall observed giraffe population operational sex ratios in the three study sites of 1:2 (220 adult males to 428 adult females) departed from the expected 1:1 male to female sex ratio. Chi-squared tests performed on giraffe sex ratios also showed significant differences ($p<0.05$) in giraffe operational sex ratios. There was also a significant difference ($p<0.05$) in giraffe sex ratio in the overall giraffe population sex ratio in the study area. The observed giraffe sex ratio of 1:2 in the three study sites therefore departed significantly from parity, that is from the expected 1:1 sex ratio (Table 5.1).

Table 5.1: Giraffe operational sex ratios in the study area

Study Site	Sex	Sex	Number	Chi-square
	Male	Female	Total	X^2
Amboseli N. Park	88	190	278	37.42
Nairobi N. Park	88	172	260	27.14
Tsavo West N. Park	44	66	110	4.40
Total	220	428	648	66.76

Tests performed on groups of sub-adult females (SAF) showed no significant difference in the means of this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). Tests performed on the means of groups of young (Y) giraffes also showed no significant difference in the means between groups of this age-class ($F_{1, 4} = 7.71$, $p > 0.05$). Chi-squared tests performed on giraffe operational sex ratios indicated that there was a significant difference in the observed (1:2) adult male to adult female sex ratios from the expected (1:1) sex ratios in Amboseli, Nairobi and Tsavo West National Parks ($X^2_{0.05, 2} = 3.0$, $p < 0.05$).

In Amboseli National Park, the adult male (AM), adult female (AM), sub-adult male (SAM), sub-adult female (SAF) and young (Y) age-classes were all represented in the giraffe populations. The number of adult female giraffes was twice that of adult male giraffes giving an adult male to adult female sex ratio of 1:2. Likewise the number of sub-adult females was twice that of sub-adult males, which again gave the sub-adult male to sub-adult female sex ratio of 1:2 in this age-class (Table 5.2a). There were variations in the giraffe numbers of each age-class during the wet and dry seasons in the three study sites. The numbers of giraffes in all the five age-classes were proportionately higher during the wet seasons than during the dry seasons in Amboseli National Park. This showed that more giraffes were found in the national park during the wet season than during the dry season. During the dry seasons, giraffes moved out of the park and dispersed to the neighbouring Group ranches in search of forage (Table 5.2b).

Table 5.2a: Wet season giraffe population age structure in Amboseli National Park

Age-class structure	Number of giraffes	Percentage
Adult male (AM)	140	24.6
Adult female (AF)	320	56.1
Sub-adult male (SAM)	20	3.5
Sub-adult female (SAF)	40	7.0
Young (Y)	50	8.8
Total	570	100.0

Table 5.2b: Dry season giraffe population age structure in Amboseli National Park

Age-class structure	Number of giraffes	Percentage
Adult male (AM)	40	29.6
Adult female (Adult female)	60	44.4
Sub-adult male (SAM)	10	7.4
Sub-adult female (SAF)	20	14.8
Young (Y)	5	3.7
Total	135	100.0

The number of giraffes in Nairobi National Park in the four age-classes of adult male (32.1%), adult female 44.4%), sub-adult male (7.4%) and sub-adult female (14.8%) were relatively high during the wet season, but the number of giraffes in the young age-class was lower (1.2%). The number of giraffes in all the five age-classes were equally high during the dry season with the numbers having the proportions of adult male (21.8%), adult female (60.0%), sub-adult male (5.5%), sub-adult female (10.9%) and young (1.8) (Table 5.3b). These age-class proportions were not un-usual since Nairobi National Park is partially enclosed with an electric fence and hosts a resident giraffe population throughout the year. The high percentage of young in Nairobi National Park during the dry season could mean that either more young were born during the dry seasons or more of them survived the challenges of the wet seasons like predation by lions and hyenas. The small difference in numbers of giraffes between the wet and dry seasons in Nairobi National Park showed that this is a resident giraffe population whose movements in and out of the park is not influenced by seasonal changes (Table 5.3a and 5.3b).

Table 5.3a: Wet season giraffe population age structure in Nairobi National Park

Age-class structure	Number of giraffes	Percentage
Adult male (AM)	130	32.1
Adult female (AF)	180	44.4
Sub-adult male (SAM)	30	7.4
Sub-adult female (SAF)	50	12.3
Young (Y)	5	1.2
Total	405	100.0

Table 5.3b: Dry season giraffe population age structure in Nairobi National Park

Age-class structure	Number of giraffes	Percentage
Adult male (AM)	60	21.8
Adult female (AF)	165	60.0
Sub-adult male (SAM)	15	5.5
Sub-adult female (SAF)	30	10.9
Young (Y)	5	1.8
Total	275	100.0

In Tsavo West National Park, the number of giraffes in all the five age-classes of adult male (27.8%), adult female (47.2%), sub-adult male (5.6%), sub-adult female (8.3%) and young (11.1%) was high during the wet season. This showed that there were more giraffes in the national park during the wet season (Table 5.4a). The number of giraffes in all the five age-classes was lower during the dry season as follows: adult male (33.3%), adult female (38.9%), sub-adult male (5.6%), sub-adult female (11.1%) and young (11.1%). This was an indication that giraffes generally moved out of the park and dispersed into the adjacent dispersal areas in search of forage and water during the dry seasons, hence, the low numbers in the park (Table 5.4b).

Table 5.4a: Wet season giraffe population age structure in Tsavo West National Park

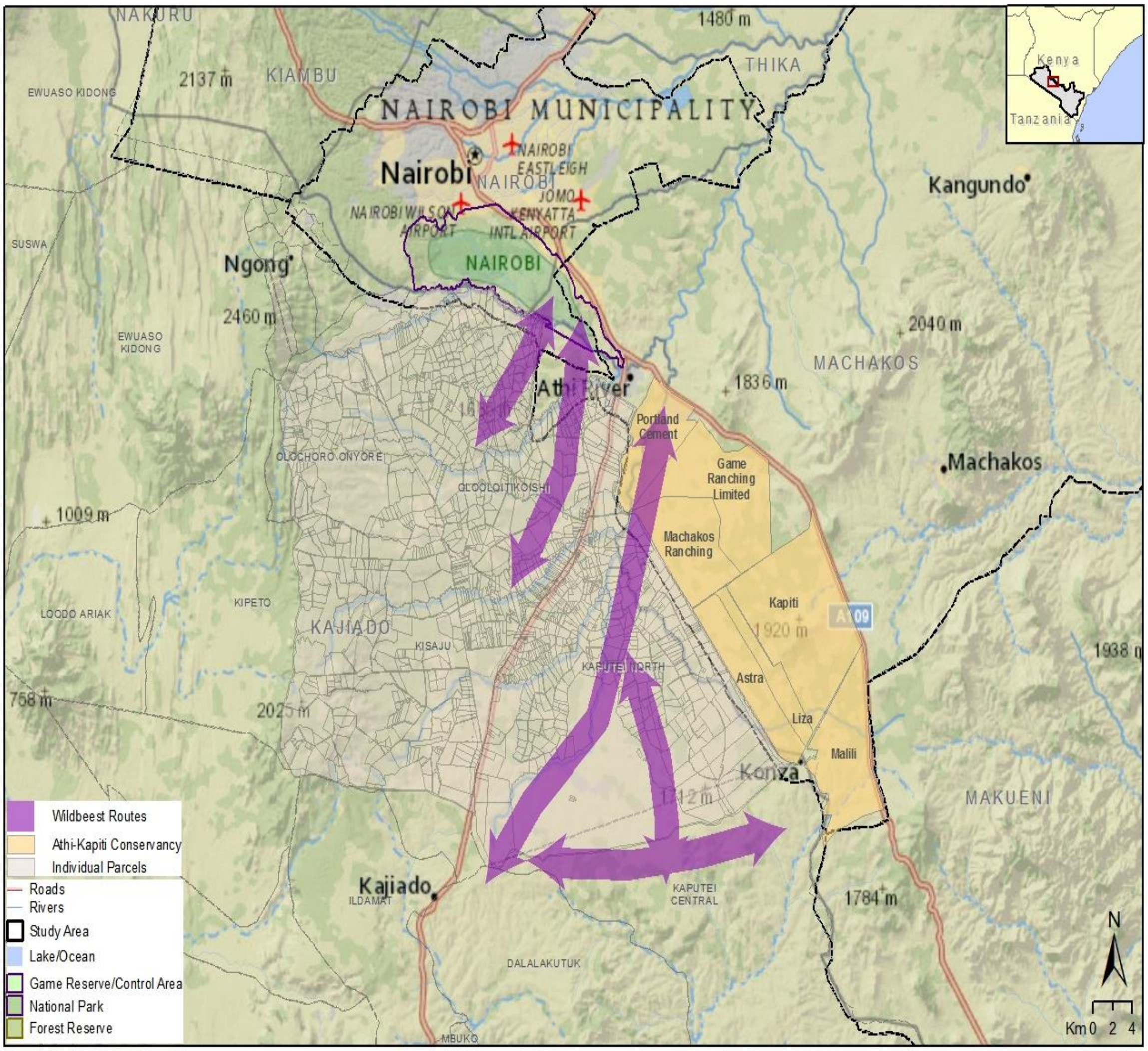
Age-class	Number of giraffes	Percentage
Adult male (AM)	50	27.8
Adult female (AF)	85	47.2
Sub-adult male (SAM)	10	5.6
Sub-adult female (SAF)	15	8.3
Young (Y)	20	11.1
Total	180	100.0

Table 5.4b: Dry season giraffe population age structure in Tsavo West National Park

Age-class structure	Number of giraffes	Percentage
Adult male (AM)	30	33.3
Adult female (AF)	35	38.9
Sub-adult male (SAM)	5	5.6
Sub-adult female (SAF)	10	11.1
Young (Y)	10	11.1
Total	90	100.0

5.5.2 Seasonal movement patterns of resident giraffes

Large herbivores, especially elephants, wildebeest and zebras disperse beyond protected area boundaries in search of forage and water resources. These wildlife species, including giraffe follow specific movement paths referred to as migration corridors. Giraffes, that are regarded as non-migratory species had conditionally adopted migration tendencies to look for forage and water during the dry seasons. These paths connect ecosystems with others and animals use them seasonally. The movement corridors are memorised by the animals and are used every other year when migration time approaches. Animal migration corridors are also used by the animals to disperse to outlying rangelands to access forage and water. The migration corridors and dispersal areas form habitats connectivity essential for maintenance of ecological processes (Figure 5.1).

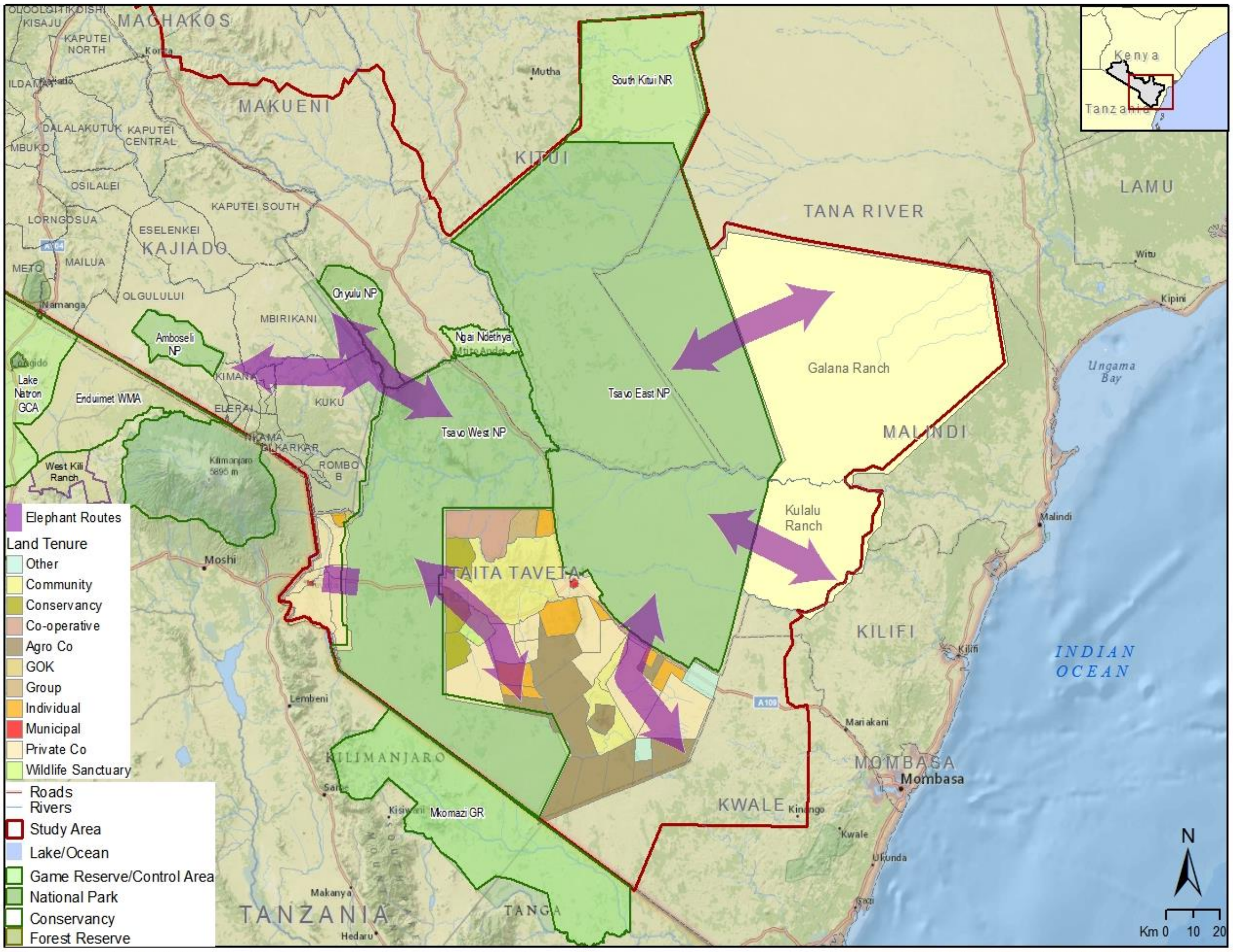


Wildbeest Movement Routes

Source: DRSRS, ILRI, KWS, Colorado State University, ESRI, Nat-Geo World Map

Figure 5.1: Map of wildlife migration corridors in Nairobi-Athi-Kapiti plains ecosystem
Source: DRSRS, KWS, Colorado State University, ESRI, Nat-Geo Map

Wildlife species like elephants move for long distances in search of water and follow specific migration routes. For example, elephants move from Tsavo West National Park to Amboseli National Park through Chyulu Hills National Park and from Tsavo East National Park to Tsavo West National Park through Taita hills. Giraffes have also adopted migration tendencies and move along the same routes used by elephants in search of forage and water, particularly during the dry seasons of the year (Figure 5.2).



Elephant Movement Routes

Source: DRSRS, KWS,AWF, ESRI, Nat-Geo World Map

Figure 5.2: Wildlife migration corridors and dispersal areas in Amboseli-Tsavo ecosystem Source: DRSRS, KWS, AWF, ESRI, Nat-Geo World Map

5.5.3 Conservation status of movement corridors

Wildlife movement corridors or habitat corridors are a stretch of land running between national parks and reserves. Corridors allow animals to disperse from one area to another and allow for gene flow and colonization of suitable sites. Thus, corridors help to sustain migratory wildlife species. These allow animals to move within different habitats in search of food and water resources or escape from adverse environmental conditions like drought or floods (Andrew, 2002). Wildlife migration corridors are important ecosystem connections between wildlife protected areas as they allow for populations gene flow and interactions. Corridors also act as pressure relievers in protected areas as they allow migration of wildlife to adjacent areas or parks (Mbane, 2012).

Dispersal areas and migration corridors between protected areas and giraffe dispersal ranges have continued to decline in the Tsavo-Amboseli ecosystems and Maasai Mara National Reserve (Ottichilo, 2000), Kilimanjaro National Park (Noe, 2003), Nairobi National Park (Western, 1997) and around Amboseli National Park (Okello and Kiringe, 2011) where they have been taken over by human settlements and cultivation. Human activities like settlement, infrastructure development, farming, and fencing have displaced wildlife in landscapes adjacent to national parks (Western, 1997; Okello, 2009).

When protected areas lose migration corridors and dispersal areas, certain wildlife species like giraffe are likely to face local extinctions and the ecological integrity and resilience of protected areas would be compromised (Western, 1982). Conservation areas like Amboseli and Nairobi National Parks largely depend on adjacent lands for giraffe dispersal. Loss and degradation of these migration corridors and dispersal areas has already caused decline in wildlife numbers in Kenya (Ottichilo, 2000; Okello & Kiringe, 2007). Corridors are essential for ecosystems connectivity. Such ecosystems connectivities are important for giraffe survival in the Amboseli-Tsavo-Mt. Kilimanjaro and Nairobi National Parks (Figure 5.3).

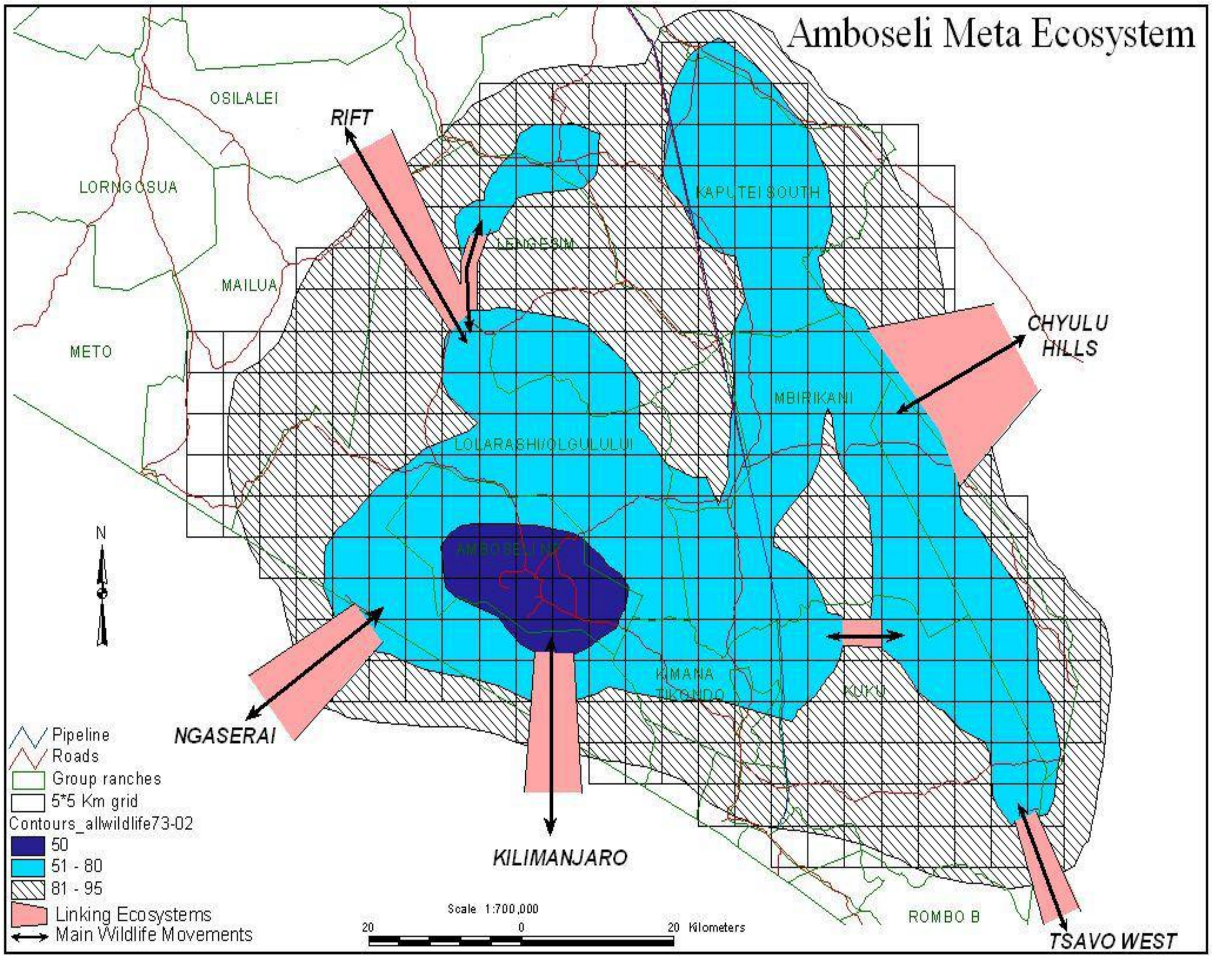


Figure 5.3: Amboseli-Tsavo/Chyulu hills-Athi-Kapiti plains ecosystems inter-connectivity. Source: Amboseli Ecosystem Management Plan (2008-2011).

5.5.4 Ecological conditions of dispersal areas

These are areas outside protected areas utilized by wildlife species during certain periods of the year. They are usually wet season dispersal areas where giraffe and other wildlife species move to and avoid the wet national park or reserve conditions. For example, both migratory and non-migratory wildlife species like zebra, Kongoni, wildebeest and giraffe move southwards out of Nairobi National Park to the Kitengela and Athi-Kapiti plains during the wet seasons. Others disperse further southwards to north Kaputei, Magadi and Shompole areas. Once the wet season is over, the animals move back to Nairobi National Park which they use as a dry season grazing ground. The Kitengela area hosts large populations of both wildlife and livestock and is important for the existence of Nairobi National Park as almost 70-80% of the park's wildlife utilizes this area at any one time (Western, 1997).

Lack of dispersal areas would cause certain wildlife populations to crash and the ecological integrity and resilience of conservation areas would be compromised (KWS, 2008). Conservation areas like, Amboseli and Nairobi National Parks are largely dependent on their adjacent areas for wildlife dispersal. Loss and degradation of these dispersal areas and migration corridors can contribute to wildlife population declines in the country (Norton-Griffiths, 1997; Ottichilo, 2000; Sindiga, 1995; Western, 1997). Wildlife migration corridors and dispersal areas between protected areas or between a protected area and dispersal ranges have continued to decline. This has happened around Nairobi National Park (Western, 1997), Tsavo-Amboseli area and Maasai Mara National Reserve (Ottichilo, 2000), where they have been taken up by human settlement and cultivation.

Loss of wildlife migration corridors and dispersal areas leads to twelve point consequences that are devastating to wildlife species survival within their ranges. These twelve point consequences, which include wildlife habitat loss and fragmentation, restricted wildlife movements, reduced wildlife numbers, increased human/wildlife conflicts, reduced ecosystem resilience, invasive species encroachment, increased range degradation, loss of dry season grazing grounds for wildlife, loss of forest vegetated areas, loss of wetland ecosystems, increased livestock incursions into protected areas and general decrease in forage and water for wildlife use.

5.6 Discussion and conclusion

5.6.1 Factors influencing giraffe population structure

Lions are the primary predators of giraffe in the wild and are only second to man in depressing giraffe numbers (Dagg and Foster, 1976). Perceived predation risk can influence herbivore behaviour. The presence of young can also influence the behaviour of a group of animals because young are vulnerable to predators. Vegetation cover can facilitate both concealment and escape from predators (Berger & Gochfield, 1994). When perceived predator risk is high, the probability of an animal going to the water sources is lower and the time to access water longer, thus allowing for more vigilance (Marion et al. 2007). Normally, giraffe young are not specifically vulnerable to lion attacks, but unhealthy giraffes of any age can become easy prey to lions (Obari, 2009).

Studies have shown that species with large individuals are less prone to predation than those species with small individuals (Sinclair et al, 2003; Radloff & du Toit, 2004). But giraffe are exceptional to this as it becomes more vulnerable to predation due to its posture while drinking water. The presence of young among giraffe herds influence time spent accessing water, thus increased vigilance levels. Females with young are therefore more alert than those without young (Berger & Gochfield, 1994). Giraffe and other smaller species are more sensitive to the distance to cover for them to make a decision to drink water due to their vulnerability to predation (Sinclair et al., 2003). Giraffe and Roan antelope are less water-dependent than other species. Because of this, giraffes spend more time being vigilant over predators or performed other activities, thus taking more time before going to drink water (Sinclair et al., 2003).

A pride of lions can go for adult giraffes, particularly the sick and injured ones. The young of giraffe can also be predated upon by leopard, hyena and wild dogs. Predation on giraffe by lion was once observed in Amboseli National Park where a pride of lions went for an adult male giraffe and brought it down in a matter of minutes. Giraffe predation by lion occurs in Tsavo West National Park but this was difficult to observe because of the thick bush vegetation and inaccessibility of the vast area. Suspected predation by lion on the young of giraffes occurs in Nairobi National Park, but no such kills had been observed as lions had a wide range of herbivores to choose their prey from.

Predation also influences herbivore population dynamics. Sinclair (1995) suggested that large herbivore populations are regulated more by food supply than predation because of their large sizes (e.g. buffalo, elephant and rhino), while predators regulate other small species. For example, species like wildebeest and zebra escape predators by way of timed migrations.

However, giraffe population dynamics has not been influenced by predation in the study area as either lions or hyenas rarely attack giraffes or their young for fear of being killed by the giraffe's powerful kicks while defending itself and its young.

5.6.2 Factors affecting giraffe movement in Southern Kenya

Giraffe movements and home range sizes are strongly linked to seasonal browsing and to a lesser extent water availability (Hall-Martin, 1974; Berry, 1978; Pellew, 1984). Seasonal movements are associated with phenological changes in preferred food plant species of the Acacia and Comiphora (Hall-Martin & Basson, 1975; Leuthold & Leuthold, 1978). Sometimes shift in forage preferences by giraffes leads to seasonal expansion and contraction of ranges (Hall-Martin & Basson, 1975; Leuthold & Leuthold, 1978; Le Pendu & Ciofolo, 2002).

Giraffes move from one habitat to the other to obtain forage with high nutrient and moisture content. Bull giraffes make long distance movements probably in search of receptive females, new forage sources and moving away from human encroached habitats. Giraffe daily movements start around dawn and increase during early morning hours in search of forage. They usually rest as from mid-day (12 noon). Giraffes move for short distances during the hottest part of the day (12noon – 3pm) as movements tend to correspond with reducing ambient temperatures (Fennessy, 2009). Giraffe movements increase during late afternoon hours (3pm) up to pre-dusk hours when movements are remarkably reduced. Giraffes are also known to move at night particularly during moon lit nights (Obari, 2009).

Migration is a periodic movement of animals from one spatial unit to another. These are regular movements to and from habitats in search of food, water and mates. Berry (1978) suggested that migrations in large herbivore populations were in response to seasonal changes in resource availability. Movements are also meant to enhance access to high quality food and reduced risk to predation. Large mammals' dispersal is regarded as widespread distribution of animal populations. Due to habitat patchiness within their home ranges, giraffes make daily localized movements and change habitats seasonally (Sinclair, 1992; Western, 1975). Western (1975) categorized animal movements as migration, resident and dispersal systems, where dispersal refers to wet season dispersal and dry season concentration of animals within their ranges.

Animal migrations are essential for sustaining their large herds and resilience to reduced rainfall, disease and predation. They also disperse in response to both intrinsic (breeding) and extrinsic (environmental) factors like droughts, floods, fires, habitat degradation, resource (food and water) inadequacy, competition for (food, water and mates), predation, parasitism (diseases) and avoidance of inbreeding. They also move to enhance their reproductive success. Migratory wildlife species sometimes achieve their nutritional needs by moving over long distances for quality forage available at any given time of the year. Most movements observed in African ungulates are those of seasonal migrations (Western, 1975; Sinclair, 1995). Some of these giraffe movements are seasonal while others show strong seasonal concentrations and movements within the same area (local migrations).

Habitat use and seasonal dynamics of herbivores have extensively been studied in the Mara-Serengeti ecosystem (Ottichilo, 2000) and Amboseli ecosystem (Western, 1973, 1975). Ungulates usually move in response to changes in seasons while migrations occur in search of water, forage quality and quantity. Seasonal changes in forage quality causes seasonal selection of forage, hence triggering animal movements (Western, 1973)

In the Mara–Serengeti ecosystems, Wildebeest and other ungulates like Burchell’s zebra and Thomsos’s gazelle migrate between their dry and wet season ranges in Kenya and Tanzania (Sinclair & Norton-Griffiths, 1979, Maddock, 1979; Sinclair & Arcese, 1995; Ottichilo, 2000). Differences in the migration patterns can be related to the food requirements of animals. Food supply determines animal migration patterns, which is largely dependent upon rainfall. Animals also move to certain areas to get more proteins or minerals and to avoid certain areas because of floods and pests like tsetse flies. Herbivore movements are also influenced by competition and predation with both inter-specific and intra-specific competition occurring particularly where various species dietary needs are similar.

The diversity and abundance of herbivore communities in savannah ecosystems have been attributed to resource partitioning and niche differentiation and their spatial and temporal use of habitats. This is a process where one herbivore provides feeding opportunities for others through the grazing down of vegetation (Lamprey, 1963; Sinclair et al., 2003). Animal movements, be it seasonal, annual or long distance is exhibited by both wildlife and livestock systematically exploiting environmental discontinuities (McNaughton & Georgiadis, 1986).

5.6.3 Conservation status of giraffe migration corridors

The importance of wildlife migration corridors has been based on the theories of Meta-population extinction of species (Hanskin & Gilpin, 1991; Hanskin, 1998), Island Biogeography (McArthur & Wilson, 1967) and Leopold's Law of Dispersion of the early 1930's. These theories emphasized that ecosystem connectivity is essential for wildlife species meta-population stability and sustainability. Corridors serve as linear landscape factors that link historically connected habitats and natural areas that facilitate movements between these areas. Corridors maintain ecosystems connectivity for species, communities, and ecological processes that are key to nature conservation in environments that have been modified by man.

Corridors physically link giraffe habitats and allow them to move between isolated habitats for they increase space available for the giraffes' utilization. Corridors maintain biodiversity, prevent in-breeding in giraffes and improve their long term genetic viability. Corridors also provide giraffes with access to larger habitats that maintain ecological processes for continuity of viable populations and provide movement of giraffes to avoid predation. Corridors have been used for wildlife conservation and management especially in response to habitat fragmentation (Bennett, 2003).

Apart from maintaining genetic diversity through enhanced gene flow, giraffe migration corridors enhance overall species meta-populations survival in connected habitat patches. Corridors also buffer animal populations' fluctuations due to seasonal and inter-annual fluctuations. They also accommodate range shifts due to climate change. Corridors act as predator wildlife species refuges, thus reducing predator pressure on certain resident prey species in national parks and reserves. Corridors maintain ecological process connectivity which includes access by giiraffes to key resource areas like minerals, nutrients, dry season grazing, breeding and calving grounds.

5.6.4 Ecological and human impacts on giraffe dispersal areas

Giraffe movement corridors and dispersal areas have come under intense pressure from increasing human population and associated activities. Human population pressure presents threats to the viability of biodiversity and habitats essential for maintenance of essential ecological processes. Giraffes move in search of forage and water and generally follow known migration paths. Giraffe migration corridors and dispersal areas have either been blocked or highly threatened by human activities. Several human activities like cultivation, infrastructure development and settlement have completely blocked some of these wildlife migration corridors. The loss of these corridors has other adverse effects like decline in giraffe numbers and restriction of their movements.

When protected areas are insularized by human related activities, giraffe populations get isolated from others. This leads to inbreeding among individuals, thus leading to loss of their genetic variability and reduced vigor within the populations. Confined giraffe populations may lead to the surpassing of certain ecosystems carrying capacities that lead to eventual habitat degradation as has happened with Rothschild giraffe in Lake Nakuru and Ruma National Parks.

Increase in human population has led to increased demand for land and associated natural resources (Mwale, 2000). Human encroachment on critical biodiversity areas has led to exploration of rangelands for agriculture thus interfering with animal migration corridors and dispersal areas (Sindiga, 1995; Mwale, 2000).

5.6.5 Conclusion

The giraffe population in the three study sites had relative age structures of adults, sub-adults and young in their sub-populations. The relative age-structures reflected the expected natural mamalian species relative age structures and sex ratios. All the three study sites’ giraffe sub-populations had a skewed adult male to adult female to sub-adult male to sub-adult female to young sex ratio of 1:2:1:1:1, which indicated unstable giraffe populations with poor recruitment of sub-adult and young individuals into the population. Giraffes in the three study sites moved for long distances in search of forage and water. They also exhibited localised movements between habitats with their preferred food plants. Increasing human population and rapid land use changes had led to degradation and loss of wildlife migration corridors and dispersal areas in Southern Kenya. Human encroachment into giraffe habitats had led to degradation of migration corridors, dispersal areas and at the same time increased human/wildlife conflicts.

5.7 Chapter summary

Giraffe populations in Amboseli, Nairobi and Tsavo National Parks had relative age structures of adults, sub-adults and young individuals. Assessment of giraffe population operational sex ratios showed that each of the three study sites had a giraffe operational sex ratio of 1:2. The overall observed giraffe population operational sex ratio in the three study sites of 1:2 (220 adult males to 428 adult females) departed from the expected 1:1 male to female sex ratio. Chi-squared tests performed on giraffe sex ratios in the three study sites showed a significant difference in the respective sex ratios. There was also a significant difference in giraffe sex ratio in the overall giraffe population in the study area. The observed giraffe sex ratio of 1:2 in the three study sites departed from parity, that is, it departed from the expected 1:1 adult male to adult female sex ratio.

Giraffes dispersed beyond protected area boundaries in search of forage and water resources and followed specific movement paths referred to as migration corridors. Giraffe that is regarded as a non-migratory species had conditionally adopted migration tendencies to search for forage and water during the dry seasons of the year. These movement paths connected ecosystems and animals used them periodically. The movement corridors were memorised by the giraffes and were used every other year when drought set in, thus the need to search for forage and water.

Giraffes used the migration corridors to disperse to outlying rangelands to access forage and water. The migration corridors and dispersal areas formed habitats connectivity essential for maintenance of essential ecological functions. Just like elephants, giraffes moved for long distances in search of forage and water and followed specific migration routes. Giraffes had therefore adopted migration tendencies and moved along the same routes used by elephants and other species in search of forage and water, particularly during the dry seasons of the year.

CHAPTER SIX

GIRAFFE HOME RANGES AND HABITAT USE IN SOUTHERN KENYA

6.1 Introduction

A home range is an area that an animal uses in the course of its daily activities and is not necessarily defended. It can also be defined as the area traversed by the animal during its normal activities of foraging, mating and caring of young. The animal may make unusual movements outside its home range resulting in outlier points which cannot be considered as its normal activity area. Giraffe home range sizes differ with habitat types and ecosystem sizes. Giraffe home range sizes of arid adapted mammals are usually larger than those of the same species in high rainfall environments (Du Toit, 1990; Dickman et al. 1999). Giraffe home range sizes can sometimes be determined by the amount of rainfall received in a particular ecosystem, giraffe security, forage and water availability. These factors tend to drive animal movements in arid and semi-arid environments where individuals or herds of these animals move to habitats in search of these resources (Du Toit, 1990; Dickman et al. 1999).

Generally, male giraffes' home ranges are almost twice as large as those of females. For example, Fennessy (2009) determined a male giraffe home range of 1950km^2 and that of a female giraffe of 1098km^2 in the Northern Namib desert, Namibia. Male and female giraffe home ranges overlap with no distinct sexual habitat segregation. Juvenile giraffe home ranges were observed to be corresponding with those of their mothers since they usually accompanied them, thus covering the same range (Fennessy, 2007). Although giraffes in arid and semi-arid areas have larger home ranges, the differences in sex home ranges are less pronounced (Berry, 1978; Leuthold & Leuthold, 1978; Le Pendu & Ciofolo, 1999).

Giraffe home range sizes also vary in areas with different giraffe population age structures and densities, forage availability and predator density (Fennessy, 2009). Decreased forage availability and high variability in both temporal and spatial rainfall amounts limit giraffe densities and increase their range in arid and semi-arid ecosystems (Le Pendu & Ciofolo, 1999). Giraffe home ranges are usually thin and elongated along the forage rich riverine habitats (Berry,

1978) but can be irregular in shape (Leuthold & Leuthold, 1978; Dagg & Foster, 1982; Pellew, 1984).

6.2 Scope of the study

This study determined giraffe home range sizes using the 95% and 50% Minimum Convex Polygon (MCP) and Kernel Density (KD) methods. It also tested for significant difference in giraffe home range sizes using the Mann-Whitney (U) signed rank test in Amboseli, Nairobi and Tsavo West National Parks. Both parental and non-parental giraffes' home range sizes were determined. The study compared the wet and dry season giraffe home range sizes and tested if there was a significant difference between the wet and dry season giraffe home range sizes in the three study sites.

6.3 Research objectives

i) To determine giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks.
ii) To determine the seasonal variations in giraffe home ranges in the three study sites.
iii) To determine giraffe habitat use and occupancy in the three study sites.

6.4 Materials and methods

6.4.1 Estimation of giraffe home ranges

Giraffe home range sizes were estimated by use of the Minimum Convex Polygon (MCP) (Mohr, 1947) as it is the most widely used method to estimate animal home range sizes. Using GIS-ARC View program, the method calculates up to the smallest convex polygon enclosing all the relocations of the animal. The polygon plots so obtained are then considered to be the home range of the animal. The home range size of an animal is automatically computed by the function of the MCP, by coercing the object returned by the function to the class data and the frame gives access to the home range size. The 95% MCP is a plot of the relocations of points within the polygon when 5% of the outlier points are excluded from the polygon plot. The 95% MCP polygon is usually larger than those polygons plotted at 50% MCP as 50% of the outlier points are excluded from the polygon (Calange, 2011).

The second method of estimating giraffe home range size is the kernel Density (KD) (Worton, 1989). This method estimates kernel densities and utilization distribution (UD) of animals. It uses the smoothening parameter ‘h’ to control the width of the Kernel functions that are placed over each other. When animals use several centres of activity, the reference smoothening parameter ‘h’ is often too large and results in a strong over-smoothening of the data. The estimated utilization distribution (UD) predicts the frequent presence of the animal in areas which are not actually used. The UD gives the probability density to relocate the animal at a given place. The home range deduced from the UD is the minimum area in which the probability to relocate the animal is equal to a specified value. For example, the 95% Kernel Density home range corresponds to the smallest area on which the probability to relocate the animal is equal to 0.95 (Mitchell, 2007).

6.4.2 Determination of seasonal variability of giraffe home ranges

Analysis was done on giraffe home range sizes that were determined by use of the Minimum Convex Polygon (MCP) method (Mohr, 1947) and the Kernel Density (KD) Method (Worton, 1989). Kernel density estimates are based on probability ‘kernels’, which are regions around each point location containing some likelihood of animal presence. Kernel methods are either adaptive or fixed. Adaptive kernels tend to perform poorly, often over-estimating home ranges. Kernel estimators work well with small amounts of data of about 50 locations. They are robust to autocorrelation, non-parametric and allow multiple centres of activity. Kernel estimators result in a utilization distribution (UD) rather than a simple home range outline. The UD is a grid where the value for each cell represents the probability of the animal occurring in that cell and it also allows for a more precise estimate of home range overlap than just a simple outline (Mitchell, 2007).

6.4.3 Assessment of giraffe habitat use

Giraffe habitats were assessed to explore the manner in which giraffes exploit the aboreal food sources. It was observed that giraffes exploit their food sources much more economically where they usually browsed at heights of 5m, but can reach 6m. They also fed on preferred food plants as low as 1-2m high. Feeding heights in giraffes was seen as a form of resource partitioning where high browsing was meant to reduce browsing pressure on vegetation where sexes feeding heights overlap. It was also observed that giraffes exhibit sexual segregation from feeding in certain habitats where males altruistically left superior habitats to reduce feeding competition between them and parental giraffes. Giraffes tended to utilize preferred habitats with the Acacia tree vegetation and sometimes fed on their bark when fresh foliage became scarce.

Giraffes were observed to be highly selective feeders feeding mainly on Acacia and Combretum tree species that were common in the three study sites of Amboseli, Nairobi and Tsavo West National Parks. Giraffes were also observed to feed at heights unreachable by other browsers except elephants. By doing so, giraffes created pruned browse lines along the under canopies of trees at heights of 4-5.5m. At most times, giraffes ate leaves and shoots of selected food plants, but also ate flowers, vines and herbs.

Giraffes have a pre-hensile tongue that is well adapted to coil and clip vegetation that is smoothened by special mouth parts and saliva before it is swallowed. At certain times, giraffes were found at natural salt licks, licking salt as mineral suppliments to their diet. Giraffes were observed to spend about 8 -10 hours of day light feeding while 2- 4 hours were spent on other activities like resting, drinking water or necking.

6.5 Results

6.5.1 Giraffe home range sizes in the three study sites

Both the wet and dry season giraffe home range sizes plotted using 95% Minimum Convex Polygon (MCP) and 95% Kernel density (KD) methods were larger than those plotted at 50%. The dry season giraffe home range sizes plotted using 95% MCP and 95% KD were larger than those of the wet season.

A two-sample Mann-Whitney (U) test was conducted to compare the wet and dry season giraffe home ranges in Amboseli, Nairobi and Tsavo West National Parks (Table 6.1a, 6.1b and 6.1c).

Table 6.1a: Wet and dry season giraffe home range sizes in Amboseli National Park.

Wet season (km^2)	Rank 1 (R_1)	Dry Season (km^2)	Rank 2 (R_2)
44.5	2	37.6	1
226.2	5	159.5	3
634.3	6	220.9	4
916.4	9	718.3	7
924.8	10	850.2	8

Table 6.1b: Wet and dry season giraffe home range sizes in Nairobi National Park.

Wet Season (km^2)	Rank 1 (R_1)	Dry Season (km^2)	Rank 2 (R_2)
36.78	3	1.12	1
88.74	4	2.45	2
110.04	5	118.0	6
154.65	8	118.9	7

Table 6.1c: Wet and dry season giraffe home range sizes in Tsavo West National Park

Wet Season (km^2)	Rank1 (R_1)	Dry Season (km^2)	Rank 2 (R_2)
89.57	1	717.14	2
992.3	3	2170.2	5
1105.61	4	3692.6	7
4613.19	6	5124.01	9
5821.2	8		

6.5.2 Seasonal giraffe home range variations

A two-sample Mann-Whitney (U) test performed on the wet and dry season giraffe home range sizes showed no significant difference ($p > 0.05$) between the wet and dry season giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks. When the test was performed on the wet season (median = 634.3 km^2) and dry season (median = 220.9 km^2) giraffe home range sizes in ANP, showed no significant difference between the two seasons giraffe home range sizes ($U_{0.05, 5, 5} = 2$, $p > 0.05$). A similar test performed on the wet season (median = 99.39km^2) and dry season (median = 60.23km^2) giraffe home range sizes in NNP, also showed no significant difference between the two seasons giraffe home ranges ($U_{0.05, 4, 4} = 0$, $p > 0.05$).

When the test was performed on the wet season (median = 1105.61km^2) and dry season (median =2931.4 km^2) giraffe home rang sizes in TWNP, there was still no significant difference between the two seasons giraffe home ranges in TWNP ($U_{0.05, 5, 4} = 1$, $p > 0.05$). The giraffe dry season home range sizes were the same as the wet season ones in ANP (Fig. 6.1). But the wet season core activity area sizes were larger than those of the dry ones meaning that giraffes moved out of the park and covered wider ranges to feed on the abundant forage during the wet seasons (Fig. 6.1a, 6.1b and Appendix 16).

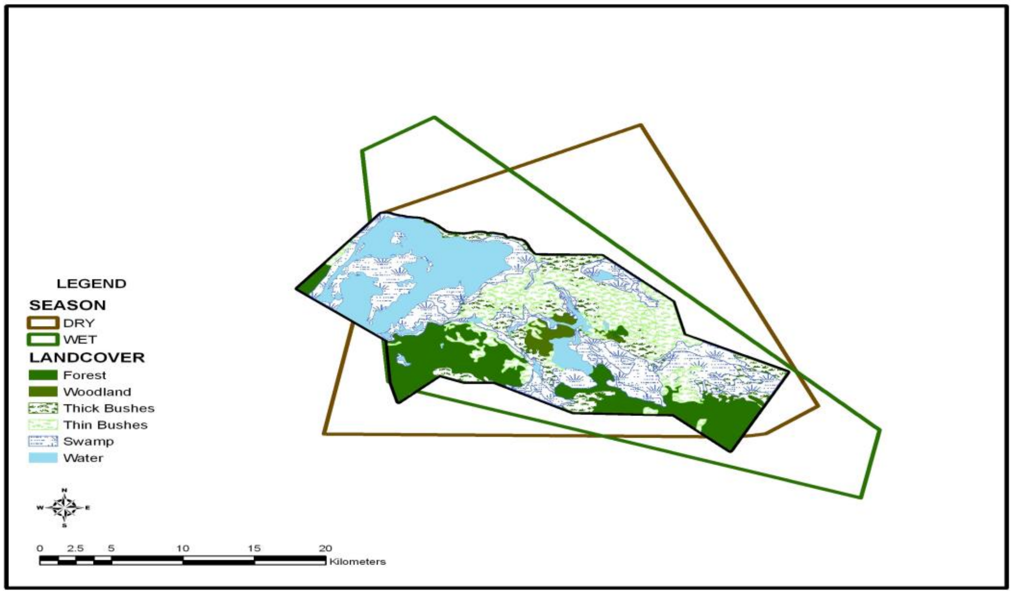


Figure 6.1a: Wet and dry 95%MCP giraffe home range sizes in Amboseli National Park.

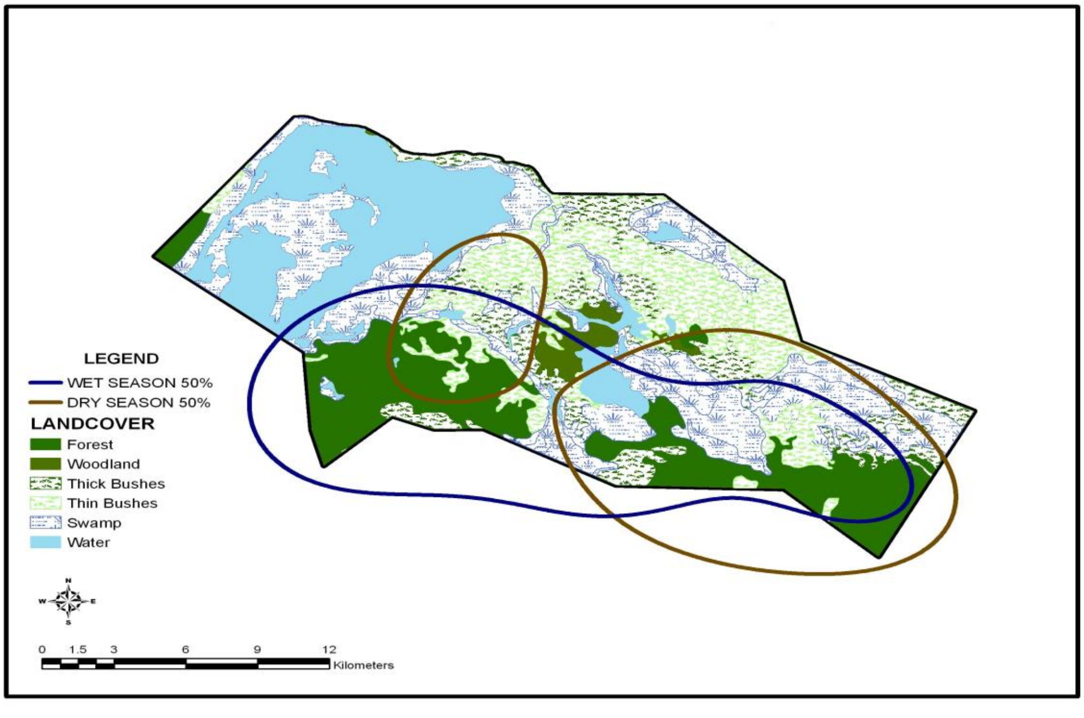


Figure 6.1b: Wet and dry season giraffe core activity areas in Amboseli National Park.

The wet season giraffe home range sizes ploted using both 95% KD and 95% MCP methods were almost the same size with those of the dry season in NNP, meaning that giraffe movements were restricted in the partially fenced up NNP (Fig. 6.2a, 6.2b and Appendix 17).

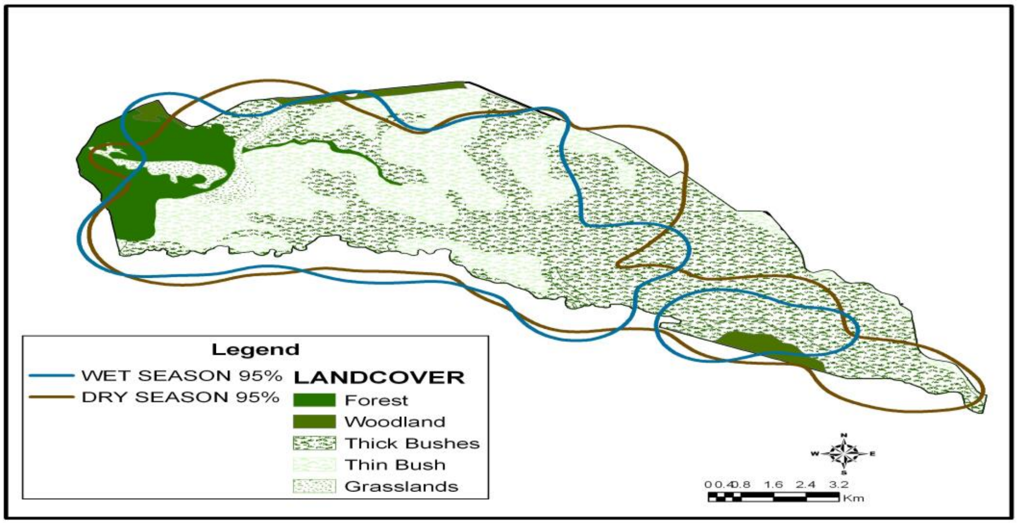


Figure 6.2a: Wet and dry season giraffe KD home range sizes in Nairobi National Park.

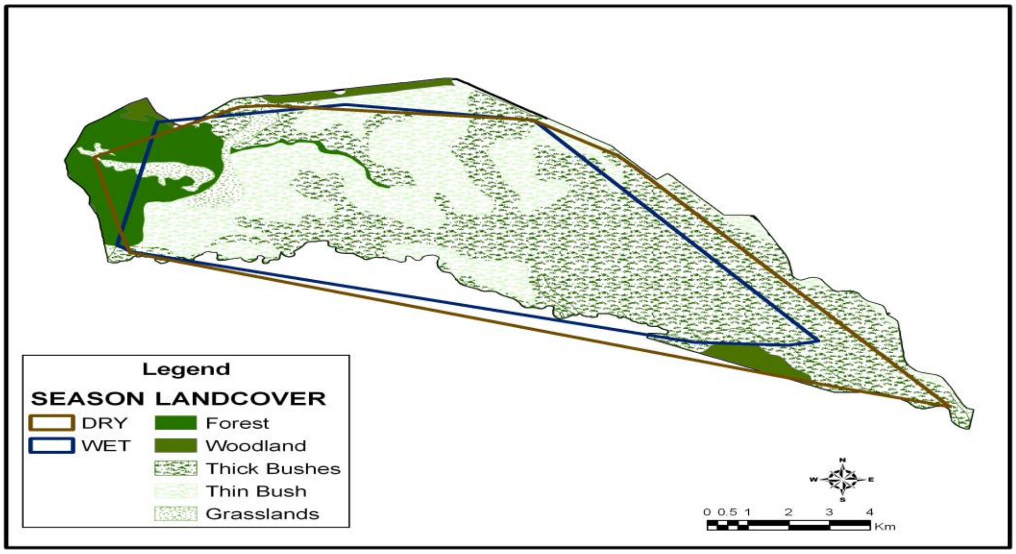


Figure 6.2b: Wet and dry season giraffe MCP home range sizes in Nairobi National Park.

The 95% MCP and 95% KD wet season giraffe home ranges were larger than the dry season giraffe home range sizes Tsavo West National Park. This was contrary to the norm where dry season giraffe home range sizes are usually larger than the wet ones. This meant that giraffes wandered far during the wet seasons when they concentrated feeding along the Tsavo River or wandered upto Chyulu hills for forage (Fig. 6.3a, 6.3b and Appendix 18).

Figure 6.3a: Wet and dry season KD giraffe home range sizes in Tsavo West National Park.

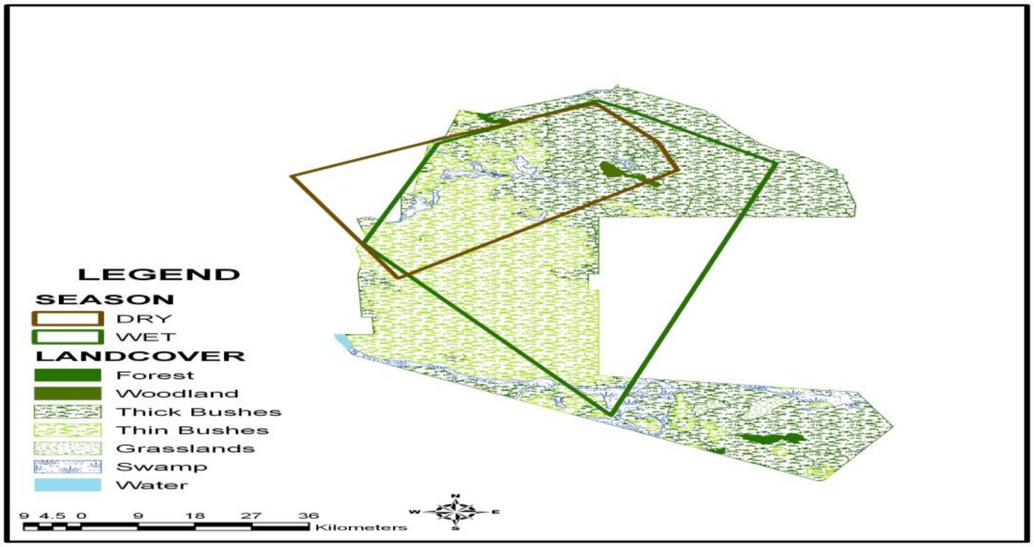


Figure 6.3b: Wet and dry season MCP giraffe home range sizes in Tsavo West National Park

6.5.3 Giraffe habitats and their use

When Chi-square tests were performed on the numbers of giraffes in different habitat types in Amboseli, Nairobi and Tsavo West National Parks, the tests showed no significant differences in giraffe numbers in the different habitat types ($X^2_{0,05,\ 4} = 9.49$, $p > 0.05$). This suggested that habitat types did not determine giraffe numbers and their distribution in the three study sites.

When One-Sample Kolmorogov-Smirnov test was used to test for uniform distribution of different giraffe age-classes during the wet and dry seasons in different habitat types in Amboseli National Park, the test showed that the different giraffe age-classes were not uniformly distributed in the different habitat types (Fig. 6.4a). But a similar test showed a significant difference in giraffe numbers in the different habitat types during the wet and dry seasons ($n= 147$, Mean = 1.47, SD = 0.501, $p < 0.05$).

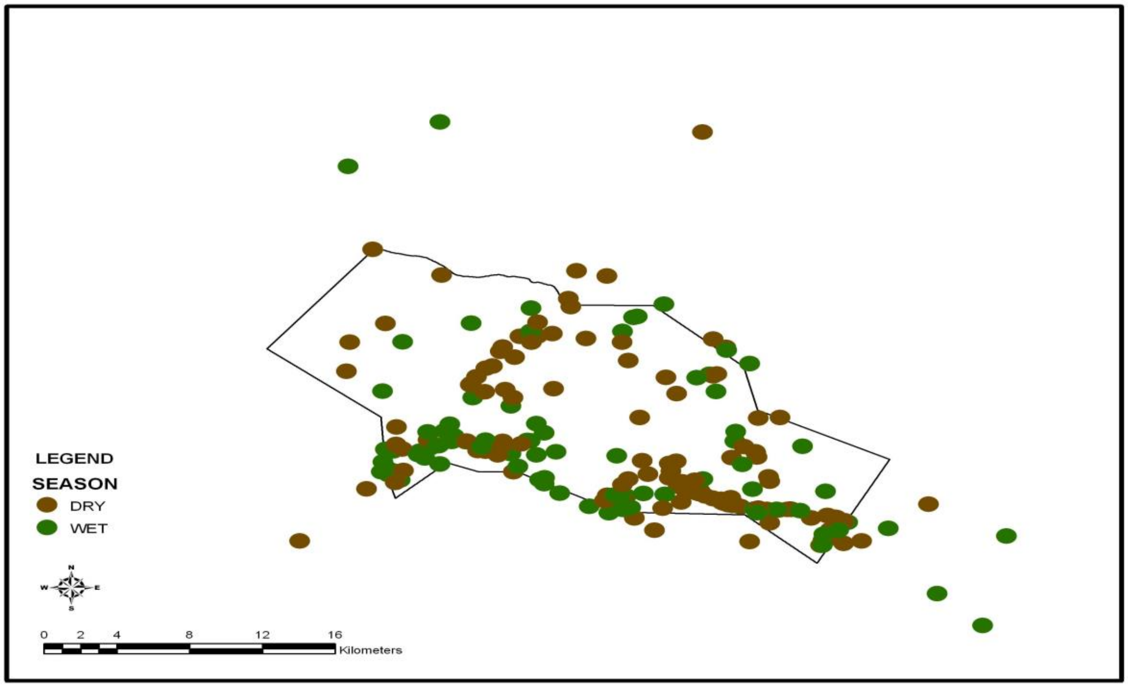


Figure 6.4a: Seasonal giraffe distribution in Amboseli Nationla Park.

One-Sample Kolmorogov-Smirnov test performed on data sets on giraffe seasonal habitat use and occupancy showed that no significant difference ($p > 0.05$) in giraffe seasonal habitat use and occupancy in Nairobi National Park. This meant that seasons did not determine giraffe habitat use and occupancy in NNP. Instead giraffes uniformly utilized or occupied the different habitat types during both the wet and dry seasons in NNP (Fig. 6.4b).

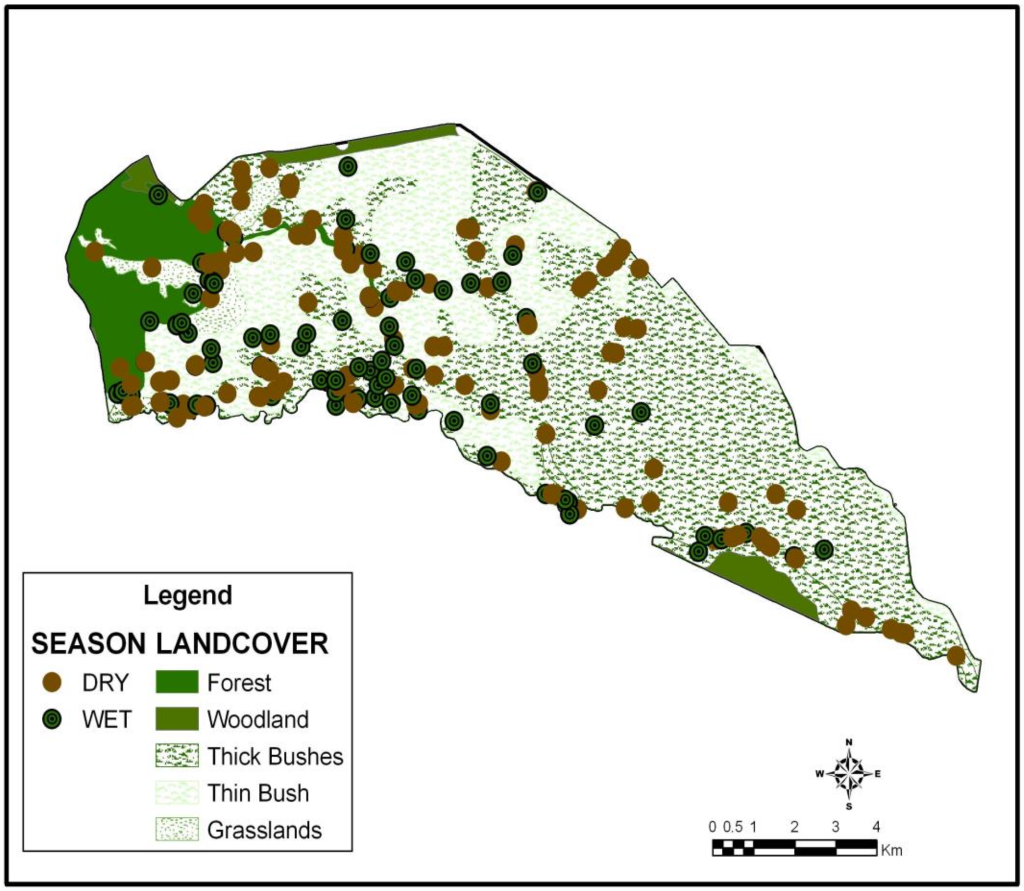


Figure 6.4b: Seasonal giraffe distribution in Nairobi National Park.

One-Sample Kolmorogov-Smirnov test used to test for significant difference in giraffe numbers (n) in different habitat types in Tsavo West National Park. The test showed no significant difference in giraffe numbers in the different habitat types ($n = 60$, Mean = 1.68, SD = 1.142, SE = 0.147, $p > 0.05$). This meant that giraffes uniformly used and occupied the different habitat types in TWNP (Fig. 6.4c).

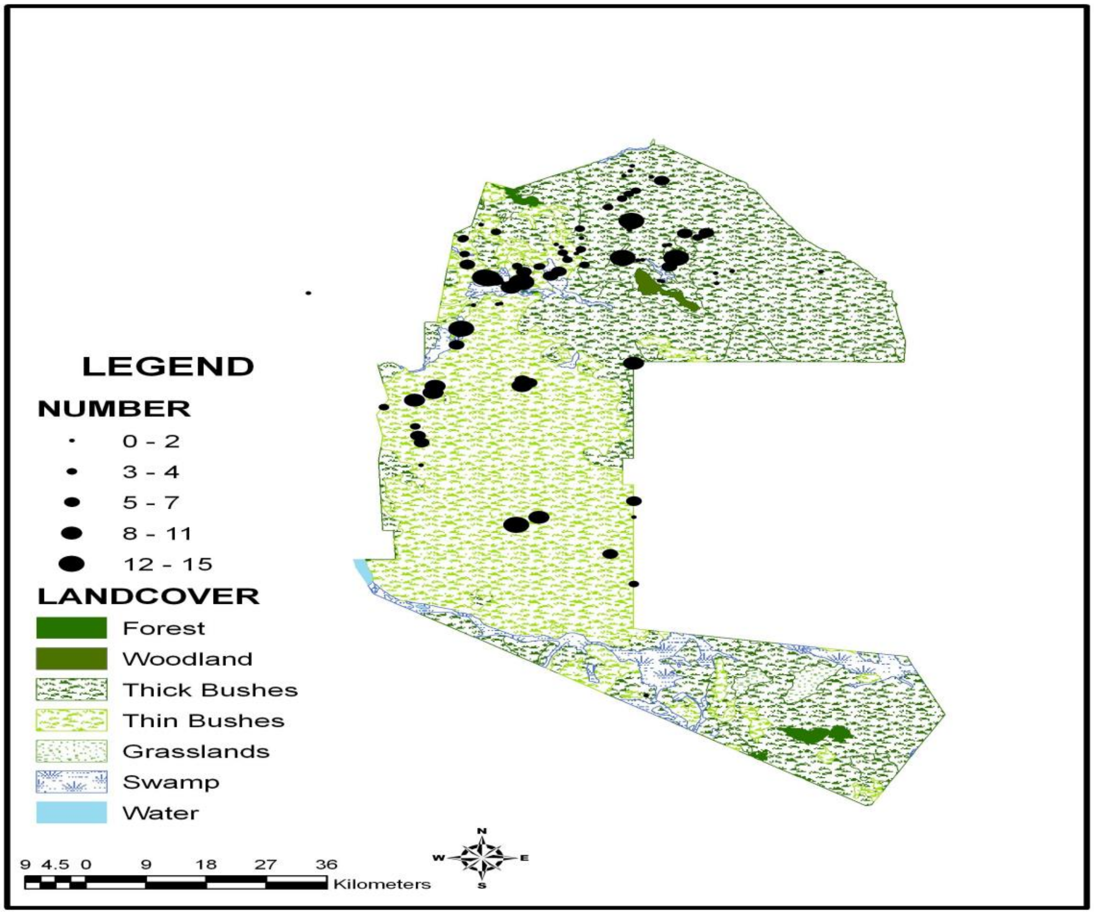


Figure 6.4c: Giraffe distribution in Tsavo West National Park.

6.6 Discussion and conclusion

6.6.1 Overall giraffe home range sizes and ranging patterns

The 95% Minimum Convex Polygon (MCP) home range sizes of giraffes were markedly produced and provided a more accurate estimate of home range sizes and core resident use areas, thus achieving maximum area of the animal's home range as compared to the 50% MCP and KD home range estimation that covers about 50% of the animal's home range. During the dry seasons giraffe core area utilization seemed fragmented and giraffes tended to concentrate in specific areas with abundant forage particularly in Tsavo West National Park.

Generally, giraffe home range sizes varied from 5 – 564km^2. Past studies by Wyatt, 1969, showed giraffe home range size for El Karama ranch (14km^2), Nairobi National Park (73.5km^2) and Tsavo National Park (164km^2). However, large differences in giraffe home range sizes have been reported across their range (Berry, 1993; Dagg, 1971). Giraffe home range sizes were smaller during wet seasons than during the dry seasons. This study found out that the wet season giraffe home range sizes were larger than the dry ones in Amboseli and Nairobi National Parks, but the dry season home range sizes were larger than the wet ones in Tsavo West National Park. However, there is usually a high level of overlap in home ranges of giraffe herds and individuals of both sexes (Berry, 1993). This has been demonstrated in this study by the analysis of giraffe home range sizes in the three study areas.

Statistical tests performed on the wet and dry season giraffe home range sizes showed no significant difference ($p > 0.05$) between the wet and dry season giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks. This study determined the average home range sizes of giraffes in ANP during the wet season as 634.3 km^2 and that of the dry season as 220.9 km^2. This showed that giraffes tended to move out of the park to the surrounding community areas during the wet seasons, thus the increase in home range size. The giraffes extended their foraging to such areas like Longomon, Kitenden, Kimana and Namelok community settlement areas. In the processes of searching for forage and water in these areas, giraffes covered larger areas, thus the large home range sizes realized.

During the dry seasons, giraffes tended to concentrate foraging in the southern woodlands of Kimana gate, Amboseli Serena lodge, Tortilis and Kitirua areas. Giraffe core activity areas in ANP overlapped as there were patchy bush/shrub and woodland habitats in the park and different giraffe herds repeatedly concentrated foraging in the same habitats with available forage, thus, causing overlaps in their core activity areas.

This study also determined the average wet season giraffe home range size in NNP as 99.39km^2 while that of the dry season was 60.23km^2. The wet season giraffe home range size was larger than the dry season one. This was because giraffes tended to move for long distances to exploit habitats with available forage and concentrated feeding on riverine vegetation along the river valleys within this partially fenced park. The electric fence confines giraffes within the park, thus restricting their movements. Consequently, giraffes cannot move beyond the fence line except when they are foraging in the un-fenced southern boundary of the park. At such points, giraffes can cross the Mbagathi River and go to forage in the community areas of Kitengela thereby widening their home ranges.

The giraffes concentrate feeding in the available bush/shrub, wooded grassland and woodland habitats inside the park, thus confining them in the park with reduced area of utilization during foraging time. The western dry forest part of the park is not utilized by giraffes except when walking along the roads and feeding on available roadside preferred food plants.

This study determined the average wet season giraffe home range size in Tsavo West National Park as 1105.61km^2 while that of the dry season as 2931.4 km^2. The average dry season giraffe home range sizes in TWNP were almost three times as large as the wet season giraffe home range sizes. This showed that giraffes moved far and wide in search of forage during the dry seasons, thus assuming wider home range sizes than those covered during the wet seasons. The determined giraffe home range sizes in this study compare well with those determined in other studies. For example, the largest recorded home range size estimate for any giraffe was that of a bull giraffe (1950km^2) and female giraffe (1098km^2) in the northern Namib Desert, Namibia (Fenessy, 2009).

It was observed that there were differences in habitat selection by the different giraffe sexes. Females with young selected open woodland habitats while males and females without young selected to feed in dense woodland habitats. Male and female giraffes tended to feed from different heights, thus showing sexual segregation in feeding styles. For example, Kingdom (1997) observed that female giraffes usually chose habitats to maximize their food intake and protection of their young from predators. He also observed that males usually moved away from areas where there were females and young and left them for females as a form of resource partitioning. Most ungulates demonstrate a form of sexual segregation when it comes to habitat use where males would altruistically leave superior ranges to reduce foraging competition between them and females with young (Kingdom, 1997).

6.6.2 Factors influencing giraffe home ranges

Giraffes' seasonal movements were influenced by forage quality and quantity. Generally, giraffes looked for forage of good nutitional value in the three study sites. Past studies have shown that herbivores move to habitat patches with good quality forage with leaves that are rich in nutrients during the wet seasons. Essential elements like nitrogen (N) and phosphorus (P) concentrations vary with leaf seasons. For example, the concentration of nitrogen is higher than that of phosphorus (N>P) during early leaf season, N=P (mid leaf season) and N<P (late leaf season). Forage that is low in phosphorus and nitrogen does not meet the dietary requirements of pregnant female giraffes.

There is usually a decline in plant nutritional quality as the growing season progresses. This has been demonstrated in grass leaves where their nutritional value declined as the leaves aged. This is due to accumulation of cell wall components that become increasingly difficult to digest. This phenomenon occurs in other plant species' leaves. Because of this, giraffes were observed in the study sites to exhibit such seasonal movements in search of quality forage that was of high nutritional value. Resident animals become adapted to forage of poor nutritive quality by migrating along catena gradients throughout the year, selecting dry hilltops during the wet seasons and the wetter bottom hillslopes during the dry seasons (Bell, 1971).

6.6.3 Effects of seasonal changes on giraffes home ranges

Climate variability triggers seasonal changes which have marked changes in giraffe home range sizes. Generally, giraffe home range sizes are large during the dry seasons while they are small during the wet seasons. However, giraffe home range sizes vary with ecosystems. In some ecosystems, giraffe home ranges are larger during the dry seasons and smaller during the wet seasons. However, seasonal changes did not affect giraffe home range sizes as the wet and dry season home range sizes were moreless the same in the three study sites.

During the dry seasons when food and water resources become scarce, giraffes tend to spread out and walk for long distances in search of forage and drinking water. This in effect causes the expansion of their home ranges and large home range sizes are assumed to meet their nutritional needs. During the wet seasons, giraffe home range sizes tend to be small as giraffes make localized movements to feed on the abundant forage at such times. Giraffes therefore move for short distances from one habitat to the other to browse on fresh foliage. There is no need to look for water at such times as surface water may also be abundant and the need for it is reduced as the giraffes feed on succulent plants that meet their water requirements.

Giraffe home range sizes remain moreless the same regardless of seasonal changes in Nairobi National Park. This is becaused of the enclosed nature of the park that is partially fenced with electric fence. The southern wildlife dispersal areas of Kitengela and North Kaputei have been blocked by the changed land use patterns where the former wildlife migration corridor has been blocked. This in essence forces giraffes forage within the confines of Nairobi National Park with the wet and dry season home range sizes therefore showing very little variations.

The dry season home ranges become elongated and strip like when the giraffes resort to feeding on vegetation along the river valleys. Almost the same home range sizes are maintained during the wet season but with varying shapes. The once regular rectangular shaped home ranges may becomed irregular and triangular shaped. Some may even become long thin strips as during the dry seasons when giraffes seek for forage along rivers and valleys in Nairobi National Park. Generally, seasonal changes have a marked effect on giraffe home range sizes where they become larger during the dry seasons and smaller during the wet seasons.

6.6.4 Conservation status of giraffe habitats

Habitat loss has had a major impact on giraffe distribution and range in Southern Kenya. As habitat loss and fragmentation occurs within giraffe ranges, there is need to assess the status of the various giraffe habitats and institute habitat management actions to restore and maintain viable giraffe habitats within its ranges. Currently, habitat conservation is focused on protected areas where KWS directs its efforts in giving intensive management to giraffe habitats inside national parks and reserves. Most of these national parks and reserves have been fenced up to mitigate against human/wildlife conflicts, thus securing critical wildlife habitats from human encroachment and eventual degradation. Such fences have been erected in Nairobi National Park, some sections of Tsavo West National Park and the Kimana wildlife sanctuary in Amboseli ecosystem.

Ecosystem conservation approach needs to be explored in securing giraffe habitats inside and outside protected areas. This will ensure that giraffe habitats in community owned lands are conserved to sustain giraffes ranging outside protected areas. The ecosystem approach will be key to promoting ecosystems connectivity for large herbivore species migrations in environments that have been modified by human impacts. The ecosystem approach of conserving giraffe habitats has been tried in areas like the Taita ranches in Tsavo ecosystem and the Group ranches in Amboseli ecosystem.

In Nairobi National Park, land easement agreements have been signed with one land owner, Honourable John Keen to set aside part of his land as a wildlife range. Similar approaches have been extended to other conservation areas neighbouring communities to start conservation activities as income generating enterprises to augment their livelihoods. This approach has improved the conservation status of giraffe and other large herbivore species in Southern Kenya.

Improving the conservation status of giraffe habitats allows giraffes forage freely between suitable habitats with preferred forage or different habitats for forage and shelter. Conservation of giraffe habitats with enhanced ecosystem connectivity between essential habitat patches has the benefit of improving giraffe genetic diversity through enhanced gene flow, enhanced meta-populations survival, create predator refuges, buffer giraffe population fluctuations due to seasonal and annual fluctuations, accommodate range shifts due to climate variations and maintain essential ecological process connectivity that include access to key resources like minerals, nutrients, dry season grazing, breeding and calving grounds.

Successful conservation of giraffe habitats needs to identify core giraffe use areas, dispersal areas and migration corridors. Giraffe habitats need prudent conservation alongside other species habitats like elephant and rhino because of their different feeding ecologies, migration strategies, body sizes, life history characteristics and vulnerability to human disturbance. Other species characteristics to be considered in giraffe habitats conservation include their spatial distribution, abundance, movement patterns and life history traits.

6.6.5 Conclusion

Availability of both forage and water resources determined giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks. Giraffe home range sizes were generally larger during the dry seasons than during wet seasons, meaning that giraffes tended to spread out and wandered far during the dry seasons in search of forage and water. Giraffes concentrated feeding along river valleys during both the wet and dry seasons. Seasonal changes do not determine giraffe habitat use and occupancy in Amboseli, Nairobi and Tsavo West National Parks. However, giraffes moved from one habitat to the other in search of forage and water. These movements may be localized and the same giraffe herds could often be located in the different habitat types in the three study sites.

6.7 Chapter summary

A two-sample Mann-Whitney (U) test performed on the wet and dry season giraffe home range sizes showed no significant difference between the two seasons giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks. In Amboseli National Park, the giraffe dry season home range sizes were similar to those of the wet season. But the wet season core activity area sizes were larger than those of the dry ones meaning that giraffes moved out of the national park and covered wider ranges during the wet seasons. In Nairobi National Park, the wet season giraffe home range sizes were almost the same size with those of the dry season, meaning that giraffe movements were restricted in the partially fenced up park. In Tsavo West National Park, the determined wet season giraffe home range sizes were larger than those of the dry season. This was contrary to the norm where dry season giraffe home range sizes were expected to be larger than the wet season ones. This meant that giraffes moved for long distances during the wet seasons than during the dry seasons as they foraged on the riverine vegetation along the Tsavo River.

Giraffes uniformly used and occupied the different habitat types in Amboseli, Nairobi and Tsavo West National Parks. Chi-squared tests showed no significant difference in giraffe numbers in the different habitat types in the three study sites. This suggested that habitat types did not determine giraffe numbers and their distribution. In Amboseli National Park, it was observed that the different giraffe age-classes were not uniformly distributed in the different habitat types. However, there was a significant difference in giraffe numbers in the different habitat types during the wet and dry seasons. In Nairobi National Park, there was no significant difference in giraffe seasonal habitat use and occupancy. This meant that seasons did not determine giraffe habitat use and occupancy in the NNP. In Tsavo West National Park, there was also no significant difference in giraffe numbers in the different habitat types. This meant that giraffes uniformly utilized and occupied the different habitat types in Tsavo West National Park. Generally, giraffes uniformly utilized and occupied the different habitat types during both the wet and dry seasons in Amboseli, Nairobi and Tsavo West National Parks.

CHAPTER SEVEN

GIRAFFE FORAGE AND WATER RESOURCES IN SOUTHERN KENYA

7.1 Introduction

Forage production is defined as the rate of change of edible biomass over a specified period of time. This is considered as the cumulative increment of new shoots (kg dry matter/hectare) below 5.75m over a given period of 3 months or 1 year when browsing is excluded. But this measure of browse production is an underestimate of the actual rate of forage production (Pellew, 1983). Available browse is the total amount of plant material produced by all woody plant species that are potentially eaten by giraffes. These comprise of all the green leaf and the young un-lignified shoots of the plants during the growth season. An adult bull giraffe feeds up to the height of 5.75m above ground level and all available biomass browse material (kg/ha) is found below this height. Biomass in the height range of 5.0-5.75m is unavailable to female giraffes (Pellew, 1983).

The survival, growth and reproduction of an ungulate is determined by its rate of nutrients intake and thus by the quantity and quality of its food supply. Evaluations of the animals’ food resource versus its population’s dynamics reflect the physiological conditions and reproductive success of the ungulates (Pellew, 1983). The effects of changes in resource availability in plant-herbivore systems were observed by Pellew (1983), who showed that as the food supply increases, herbivores respond by changing their population densities. These changes may increase as a result of the difference between the carrying capacity of the habitat and the animals present in it. For example, in the Serengeti National Park, Tanzania, the principal environmental change that affected Maasai giraffes (*G. c. tippelskirchi*) had been increase in the availability of browse. The conversion of mature Acacia woodlands to more open woodlands by elephants and fire increased forage available for giraffe throughout the year (Pellew, 1983).

Forage quality and quantity play a significant role in the abundance, distribution and seasonal movements of herbivores in both wet and dry seasons in conservation areas (McNaughton, 1990, Murray, 1995). Forage quality and quantity are limited during the dry seasons, but during the wet seasons, forage quality meets the herbivore nutritional requirements (Prins & van Wieren, 2008). Herbivore food resources vary temporally and spatially in both quality and quantity, hence eliciting herbivore seasonal movements that are related to differences in food quality, quantity and availability during both the dry and wet seasons (Murray, 1995).

Generalist feeders like giraffe can promote or maintain palatable high nutritive quality plant species with nutrient input where temporal variability or the timing of defoliation are sufficient to maintain such plant species (McNaughton, 1998). Nutrient concentration is increased in post defoliation regrowth through the replacement of older, low quality leaves by younger, high quality tissue (Hamilton, 1998). Decreased leaf nutrient concentrations are expected to be associated with decreased mineralization rates and accumulated nitrogen (N) loss from repeated burning (Blair, 1997).

Research in Serengeti National Park, Tanzania, has shown that the spatial and temporal distribution of at least seven elements is associated with resident herbivore densities (McNaughton, 1990). In particular, phosphorus (P) and sodium (Na) in above ground forage are important to herbivores as they are required to sustain pregnancies and lactation in females (Murray, 1993, 1995).

Habitat use by giraffes in the Southern Kenya is influenced by forage and water availability, predation, inter-specific and intra-specific competition, security and human influence. Giraffes will always move to habitats with available forage and water resources. Security from predators is usually a matter of great concern to giraffes, particularly those with young ones. Giraffes are usually vigilant for predators, particularly lions. Other predators of concern to giraffes are the hyenas, wild dogs and to a lesser extent leopards.

Competition for food and water resources is key to habitat use by giraffes. Both inter-specific and intra-specific competition for forage and water resources occurs to giraffes. Several browser wildlife species like elephants and rhinos compete for forage with giraffe in Amboseli, Nairobi and Tsavo ecosystems. The elephant, in particular, is a major competitor when it comes to foraging as it can access foliage above 5m, thus competing with giraffe for forage (Obari, 2009).

Successful management of African savanna ecosystems requires understanding the relationship between surface water and herbivore populations. Past studies have shown that in arid and semi-arid savannas, herbivore distribution is influenced by the location of water sources particularly during the dry season (Redfern et al., 2008; Chammaille-James et al., 2007). As the dry season progresses, these water resources become scarce and patchily distributed resulting in high levels of herbivore aggregation near water sources (Western, 1975).

High mortality in herbivore populations occurs during drought (Dunham, 1994; Dudley et al., 2001) and the creation of water holes has led to increase in herbivore populations in many protected areas and wildlife sanctuaries (Davison, 1967). Animal distributions are limited by water availability which also regulates food quality and quantity. Increased rainfall increases forage, which attracts increased wildlife numbers. Increased rainfall also accelerates the growth of quality forage and water abundance, both of which are essential for the animals physiological processes. However, too much rainfall may cause flooding that may directly or indirectly reduce animal species populations when they cannot access water logged forage. For example, the *El Nino* phenomenon of 1998 in East Africa claimed both animal and human lives that were killed by raging floods. Apart from availability of water resources, wildlife distribution and abundance vary with forage supply, seasons, presence of predators and a host of other biotic factors (Morrison et al., 1992).

Lamprey (1963), suggested that water was the most limiting factor in the number and distribution of wild animals in the savanna ecosystems of East Africa. Most water-dependent species are grazers while most browser wildlife species are water-independent (Western, 1975). Western (1975) discussed the influence of water availability and seasonality on the distribution of various wildlife species. He further provided profiles of distance to water for various species and found out that during dry seasons, most animal species were concentrated around water sources, while during the wet seasons, animals were more spread out. Availability of ephemeral water sources during the wet seasons allowed animals to disperse (Western, 1975; Anyieni, 1975).

Seasonal movements of large herbivore species between the dry and wet season ranges are attributed to water availability, pasture conditions or a combination of both (Western, 1975). Mineral salt locations also influenced animal movements and animals usually avoid those salt licks where they are most likely to be attacked by predators (Anyieni, 1975).

7.2 Scope of the study

The study assessed giraffe food and water resources in the three study sites of Amboseli, Nairobi and Tsavo West National Parks. It also assessed the relative abundance of giraffe food plants, seasonal availability of giraffe forage and surface water resources.

7.3 Researh objectives

i) To determine availability and relative abundance of giraffe forage in Amboseli, Nairobi and Tsavo West National Parks.

ii) To determine availability of surface water sources in the three study sites

7.4 Materials and methods

7.4.1 Determination of giraffe forage availability

Giraffe forage relative abundance was determined by using the Point Centered Quardrant (PCQ) method of vegetation sampling in the three study sites. Focal animal sampling was done by observing giraffe feeding on the preferred food plants. The plant species they fed on were visually identified and listed. Giraffe forage availability was determined by recording the frequency at which giraffes fed in the preferred feeding habitats.

From the listed giraffe, there was similarity in the giraffe food plants in ANP (Appendix 13), NNP (Appendix 14) and TWNP (Appendix 15). It was determined that most of the giraffe food plants were of the Acacia tree species across the three study sites. However, the food plants varied in TWNP as a number of them were of Commiphora and Combretum tree species. The similarity in giraffe food plants in the three study sites was because they were all of savanna ecosystem with similar attributes in terms of plant species diversity (Appendix 19).

7.4.2 Determination of giraffe surface water sources

Using the GPS locations, giraffe water sources were located and and mapped out. They were assessed as to whether they contained water or not. The water sources were categorized as rivers, streams, lakes, springs, swamps, water pans, water tanks and water pools. The water sources were also categorized as permanent or seasonal and their sizes determined as very large, large, medium, small or very small depending on the scaled sizes in km^2.

Seasonal availability of surface water for wildlife was assessed in the three study sites of ANP, NNP and TWNP. The assessment was based on the type of water source, size, and status and ranked in order of importance. The water sources were categorized as rivers, river channels, streams, swamps, lakes, dams, springs, bore holes, water pans and water pools. The water sources were also located using the topographical maps of the respective study sites. The water source size was categorized as very large (>20km^2), large (15-20km^2), medium (10-15km^2) and small (<10km^2). The water source status was categorized as permanent and seasonal. The water sources were categorized in order of importance which raged from very important (4), important (3), Less important (2) and not important (1) (Appendix 7).

7.5 Results

7.5.1 Giraffe forage abundance in the three study sites

There were generally more food plants eaten by giraffes during the wet season than during the dry season in Amboseli, Nairobi and Tsavo West National Parks. In ANP, 14 plant species were eaten by giraffes during the wet season as compared to 12 plant species that were eaten by giraffes during the dry season. In NNP, 38 plant species were eaten by giraffes during the wet season as compared 35 plant species eaten by giraffes during the dry season. In TWNP, 18 plant species were eaten by giraffes during the wet season as compared to only 10 plant species that were eaten by giraffes during the dry season. The small difference in the number of plant species eaten by giraffes during the wet and dry seasons in ANP (2) and NNP (3) indicated that most of the giraffe food plant species in the two study sites were perennial plants that were available for giraffes' consumption throughout the year. Meanwhile, the large difference in the number of plant species consumed by giraffes in TWNP (8) indicated that most of the food plant species eaten by giraffes in TWNP during the wet season sprouted or grew fresh foliage only during the wet season. Some of these plant species became dormant and looked dry during the dry season, a survival tactic against the desicating effects of strong winds blowing across during drought.

Using the point centered quarter (PCQ) method of vegetation sampling analysis results, this study found out that plant species with high relative frequencies (Rel.freq) meant that such plant species occurred more frequently near the sampling points. They were therefore well distributed along the sampling transect lines in the habitats where giraffes could easily access them.

In ANP the importance value index (IVI) value for the sampled giraffe food plants was 210. This was a high value which indicated high relative abundance of giraffe food plants, thus high forage abundance in ANP. In NNP the importance value index (IVI) value of the sampled giraffe food plants was 254.21. This high value suggested that NNP had a very high giraffe plant species relative abundance, hence high giraffe forage abundance. It also indicated that there was high giraffe plant species diversity and richness in NNP. This study found out that Nairobi National Park had the highest IVI of 254 followed by Tsavo West National Park (216) and Amboseli National Park (210). The high IVI for NNP indicated that NNP had the highest density of giraffe food plants, hence had the highest giraffe forage abundance as compared to either TWNP or ANP.

7.5.2 Seasonal availability of giraffe forage

Giraffe forage availability was assessed during the wet and dry seasons in Amboseli, Nairobi and Tsavo West National Parks. The vegetative state of both perennial and annual giraffe food plant species was assessed to find out what state of growth they were in. They were assessed as to whether they had shed their leaves, growing new foliage, flowering or fruiting. The degree of browsing on vegetation by giraffes was also assessed.

The percentage canopy cover of each of the giraffe food plants was determined during vegetation sampling using the point centred quadrant (PCQ) method (Kevin, 2007). The amount of canopy cover of the respective food plants was regarded as the measure of the availability of its foliage for browsing by giraffes. Generally, there was more canopy cover in giraffe food plants during the wet seasons than during the dry seasons, hence the availability of forage for giraffes.

Seasonal availability of forage for giraffes varied from one study site to the other. There was more forage availability for giraffes in Nairobi National Park (Plate 7.2) during both the wet and dry seasons than in Amboseli (Plate 7.1) and Tsavo West National Parks (Plate 7.3). Likewise, there was more forage available for giraffes during both the wet and dry seasons in Tsavo West National Park than in Amboseli National Park. The differences in forage availability for giraffes in the three study sites was demonstrated in the determined relative abundances of forage in the three sites with NNP having the highest forage relative abundance with an importance value index (IVI) of 254.21, TWNP (215.76) and ANP (210). Forage availability for giraffes in the three sites was therefore in the order of NNP > TWNP > ANP.

Plate 7.1: Giraffe feeding on Acacia vegetation in Amboseli National Park

Plate 7.2: *Acacia xanthophloea* – an important giraffe food plant in Nairobi National Park

Plate 7.3: Giraffe habitat fragmentation: Road and dry fuel wood at a camp site established in mixed Acacia - Commiphora vegetation in Tsavo West National Park.

7.5.3 Composition and availability of giraffe food plants in the three study sites

The small difference in the number of plant species eaten by giraffes during the wet and dry seasons in ANP (2) and NNP (3) indicated that most of the giraffe food plant species in the two study sites were perennial plants that were available for giraffes' consumption throughout the year. The large difference in the number of plant species consumed by giraffes in TWNP (8) indicated that most of the food plant species eaten by giraffes in TWNP during the wet season grew fresh foliage only during the wet season, thus availing foliage for giraffes to browse on. Meanwhile, Chi-squared tests performed on the number of plant species consumed by giraffes during the wet and dry seasons showed no significant difference in the three study sites ($X^2_{0.05, 2} = 1.282$, $p > 0.05$). Nairobi National Park had the greatest richness of giraffe food plants with 38 species, followed by Tsavo West National Park (18) and Amboseli National Park (14).

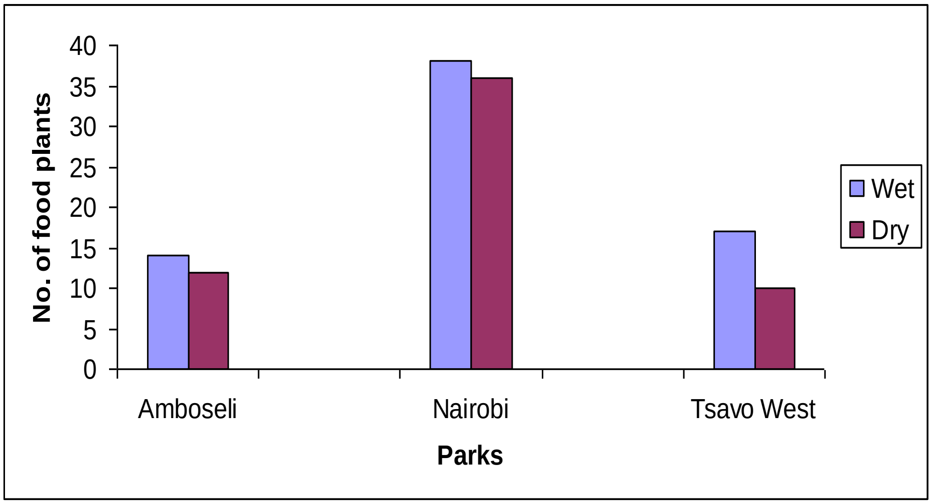


Figure 7.1: Seasonal giraffe food plant species in Amboseli, Nairobi and Tsavo West National Parks.

7.5.4 Relative abundance of giraffe food plants the three study sites

The relative abundance (RA) of giraffe food plants in ANP was determined using the point centered quarter (PCQ) method of vegetation sampling. A total of 9 different plant species were measured in ANP. The most commonly encountered plant species located nearest to the transect sampling points had high frequencies of occurrence. They equally had high densities (D) and relative densities (RD). These plant species also had high dominance (Dom.), relative dominance (Rel. Dom.) and importance value index (IVI) values.

In Amboseli National Park, *Balanites aegyptiaca* had the highest value followed by *Salvadora persica*, *Acacia tortilis*, *Azyema tetracantha* and *Balanites pendasalis* in declining order. Plant species with high relative frequencies meant that such plant species occurred more frequently nearest the sampling points. They were well distributed along the sampling transect lines in the habitats where giraffes could easily access them. The total importance value index (IVI) value for the sampled giraffe food plants in ANP was 210. This was a high value which indicated high relative abundance of giraffe food plants, thus high forage abundance for giraffes in ANP (Table 7.1 and appendix 13).

Table 7.1: Importance Value Index (IVI) of giraffe food plants in Amboseli National Park.

Species	**No. ind.**	**Freq.**	**Density**	**Dom.**	**Rel. dom.**	**Rel.den.**	**Rel. freq**	**IVI**
Acacia tortilis	18	5.81	2.00	0.84	1.69	6.95	11.76	24.53
Azyema Tetracantha	17	18.02	6.20	0.08	0.51	2.09	11.11	31.22
Balanites aegyptiaca	51	42.73	14.70	0.01	0.08	0.33	33.33	76.39
Balanites glabra	1	0.29	0.10	0.00	0.00	0.00	0.65	0.94
Balanites pendasalis	12	5.81	2.00	0.04	0.08	0.33	7.84	13.99
Caparis tomentosa	3	0.87	0.30	0.00	0.00	0.00	1.96	2.83
Mailua endrichii	3	1.74	0.60	0.00	0.00	0.00	1.96	3.71
Mailua trifolia	1	0.29	0.10	0.00	0.00	0.00	0.65	0.94
Salvadora persica	41	22.09	7.60	0.01	0.07	0.29	26.80	49.18
Unidentified	6	2.33	0.80	0.00	0.00	0.00	3.92	6.25
Grand Total	**153**	**100.00**	**34.39**	**0.07**	**2.43**	**10.00**	**100.00**	**210.00**

Key: No. ind. – Number of individuals, **Freq**.-Frequency, **Dom**.-Dominance, **Rel. dom**.-Relative dominance, **Rel. den**.-Relative density, **Rel. freq**.-Relative frequency, **IVI**-Importance Value Index.

In NNP, plant species of *Acacia geradii, Acacia xanthophloea, Acacia kirkii, Acacia tortilis, Dovyalis caffra* and *Acacia hockii* recorded high values. These plant species were more frequently encountered nearest to the sampling points. They were also well distributed within the giraffe habitats and were easily accessed by giraffes. The total importance value index (IVI) of the sampled giraffe food plants in NNP was 254.21. This was comparatively a very high value which indicated very high giraffe forage relative abundance, hence high giraffe forage abundance (Table 7.2 and Appendix 14).

Table 7.2: Importance Value Index (IVI) of giraffe food plants in Nairobi National Park.

Species	**No.ind.**	**Freq.**	**Density**	**Dom.**	**R.dom.**	**Rel.den.**	**Rel. freq.**	**I.V.I**
Acacia abysinica	5	0.02	0.02	0.80	0.01	1.56	2.00	4.36
Acacia aegyptiaca	4	0.01	0.02	0.64	0.01	1.25	1.00	2.89
Acacia brevispica	8	0.03	0.04	1.28	0.01	2.50	3.00	6.78
Acacia drepanolobium	2	0.01	0.01	0.32	0.003	0.63	1.00	1.95
Acacia. geradii	51	0.16	0.23	8.17	0.07	15.94	16.00	40.11
Acacia glabra	9	0.03	0.04	1.44	0.01	2.81	3.00	7.25
Acacia hockii	19	0.06	0.08	3.05	0.03	5.94	6.00	14.99
Acacia kirkii	47	0.15	0.21	7.53	0.07	14.63	15.00	37.20
Acacia mellifera	14	0.04	0.06	2.24	0.02	4.38	4.00	10.62
Acacia nilotica	9	0.03	0.04	1.44	0.01	2.81	3.00	7.25
Acacia senegal	1	0.003	0.005	0.16	0.001	0.31	0.30	0.78
Acacia tortilis	33	0.10	0.15	5.29	0.05	10.31	10.00	25.60
Acacia xanthophloea	48	0.15	0.21	7.69	0.07	15.00	15.00	37.69
Balanites aegyptiaca	4	0.01	0.02	0.64	0.01	1.25	1.00	2.89
Balanites glabra	3	0.01	0.01	0.48	0.004	0.94	1.00	2.42
Caparis tomentosa	2	0.01	0.01	0.32	0.003	0.63	1.00	1.96
Commiphora africana	1	0.003	0.005	0.16	0.001	0.31	0.30	0.78
Cordia monoica	10	0.03	0.04	1.60	0.01	3.13	3.00	7.73
Dovyalis caffra	19	0.06	0.08	3.05	0.03	5.94	6.00	14.99
Lantana camara	2	0.01	0.01	0.32	0.00	0.63	1.00	1.95
Lipia sp.	5	0.02	0.02	0.80	0.01	1.56	2.00	4.36
Maytenus senegalensis	1	0.003	0.005	0.16	0.001	0.31	0.30	0.78
Phyllanthus. sepialis	5	0.02	0.02	0.80	0.01	1.56	2.00	4.36
Unidentified.	18	0.06	0.08	2.89	0.03	5.63	6.00	14.52
TOTAL	**320**	**1.00**	**1.45**	**51.29**	**0.47**	**100.00**	**100.00**	**254.21**

In Tsavo West National Park, the plant species *Acacia tortilis, Comiphora africana* and *comiphora capestris* had high importance value index (IVI) values in that declining order. The plant species were easily encountered nearest the transect sampling points. They were also well distributed within the sampled giraffe habitats and easily accessed by giraffes. The total importance value index (IVI) value of the sampled giraffe food plants in TWNP was 215.76. This was a comparatively high value that indicated high giraffe forage abundance that was second to that of NNP of the three study sites (Table 7.3 and appendix 15).

Table 7.3: Importance Value Index of giraffe food plants in Tsavo West National Park.

Species	**No. Ind.**	**Freq.**	**Density**	**Dom.**	**Rel. dom.**	**Rel. den.**	**Rel. freq.**	**IVI**
Acacia drepanolobium	1	0.16	0.16	0.00	0.00	0.00	0.27	**0.33**
Acacia brevisfica	1	0.16	0.16	0.00	0.00	0.00	0.27	**0.33**
Acacia mellifera	10	2.94	2.84	0.01	0.01	0.17	2.67	**6.06**
Acacia nilotica	1	0.16	0.16	0.00	0.00	0.01	0.27	**0.33**
Acacia senegal	7	1.31	1.26	0.04	0.04	0.52	1.87	**3.13**
Acacia seyal	1	0.16	0.16	0.03	0.00	0.05	0.27	**0.38**
Acacia spp	1	0.16	0.16	0.00	0.00	0.01	0.27	**0.34**
Acacia tortilis	9	41.83	0.6	0.02	0.69	8.05	31.73	**91.71**
Acacia xanthophloea	2	0.33	0.32	0.12	0.04	0.44	0.53	**1.09**
Balanitis aegyptiaca	5	1.47	1.42	0.02	0.02	0.29	1.33	**3.23**
Casia abbreviate	2	0.33	0.32	0.00	0.00	0.00	0.53	**0.66**
Codia monoica	2	0.49	0.47	0.00	0.00	0.01	0.53	**0.99**
Combretum spp	2	0.82	0.79	0.00	0.00	0.04	0.53	**1.67**
Commiphora africana	71	16.83	16.4	0.01	0.20	2.31	18.93	**35.97**
Commiphora baluensis	3	0.49	0.47	0.02	0.01	0.09	0.80	**1.07**
Commiphora campestris	39	8.50	8.20	0.02	0.16	1.93	10.40	**18.92**
Commiphora schemperi	22	4.74	4.57	0.01	0.06	0.74	5.87	**10.21**
Commiphora spp	13	5.72	5.52	0.01	0.04	0.41	3.47	**11.85**
Dalbergia melanoxylon	10	1.63	1.58	0.00	0.00	0.05	2.67	**3.32**
Grewia bicolor	4	0.82	0.79	0.00	0.00	0.00	1.07	**1.64**
Grewia similis	1	0.16	0.16	0.00	0.00	0.00	0.27	**0.33**
Lannea schweinfurthii	7	1.14	1.10	0.02	0.02	0.22	1.87	**2.50**
Lannea triphylla	37	7.35	7.10	0.00	0.03	0.34	9.87	**15.05**
Leuchocarpus eriocarlyx	4	0.65	0.63	0.00	0.00	0.02	1.07	**1.33**
Mellia volkensii	1	0.16	0.16	0.00	0.00	0.01	0.27	**0.33**
Omocarpus kirkii	5	0.82	0.79	0.00	0.00	0.00	1.33	**1.64**
Raus natalensis	1	0.16	0.16	0.02	0.00	0.04	0.27	**0.37**
Sterculia africana	1	0.16	0.16	0.00	0.00	0.00	0.27	**0.33**
Unidentified	2	0.33	0.32	0.00	0.00	0.00	0.53	**0.65**
TOTAL	**371**	**99.98**	**96.56**	**0.33**	**2.32**	**21.84**	**100.03**	**215.76**

7.5.5 Seasonal patterns of availability of giraffe food plants

There were generally more food plants available for giraffes during the wet seasons than during the dry seasons in the three study sites. Most of the available food plants were the perennial plant species that were available throughout the year. Those food plants that only became available for giraffes during the wet seasons were the annuals and of herbaceous or shrub types. In Tsavo West National Park, some of the perennial food plant species became available for giraffes during the wet seasons when they sprouted foliage but shed their leaves on the onset of the dry seasons. Such plants looked dry and dead during the dry seasons, but in actual sense they were much alive and only went into a state of dormancy to avoid the severity of the dessicating effects of the dry seasons.

Most of the giraffe food plants were found in the riverine vegetation along the river valleys during the dry seasons. During the wet seasons, the giraffe food plants were spread across the preferred giraffe habitats where giraffes foraged on them. Most giraffe forage was found in the woodland vegetation during the dry seasons, while during the wet seasons they were found foraging in all the available habitats in the three study sites. Some herbaceous giraffe food plants were found in the swamps and dry river beds during the dry seasons. Hence giraffes went to forage on them despite the soggy conditions in the swamps and river beds.

Stiff inter-specific competition for forage between giraffes and elephants was experienced in TWNP and between giraffes and rhinos in NNP. Stiff competition for forage between elephants and giraffes occurred in ANP. There are no rhinos in Amboseli National Park to compete with giraffes for forage (Table 7.4).

Table 7.4: Number of key competitor browser species in ANP, NNP and TWNP.

Species	Amboseli N. Park ($392km^2$)	Nairobi N. Park ($117km^2$)	Tsavo West N. Park ($9065km^2$)	Ngulia Sanctuary ($92km^2$)
Giraffe	130	200	800	20
Elephant	1292	0	2142	0
Rhino	0	70	17	60

7.6 Distribution of surface water sources

Until the mid-1980's, changes in the main Amboseli swamps were linked to the regional changes in the seasonal and longterm rainfall patterns. The expansion of the Enkong Narok-Simek swamp in the 1950's was attributed by the then park wardens to the tectonic plates' movements. But Western (2006) attributed the expansion of the swamps to decadal increase in rainfall that had led to the rise in the water table across the entire Amboseli basin and the expansion of the Longinye as well as Enkong Narok-Simek swamps (Western, 2006).

The contraction of the swamps in the 1970's was attributed to the severe drought then. In the 1980's, the expansion and extensive seasonal flooding was only experienced in Longinye swamp which was then attributed to internal re-charging associated with vegetative changes (Mufflin, 1993). More small swamps emerged in the former woodland areas since the 1970's and the structure and composition of vegetation changed considerably. The tall sedges were heavily grazed down by both wildlife and livestock and the tall dominant sedges like *Cyperus immensus* were replaced by small sedges.

Nairobi National Park presents a gently undulating gradient from high elevations around woodland areas in the north-west (1790 m) to mosaic grasslands of lowland plains in the south - east (1508 m). The Mokoyiet River forms the main tributary discharging water into the Mbagathi River and drains the upper reaches of the park. Other small tributaries that drain the lower reaches of the park are the Sosian, the Donga and the Bomas streams. Several seasonal streams traverse the park along the north - east axis. With the exception of the Mbagathi River, which forms the southern boundary of the park, most of the rivers inside the park dry up during the dry seasons.

Tsavo West National Park is a water source scarce ecosystem. The only available water sources in the park are the permanent Tsavo River which drains across the park from west to east, Mzima springs located in the western part of the park and Lake Jipe which is located in the southern tip of the park. Other water sources are the 12 scooped dams that were strategically located as rain flood water catchments to provide water to wildlife during the dry seasons (Plate 7.4). Water is also piped from the Mzima springs to the Kilaguni and Severin lodges water points and Komboyo park headquarters. Water is piped from the Tsavo River to the Ngulia Rhino Sanctuary to provide water for giraffes and rhinos that are enclosed within the sanctuary.

Plate 7.4: Water pan at Komboyo in Tsavo West National Park Headquarters

Provision of water has been assumed to be beneficial to wildlife particularly during the dry seasons and in areas where surface water is scarce. Degradation of naturally occurring water sources resulting from human activities leads to decreased surface water available to wildlife. Artificial provision of water is designed to serve as perennial sources of water for wildlife and can be man-made or natural (Dolan, 2006). Among herbivores, dependence on free standing water and rates of forage consumption are associated with moisture content of forage (Jaman, 1973). Kenya Wildlife Service, a statutory government agency mandated to manage wildlife resources in Kenya has provided additional sources of water for wildlife by scooping several dams and water pans in Nairobi and Tsavo West National Parks (Personal Observation).

Biological factors most likely to affect water quality at natural or artificial water sources are as a result of high temperatures, high evaporation rates, contamination by animal fecal material or other organic matter and infrequent flushing during the dry season (Broyles, 1995). Surface evaporation of water raises the ionic concentration of already mineralized water that eventually becomes saline in nature and therefore detestable for wild animals' consumption.

The closed nature of Amboseli basin has created the expanding and contracting habitats of perennial marsh , ephemeral marsh and short term inundated seasonal run-off and direct rainfall ponds. The flat nature of Amboseli National Park, particularly in areas north of Longinye swamp and the margins of Lake Amboseli cause small seasonal changes in water volumes that spread over large areas and create a variety of seasonal habitats for grazing herbivores (Croze, 2007). Generally, Amboseli National Park is well watered as it has huge swamps that are permanently water logged. The swamps hold large amounts of water throughout the year and act as permanent surface water sources for both wildlife and livestock. The central part of the park contains most of the large swamps of Enkong Narok, Ol Tukai and Longinye. The Amboseli swamps are contiguous with one another and distribute water from the high elevation areas of Ol Dare and Amboseli Serena lodge to the central parts of the park of lakes Kioko and Konch.

During the rain seasons, huge volumes of water from Mt. Kilimanjaro enter Amboseli basin as storm water through the Ol Dare swamp. Storm waters from the Chyulu hills catchment enters Amboseli basin through Kitirua and Namelok areas and drain into the Ol Tukai swamp which retains large volumes of water within the basin. The only river systems that drain into the Amboseli basin from the north are the seasonal Namanga River which originates from the Namanga hills catchment area and the surrounding hills. To the west of the park drains the Isinet channel which originates from highland areas of Mt. Longido in Tanzania. All these seasonal rivers empty their waters into the seasonal Lake Amboseli, thus flooding the area during the rain seasons. From these water sources, Amboseli National Park holds large volumes of water throughout the year, thus providing permanent water sources for both wildlife and livestock.

Rivers and streams running across Nairobi National Park drain into the Mbagathi River and give it a perennial river status that maintains a permanent flow throughout the year. But during times of extreme drought, the Mbagathi River breaks its flow and forms water pools like the Hippo pools which hold large volumes of water during drought periods. Such pools of water become essential watering points for both wildlife and livestock during drought periods. Other water sources that drain into Nairobi National Park river systems are sewerage drains from the Carnivore restaurant which discharge their effluence into the hyena dam that holds large volumes of water throughout the year. Man made water pans have been scooped in NNP to supplement water for wildlife.

Tsavo ecosystem is virtually the main rainfall catchment area for much of Southern Kenya. The permanent Tsavo River traverses the northern part of Tsavo West National Park from the West to the East and serves as the only source of surface water for wildlife in the ecosystem. The Mzima springs which are found on the extreme west edge of northern Tsavo West National Park serve as the main source of water for wildlife and also supply water to the city of Mombasa. Additional water sources for giraffes have been provided in the form of scooped dams and water pans.

Amboseli National Park is found within the Amboseli basin which lies in the rain shadow of Mt.Kilimanjaro and has a closed drainage system. The park’s water source is mainly from the springs that form Enkong Narok-Simek, Longinye, Ol Dare and Ol Tukai swamps. Melting snow and rainfall from Mt. Kilimanjaro flows and infiltrates the porous lava terrain to reach the lower foot hills before emerging in the Amboseli basin as permanent springs and swamps (Mifflin, 1993). There are no perennial streams flowing from Mt. Kilimanjaro into the Amboseli basin. Giraffe water sources in Amboseli National Park are found in the southern and middle part of the park running laterally from north-west to south-east of the basin (Figure 7.2 and Appendix 7).

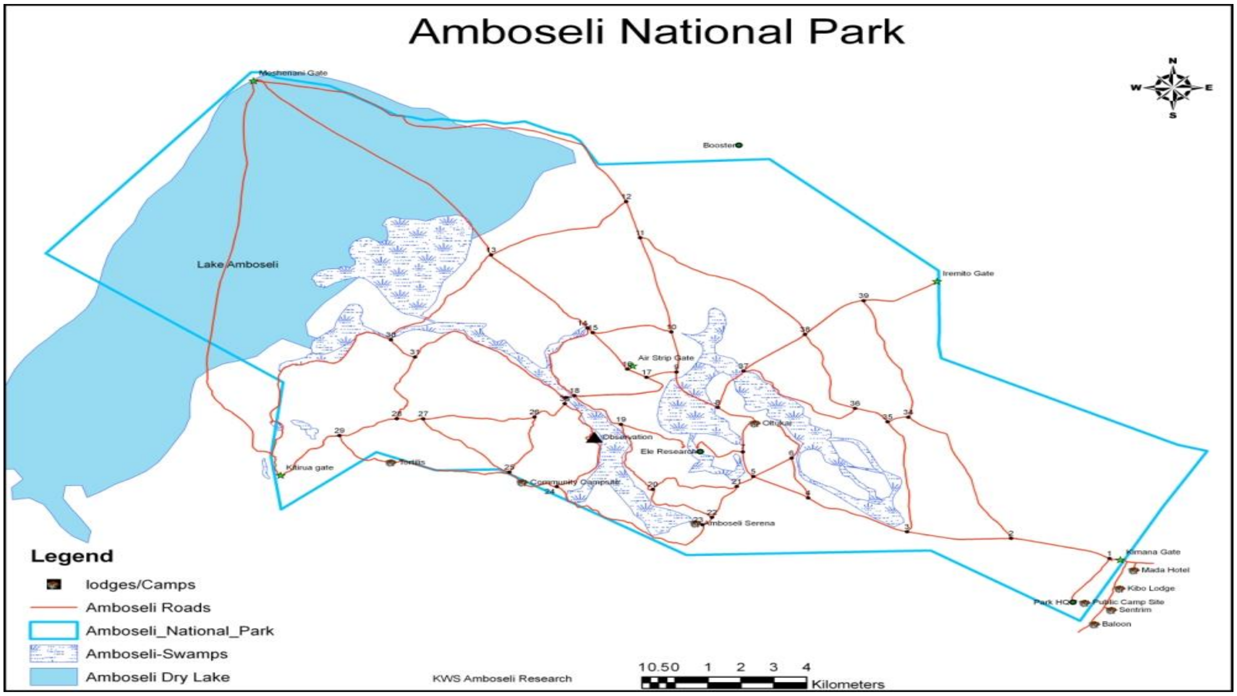


Figure 7.2: Giraffe water sources in Amboseli National Park.

Source: KWS GIS Lab.

Because of the seasonality of water sources in Nairobi National Park, Kenya Wildlife Service has dug a total of 15 dams located in different parts of the park to serve as wildlife water sources during the dry season. With both permanent and seasonal rivers criss-crossing the park, Nairobi National Park has adequate water supply to serve the large wildlife populations that concentrate in the park, during the dry seasons of the year. Other water drains are those through culverts from remnant woodlands in the compounds of Catholic University of Eastern Africa (CUEA) and those from the Bomas of Kenya (BoK) and the Wildlife Clubs of Kenya (WCK). The Mokoiyet River that originates from Ololua forest in Karen area is a perennial river and supplies large volumes of water to Nairobi National Park. With rivers Mbagathi and Mokoiyet originating from the Ngong hills catchment, the park has adequate water supply that is augmented by man-made dams located in different parts of the park, thus providing water sources for the wildlife (Figure 7.3 and Appendix 8).

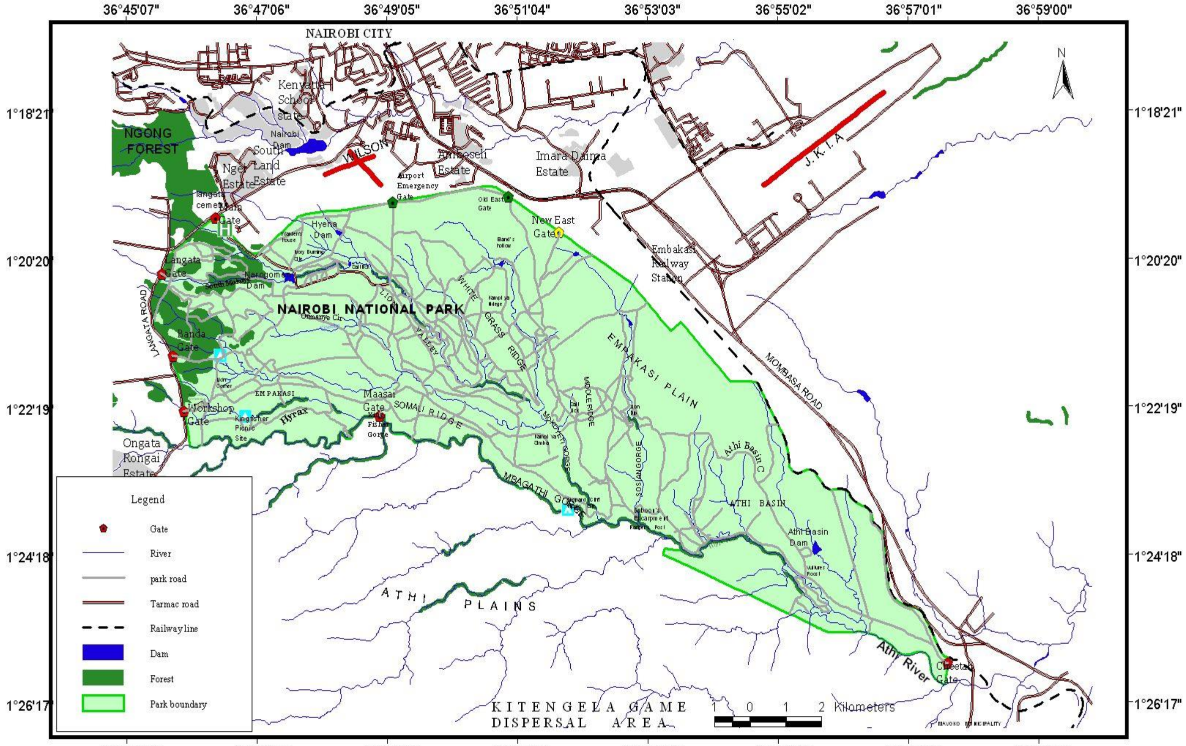


Figure 7.3: Giraffe water sources in Nairobi National Park.
Source: KWS GIS Lab.

Because of the arid nature of Tsavo West/Chyulu Hills ecosystem, Kenya Wildlife Service surveyed the Tsavo ecosystem and mapped out strategic locations to dig dams to trap rain water for use by wildlife during the dry seasons. Water is also pumped into some watering points at Komboyo park headquarters and Ngulia Rhino Sanctuary for use by wildlife. In addition to these, a total of 12 dams were scooped in the northern part of TWNP. 13 more dams are located in the central part of Tsavo East National Park. With these water sources, giraffes and other wildlife species that are water dependent do not move for long distances in search of water (Figure 7.4 and Appendix 9).

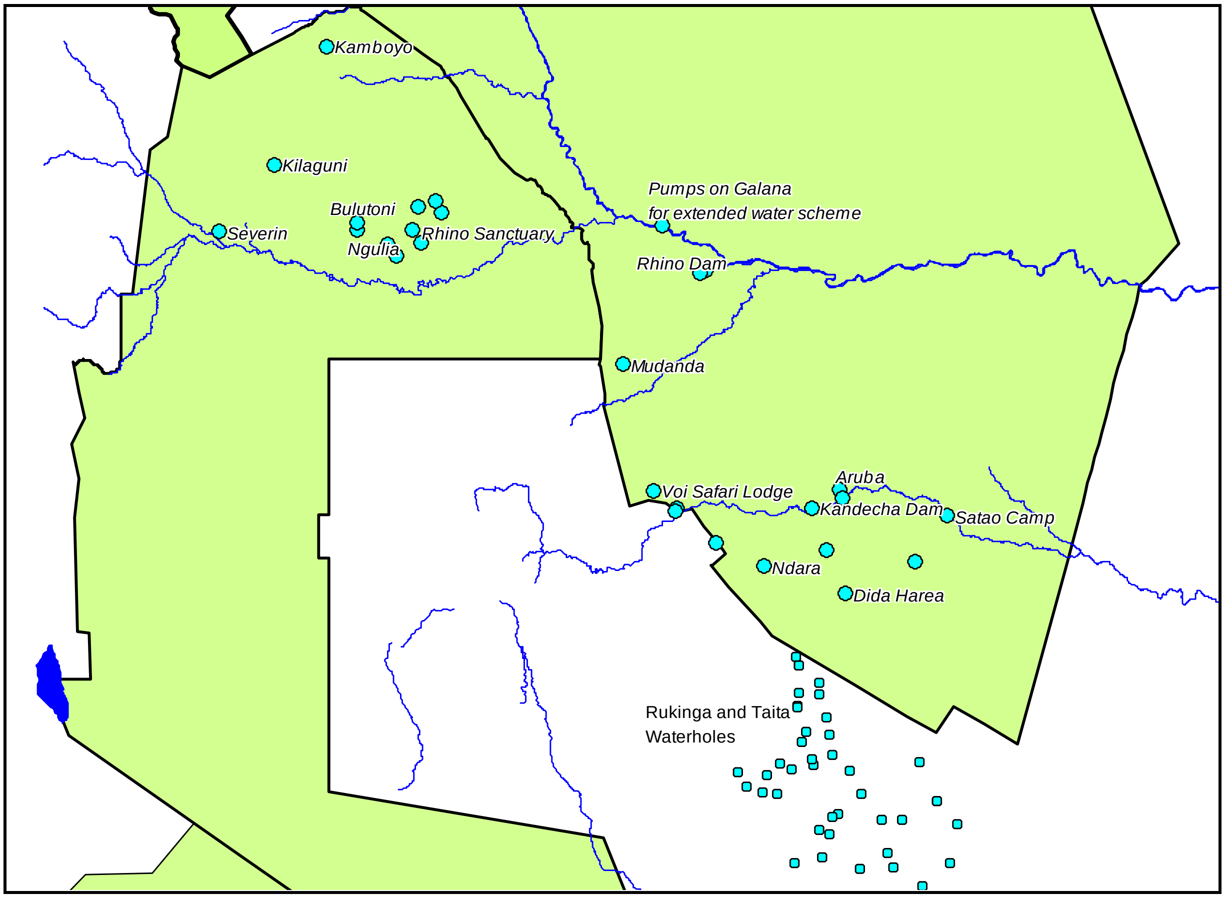


Figure 7.4: Giraffe water sources in Tsavo West National Park (Left) and Tsavo East National Park (Right).

Source: KWS GIS Lab.

7.6.1 Seasonal patterns of distribution of surface water sources

There were more water sources during the wet seasons than during the dry seasons in the three study areas. There are usually increased volumes of water in both rivers and streams in Nairobi and Tsavo West National Parks. Pattens of water sources distribution in ANP is almost the same during both the wet and dry seasons. The permanent swamps in the Amboseli basin hold substantial amounts of water throughout the year. A slight difference in water sources distribution occurs during the wet seasons when the seasonal Lake Amboseli fills up with flood waters from the Namanga River which originates from the Namanga hill to the north of the park and the Isinet channel which originates from Mt. Longido in northern Tanzania.

Other notable changes in water sources distribution are the expansion of the Ol Dare and Ol Tukai swamps with flood waters flowing from the slopes of Mt. Kilimanjaro and the high elevation areas of Iremito hills. During the dry seasons, the swamps shrink in size with the seasonal Lake Amboseli drying up completely. This leaves only the main water sources in the main swamps of Enkong Narok, Longinye, Serena, Ol Dare, Ol Tukai and lakes Kioko and Konch where giraffes go for water (Fig. 7.5).

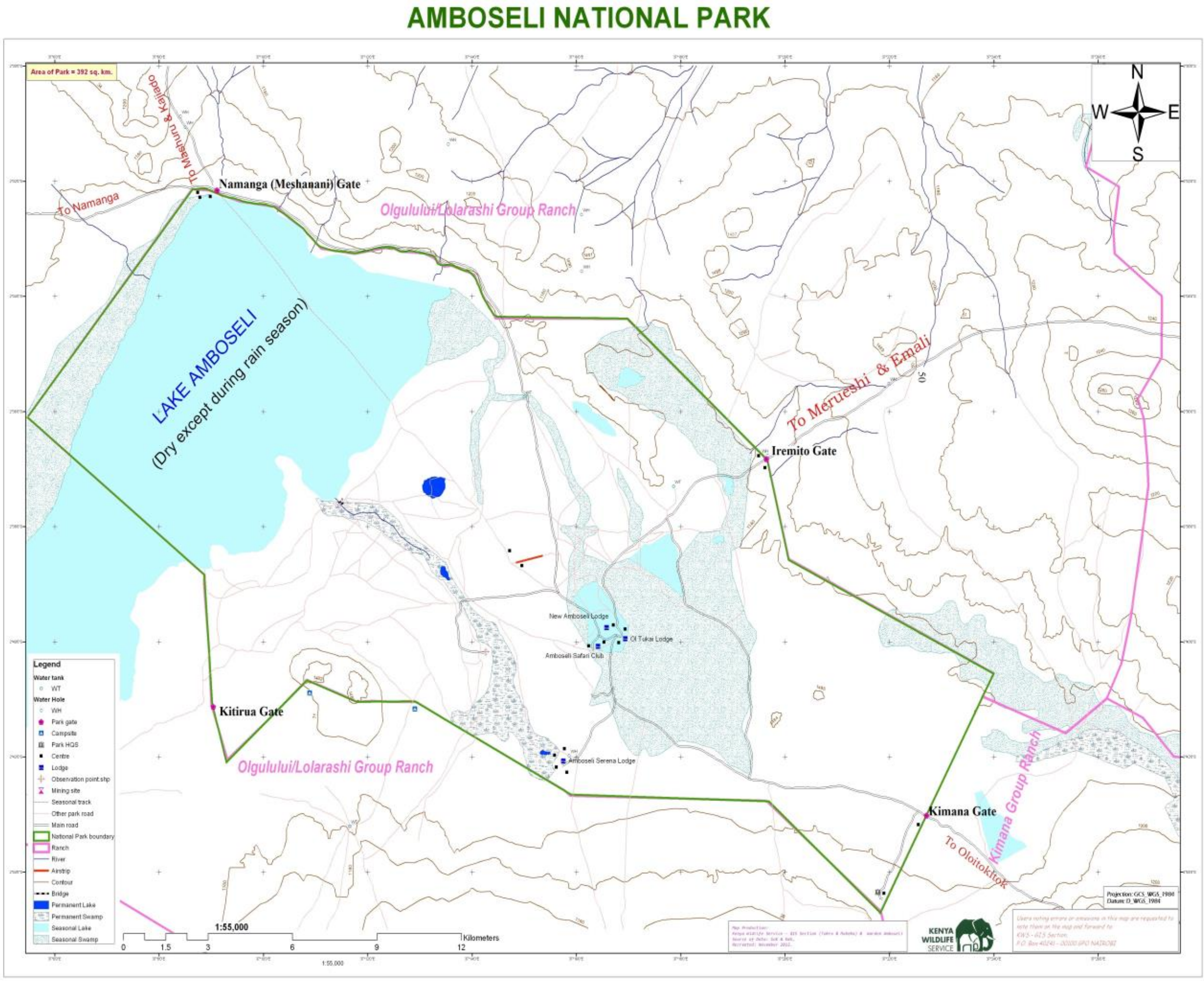


Figure 7.5: Dry season wildlife water sources in Amboseli National Park.

Source: KWS GIS Lab.

Rainfall received in the high elevation Ngong hills catchment area fills the rivers which discharge their waters into the Mbagathi, Mokoyiet, Sosian, Bomas and Songa rivers. These rivers empty their waters into the main Mbagathi River that empties its waters into the Athi River that drains through the Athi-Kapiti plains providing drinking water for giraffes and other wildlife species found within this ecosystem (Fig 7.3).

During the dry seasons, most of the streams flowing through NNP dry up leaving dry river beds. During this time, water will only be found in the permanent rivers of Mbagathi, Mokoyiet, Sosian, Songa and Bomas. Other permanent water sources are the man made Longomon, Hyena and Athi plains dams that are located in different parts of the park. Water sources can also be found in ponds in forest glades, salt licks and the 15 dug up dams (Figure 7.6).

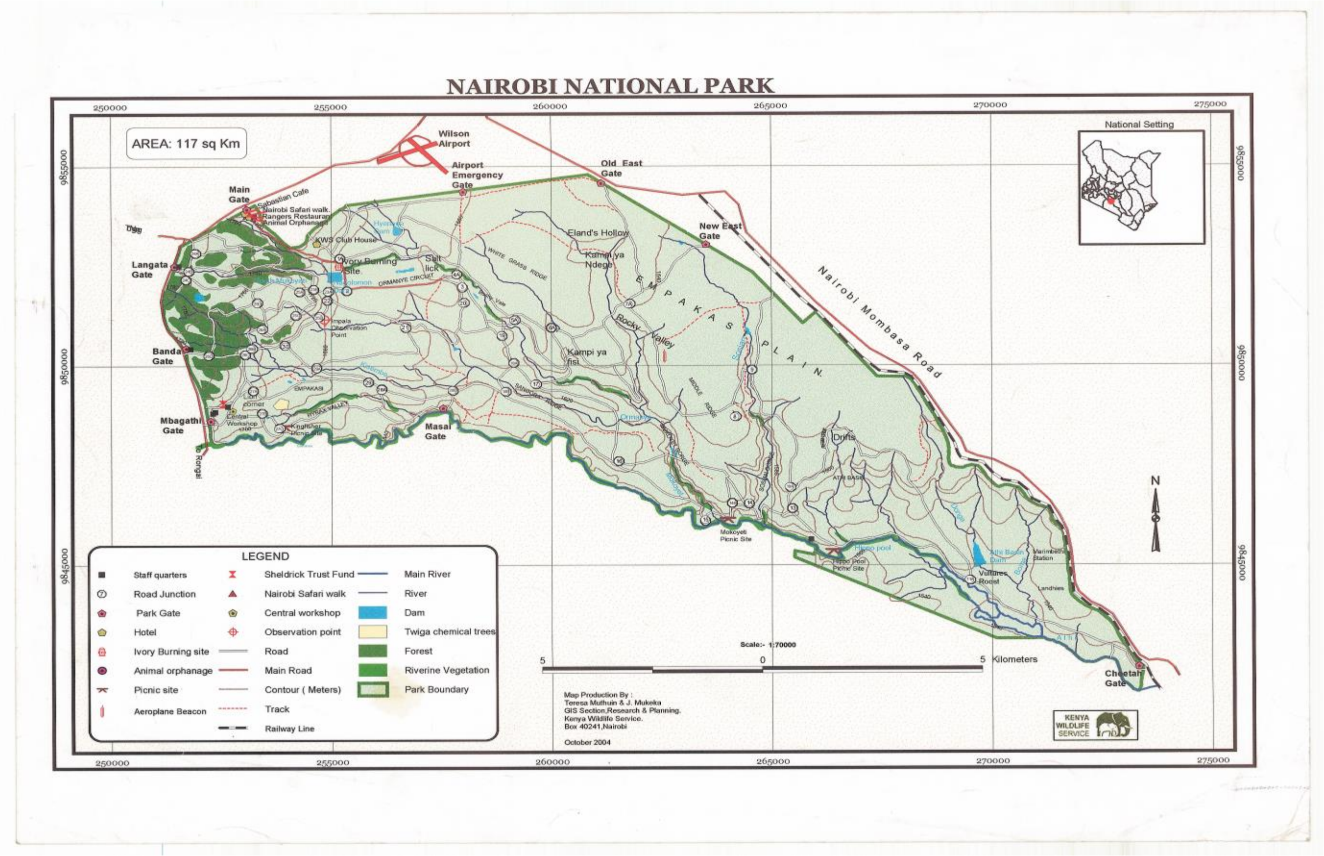


Figure 7.6: Dry season giraffe water sources in Nairobi National Park.
Source: KWS GIS Lab.

In the Tsavo West National Park, the main giraffe water sources are the permanent Tsavo River which drains across the park from the west to east. Other permanent water sources are the Mzima springs to the west of the park and Lake Jipe which is located in the southernmost part of the park. During the wet seasons, additional water sources will be found in the 12 scooped dams and a series of water pans and tanks (Fig. 7.7).

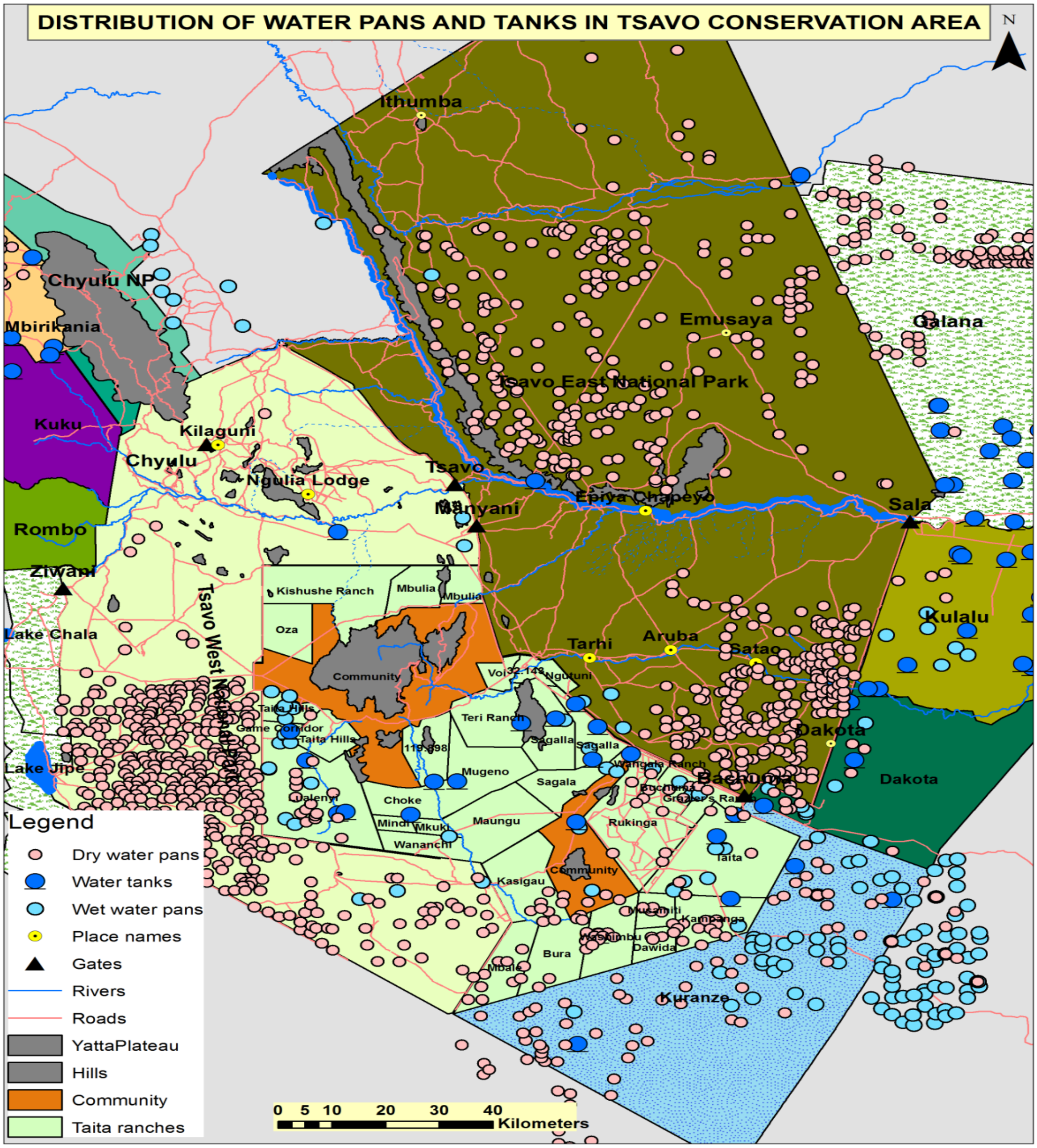


Figure 7.7: Wet season giraffe water pans and tanks in Tsavo conservation area.

Source: KWS GIS Lab.

7.6.2 Availability of surface water resources in the three study sites

Amboseli National Park had moreless constant amounts of available surface water during both the wet and dry seasons, except for the seasonal Lake Amboseli whose surface water is only available during the wet season after receiving flood waters from the seasonal Namanga River which originates from the Namanga hill and the Isinet channel from Mt. Longido in Tanzania. The Amboseli basin has a good supply of surface water from its large swamp springs which serve as permanent water sources for giraffes. The large swamps of Enkong Narok-Simek, Longinye, Ol Dare, Ol Tukai and Amboseli Serena lodge hold large volumes of water throughout the year. The Enkong Narok swamp directs its water into the Longinye swamp which then channels its water into the man made Lakes Kioko and Konch which hold large volumes of water throughout the year, hence its availability during both the wet and dry seasons of the year.

Availability of surface water in Nairobi National Park during the wet season is through the permanent Mbagathi, Mokoyiet, Sosian, Donga and Bomas rivers which originate from Ngong hills catchment. These rivers act as permanent water sources for giraffes during both the wet and dry seasons of the year. In addition to these, there are numerous seasonal streams which only flow during the wet seasons and dry up during the dry seasons. The man made Longomon, Hyena and Athi plains dams hold large volumes of water throughout the year. Additional 15 dams have been dug up in strategic locations of the park to augument surface water supplies for wildlife during the dry seasons.

Tsavo West National Park is the most surface warter scarce area of the three sites. The Ketani – Severin river which originates from Mt. Kilimanjaro feeds its waters into the Mzima springs which then release its waters into the Tsavo River. Lake Jipe, Mzima Springs and Tsavo River serve as permanent sources of surface water for giraffes during both the wet and dry seasons. Since the vast ecosystem has no other sources of surface water, KWS has dug up a toal of 12 dams in strategic locations of the park to serve as watering points for wildlife during the dry seasons. Water has also been piped from Severin River which originates from the Mzima springs to supply water to Severin lodge. Kilaguni lodge and Komboyo park headquarters have bore holes which serve as water sources for both human and wildlife use. Water is pumped from these two points to nearby dams to supply water for wildlife consumption. Water has also been piped from Tsavo River to Ngulia Rhino Sanctuary for consumption by giraffes and rhinos residing in the sanctuary.

7.7 Discussion and conclusion

7.7.1 Factors influencing food access by giraffes

Competition for forage and water resources are bound to increase in the study area as these ecosystems are experiencing increase in both elephant and giraffe numbers against reducing space for the two species due to habitat loss, fragmentation and constriction. Because of the intensity of human /wildlife conflicts, more elephants and giraffes are increasingly being confined in protected areas by use of electric fencing. At the same time displaced giraffes from their traditional ranges outside protected areas are moving into protected areas for forage, water and security.

Vegetation changes in Amboseli ecosystem also influence food acces by giraffes. Long term vegetation monitoring in Amboseli basin showed extreme changes in Amboseli National Park in halve a century (Western, 2005). The notable changes were that woodlands contracted from 30% of the area to less than 10% and had been replaced by Sueda/Salvadora scrub and grassland. The dense bushes fringing the Amboseli basin had been thinned and replaced by bush/shrub vegetation. The permanent swamps increased three fold in area and spread north-east across the basin towards the seasonal lake Amboseli (Western, 2007), thus reducing the amount of forage that giraffes can access.

The Amboseli ecosystem vegetation changes were consistent with the trends earlier documented by Western (1973), where he showed that 75% decline in *Acacia xanthophloea* woodlands between 1950 and 1967 and projected the disappearance of the woodlands in the following decade. Western (1973) attributed woodland loss and replacement by xeric scrub and halophytic grasses to salinization of the Amboseli basin. He also observed that this situation was further accelerated by increasing rainfall and rising water table.

The concentration of elephants in Amboseli National Park also contributed to loss of woodlands, thus affecting giraffe browse base. Western (1973) showed that the death of *Acacia xanthophloea* woodland was a sign of the widespread shift to drier (xeric) vegetation in the Amboseli basin which has continued since then. By then, wild animal species counts in the Amboseli basin indicated a significant increase in Zebra, elephant, Ostrich and waterbuck, but with a significant decrease in Kongoni, Thomson’s gazzel, Impala, Eland, Giraffe, Rhino and Kudu numbers. Maasai community settlements also increased with increased traditional settlements of thatched huts and tin roofed houses. These affected giraffe habitats and pushed giraffes to the periphery of the ecosystem to seek forage.

Loss of woodlands in Amboseli National Park is similar to widespread losses across the African savanna parks (Laws, 1970, Cumming, 1997). The reasons for woodlands loss in Amboseli include climate change, fires and herbivory. Dublin (1990) pointed out the difficulty of identifying specific causes of woodland vegetation decline in Amboseli National Park. Fires are rare in Amboseli due to the patchy vegetation that is broken by large alkaline pans (Western, 1973). In the absence of fires, elephants played a major role in woodland vegetation decline in Amboseli basin. The changes of woodland and grassland habitats, mediated by elephants and livestock grazing have been linked to the creation of tapestry habitats in Amboseli over many years (Western, 1997) and influence access of forage by giraffes .

High elephant densities inside the park have over the years creatd open grassland conditions dominated by grazing ungulates, while outside the park, high livestock densities create dense woodlands favored by browsing ungulates. This makes giraffes move out of the park to browse on dense woodlands while livestock get into the park to graze on lush grassland vegetation (Western, 1989). The salinization hypothesis predicted that woodlands would regenerate as the water table and salinity levels dropped. This hypothesis could not stand as woodlands loss increased during the severe droughts experienced in the Amboseli basin in the 1970’s.

When experimental plots were used as exclosures to exclude large herbivores from browsing on woodland vegetation, elephants were found to be primarily responsible for woodland loss in the

Amboseli basin (Western & Maitumo, 2004). Altmann et al., (2002) longterm (30 years) rainfall monitoring showed that there had been no significant reduction in mean annual rainfall amounts, thus, dispelling the climate based hypothesis. Neither climate nor salinity were significant factors contributing to woodlands loss and reduction of forage for giraffes in Amboseli basin.

7.7.2 Effects of seasonal patterns of food availability

The high level of rhino, elephant and giraffe browsing combined with a period of low rainfall has a retarded growth of *Acacia drepanolobium* trees in Southern Kenya. For example, in Tsavo West National Park, elephants tended to remove mature trees taller than 3m which were not replaced first enough from the lower classes due to browsing pressure from giraffes (Oloo et al., 1994). Intra-specific competition among giraffes stresses mature trees to the extent that they become susceptible to death particularly during low rainfall periods. Prolonged browsing of more than 10 years by giraffes causes long term damage to trees that may not be reversed unless there is a protracted period of growth under very low or no giraffe browsing pressure on its habitats (Birket & Stevens-woods, 2005). Giraffe browsing pressure on *Acacia drepanolobium* tree species has led to stunted growth of this tree species in Nairobi National Park (Personal observation).

Inter-specific competition between elephants and giraffes can be reduced as elephants can eat a mixture of grass and browse in the wet season but increased browse proportion during the dry season (Field & Ross, 1976; Dublin, 1995). Similarly, rhinos will eat more woody plant items as opposed to giraffes that will eat plant shoots when availability of herbaceous plant species decreases during the dry periods. When the density of grazers in an enclosed system is high during the dry seasons, elephants are forced to switch to trees and seedlings, hence destroying more trees (Oloo et al., 1994). This act by elephants has been experienced in Amboseli and Tsavo West National Parks where most trees of the Acacia species have been destroyed by elephants (Personal observation).

Apart from inter-specific competition for forage by giraffes, elephants and rhinos, there is intra-specific competition for forage among the giraffes themselves. Competition for forage from elephant and rhino is mostly felt in Tsavo West National Park while stiff competition between giraffe and elephant for browse is experienced in Amboseli National Park. Competition for forage between giraffe and rhino is only felt in Nairobi National Park. There is no competition for forage between rhinos and giraffes in Amboseli National Park as there are no rhinos in the Park since they were removed from Amboseli National Park in the late 1980's by the then Wildlife Conservation and Management Department (WCMD) (Obari, 2009).

7.7.3 Factors influencing water availability and access by giraffes

The amount of rainfall received in a given ecosystem determines the hydrology and availability of surface water for wildlife. Areas that received more rainfall had more hydrology systems, thus more water sources and watering points for wildlife. For example, this study found out that Nairobi National Park which receives more rainfall had more streams and rivers that provided more surface water for wildlife compared to Amboseli and Tsavo West National Parks. Contrary to this, Amboseli National Park had more water sources in the form of springs and swamps that were fed through underground seepage and snow melt fom Mt. Kilimanjaro.

This study observed that Amboseli basin which is recognized by the United Nations Educational Scientific and Cultural Organization (UNESCO) as 'Man and Biosphere Reserve' acts as a dry season grazing ground for several wildlife species and livestock that concentrate in the basin due to its abundant forage and water resources during the dry seasons. However, giraffes that are less water-dependent do not concentrate in the Amboseli basin because of its water resources but rather spread out into the neighbouring Group ranches to seek for forage resources.

Water scarcity is evident in the entire Tsavo ecosystem. For example, Tsavo West National Park has the perenial Tsavo River as the only permanent source of water for wildlife. Other sources are the Mzima springs which still feed part of their water into the Tsavo River and the artificial dams that are man-made. This study found out that giraffes in the northern parts of Tsavo West National Park moved to and from the Chyulu hills passing through community occupied areas in search of both forage and water. The study also found out that the Kenya Wildlife Service (KWS) created artificial water sources for wildlife within TWNP. Several rain-fed dams have been dug at strategic locations to provide surface water for wildlife. Additional dams were established at Komboyo park headquarters and the Ngulia rhino Sanctuary where water was pumped into the dams for use by wildlife.

Since giraffes were less water-dependent, they were equally less frequently found at the watering points. Giraffes and roan antelope are known to be less water-dependent than the other wildlife species (Western, 1975). They instead spent most of their time feeding on sacculent plants and being vigilant over predators or did other activities, thus taking longer time to go to drink water. When water abundance decreases, the need to drink water becomes crucial particularly for grazer species like Zebra and Warthog which are highly water-dependent (Western, 1975).

Predation is generally greater around animal watering points. Although predators drink at surface water sources when water is available, they do not appear to use them as focal points for hunting. According to the ambush-habitat hypothesis, predators spend more time and make more kills in habitats with greater cover where they conceal themselves from being detected by prey. Also according to the prey-abundance hypothesis, predators spend more time and make more kills in areas where their prey are at highest density (Pennycuik, 1975, Maddock, 1979).

Contrary to the above hypotheses, Grant, 2005 studied the African Lion (*Panthera leo*) and observed successful predation with respect to different habitats, including sources of surface water. He concluded that lions selected fine-scale areas where prey species were easier to catch, rather than in areas where prey densities were highest, such as water sources. He also concluded that lions selected water sources for shade or dens rather than for hunting prey.

7.7.4 Consequences of climate variability on giraffe and its food resources

Rainfall is an important factor in determining the dynamics of migratory species in the African savannas, where the reproduction, survival and movements of ungulates strongly respond to rainfall fluctuations (Ogutu, 2008). Cyclic droughts can cause decline in giraffe numbers. For example, herbivore species in the Mara-Serengeti ecosystem declined by 50% at the turn of the century due to drought related effects on vegetation (Ottichilo, 2000). The 2009 drought in the Amboseli ecosystem affected giraffe forage base and seriously reduced Wildebeest (*Connochaetes taurinus*) and Zebra (*Equus quagga*) populations by 70-95% (KWS, 2010).

Climate change affects the productivity of vegetation and composition of grassland vegetation species (Widdell, 1996). Droughts, in particular, cause a shift to less productive and more drought tolerant plant species (Grime, 2008). This can affect herbivore species, including giraffes that feed on such vegetation and can lead to population collapse as it occurred in Gonarezhou National Park, Zimbabwe, where about 1500 elephants (*Loxodonta africana*) died after the severe drought of 1991-1992 (Gandiwa and Zisadza, 2010).

Reduced rainfall has an impact on fire regimes which affects the survival of plant seeds in the soils, thereby regulating plant productivity including the shrubs and trees utilized by giraffes (Gandiwa and Kativu, 2009). Drought kills many tree and succulent plant species that giraffes mostly feed on. The drought also affects the life cycles and regeneration of the affected plant species. This can lead to significant variability in food availability and decline of the giraffe population that depends on such plants (Gandiwa and Zisadza, 2010).

7.7.5 Conclusion

Forage and water availability have an influence on giraffe movements and distribution in Amboseli, Athi-Kapiti plains and Tsavo ecosystems. Giraffes will move in search of forage and water within their ranges. At times of extreme droughts, giraffes move far and wide in search of forage and water, thus covering wide home ranges. More giraffe food plant species were available for giraffes' consumption during the wet seasons than during the dry seasons in Amboseli, Nairobi and Tsavo West National Parks. Annual plant species flourish during the wet seasons in addition to the perennial giraffe food plants. This increases the number of food plants available for giraffes. There were more food plants available for giraffes in NNP, followed by TWNP and the least number of giraffe food plants was recorded in ANP.

Predation tended to influence giraffe habitat use and occupancy in the three study sites. Areas where lions use as hide outs to catch prey were avoided by giraffes, particularly those with young ones. Family giraffes would forage in open woodlands so as to protect their young from attacks by lions. Both interspecific and intra-specific competition influenced giraffe access to forage and water sources. Areas that were frequently foraged by elephants were avoided by giraffes to reduce competition for forage. Non-parental giraffes left some foraging areas for family giraffes to reduce intra-specific competition within the giraffes themselves. Climate change affects the primary productivity in Amboseli, Nairobi and Tsavo West Natinal Parks, thus affecting forage availability for giraffes. Cyclic droughts caused a shift to less productive and more drought tolerant plant species which giraffes rely on as their food sources during the drought periods. This is demonstrated by the survival of the perennial Acacia trees, thus providing forage for giraffes during dry periods when there is shortage of forage. There was more surface water availability during the wet seasons than during the dry seasons in all the three study sites. Rain water was trapped in the man made water pans during the wet seasons in Nairobi and Tsavo West National Parks.

7.7.6 Chapter Summary

There was a similarity in the giraffe food plants in Amboseli, Nairobi, and Tsavo West National Parks. Most of the giraffe food plants were of the Acacia tree species across the three study sites. However, giraffe food plants varied in Tsavo West National Park as many of them were of Acacia, Commiphora and Combretum tree species. The similarity in giraffe food plants in the three study sites was because they were all of savanna ecosystem with similar attributes in terms of plant species diversity. There were generally more giraffe food plants during the wet seasons than during the dry seasons in the three study sites.

In Amboseli National Park, the relative abundance of giraffe food plants was 210. This was a high value which indicated high relative abundance of giraffe food plants, thus high forage abundance. In Nairobi National Park the relative abundance of giraffe food plants was 254.21. This high value suggested that NNP had high giraffe food plants diversity, hence high giraffe forage abundance. In Tsavo West National Park, the relative abundance of giraffe food plants was 216. This was equally a high value that suggests a high giraffe forage abundance in the park. Nairobi National Park had the highest relative abundance of giraffe forage with an importance value index (IVI) of 254 followed by Tsavo West National Park (216) and Amboseli National Park (210). The giraffe relative forage abundance in the three study sites was in the order of NNP>TWNP>ANP.

In Amboseli National Park, patterns of water sources distribution were almost the same during both the wet and dry seasons. The permanent swamps in the Amboseli basin held substantial amounts of water throughout the year. A slight difference in water sources distribution only occcured during the wet seasons when the seasonal Lake Amboseli filled up with flood waters from the Namanga River which originated from the Namanga hill to the north of the park and the Isinet channel which originated from Mt. Longido in northern Tanzania.

In Nairobi National Park, most streams draining the park dried up during the dry seasons leaving dry river beds. During this time, water was only found in the permanent rivers of Mbagathi, Mokoyiet, Sosian, Songa and Bomas. Other permanent water sources were the man made Longomon, Hyena and Athi plains dams that were located in different parts of the park.

In Tsavo West National Park, the main giraffe water source is the permanent Tsavo River which drains across the park from the west to east. Other permanent water sources are the Mzima springs to the west of the park and Lake Jipe which is located in the southernmost part of the park. During the wet seasons, additional water sources were the 12 dug dams and a series of water pans and tanks located in different parts of the park. There were generally more water sources during the wet seasons than during the dry seasons in all the three study sites.

CHAPTER EIGHT

HUMAN IMPACTS ON GIRAFFES IN SOUTHERN KENYA

8.1 Introduction

Human beings pose a serious security risk to giraffes in terms of poaching for meat, skin and tail brushes. In the arid and semi-arid lands (ASALs) famine prone areas of Kenya, giraffes are a major source of meat for the people. Human influence like land use changes and persecution of giraffes also play a major role in giraffe habitat use within their ranges. Habitats with heavy human interference in terms of logging, vegetation clearance for cultivation, charcoal burning and systematic poaching are usually avoided by giraffes. Most human activities lead to giraffe habitat loss, fragmentation, constriction and degradation when people encroach into wildlife habitats.

The negative anthropogenic effects on giraffe habitats have been felt in Amboseli, Athi-Kapiti plains and Tsavo ecosystems. These impacts have been greatly experienced in the Athi-Kapiti plains ecosystem where land use patterns had rapidly changed. For example, there has been expanded urban development in the townships of Athi-River, Kitengela, Isinya, Ongata-Rongai and the proposed Konza ICT City. There has also been increased industrial development, human settlement, fencing, mining, farming and other human activities practiced in the ecosystem. Similar negative impacts have been experienced in the Amboseli ecosystem where anthropogenic activities like livestock grazing, infrastructure development, cultivation and human settlement have occured.

In the Tsavo West-Chyulu hills ecosystem, the greatest impacts have been felt in terms of human encroachment into the conservation areas. Such activities like livestock grazing, tree logging, bush fires and poaching wildlife for meat in protected areas have been increasing in the recent past. Generally these anthropogenic activities have had devastating impacts on giraffe habitats in the Amboseli, Athi-Kapiti plains and Tsavo ecosystems.

Most of Kenya's population lives in about 20% of the country's high agricultural potential areas that support both small and large scale agriculture (GOK, 2001). Protected areas around these high agriculture potential areas are surrounded by human settlements and agricultural farms, while rangelands are surrounded by pastoral communities and their livestock. Increasing human population and its activities have led to decline in wildlife abundance through habitat loss, fragmentation, constriction of dispersal areas and blockage of migration corridors/routes leading to confinement of wildlife in national parks and reserves. This has led to increased human/wildlife conflicts in such areas as wildlife competes for space, forage and water resources with livestock.

As agricultural activities continue to surround protected areas, wildlife populations outside protected areas will continue to decline due to loss of its habitats. Protected areas are elaborate systems of national parks and reserves, sanctuaries and conservancies for the protection and conservation of wildlife resources. About 10-20% of Kenya's land mass is designated as protected areas where Kenya Wildlife Service (KWS) manages about 8% of this area as national parks and reserves. A majority of Kenya's wildlife is found in rangelands in arid and semi-arid lands (ASALs). These ASALs provide habitats suitable for wildlife and livestock production. These rangelands cover about 80% of Kenya's land surface and support about 20-25% of the human population. It is estimated that these rangelands support over 50% of the country's livestock and about 90% of the large wild herbivores in and outside protected areas (GOK, 2001).

Human activities like encroachment into wildlife habitats through cultivation and settlements cause wildlife habitats shrinkage and fragmentation thus reducing ranging space for wildlife (Ottichilo, 2000). Morrison et al. (1992) noted that no single factor had a greater cause of decline in wildlife populations than loss of its habitats while habitat fragmentation threatened wildlife populations' viability. Livestock at the same time drastically alters vegetation composition and physiognomy at the expense of wildlife.

8.2 Scope of the study

This study determined human activities in giraffe habitats in Southern Kenya. It also assessed the effects of human activities on giraffes and their habitats. The study looked at the landscape changes in the study area as has been influenced by human socio-econmic activities practiced in the Amboseli, Athi-Kapiti plains and Tsavo ecosystems, thus having negative impacts on giraffes and other wild herbivore species' habitats. The study looked at the gravity of the impacts and how the resource managers can mitigate the impacts for sustainable conservation and management of giraffes in Southern Kenya rangelands.

8.3 Research objectives

i) To determine human activities within giraffe home ranges in Southern Kenya.
ii) To assess the impacts of human activities on giraffes and their habitats in Southern Kenya.

8.4 Materials and methods

8.4.1 Determination of human activities in the study area

Human activities were determined in Amboseli, Athi-Kapiti Plains and Tsavo ecosystems. The Group ranches and community areas of Kimana, Namelok and Imbirikani were chosen for the determination of the human activities in Amboseli ecosystem. In Athi-Kapiti plains, human activities were determined in Kitengela, Isinya, Kapiti plains, Konza and Athi River Township. In Tsavo ecosystem, They were also determined in Chyulu hills, Taveta area, Taita hills, Mackinon and Voi areas in Tsavo ecosystem. Primary data on the human activities were obtained by interviewing local government departments' officials, NGOs and wildlife conservation agencies. Secondary data was also obtained from government official records on land use changes and the socio-economic activities being undertaken in the study area. Data on illgal human activities were obtained from KWS Wardens in-charge of Amboseli, Nairobi and Tsavo West National Parks and the KWS County offices of Kajiado and Taita Taveta.

8.4.2 Assessment of land use changes in the three study sites

The Amboseli ecosystem which includes Amboseli National Park (392km^2) has an estimated area of 8,797km^2 was assessed for the impacts of human activities on giraffe and its habitats. Such activies like tree logging for charcoal burning, livestock grazing and watering, cultivation, settlements, infrastructure development and tourism business were assessed. The ecosystem has experienced rapid land use changes that have seen the resident Maasai pastoral community change from their traditional pastoralism activities to agro-pastoralism and other businesses. They have at the same time shifted from their nomadic way of life to that of setting up permanent settlements that have negatively impacted on giraffes and their habitats. The land use change and tenure systems have caused giraffe habitat loss, fragmentation, constriction and degradation. It has also caused the loss and blockage of giraffe migration corridors and dispersal areas. Infrastructure development and associated activities has equally impacted negatively on giraffes and their habitats through loss of giraffe ranges.

The Athi-Kapiti plains ecosystem has an area of about 2,456 km^2 and is surrounded by Nairobi Metropolis to the north, Kajiado District to the south and the Lukenya hills and Machakos ranches to the East. Nairobi National Park is fenced with electric fence on its northern, eastern and western boundaries. The Athi-Kapiti plains host large herds of both wildlife and livestock and serve as critical wet season wildlife dispersal areas for Nairobi National Park. The plains extend to the large Machakos ranches to the east and linked to Amboseli ecosystem to the south by the gently sloping Emarti valley. This ecosystem has experienced a lot of land use changes that have greatly affected the integrity of the ecosystem as a giraffe ranging area. There have been rapid land use changes resulting in widespread urbanization and expansion of the Athi River and Kitengela townships. Some of the land use changes in this ecosystem included establishment of fenced cattle ranches, cultivation, quarrying, human settlements and development of the export processing zones (EPZ). These developments have caused habitat loss for wildlife as the landscape has been greatly transformed and become unsuitable for giraffe use.

The Tsavo ecosystem has an estimated area of 40,000km^2 and is located in the south-eastern part of Kenya with Tsavo West National Park covering an area of 9,065km^2 with Chyulu Hills

National Park lying adjacent to it to the North-west. In the last 20 years, areas outside the protected areas of Tsavo West and Chyulu Hills National Parks have witnessed high density human settlement and spread of small scale farming, particularly in those areas between the northern part of Tsavo West National Park and Chyulu Hills National Park, thus blocking wildlife traditional migration routes.

Elephants in the Tsavo ecosystem move in search of forage and water and generally follow known migration routes. These movements occur between TWNP and ANP through Chyulu hills and Kuku ranch and between TWNP and TENP through Taita hills. But intense human activities around the Taita and Rukinga hills have curtailed elephant movements between Tsavo East and Tsavo West National Parks. Human agricultural activites have equally affected the Amboseli-Tsavo ecosystem wildlife movement routes.

8.5 Results

8.5.1 Human activities in wildlife dispersal areas

Human activities have generally had devastating effects on giraffe habitats in Southern Kenya. Human impacts on giraffe and its habitats have been experienced in Southern Kenya rangelands due to increasing human population, government policies and changing land use patterns. For example, infrastructure development in Amboseli ecosystem has caused fragmentation of wildlife habitats, reduced extent of wildlife dispersal areas and curtailed animal movements. There has also been increased industrial development, human settlement, fencing, mining, farming and other human activities practiced in the ecosystem. All these developments have had negative impacts on giraffe habitats in Amboseli, Athi-Kapiti plains and Tsavo ecosystems.

8.5.2 Human – giraffe interactions in the study area

Amboseli National Park is a dry season grazing area for wildlife which disperses to the adjacent Group ranches during the wet seasons to exploit the forage and water resources in these areas. The future of Amboseli National Park is threatened by the loss of wildlife migration corridors and dispersal areas which are critical for the survival of the various ungulate populations in the Amboseli ecosystem.

Migratory wildlife species of zebra and wildebeest together with giraffe move in and out of Nairobi National Park during the dry and wet seasons respectively. These wildlife species move into the park in the month of July to utilize the accumulated pasture and water resources in the park. As the short rains set in during the month of October, the wildlife species move south into the Kitengela and North Kaputei dispersal areas.

In the Tsavo ecosystem, human impacts on giraffe habitats have been felt in terms of human encroachment into the conservation areas. Such activities like livestock grazing, tree logging, bush fires out breaks and poaching in Tsavo West and Chyulu Hills National Parks have increased over time. There has also been intensified cultivation in areas surrounding the parks.

8.5.3 Human-livestock- giraffe interactions in the study area

Human impacts on giraffe habitats are those impacts due to activities associated with changes in human land use patterns. Such anthropogenic activities like settlement, mining, infrastructure development, livestock grazing, logging, charcoal burning, cultivation and fencing have been experienced in Amboseli, Athi-Kapiti plains and Tsavo ecosystems. These activities have led to giraffe habitat loss, constriction, fragmentation, degradation, and loss/blockage of wildlife migration corridors and dispersal areas.

Such activities as livestock grazing, cultivation, human settlement, logging, infrastructure development, fencing, charcoal burning and mining have impacted negatively on giraffe habitats in Amboseli ecosystem. Livestock keeping was observed to be carried out by man in the entire Amboseli ecosystem. Cattle were the main livestock kept by the traditional Maasai pastoralists in Amboseli ecosystem. Other livestock included sheep, goats and donkeys. Camels had recently been introduced into the ecosystem by migrant herders and compete with giraffes for forage and water. Livestock populations started rising sharply in Amboseli ecosystem in the 1960's due to availability of water and improved veterinary services (Western, 1973). These livestock ranged widely and competed for forage and water resources with wildlife. Livestock also caused a lot of habitat degradation through overgrazing and trampling of vegetation. Cattle tracks create gulleys which enhance serious soil erosion through these gulleys.

The grazing and browsing styles of these livestock had degraded wildlife habitats as their sheer huge numbers exceeded the ecosystem's carrying capacity. Livestock grazing had encroached into wildlife habitats and exerted pressure on both forage and water resources in and outside protected areas. Competition for these resources between livestock and wildlife was severe particularly during the dry seasons when pastoralists and other herders drove their livestock into protected areas for water and pasture. Serious human/wildlife conflicts occured as the livestock interacted with wildlife within its habitats. Poaching and arson by herders increased in the parks.

This study observed that cultivation in Amboseli ecosystem was mainly concentrated on the slopes of Mt. Kilimanjaro, Kimana swamps, Namelok swamps and along rivers kikaronko in Esambu and Il kisanjani areas. Limited cultivation was also carried out in the slopes of the Chyulu hills in Lemasusu and Loitokitok areas. Other cultivation areas were along the Nol-turesh water pipeline, Emali and Sultan Hamud areas.

This study also observed that mining activities involved quarrying for stones and ballast, hole mines for blue stones and open cast mining for limestone. Mining activities were mainly concentrated in south Kaputei area and along the Emali-Loitokitok and Athi River-Namanga roads. Charcoal burning had picked up in the entire Amboseli ecosystem. This illegal activity involved felling and logging of mature and old trees of the Acacia species to provide fuel wood and charcoal for domestic use in the urban centers. Fencing was mainly concentrated around tourism facilities like lodges, tourist camps and camping sites. Two community fences at Kimana and Namelok community land in Loitokitok district had annexed a total area of 63km^2 that has completely excluded wildlife from their use (Western, 1997).

There has been increased industrial development, mining and horticultural farming in the ecosystem. The rapid expansion of Athi-River and Kitengela townships has taken up the previously wildlife utilization areas. Activities like cement and gypsum mining and the establishment of the export processing zones (EPZ) have encroached into giraffe ranges. Other activities like horticultural farming, quarrying for ballast/stones and sand harvesting have converted good wildlife pasture areas into dangerous pits and wastelands.

Land use patterns have changed in some areas of this ecosystem from Group ranches to private ownership that have been sub-divided into small parcels with individual title deeds. Livestock numbers have also increased tremendously in the ecosystem. Infrastructure development has increased with the constraction of many storey houses, estates and residential units. The proposed 5,000 hactare Konza City information communication and technology center has taken up much of the Kapiti plains wildlife ranges in the ecosystem.

Fences constitute 341km (16.5%) of the Kitengela dispersal area. The fences are increasingly being erected on private land along the Athi-River-Namanga tarmac road and are spreading outwards towards the adjacent wildlife dispersal areas. The Nairobi-Mombasa highway, kitengela-Namanga and Mlolongo-Langata-Dagoreti southern by-pass are human development activities that are major threats to wildlife species, especially giraffes that have in the past been killed by speeding motorists on the highways and trains on the railway lines (Western, 1997).

Because of intense human-wildlife conflicts in the area, several electric fences have been erected by Kenya Wildlife Service (KWS) to mitigate the conflicts. These fences have curtailed giraffe and other wild herbivore movements to and from water sources and foraging areas located outside protected areas during the dry seasons. Human illegal activities such as charcoal burning, mining, logging and setting up of snares to poach animals for meat and fire outbreaks are common in the Tsavo ecosystem. However, charcoal burning is limited to areas outside the national parks except for the northern boundaries of Tsavo West National Park near the Chyulu hills where cases of tree logging for charcoal burning occur.

8.5.4 Trends in landuse changes

The savanna rangelands of Southern Kenya have been greatly affected by the inherent land use changes and tenure systems. For example, the northern parts of Kajiado district and Kitengela wildlife dispersal areas around Nairobi National Park have almost completely been taken up by farming, industrial development and human settlement. A majority of Kenya’s national parks and reserves are found in the savanna rangelands (KWS, 1996). The importance of these savanna ecosystems as wildlife conservation areas cannot be overemphasized. Their loss as a result of change in land use and land tenure systems has serious implications for wildlife conservation.

In Amboseli ecosystem, the period 1988-1993 saw an increase in cultivated land with more land area being converted into agriculture. This period coincided with the government directive to sub-divide and privatise the rangelands in Amboseli ecosystem (Esikuri, 1991). When land privatisation started in this area, more agricultural immigrant communities moved in to start agricultural activities, thus changing the landscape.

8.6 Discussion and Conclusion

8.6.1 Trends in settlements development

Human settlement has occured in the Amboseli ecosystem since most Maasai families had changed from nomadic lifestyles to that of sedentarization. It was observed that Maasai people had moved from the manyatta type of homesteads to those of permanent houses built with corrugated iron sheets. Such buildings had come up in several market centres and in other social amenities like schools and hospitals. Settlements were mainly concentrated near water points in Kimana and Namelok community areas where wildlife also went to drink water.

The main anthropogenic activity in Athi-Kapiti plains ecosystem was human settlement. For example, human population in this area increased from 6,548 to 17,347 persons and the number of households increased nearly fivefold from 1,044 to 5,005 between 1989 and 1999 due to human immigration from Nairobi City (GOK, 2001). The land tenure system changed rapidly with people acquiring individual land title deeds and fenced them up, thus closing out wildlife.

In the past 20 years, there has been increased human settlement and small scale farming around the protected areas especially the area between Tsavo West National Park (northern area) and Chyulu Hills National Park. These anthropogenic activities have blocked the traditional wildlife migration routes between Tsavo West and Chyulu Hills National Parks. Intensive farming activities around Taita and Rukinga hills have blocked direct elephant and other wild herbivores movement routes between Tsavo East and Tsavo west National Parks.

8.6.2 Trends in tourism development

Tourism has experienced rapid development in southern Kenya over the past decades. Due to increased numbers of tourists visiting Nairobi, Amboseli, Tsavo East and Tsavo West National Parks, the tourism industry became one of the leading foreign exchaqnge earners to Kenya. With visitors eager to view wildlife and conduct beach tourism at the coast, southern Kenya became one of the main tourist destination areas that only rivalled the Maasai Mara National Reserve in the region. Mombasa, Tsavo East, Tsavo West, Amboseli and Nairobi National Parks form one of the longest tourist circuits in Kenya.

Amboseli National Park is probably the most visited site in the region because of its elephant population that is regarded as the most friendly elephants and the rich Maasai people culture. Tourism facilities rapidly developed with the expansion of hotels and lodges to accommodate the increasing visitor numbers. There was also increased development of community owned camp sites and curio shops where visitors could book for accommodation and buy curios and other artifacts.

Tourist visitation to Nairobi National Park has increased over time because of its proximity to the City of Nairobi. The presence of the Nairobi Animal Orphanage/Safari Walk, Dalphine Sheldrick home for the orphaned elephants and the Giraffe Centre at Karen attracted both local and foreign visitors. Access to these attraction centres is easy and preffered by international guests including Heads of States and Governments, school children and the general public.

Because of their proximity to Mombasa, the Tsavo East and Tsavo West National Parks are highly visited by tourists who come to Mombasa for beach tourism. The two national parks are also highly visited because of their historical attractions of ‘Man-eaters of Tsavo’, Luggards Falls, Mdanda rock, Shetani Lava flow and the Yatta plateau, which is reputed to be the second longest plateau in the world. There has therefore been increased tourism infrastructure development to meet the needs of the increasing tourist numbers in southern Kenya.

8.6.3 Effect of land use changes

The land tenure system and its associated land use changes have compromised the integrity of the Amboseli ecosystem as activities incompartible with conservation have taken center stage.
For example, Kimana/Tikondo Group ranch has been completely sub-divided and other Group ranches are in the process of being sub-divided. Land use changes in Amboseli ecosystem deny wildlife critical habitats to use particularly during the dry periods of the year. Amboseli basin swamps remain crucial habitats for all wildlife species throughout the year where they go for both forage and water.

Human encroachment into giraffe habitats interferes with giraffe daily ranging activities in southern Kenya. For instance, giraffes avoided pastoral communities' settlements and areas occupied by human livestock. In Amboseli ecosystem, giraffes avoided Maasai manyattas including even those that have been abandoned. Giraffes avoided such areas for fear of being caught up in snares or speared when they are in close proximity to human settlements. Giraffes also avoided such places because of the noise from people and the loud barkings from domestic dogs which are virtually found in every Maasai homestead or accompanying herders tending the livestock particularly goats and sheep.

Giraffes avoided foraging and drinking water in areas occupied by livestock as they avoided mixing with them all together. The presence of cattle can reduce the use of water sources by giraffes suggesting that livestock and human activities near water sources have a negative effect on the distribution of wildlife. Human presence and his associated activities in giraffe ranges virtually act as barriers to giraffes accessing both forage and water resources (de Leeuw, 2001).

Human impacts on giraffe ranges have been experienced in the Athi-Kapiti plains ecosystem where land use patterns have rapidly changed over time. There has been expanded urban development in the townships of Athi-River, Kitengela, Isinya, Ongata-Rongai and the proposed Konza ICT City in Machakos County. The Athi-Kapiti plains ecosystem has experienced a lot of land use changes that have greatly affected the integrity of the ecosystem as a giraffe ranging area. There have been rapid land use changes resulting in widespread urbanization and expansion of particularly Athi River and Kitengela townships. Some of the land use changes in this ecosystem include establishment of cattle ranches, cultivation, quarrying, human settlements and establishment of the export processing zones (EPZ). These developments have caused habitat loss for giraffes as the landscape has greatly been transformed and become unsuitable for wildlife habitation.

Areas outside Tsavo West and Chyulu Hills National Parks have witnessed high density human settlement and small scale farming, particularly in those areas between the northern part of TWNP and Chyulu Hills National Park, thus blocking wildlife traditional migration routes. Elephants in the Tsavo ecosystem move in search of forage and water and generally follow known migration routes which giraffes also use. These movements occur between TWNP and ANP and between TWNP and TENP through Taita hills. But intense human activities around the Taita, Rukinga and Chyulu hills have blocked these movement routes.

8.6.4 Impacts of settlements and tourism development

Tourism development has both positive and negative impacts on giraffe habitats in the three study sites with the negative impacts far much outstripping the positive impacts. Some of the positive impacts associated with the development of tourism facilities are improved habitat management and protection and improved giraffe security. The negative impacts of infrastructure development of tourism facilities include: construction of game viewing road circuits, lodges, camping sites, picnic sites and electric fences. The establishment of these facilities involves vegetation clearance and general giraffe habitat destruction and degradation.

Some of the negative impacts associated with the development of tourism facilities are habitat loss and degradation, blockage of giraffe movement corridors and alteration of the scenic nature of the environment. Both human and vehicle traffic problems have been experienced in Amboseli, Nairobi and Tsavo West National Parks where there have been both human and vehicle congestion on the road circuits in the respective national parks. There have been cases of vegetation destruction through off-road driving by tour drivers and wildlife harassment and kills. Other negative impacts of tourism facilities development include; noise pollution from power generators, pollution from dust, water pollution, giraffe electrocution from fences around lodges and camping sites.

These negative impacts on giraffe habitats need to be prevented by instituting appropriate environmental conservation measures. Proper siting and location of tourism facilities must be adhered to. For example, serine giraffe habitats must be avoided as much as possible when siting lodges and camping sites in the three study sites. Game viewing road circuits must be properly planned and constructed with minimum interference on giraffe habitats. Good habitat management practices must be applied for sustainable conservation of wildlife in Amboseli, Athi-Kapiti Plains and Tsavo ecosystems. Other mitigation measures should include the introduction of new tourism products like cultural tourism, horse riding, bird watching and general eco-tourism ventures. These new tourism products will go a long way in reducing the negative impacts of tourism facilities development on giraffe habitats in the three ecosystems.

8.6.5 Impacts of infrastructure development

Infrastructure development along the park boundary has caused fragmentation of wildlife habitats, reduced extent of wildlife dispersal areas and curtailed animal movements. The land tenure system and its associated land use changes have compromised the integrity of the Amboseli ecosystem as activities incompartible with conservation have taken center stage. For example, Kimana/Tikondo Group ranch has been completely sub-divided and other Group ranches are in the process of being sub-divided. The sub-division of these critical conservation areas has led to changes in land use where the parcel owners have adopted new land use practices like agricultural cultivation, tourism facility development and establishment of business centers and other ammenities. These new developments have led to loss of critical giraffe habitats in Amboseli ecosystem.

The construction of major highways through the three ecosystems has had serious impacts on wildlife habits. For example, the Nairobi-Momabasa highway and railway line have cut through giraffe habitats in the Tsavo ecosystem. These infrastructure developments have led to vegetation destruction along the construction lines, thus leading to habitat loss for giraffes. Other serious impacts associated with these developments include death to giraffes and elephants that have in several occasions been knocked down by speeding trains and Lorries plying these routes.

The other highways of concern are the 100km Emali-Loitokitok tarmac road in Amboseli ecosystem and the 120km Athi-River-Namanga tarmac road in the Athi-Kapiti plains ecosystem. The proposed Mombasa-Nairobi standard gauge railway line, Konza ICT City and the southern by-pass will have far reaching consequences on giraffe habitats in both Tsavo and Athi-Kapiti plains ecosystems.

Other infrastructure developments that have affected giraffe habitats are the high voltage Nairob-Arusha power supply line that runs through the Athi-Kapiti plains-Amboseli ecosystems, the electric and barbed wire fences in Tsavo, Athi-Kapiti plains and Amboseli ecosystems. These have affected giraffes in terms of curtailing their movement, habitat loss, habitat fragmentation and in some instances strangulation and electrocution of giraffes and other wildlife species.

8.6 Conclusion

Human activities like, tree logging for charcoal burning and fencing posts, livestock grazing, settlement and cultivation impact negatively on giraffes by reducing their foraging ranges. It has also contributed to giraffe habitat loss, fragmentation, constriction, degradation and loss of their migration corridors and dispersal areas. Increasing human population and encroachment into wildlife ranges pose a great threat not only to wildlife but to entire ecosystems functionality. Killing giraffes for meat, competition for forage and water as well as space with livestock and humans has contributed to a considerable decrease in numbers of giraffes in Southern Kenya.

8.7 Chapter summary

Human activities have had negative impacts on giraffe habitats in Southern Kenya. Some negative impacts of human activities on giraffe habitats have been experienced in Southern Kenya due to increasing human population, government policies and changing land use patterns. In Southern Kenya, infrastructure development has caused fragmentation of giraffe habitats, reduced dispersal areas and curtailed their movements.

There has been increased industrial development, human settlement, fencing, mining, farming and other human activities practiced in Southern Kenya. All these activities have had negative impacts on giraffe habitats in Amboseli, Athi-Kapiti plains and Tsavo ecosystems as they have led to giraffe habitat loss, constriction, fragmentation, degradation, and loss or blockage of giraffe migration corridors and dispersal areas in Southern Kenya.

The giraffe habitats in Southern Kenya were riverine forest, forest edges, woodlands, bushed grasslands and open grasslands with scattered trees. These habitats have been greatly affected by the inherent land use changes and tenure systems in the study area. For example, the northern parts of Kajiado County and Kitengela wildlife dispersal areas outside Nairobi National Park have been taken up by farming, industrial development and human settlement. These developments have been accompanied by roads and fences and solid waste generation. These changes can also be seen in the Amboseli and Tsavo ecosystems where land use changes and tenure systems have impacted negatively on giraffe habitats.

CHAPTER NINE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1 General discussion

9.1.1 Trends in giraffe population size and structure in Southern Kenya

This study has shown that giraffe numbers had increased over time inside protected areas of Amboseli, Nairobi and Tsavo West National Parks. The increase of giraffe numbers in the three protected areas was attributed to concentration of giraffes in the three national parks due to habitat loss and fragmentation as well as their displacement by human settlements and persecution by man in thier traditional ranges outside protected areas (Personal observation).

9.1.2 Influence of climate variability on food and water availability for giraffes

This study has shown evidence of climate variability as there has been a general rise in temperatures and increased rainfall variability in the study area. Extreme mean maximum and minimum day and night temperatures have been experienced particularly in Amboseli and Tsavo ecosystems. At the same time mean annual rainfall amounts have shown increased variability over time with a general decline in annual rainfall amounts. Results from this study have also shown that occurance of droughts during the once long rains seasons had become more frequent and prolonged and that more rainfall amounts had been received during the short rain seasons of September-December as opposed to the long rain seasons of March-May.

This study has shown that surface water abundance was low during the dry seasons, thus forcing wild herbivores including giraffes to move for long distances in search of drinking water. By doing so, herbivore time budgets become critical as they are forced to look for water by all means and take a very short time to drink it. This study observed that giraffes in the study sites took a very short time to drink water during hot times of the day and moved to tree shades for shelter from the hot sun. Marion et al. (2007) also observed that during the dry periods, herbivores took less time to drink water and moved to tree shades to shield themselves from the intense heat and thereby maintaining their bodies' temperature regulation.

9.1.3 Factors influencing local habitat use by giraffes in Southern Kenya

Habitat use or utilization by any wildlife species is usually characterized in terms of the probability of its use and can be a useful index of habitat quality. There is therefore a higher probability of finding an animal in a higher quality habitat since high quality habitats tend to support more animals (Obari, 2009). Giraffes exploit the arboreal food sources much more economically, where they browse at heights of 5m above ground level. But they can reach 6m and can also feed on preferred food items as low as 1-2m high. Feeding heights in giraffe is a form of resource partitioning where high browsing is meant to reduce browsing pressure on vegetation where sexes feeding heights overlap. Most ungulates sexually segregate from certain habitats with males altruistically leaving superior ranges to reduce foraging competition between them and lactating females (Obari, 2009).

Giraffes utilize preferred habitats with Acacia tree vegetation and sometimes feed on their bark when foliage is scarce. Male giraffes usually utilize thick woodlands while female giraffes utilize open wooded grasslands to ensure safety of their young (Young & Isbell, 1991). Males and non-lactating females select to feed in dense woodlands where they select different feeding heights. Sometimes females show generalised feeding heights while males feed from high points (Obari, 2009).

Huto (1985) proposed that animals select habitats through a hierarchical spatial scaling process which is achieved through a series of processes. The first habitat selection process occurs at the level of the geographic range and the second one occurs at the home range level, that is, the level where animals conduct their activities. The third level of habitat selection is that of the specific sites or for specific components within their home ranges. The fourth level of habitat selection is that of the niche where habitat selection is done according to how the animals will procure resources within these micro-sites (Huto, 1985). He also suggested that habitat selection at the geographic level is probably genetically determined. Wicker (1964) and Wiens (1972) demonstrated that habitat selection at the micro-site (Niche) level may be influenced by learning and experience and may be intentionally directed by individual animals and that wildlife-habitat relationships are distinctly different at different levels.

This study has shown that male giraffes utilized thick woodlands while females with young ones utilized open wooded grasslands to ensure security of the young from predators like lions. The study has also shown that non-parental giraffes selected to feed in dense woodlands where male giraffes selected high feeding levels, while females showed generalized feeding heights.

This study has showed that giraffes foraged in all the habitat types during both the wet and dry seasons as there was no significant difference ($p > 0.05$) in giraffe seasonal habitat use and occupancy in Amboseli, Nairobi and Tsavo West National Parks. This meant that seasons did not determine giraffe habitat use and occupancy in the three study sites and that giraffes uniformly utilized or occupied the different habitats in the three study sites. There was also no significant difference in giraffe numbers in the different habitats in the three study sites.

9.1.4 Giraffe homeranges and dispersal in Southern Kenya

The giraffe (*Giraffa camelopardalis*) with a large body mass and high bio-energetic requirements has a more expansive home range than smaller ungulates in the same environment (Du Toit, 1990). However, large differences in giraffe home range sizes have been reported across their range (Berry, 1978; Dagg & Foster, 1982). Home range size analysis has historically been limited to direct field observations (Dagg & Foster, 1972; Berry, 1978; Van der Jeugd & Prins, 2000). Advanced methods of animal movement and core home range size analysis used for other species, for example, elephants have more recently provided a more accurate estimate of animal ranges and movements.

A home range is an area that an animal uses in the course of its daily activities and is not necessarily defended. It can also be defined as the area traversed by the animal during its normal activities of foraging, mating and caring of young (Burt, 1943). The animal may make unusual moves outside its home range resulting into outlier points which cannot be considered as its normal activities. Giraffe home range sizes differ with habitat types and ecosystem sizes.

Giraffe dispersal and home range sizes of arid adapted mammals are usually larger than those of the same species in high rainfall environments (Du Toit, 1990). Giraffe home range sizes can sometimes be determined by the amount of rainfall received in a particular ecosystem, security, forage and water availability. These factors tend to drive animal movements in arid and semi-arid environments where individuals or herds of these animals move to habitats in search of these resources.

Previous studies of giraffe home range sizes (e.g., Fennessy, 2004) have shown that giraffe home range sizes are highly variable. For example, in Amboseli National Park, giraffe home range sizes determined using both the Minimum Convex Polygon (MCP) and Kernel Density (KD) methods varied from 634-1005 km^2 (95% MCP) and 37-916km^2 (95% KD). In Nairobi National Park, the home ranges were very variable between individual herds and ranged from 88.74-118.88km^2 (95% MCP) and 36km^2 – 118.90km^2 (95% KD). In Tsavo West National Park, giraffe home ranges varied from 2170-5124km^2 (95% MCP) and 774-5821km^2 (95% KD) (Appendix 16).

The two-sample Mann-Whitney (U) rank test results conform to the Minimum Convex Polygon (MCP) and Kernel Density (KD) wet and dry season giraffe home range sizes calculated at both 95% and 50% of plots of relocations of points within the polygon when 5% and 50%, respectively of the outlier points are excluded from the polygon plots. However, the test result was true for ANP and NNP where the wet and dry season giraffe home range sizes were almost the same, but, for TWNP, the wet season giraffe home range size was almost twice as large as the dry season home range. Generally the wet season giraffe activity core areas were larger than those of the dry season in ANP and TWNP, but the dry season giraffe activity core areas were larger than those of the wet season in NNP (Appendix 17).

Giraffe home range sizes in Tsavo West National Park were larger than those of Amboseli and Nairobi National Park because NNP is almost completely fenced up forcing giraffes to forage in an enclosed system, thus making localized movements with reduced area of coverage. Because TWNP and ANP are open systems, giraffes have more open space and move for longer distances in search of forage and water. In the process, giraffes end up covering larger areas during foraging time, thus larger home range sizes (Appendix 18).

Because of forage scarcity in Amboseli National Park, giraffes tend to move out of the park to the surrounding Group ranches of Olgulului/Lolorashe and Kimana in search of forage. Tsavo West National Park with an area of 9,065km^2 provides giraffes with more space to roam around. In the process of giraffes searching for forage and drinking water in the vast ecosystem, they end up covering larger areas, thus larger home range sizes.

This study showed that availability of both forage and surface water resources influenced giraffe home range sizes in Amboseli, Nairobi and Tsavo West National Parks. As giraffes moved in search of food and drinking water, they covered areas that were considered to be their daily home ranges. Generally, giraffes had larger home ranges during the dry seasons than during the wet seasons. However, this study has showed that seasonal changes did not affect giraffe home range sizes as Chi-squared tests performed on both parental and non-parental giraffes' home range sizes showed no significant difference ($P > 0.05$) between the wet and dry season.

The study has also shown that giraffes, which are categorized as non-migratory species, have adopted migratory tendencies and moved alongside other large herbivore migratory species like elephants in search of forage and drinking water. For example, a herd of giraffes led by a male with one broken right ossicone that were frequently sighted in Amboseli National Park moved all the way to the slopes of Chyulu hills, Kuku ranch and at one point was located at In'tilal area of Tsavo West National Park, a distance of about 100km from Amboseli National Park. The migratory tendencies have been adopted by giraffes as a means of survival due to the effects of climate variability in Southern Kenya.

9.1.5 Human impacts on giraffes and their habitats in Southern Kenya

This study has shown that human activities had negative impacts on giraffes and their habitats in the study area. For example, human activities like charcoal burning, logging, livestock grazing, settlement and cultivation had impacted negatively on giraffes and their habitats and had led to habitat loss, fragmentation, constriction, degradation and loss of migration corridors and dispersal areas in giraffe traditional ranges in Southern Kenya.

9.2 Conclusion

1. Increasing human population and human encroachment into wildlife habitats pose a great threat not only to wildlife but to the functionality of the entire ecosystem.

2. Giraffes' competition for forage, water as well as space with livestock and humans has contributed to increasing incidents of human-giraffe conflicts in the study area.

3. Human activities, particularly charcoal burning, tree logging, livestock grazing, establishment of permanent settlements and cultivation have led to giraffe habitats degradation and loss. Construction of roads and establishment of tourist campsites and lodges ha contributed to giraffe habitat fragmentation. Human encroachment into giraffe habitats has led to the degradation of wildlife migration corridors and dispersal areas.

4. This study has shown that climate of Southern Kenya is highly variable. Marked temperature increases were recorded in Amboseli and Nairobi, but moderate increases in Tsavo West National Park. Temperature influences the rates of evapouration and therefore the availability of surface water for giraffes and other herbivores. Long term temperature increases are likely to have deleterious effects on wild herbivore species as they affect their physiology and food availability. This could result in local extinction of those species that may not be able to adapt to climate change.

5. This study found that rainfall in Southern Kenya varied annually, but also seemed to change after every five years. These changes were associated with the ENSO phenomenon especially the wet El Nino periods and the dry La Nina periods. Cyclic droughts had influence on availability of giraffe forage and water resources. It is the variability of thes e resources that determined giraffe movements and distribution in Amboseli, Athi-Kapiti plains and Tsavo ecosystems.

6. Seasonal changes had no significant effect on giraffe habitat use and occupancy in the study area. This was because giraffe forage did not seem to change significantly between seasons. However, giraffes moved locally from one habitat to the other in search of fresh forage and water.

7. The land use changes outside the protected areas especially development of agriculture, settlements and tourism are major threats to the survival of the Maasai giraffe (*Giraffa camelopardalis tippelskirchi*) in Southern Kenya. Climate variability is likely to exercebate the negative effects of human activities including increased poaching of giraffes in Southern Kenya.

8. Effective conservation and management of giraffes in Southern Kenya requires concerted efforts to ensure security of the species, its key foraging habitats and access to water. This necessitates community commitment and involvement.

9.3 Recommendation

9.3.1 Recommendation for further study

1. A concise study needs to be done on Maasai giraffe population trends and distribution in relation to inherent land use changes and infrastructure development in Southern Kenya.

2. Research should be conducted on the impacts of poaching of giraffes for bush meat trade in Southern Kenya.

3. A genetics study should be conducted to determine the breeding success across the giraffe sub-populations in the study area

4. Robust climate oriented models using GIS and Remote Sensing Technology (RTS) need to be used to make effective predictions of the spatio-temporal effects of climate variability in the savanna ecosystems of Southern Kenya.

5. There is a need for the assessment of the ecological needs of giraffes within the migration corridors and dispersal areas. This should include habitat quality, edge effects, width and length space. A participatory approach involving researchers, conservation agencies, NGOs, land owners and other conservation stakeholders need to be involved.

9.3.2 Recommendation for management actions

1. There is a need to enhance good conservation practices such as creating protected area systems (PAS) and biodiversity networks that will assist in minimizing habitat degradation and effective control of invasive species as starting points in response to the effects of climate variability in Southern Kenya.

2. There is need to focus on the development and implementation of appropriate strategies to tackle the impacts of climate change/variability on giraffe and its habitats in the study area.

3. Establish game sanctuaries and community wildlife conservancies. The establishment of the conservancies and sanctuaries will ensure availability of contiguous habitats outside protected areas and at the same time improve human livelihoods with benefits being derived from eco-tourism activities in Southern Kenya.

4. Conservation agencies need to implement trans-boundary conservation initiatives between Kenya and Tanzania governments in the Tsavo West-Mkomazi Game Reserve and Amboseli-Mt. Kilimanjaro National Parks.

5. An integrated land use plan needs to be put in place to address issues of the creation of buffer zones between protected areas and community settlements to reduce human/wildlife conflicts and activities that impact negatively on giraffe habitats.

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Appendices

Appendix 1: Annual giraffe and rainfall trends in Amboseli National Park.

Year	**Rainfall(mm)**	**Giraffe numbers**
2000	200	57
2001	495	52
2002	180	55
2003	400	89
2004	380	76
2005	330	80
2006	270	69
2007	280	56
2008	420	70
2009	275	64
2010	428	82
2011	229	115
2012	226	130

Appendix 2: Annual giraffe and rainfall trends in Nairobi National Park.

Year	**Rainfall(mm)**	**Giraffe numbers**
2000	520.3	71
2001	1431.2	61
2002	1219.5	64
2003	936	71
2004	920.4	72
2005	781.4	66
2006	1170.3	71
2007	408.1	84
2008	640	150
2009	941.4	115
2010	840	120
2011	1050	94
2012	820.6	200

Appendix 3: Annual giraffe and rainfall trends in Tsavo West National Park.

Year	**Rainfall(mm)**	**Giraffe numbers**
2000	295	272
2001	611	292
2002	849.4	611
2003	558.3	534
2004	782.9	711
2005	420.7	568
2006	1091.6	640
2007	436.7	900
2008	436.1	678
2009	419.4	650
2010	838.7	790
2011	456.4	691
2012	589.5	800

Appendix 4: Annual giraffe population trends in Amboseli National Park.

Year	**Number of giraffes**	**Relative change**	**Relative % change**
2000	57		
2001	52	-5	-8.8
2002	55	+3	+5.8
2003	89	+34	+61.8
2004	76	-13	-14.6
2005	80	+4	+5.3
2006	69	-11	-13.8
2007	56	-18	-26.1
2008	70	+14	+25
2009	64	-6	-8.6
2010	82	+18	+28.1
2011	115	+33	+40.2
2012	130	+15	+13

Appendix 5: Annual giraffe population trends in Nairobi National Park.

Year	Number of giraffes	Relative change	Relative % change
2000	71		
2001	61	-10	-14.1
2002	64	+3	+4.9
2003	71	+7	+10.9
2004	72	+1	+1.4
2005	66	-6	-8.3
2006	71	+5	+7.6
2007	84	+13	+18.3
2008	150	+64	+76.2
2009	115	-35	-41.7
2010	120	-5	-4.3
2011	94	-26	-21.7
2012	200	+106	+112.8

Appendix 6: Annual giraffe population trends in Tsavo West National Park.

Year	Number of giraffes	Relative change	Relative % change
2000	277		
2001	292	+65	+28.6
2002	611	+319	+109
2003	534	-77	-12.6
2004	711	+177	+33.1
2005	568	-143	-20.1
2006	640	+72	+12.7
2007	900	+260	+40.6
2008	678	-222	-24.7
2009	650	-28	-4.1
2010	790	+144	+21.5
2011	691	-99	+12.5
2012	800	+109	+15.8

Appendix 7: Giraffe water sources in Amboseli ecosystem.

Water Sources	**Size**	**Status**	**Importance value**
Enkong Narok swamp	Large	Permanent	4
Simek swamp	Medium	Permanent	3
Serena swamp	Large	Permanent	4
Ol Dare swamp	Large	Permanent	4
Ol Tukai swamp	Very large	Permanent	4
Longinye swamp	Large	Permanent	4
Namelok swamp	Large	Permanent	3
Kimana swamp	Large	Permanent	3
Lake Amboseli	Very large	Seasonal	1
Lake Konch	Small	Permanent	2
Lake Kioko	Medium	Permanent	3
Namanga River	Medium	Seasonal	1
Isinet River	Small	Permanent	2
Imbirikani River	Small	Permanent	2
Kimana River	Medium	Permanent	2
Namelok River	Medium	Permanent	2
Isinet channel	Small	Seasonal	2

4- Very important **3-** Important **2-** Less important **1**-Not important

Very large- >20km^2 **Large -** 15-20km^2, **Medium**-10-15km^2, **Small -** <10km^2

Appendix 8: Giraffe water sources in Nairobi National Park.

Water Source	**Size**	**Status**	**Importance value**
Mbagathi River	Large	Permanent	4
Mokoyiet River	Medium	Permanent	3
Sosian River	Medium	Permanent	3
Donga River	Medium	Seasonal	3
Bomas River	Medium	Seasonal	3
Longomon dam	Large	Permanent	4
Hyena dam	Small	Permanent	3
Athi-Plains dam	Large	Permanent	4
Hippo pools	Medium	Permanent	2
Maasai gate quarry	Medium	Seasonal	4
15 pans	Small	Seasonal	1

4- Very important **3-** Important **2-** Less important **1**-Available

Very large- >20km^2 **Large -** 15-20km^2, **Medium-**10-15km^2, **Small -** <10km^2

Appendix 9: Giraffe water sources in Tsavo ecosystem.

Water Source	**Size**	**Status**	**Importance**
Tsavo River	Big	Permanent	4
Athi River	Big	Permanent	4
Galana River	Big	Permanent	4
Voi River	Big	Permanent	4
Mzima Springs	Large	Permanent	4
Kamboyo dam	Small	Seasonal	3
Severin dam	Small	Seasonal	2
Kilaguni dam	Small	Seasonal	2
Bulutoni dam	Small	Seasonal	2
Ngulia dam	Small	Seasonal	3
Rhino Sanctuary dam	Small	Seasonal	2
Rhino dam	Small	Seasonal	3
Mudanda dam	Small	Seasonal	2
Voi Safari Lodge	Small	Seasonal	2
Aruba dam	Small	Permanent	3
Kandecha dam	Small	Seasonal	2
Satao dam	Small	Seasonal	2
Ndara dam	Small	Seasonal	2
Dida dam	Small	Seasonal	2
Harae dam	Small	Seasonal	2
Lake Jipe	Medium	Permanent	4
Lake Chala	Small	Permanent	3
Rukinga water hole	Small	Seasonal	1
Taita water hole	Small	Seasonal	1

Appendix 10: Mean annual rainfall amounts and temperatures for Amboseli ecosystem.

Year	**Temperature**		**Rainfall**	
Measure	Ave. Min.(T^{o}C)	Ave. Max. (T^{o}C)	Mean Ppt. (mm)	
1982	14.65	31.43	28.8	
1983	14.12	33.03	30.7	
1984	13.53	32.57	11	
1985	13.64	31.23	24.6	
1986	14.13	31.84	26.3	
1987	14.13	33.05	21.1	
1988	14.8	33.53	29	
1989	14.09	32.58	46.1	
1990	14.48	32.57	29.5	
1991	14.69	33.57	34.2	
1992	14.96	37.12	13.9	
1993	14.38	37.57	38	
1994	14.85	37.68	32.6	
1995	14.46	36.46	32.7	
1996	14.54	37.03	18.5	
1997	14.79	34.98	39.3	
1998	14.38	33.25	45.6	
1999	14.38	34.18	38.3	
2000	14.14	34.4	16.6	
2001	14.53	33.28	31.7	
2002	15.38	31.85	33.5	
2003	14.77	32.65	15.4	
2004	14.94	32.63	22.9	
2005	14.23	33.06	23.9	
2006	14.63	32.75	41.3	
2007	14.13	33.39	15.1	
2008	14.13	33.19	16.5	
2009	14.76	33.89	15.8	
2010	14.62	32.62	45.4	
2011	14.35	33.13	22.1	
2012	14.14	32.98	35.8	

Appendix 11: Mean annual rainfall amounts and temperatures in Athi-Kapiti ecosystem.

Year	**Ave. Max. Temp. (T^{o}C)**	**Ave. Min. Temp. (T^{o}C)**	**Mean Ppt. (mm)**
1984	N/R	7.27	37.33
1985	24.38	8.93	70.22
1986	24.83	8.89	40.79
1987	25.16	9.27	71.74
1988	24.43	9.37	68.62
1989	23.59	9.37	90.53
1990	24.01	9.16	53.8
1991	25.18	9.2	40.05
1992	24.74	9.67	39.53
1993	24.73	9.07	68.43
1994	24.67	9.63	65.18
1995	25.18	10.23	55.27
1996	24.7	10.11	68
1997	24.9	10.6	82.44
1998	24.4	10.64	52.46
1999	24.88	10.48	54.68
2000	25.61	9.9	38.3
2001	24.7	10.08	61.57
2002	24.83	10.18	87.1
2003	25.14	9.89	67.17
2004	24.88	10.09	58.58
2005	24.70	10.10	36.75
2006	24.06	10.95	88.25
2007	24.39	10.43	59.33
2008	24.78	10.34	51.58
2009	25.55	11.26	48.33
2010	24.63	11.19	66.65
2011	25.13	11.08	77.32
2012	24.73	10.43	64.97

Appendix 12: Mean annual rainfall amounts and temperatures in Tsavo ecosystem.

	Minimum temperature (T^{o}C)	**Maximum temperature (T^{o}C)**	**Rainfall (mm)**
Year	Ave. Annual	Ave. Annual	Mean Ppt.
1982	19.24	30.53	57.97
1983	20.07	31.71	27.12
1984	19.43	30.78	44.03
1985	19.5	30.53	37.85
1986	19.63	30.65	46.23
1987	19.8	31.58	28.93
1988	20.94	31.06	50.79
1989	19.58	30.31	40.49
1990	19.68	30.68	62.31
1991	19.7	30.92	49.45
1992	19.72	30.84	50.64
1993	19.48	30.63	44.78
1994	19.9	30.87	64.03
1995	19.87	31.18	36.13
1996	19.68	30.93	39.72
1997	19.79	30.68	59.57
1998	19.93	30.45	94.98
1999	19.61	30.78	36.65
2000	19.54	30.85	45.31
2001	18.13	28.36	48.29
2002	19.99	30.68	66.54
2003	20.21	31.69	17.53
2004	20.04	30.84	66.66
2005	20.17	31.4	23.43
2006	20.3	30.83	64.83
2007	20.23	31.48	21.26
2008	19.95	31.15	40.08
2009	20.34	31.48	57.33
2010	20.34	31.48	38.58
2011	20.38	31.44	57.66

Appendix 13: Checklist of giraffe food plant species in Amboseli National Park.

Family	**Species**	**Life form**
Salvadoraceae	*Azima tetracantha* **Lam.**	Shrub
Mimosaceae	*Acacia brevispica* **Harms**	Tall tree (5m)
Mimosaceae	*Acacia drepanolobium* **Sjostedt**	Slender tree (2.5m)
Mimosaceae	*Acacia mellifera* **(Vahl) Benth**	Medium height (2m)
Mimosaceae	*Acacia nilotica (***L.) Del.**	Tall tree (6m)
Mimosaceae	*Acacia Senegal* **(L.)Wild**	Tall tree (5m)
Mimosaceae	*Acacia Seyal* **Del.**	Tall tree (>5m)
Mimosaceae	*Acacia spp*	Short tree (3m)
Mimosaceae	*Acaciatortilis (***Forssk.) Hayne**	Tall tree (>6m)
Balanitaceae	*Balanites aegyptiaca (***L.***)*	Tall tree (7m)
Balanitaceae	*Balanites glabra* **Mildbr. & Schltr**	Short tree (3m)
Burseraceae	*Commiphoramadagascariensis* **Jacq.**	Tall tree (>5m)
Combretaceae	*Combretum molle* **G.Don**	Tall tree (>4m)
Burseraceae	*Commiphora rostrata* **Engl**. Var. *rostrata*	Short tree (<4m)
Burseraceae	*Commiphora schimperi (***O. Berg.) Engl**.	Tall tree (>5m)
Burseraceae	*Commiphora spp*	Short tree (4m)
Boraginaceae	*Cordia monica* **Roxb**	Short tree (3m)
Tilaceae	*Grewia bicolor* **Juss**	Tall shrub
Tilaceae	*Grewia tembensis*	Tall shrub
Tilaceae	*Grewia vilosa* **Willd**	Short shrub
Anacardaceae	*Lannea virae (***Chiv.) Sacl**	Climber
Solanaceae	*Lycium europeaneum* **L.**	Tall tree (>5m)
Capaceae	*Maerua edulis (***Gild-Ben & Benedict) De Wolf**	Short shrub (3m)
Celstraceae	*Maytenus putterickioides* **(Loes)Excell**	Tall shrub
Opilaceae	**Medonca**	Tall shrub
Anacardaceae	*Opilia capenstris* **Engl**. Var. *campestri*	Shrub
Anacardacea	*Ozorea insignis* **Del.** *Ssp Reticulata (***Bak.F) Gillet**	Tall shrub
	Rhus vulgaris **Meikle**	

Appendix 14: Checklist of giraffe food plant species in Nairobi National Park.

Family	**Species**	**Life form**
Leguminose	*Albizia amara* (**Roxb**.) **Bovin**	Tall tree
Leguminose	*Acacia Senegal* **(L.) Willd**	Tall tree
Leguminose	*Acacia geradii* **Benth**	Tall tree (5m)
Leguminose	*Acacia tortilis* **(Forssk.) Hayne**	Tall tree (>6m)
Leguminose	*Acacia drepanolobium* **Sjostedt**	Slender tree (4m)
Leguminose	*Acacia kirkii* **Oliv.**	Tall tree (5m)
Leguminose	*Acacia mellifera* (**Vahl) Benth**	Short tree (3)
Leguminose	*Acacia xanthophloea* **Benth**	Tall tree (>5m)
Leguminose	*Acacia polycantha*	Short tree (3m)
Leguminose	*Acacia brevispica* **Harms** ssp brevispica	Tall tree (4m)
Compositae	*Aspilia pluriseta* **Schweinf. Ex Engl**.	Shrum
Compositae	*Aspilia mossambicansis* (**Oliv.) Wild**	Shrub
Leguminose	*Acacia hockii* **De Wild**	Tall tree (4m)
Balanitaceae	*Balanites aegyptiaca* **(L.) Delile**	Tall tree (>5m)
Balanaticeae	*Balanites glabra* **Mildbr & Schltr.**	Tall tree (4m)
Euphobiaceae	*Croton megalocarpus* **Hutch**	Very tall tree (6m)
Burceraceae	*Commiphora madagascariensis* **Jacq.**	Short tree (4m)
Burceraceae	*Commiphora africana* (**A. Rich.) Engl**.	Tall tree (5m)
Capparaceae	*Capparis tomentosa* **Lam.**	Short shrub
Combretaceae	*Combretum molle* **G. Don**	Short tree (>4m)
Apocynaceae	*Carissa spinorum* **(Forssk.) Vahl**.	Tall shrub (>3m)
Boraginaceae	*Cordia monoica* **Roxb.**	Short tree (4m)
Sterauliaceae	*Dombeya burgessiae* **Gerr ex Harv**.	Tall tree
Sterauliaceae	*Dombeya torrida* (**J.F. Gmel.) Bamps**	Tall tree
Leguminosae	*Dichrostachys cinerea* **(L.) Wight & Arn**.	Short tree
Flacourtiaceae	*Dovyalis caffra* **(Hook. F. & Harv.) Warb**.	Shrub
Euphorbiaceae	*Erythrococca bongensis* **Pax.**	Shrub
Euphorbiaceae	*Fluggea virosa* **(Wild.) Voigt**.	Shrub
Thymelaeaceae	*Gnidia subcordata* **Meisn**	Short tree
Tiliaceae	*Grewia similes* **K. Schum**.	Shrub
Tiliaceae	*Grewia tembensis* **Fresen.**	Shrub
Tiliaceae	*Grewia bicolor* **Juss**	Shrub
Celestraceae	*Hippocratea africana* **(Wild.) Loes**.	Tall tree
Malvaceae	*Hibiscus aponeurus* **Sprague & Hutch**.	Shrub
Malvaceae	*Hibicus micranthus* **L.F.**	Shrub
Verbenaceae	*Lantana camara*	Shrub
Verbenaceae	*Lippia Kituensis* **Vat Ke.**	Herb
Verbenaceae	*Lippia javanica* **(Burn. F.) Spreng**.	Herb
Celastraceae	*Maytenus senegalensis* **(Lam.) Excell.**	Tall tree
Celastraceae	*Maytenus heterophylla* (**Eckl. & Zeyh.)**	Tall tree
Lythraceae	*Nesaeae* kilimandscharica **Koehne.**	Tree
Labiatae	*Ocimum kilimansdscharica* **Gurke**	Herb
Ochnaceae	*Ochna ovate* **O. Hoffm**.	Herb
Ochnaceae	*Ochna insculpta* **Sleume**.	Herb
Ochnaceae	*Ochna holstii* **Engl.**	Herb
Compositae	*Psiadia punctulata* **(D.C) Vatke**	Shrub
Euphorbiaceae	*Phyllanthus sepialis* **Mull. Arg.**	Shrub
Rubiaceae	*Pyrostria phyllanthoidea* (**Baill.) Bridson**	Shrub
Anacardiaceae	*Rhus natalensis* **Krauss**	Shrub
Rhammaceae	*Scutia myrtina* (**Burm.f.) Kurz**	Shrub
Rubiaceae	*Vangueria madagascariensis* **J.F. Gmel**.	Tree
Rubiaceae	*Vangueria infaustta* **Burch**.	Tree

Appendix 15: checklist of giraffe food plant species in Tsavo West National Park.

Family	**Species**	**Life form**
Leguminose	*Acacia brevispica* **Harms** *ssp*	Tall tree (5m)
Leguminose	*brevispica*	Short tree (3m)
Leguminose	*Acacia mellifera* **(Vahl) Benth**.	Tall tree (>5m)
Leguminose	*Acacia nilotica* **(L) Wild**	Tall tree (5m)
Leguminose	*Acacia Senegal* **(L) Wild**	Tall tree (>5m)
Leguminose	*Acacia seyal*	Tall tree (7m)
Leguminose	*Acacia tortilis (*__Forssk) Hayne__	Tall tree (>8m)
Balanitaceae	*Acacia xanthophloea* **Benth**	Tall tree (7m)
Fabaceae-caesalpinioideae	*Balanites aegyptiaca* **(L) Delile**	Tall tree
Boraginaceae	*Cassia abbreviate*	Tall tree (5m)
Combrtaceae	*Cordia monoica* **Roxb**	Tall tree (>4m)
Combretaceae	*Combretum molle* **G. Don**	Tall tree (>5m)
Burseraceae	*Combretum africana*	Tall tree (>4m)
Burseraceae	*Commiphora baluensis*	Tall tree (>5m)
Bureraceae	*Commiphora campestris*	Tall tree (>4m)
Burseraceae	*Commiphora schemperi*	Tall tree
Burseraceae	*Commiphora sp*	Tall tree (6m)
Fabaceae-caesalpinioideae	*Commiphora africana*	Short tree
Tilaceae	*Dalbergia melanoxylon*	Shrub
Tilaceae	*Grewia bicolor* **Juss**	Shrub
Anacardaceae	*Grewia similis*	Climber
Anacardaceae	*Lannea schhweinfurthii*	Climber
Leguminosae	*Lannea triphyla*	Shrub
Meliaceae	*Laicocarpus eriocalyx*	Shrub
Arecaceae	*Melea volkensii*	Tall tree
Anacardaceae	*Omorcarpus/Oenocarpus kirkii*	Tall shrub (>5m)
Malvaceae	*Rhus natalensis* **Krauss**	Short tree
Malvaceae	*Sterculia africana*	Tall tree

Appendix 16: Kernel density home range sizes in Amboseli National Park

Kernel density (KD) ranges			
Season	**MCP %**	**Area (Km^2)**	**Perimeter(km)**
Wet	95	916.40	115.69
	50	226.20	67.50
Dry	95	850.20	111.60
	50	159.50	46.30
Wet	95	924.10	120.40
	50	44.50	24.80
Dry	95	220.90	66.90
	50	37.60	22.60
Minimum Convex Polygons (MCP) ranges			
MCP	95	1005.20	127.40
Wet	95	634.30	114.70
Dry	95	718.30	107.80

Appendix 17: Kernel density home range sizes in Nairobi National Park

SEASON	**MCP %**	**AREA(Km^2)**	**PERIMETER(Km)**
	95	118.00	58.98
	50	2.45	5.80
Dry	95	118.90	63.20
	50	1.12	3.90
Wet	95	154.65	52.57
	50	36.78	23.61
Minimum Convex Polygons			
MCP	95	118.88	50.78
MCP- WET SEASON	95	88.74	42.42
MCP-DRY SEASON	95	110.04	50.60

Appendix 18: Kernel density home range sizes – Tsavo West National Park

SEASON	**MCP %**	**AREA(Km^2)**	**PERIMETER (Km)**
	95	5821.20	345.31
	50	992.10	119.01
DRY	95	3692.60	266.45
	50	717.14	100.97
WET	95	89.57	33.58
	50	1105.61	123.78
Minimum Convex Polygons			
MCP	95	5124.01	310.69
WET	95	4613.19	296.73
DRY	95	2170.20	193.64

Appendix 19: Number of plant species eaten by giraffes during the wet and dry seasons in Amboseli, Nairobi and Tsavo West National Parks

Season	**ANP**	**NNP**	**TWNP**
Wet	14	38	18
Dry	12	35	10
Total	26	73	28