BIRD SPECIES COMPOSITION AND DIVERSITY ALONG AN ECOLOGICAL GRADIENT ON MOUNT KASIGAU IN TAITA-TAVETA COUNTY, SOUTH EAST KENYA

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Environment and Natural Resource Management in the Department of Environment and Natural Resource Management and the School of Science and Technology of Africa Nazarene University

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DECLARATION

I declare that this document and the research that it describes are my original work and that they have not been presented in any other University for academic work

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17JO1DMEV009

This research was conducted under our supervision and is submitted with our approval as University supervisors.

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DEDICATION

Dedication goes to all Avian communities for their resilience in the face of adversity due to changes in weather patterns and unrelenting urbanization juggernaut.

ACKNOWLEDGEMENTS

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ABSTRACT

Interactions of bird species with their biotic and abiotic environment influence their occurrence and spatial distribution. This is because physical and biological conditions vary along an ecological gradient. Elevation gradient, vegetation mosaic and climate variations can influence avifaunal diversity and assemblages. Birds being very good indicators of the state of the environment can be used to demonstrate the impact of these changes on species communities especially in an Afromontane environment in face of unprecedented habitat loss and vagaries of climate change. This study assessed trends in avian diversity, distribution and composition along an elevation gradient and different vegetation mosaic at Mount Kasigau. Birds were captured at various elevations using mist-nets set on a 300-meter-long transect per each ringing ecotone from 850 meters up to 1,550 meters above sea level. The captured birds were identified and ringed and their sex and ages determined. A series of biometrics such as body mass, wing, and tarsus, and molting. The habitats were mapped, vegetation cover, canopy height and dominant plant species along transects were determined. Four habitat related to altitude were used: bushland (850-1104m), woodland (1105-1327m), evergreen forest (1328-1546m), and montane cloud forest (1547-1640m). Data were analyzed using both descriptive statistics and inferential statistics Plant species recorded on the mountain were 84 belonging to 36 families. Plants relative abundance ranged between 1.2 to 11.9 and the common families were Euphorbiaceae (11.9), Fabaceae (11.9) Rubiaceae (8.3), and Apocynaceae (6).Plant species composition decreased with increase in altitude from 48 species and 23 families in the bushland; 27 species and 15 families in the woodland; 18 species and 17 families in the evergreen forest; and 15 species and 13 families in the montane cloud forest. Bird species richness recorded on the mountain was 53 species belonging to 31 families and the relative abundance ranged between 1.9 and 11.3. The highly represented families were Muscicapidae (11.3), and Pycnonotidae (9.4). Relative abundance of bird species ranged from 0.24 to 10.78. The species with the highest relative abundance were Black-backed puffback (*Tchagra jamesi),* Red-capped Robin Chat (*Cossypha natalensis)* and collared sunbird *(Hedydipina collaris)* all with a relative abundance of 0.167. Bird species diversity (H') decreased with increase in altitude; the bushland area had (H'= -2.264) which rated as high; the woodland had (H'= -2.144); evergreen forest (H'= - 1.748); and montane cloud forest (H'= -1.471), which classified as low. There were temporal differences in bird species diversity over the seven (7) year period of the study (2011-2019) and these differences were statistically ($p < 0.05$) significant. There were no statistical ($p > 0.05$) significant correlation (r) between bird species diversity and the mean annual rainfall distribution. Bird species distribution were related to differences in altitudinal physical (abiotic) conditions and biotic (vegetation differences). To guide the conservation of bird diversity the conservation interventions should be geared at safeguarding the integrity of these valuable ecosystems. Conservation managers can use these results to detect, measure and accurately predict range shifts to promptly mitigate impacts on biodiversity.

DEFINITION OF TERMS

Ecosystem Services: These are the benefits derived from natural environment through regulation of ecosystem processes such as supply of food, water and timber (provisioning services); the regulation of air quality, climate and flood risk (regulating services); opportunities for recreation, tourism and education (cultural services); and essential underlying functions such as soil formation and nutrient cycling (supporting services) (Smith *et al*., 2013)

Endemic Bird Area (EBA) is defined as an area that encompasses the overlapping breeding ranges of two or more restricted-range land birds, such that the complete ranges of at least two species fall entirely within the boundary of the EBA.

Moulting: Process where the bird sheds old feathers and regrows new ones

Nature-based Solutions (NbS) are defined by IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

Ringing: The catching and banding of birds for scientific study

ABBREVIATIONS AND ACRONYMS

ES	Ecosystem Services
KFS	Kenya Forestry Service
RSEA	Ringing Scheme of East Africa
WWF	World Wildlife Fund

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The study was an assessment of bird species composition and diversity along an ecological gradient on Mount Kasigau in Taita-Taveta county, south eastern part of Kenya. The study endeavored to associate bird species composition within different habitats arising from elevational differences on Mount Kasigau. The temporal and spatial dimensions of these relationships were also determined. Mount Kasigau rises in elevation from 550m in the surrounding bushland to 1,641m ASL and has a typical Afromontane type of vegetation with four distinct vegetation types which vary along the elevation of the mountain, the vegetation at the lowest elevation is a bushland, followed by a woodland, evergreen forest and finally montane cloud forest towards the peak. The independent variables was the ecological gradient arising from the elevational differences found on the mountain in terms of climate and vegetation mosaics. The study recognized four different altitudinal gradient, these included: lower zones (850-1103m), the middle zones (1104-1326m), the higher zone (1327-1546) and finally top zone (1547-1640). The habitat factors, designated by the different vegetation mosaics included the bushland on the lower horizons, woodland, evergreen forest and finally the tropical montane forest at the top. The dependent variable was trends in bird species composition indicated by bird species composition and bird species richness.

This chapter introduces the study under the following sub-headings: background of the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, scope of the study, delimitation of the study, limitations of the study, assumptions of the study, theoretical framework, and conceptual frame work.

1.2 Background of the Study

Biodiversity monitoring is critical to assessing the health of an ecosystem and requirements of all organisms living within the given ecosystem. This is more so relevant considering impacts of extreme weather event trends which adversely affect an ecosystem over time (Cavarzere & Silveira, 2012). Monitoring methods able to identify species most likely to be affected by environmental changes and show those changes with the strongest impacts will enable policy making to target efforts towards vulnerable species and ecosystems under threat (Şekercioğlu, çağan, Primack, & Wormworth, 2012).

Birds are among the most widely studied organisms and are important indicators to changes in the ecosystem where they habituate. Birds can be used to study the effects of climate variability especially on tropical ecosystems. Birds are highly sensitive to climate and weather changes (Cox, Prys-Jones, Habel, Amakobe, & Day, 2014). Birds are pioneer indicators of climate and weather variability and can be used as an early warning system to changes occurring within an ecosystem (Berthold et al., 2004).

The Taita Hills are under the influence of the intertropical convergence zone that brings heavy rains twice yearly (April and November), but more important to the peaks are year-round rain-bearing clouds blown in from the Indian Ocean. At elevations above 1500 m, the natural vegetation is characterised as secondary moist to intermediate forest, but the majority of the land is now used for agriculture or forestry; native forest patches are small and remain only on a few hilltops (Aerts et al. 2011, Beentje 1988).

Bird species composition, diversity and richness tends to occur in relation to climate, vegetation and habitat factors. Species diversify and the number of species for most taxa decline as the elevation increases within a tropical forest context (Bellis et al., 2009; Carothers et al., 1996). Species become fewer but more specialized in the higher echelons of a forest system and more diverse and generalist feeders in the lower echelons of the same forest system (Luca Borghesio, Samba, Githiru, Bennun, & Norris, 2010; Githiru & Lens, 2005; Sanders & Rahbek, 2012). Though changes in species diversity and composition along an elevational gradient with various distinct ecotones are well known, it is less well understood how and why species' distribution patterns occur as they do (Bellis et al., 2009; Oiselle & Rica, 2001; Şekercioğlu, Primack, & Wormworth, 2012). Species especially the ones with a restricted home range are at a higher risk of extermination due to their narrow range and endemism (Jetz, Wilcove, & Dobson, 2007). Species without access to higher elevations or range-restricted are particularly vulnerable (Sekercioglu, 2012).

Species may respond to weather changes by moving to higher latitudes or elevations; shifts in geographic ranges are common responses in temperate regions, but as for the tropics, latitudinal temperature gradients are shallow; the only escape for species may be to move to higher elevations. There are a few data to suggest that they do, yet the greatest loss of species from climatic disruption may be for Tropical Montane Species (Forero-Medina et al., 2011). Birds are highly sensitive to climate and weather changes. Birds are pioneer indicators of climate and weather variability and can be used as early warning systems to changes in habitat use for a whole ecosystem (Berthold *et al.*, 2004). Studies have shown that tropical bird species richness is strongly associated with patterns of primary productivity that can be captured by the Dynamic Habitat Indices

such as cumulative annual productivity, which has been found to have a high explanatory (R^2_{adj} 0.85) power (Suttidate, Hobi, Pidgeon, Round, Coops, Helmers, Keuler, Dubinin, Bateman, Radeloff, 2019). The threats affecting Mount Kasigau are unsustainable harvesting of resources, Agricultural intensification and expansion, deforestation and habitat loss, fragmentation, pollution, and climate change (Kalibo & Medley, 2007; Williams, Bartholomew, Amakobe, & Githiru, 2018).

The study addressed three main gaps in knowledge regarding bird and plant populations on Mount Kasigau, which are important in ecosystem management, these included: woody plant species composition, diversity, and richness along the elevation gradient of Mt. Kasigau, the bird species composition, diversity and richness within the four different vegetation types along the elevation gradient, bird species, trends in bird species in relation to climatic (rainfall variability) along the elevation gradient of the mountain.

1.3 Statement of the Problem

Birds are everywhere within all ecosystems. Though they can fly, they still have restrictions as they have ranges, inter-specific competition and need specific habitats for roosting and breeding. This makes them good indicators for any changes that occur to an ecosystem (Cox, Prys-Jones, Habel, Amakobe, & Day, 2014). Bird species respond to changing weather conditions by moving to higher latitudes or elevations in tropical ecosystems. In temperate regions shifts in geographic ranges are common (Forero-Medina, Terborgh, Socolar, & Pimm, 2011). Bird species respond to weather variations differently within spatial and temporal frameworks. There is therefore a need to document species composition, diversity, and richness along an environmental gradient in order to understand the species' habitat use.

Mount Kasigau (1641m) is isolated from the Taita Hills 50 km to the South-East. It is has biogeographical similarities with the Taita hills (Collar and Stuart 1988). In a mountainous ecosystem like Mount Kasigau weather changes along the altitudinal gradient. These changes in climate have an influence on vegetation communities, availability of food, water, cover and breeding sites for the birds (Tingley, Koo, Moritz, Rush, & Beissinger, 2012). In order to understand the effects of these changes on bird life, studies that document these variations in bird species composition and assemblages along the altitudinal elevation gradient are needed (Carothers, Jaksic, & Marquet, 1996; Cavarzere & Silveira, 2012). Few studies have been performed on this mountain and there is need therefore to study the bird life on this mountain to aid in their conservation. As there is paucity of data on bird species richness and abundance on Mt. Kasigau, ringing birds and doing point counts will enable us to quantify what assemblages are occurring in the different ecotones (Cox et al., 2014; Habel et al., 2014). This study therefore will help understand these dynamics and how they contribute to variations in avifaunal assemblages, diversity, species richness and distribution within space and time (Thomas *et al.,* 2004).

1.4 Purpose of the Study

The purpose of this study is to increase biological knowledge of the Afromontane biodiversity of bird species through understanding the impact of elevation gradient on species habitat use, habitat preferences, spatial distribution and diversity for improved conservation and management.

1.5 Objectives of the Study

The following were the objectives of the study:

(i) To determine woody plant species composition along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya;

(ii) To determine bird species composition along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya;

(iii) To assess bird species diversity along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya;

(iv) To assess trends in bird species diversity in relation to spatial and temporal dimensions on Mount Kasigau in Taita-Taveta County, South East Kenya.

1.6 Research Questions

(i) What are the differences in species composition along an altitudinal gradient in Mount Kasigau in Taita-Taveta County, South East Kenya?

(ii) Do bird species composition depend on elevation gradient in Mount Kasigau in Taita-Taveta County, South East Kenya?

(iii) How is bird species diversity influenced by altitudinal gradient in Mount Kasigau in Taita-Taveta County, South East Kenya?

(iv) Are trends in bird species diversity influenced by spatial and temporal dimensions on Mount Kasigau in Taita-Taveta County, South East Kenya?

1.7 Significance of the Study

The study will assist in creating awareness among local users on the importance of the Mt Kasigau and help in encouraging sustainable utilization of the primary product resource base. As not much is known about movements of bird species within the

ecotones, the study will open a window of opportunity in creating new knowledge of how the species interact both with their biotic and abiotic environment.

As an endemic hotspot, all measures should be taken to conserve Mt Kasigau. Threats like unsustainable harvest of ecological resources, grazing in restricted zones are a major threat to the forest. The study will help highlight the problems as the researchers will have a better understanding of the different indirect dynamics that hold together Mt Kasigau a major water tower in an area bereft of any permanent water source.

Mt Kasigau is a forest reserve meaning Kenya Forestry Service (KFS) is holding it in trust for the local community but the mandate of the management of the forest lies with the local community (Bills, 2015). This study will create an awareness to the locals on the importance of the forest and assist KFS in its effort to police and conserve it.

1.8 Scope of the Study

The study focused on birds within the Mt Kasigau forest area and how they react to elevation gradient and habitat changes. Two surveys one in February 2019 and another May 2019 were undertaken. The survey covered from 850m above sea level, as the lowest transect and 1550m above sea level as the highest level of the transect.

1.9 Delimitation of the Study

This study did not count the entire population of birds on Mt. Kasigau, but was limited to the sample that was caught using the mist nets along the set transects. It would be a proper to realize that some birds and especially the canopy feeders cannot be caught using mist nets, though, such species will be captured in the birds' list.

1.10 Limitations of the Study

Mt Kasigau has two major rainy seasons, March to May for long rains and October to December for short rains. The plan was to conduct the survey when it was dry in February to avoid wet season as the terrain would be difficult to navigate and May just when the long rains had stopped. The terrain on the lower reaches of the mountain were stony and rough, but with care and planning, they were navigated. The temperatures especially in the lower echelons were high leading to dehydration and fatigue. The appropriate gear and enough water were carried by the team to avoid exhaustion.

1.11 Assumptions of the Study

Weather conditions during the sampling period would not fluctuate unpredictably and the equipment needed for the study would be in good condition throughout the entire period of the field work research. Birds will behave naturally and be caught not by the influence of our equipment, but because their movement was natural.

1.12 Theoretical Framework

The study of species distributions along environmental gradients has, in the main, been the province of plant ecologists. The motivation behind their investigations is largely a desire to resolve the long-standing controversy over the community vs. continuum issue (McIntosh 1967, Whittaker 1967). Several ambitious and meticulously conducted projects have yielded a large body of detailed information (e.g. Whittaker 1956, Bray and Curtis 1957, Daubenmire 1966). But disagreement over methods and the interpretation of results, as well as a lack of consistency in findings from different localities, has prevented a satisfactory resolution of the main question (Popy, Bordignon, & Prodon, 2010). The researcher intends to use the data collected to assess

the correlation between weather changes, vegetative variations and elevation gradient to see how this affects bird movement (Thomas *et al.,* 2004).

Much of the complexity that has been encountered heretofore in gradient analysis has resulted from two practices: the use of temperate localities, and the use of plants. Aside from their erratic character, temperate climates vary locally in such factors as the length of the growing season, amount and duration of snow cover, etc., while plants are highly sensitive to local conditions of soil, drainage and exposure and hence are subject to uncontrolled variation in abundance along any major environmental gradient. In the belief that distributional patterns would be relatively simple and obvious if one avoided these two handicaps, the present investigation was undertaken with birds in a nearly non- seasonal tropical locality (Terborgh, 1971).

Much emphasis has been put on range shifts due to change in temperature while downplaying changes brought about by precipitation. Birds will be likely to change their elevational range than ecological range when they have a small clutch-size or while defending an all-purpose territory (Tingley *et al.,* 2012).

1.13 Conceptual Framework

The study conceptualized that there was an existing relationship between altitude as it affects the type and composition of the vegetation which form habitat for birds. Therefore in understanding the different habitats on Mount Kasigau and bird species composition, we could conserve the bird species on the mountain.

Mount Kasigau rises in elevation from 550m in the surrounding bushland to 1,641m ASL and has a typical Afromontane type of vegetation with four distinct vegetation types which vary along the elevation of the mountain, the vegetation at the lowest

elevation is a bushland, followed by a woodland, evergreen forest and finally montane cloud forest towards the peak. The independent variables was the ecological gradient arising from the elevational differences found on the mountain in terms of climate and vegetation mosaics. The study recognized four different altitudinal gradient, these included: lower zones (850-1103m), the middle zones (1104-1326m), the higher zone (1327-1546) and finally top zone (1547-1640). The habitat factors, designated by the different vegetation mosaics included the bushland on the lower horizons, woodland, evergreen forest and finally the tropical montane forest at the top. The third independent factor was climatic factors, which included rainfall, temperature and change in climate.

The dependent variable was trends in bird species composition indicated by bird species composition and bird species richness.

It was hypothesized that these three independent variables can affect the dependent variable bird species composition and diversity. This relationship can be also influenced by anthropogenic factors (bird poaching and unstainable harvesting of plants). The temporal and spatial dimensions of these relationships were also determined to recommend on conservation management.

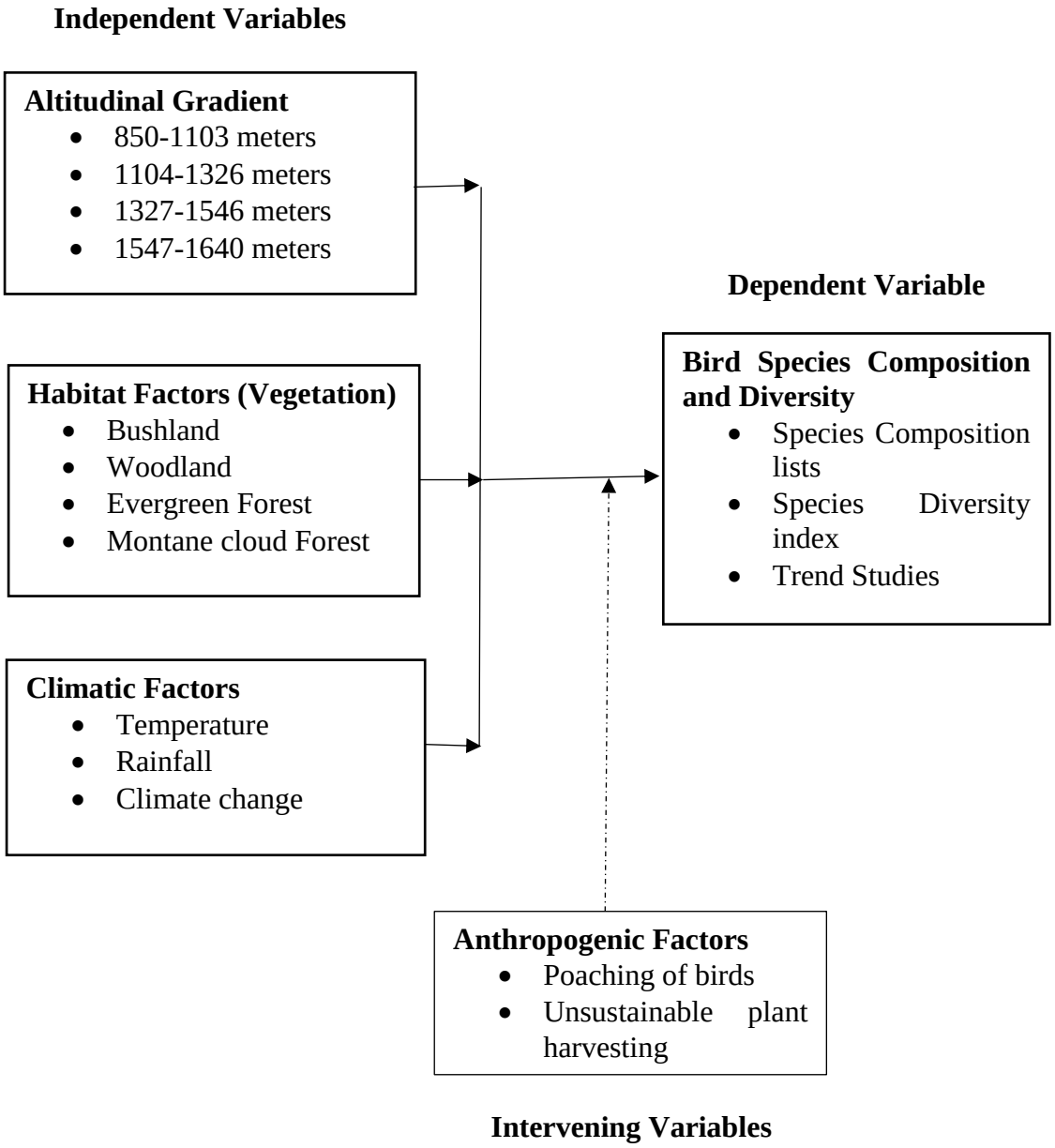


Figure 1.1: Conceptual framework depicting the relationship between factors influencing bird species composition and diversity in Mount Kasigau

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This achpter contains a review of literature pertaining to this study. It includes: Eastern Arc Mountain, climate change and biodiversity, bird diversity and threats affecting birds, socioeconomics and ecological importance of birds, climate change and its effects on birds, species diversity and distribution along elevational gradient, biodiversity importance and summary and gaps in knowledge.

2.2 Eastern Arc Mountains

The Taita Hills in southeastern Kenya belong to the chain of Eastern Arc Mountains that rise from the surrounding plains (of ca. 600–700 m elevation) to a series of peaks and ridges, with the highest point being Vuria (2208 m). The soils are deep and low in nutrients; they have a low pH and poor water-holding capacity. The Taita Hills are under the influence of the intertropical convergence zone that brings heavy rains twice yearly (April and November), but more important to the peaks are year-round rain-bearing clouds blown in from the Indian Ocean. At elevations above 1500 m, the natural vegetation is characterised as secondary moist to intermediate forest, but the majority of the land is now used for agriculture or forestry; native forest patches are small and remain only on a few hilltops (Aerts et al. 2011, Beentje 1988).

2.3 Climate Change and Biodiversity

Though it takes a lot of time to study changes in weather pattern and how this affects an ecosystem, a baseline must be laid somehow (Tingley *et al.,* 2012). The literature review shows that most studies on this subject are not conclusive as we are captured in

a time capsule where ‘real climate change is happening, and no one knows for sure what shape this will take, though most are agreed that we are headed for a disaster (Cavarzere & Silveira, 2012).

Global warming and climate change are contentious issues, but extreme weather events like flooding Tsunamis, droughts in the recent past point to something being amiss (Arbor & Road, 2008; Forero-Medina, Terborgh, Socolar, & Pimm, 2011). Many studies have in recent times being conducted on the subject of global warming, but we are all attuned to the fact that it takes a long time for effects of such changes to be measured but sadly we are feeling them (Arbor & Road, 2008; Jetz et al., 2007; Thomas et al., 2004).

Species diversify and the number of species for most taxa decline as the elevation increases within a tropical forest context (Bellis et al., 2009; Carothers et al., 1996). Species become fewer but more specialized in the higher echelons of a forest system and more diverse and generalist feeders in the lower echelons of the same forest system (Luca Borghesio, Samba, Githiru, Bennun, & Norris, 2010; Githiru & Lens, 2005; Sanders & Rahbek, 2012). Though changes in species diversity and composition along an elevational gradient with various distinct ecotones are well known, it is less well understood how and why species’ distribution patterns occur as they do (Bellis et al., 2009; Oiselle & Rica, 2001; Şekercioğlu, Primack, & Wormworth, 2012).

Species diversity and richness changes rapidly along an elevational gradient with the lower echelons of a mountain being richer in species diversity than the top. This is

especially true with the tropic montane forests (L Borghesio et al., 2009; Forero-Medina et al., 2011; Island, 2012; Popy et al., 2010).

2.4 Bird Diversity and Threats Affecting Birds

The species diversity globally is estimated at 9200 globally (Chapman, 2009), 2300 in the African continent and 1100 for Kenya (Jetz *et al.,* 2007). The wider Kasigau corridor consists of about 300 bird species (Hawk, n.d.) but previous surveys of mark-release of birds in the forest has yielded 50 bird species in the forest itself (Bernard Amakobe. *pers com*.,).

The study of species distributions along environmental gradients has, in the main, been the province of plant ecologists. The motivation behind their investigations was largely a desire to resolve the long-standing controversy over the community vs. continuum issue (McIntosh 1967, Whittaker 1967). But disagreements in methods and result interpretation has necessitated a new approach to elevation gradient analysis defining associations among species both in biotic, abiotic and other relationships like inter-specific competition (Carothers *et al.*, 1996).

Species richness and high rates of endemism increases as we approach the equator. Various latitudinal diversity gradient explanations such as ecological, historical and evolutionary hypothesis have been floated to explain the phenomena (Bellis et al., 2009; Cornell et al., 2007; Şekercioğlu et al., 2012). Though we have cases where species are resilient and speciation and differentiation can occur to adopt to certain local conditions, a lot more work needs to be done to make such conclusions as appertains adaptation (Mccormack & Smith, 2008; Mcinnes, Purvis, & Orme, 2009).

Mt Kasigau is part of the Eastern Arc Mountains and is a hotbed of biodiversity endemism. Species richness is quite high considering its small geographic area. Bird species both local and palearctic find it as a hub and a refueling point (Acharya & Vijayan, n.d.; Fuchs, Fjeldså, & Bowie, 2011).

The threats affecting Mt Kasigau are unsustainable harvesting of resources, Agricultural intensification and expansion, deforestation and habitat loss, fragmentation, pollution, and climate change (Kalibo & Medley, 2007; Williams, Bartholomew, Amakobe, & Githiru, 2018).

2.5 Socio-Economic and Ecological Importance of Birds

The population within the six locations around Mt Kasigau is about 250,000 and their predominant socio-economic activities are livestock rearing, small scale farming and hunting for subsistence. Mining is also a major activity but controlled by a few elite. (Freund & Bird, 2013).

Species response to change in climate and concerted anthropogenic activities are critical factors in biodiversity conservation especially for high conflict areas. These coupled with traditional land rights and other socio-economic activities especially infrastructural development have adverse effects on the ecosystem (Arbor & Road, 2008; Medley & Kalibo, 2005; Rosaceae, Elven, Hansen, & Brochmann, 2010).

Rapid human development and the attendant socio-economic challenges that accompany such developments cause a major strain to natural resource due to unsustainable utilization and overexploitation (Bytebier, 2001; Freund & Bird, 2013; Kalibo & Medley, 2007; Wormworth & Mallon, 2006). This coupled with factors such

as extreme weather changes and climate change cause undue pressure on the resource (Luca Borghesio et al., 2010; Şekercioğlu et al., 2012; Wormworth & Mallon, 2006)

2.5 Climate Change and Its Effect on Birds

Birds are a widely studied species and good indicators on any climatic changes that happen within an ecosystem. Birds that are especially vulnerable are the range-restricted species, or species that have specific ecotone needs and any small changes can adversely affect them (Wormworth & Mallon, 2006). Tropical mountain birds, species without access to higher elevations, coastal forest birds, and restricted-range species are especially vulnerable (Cavarzere & Silveira, 2012). Some birds may be especially susceptible to increased rainfall seasonality and to extreme weather events, such as heat waves, cold spells, and tropical cyclones (Şekercioğlu et al., 2012). Though altitudinal movements can have effects on different species of flora and fauna, some of the changes should be interpreted carefully so as not to link them to global warming and climate change without sassing out some underlying causes (Jetz *et al.*, 2007; Popy *et al.*, 2010).

2.6 Species Diversity and Distribution along Elevation Gradient

Bird species especially in the tropics have very narrow home ranges which makes them highly vulnerable to any changes in vegetative composition or extreme/mild changes in weather conditions. These changes may be both biotic and abiotic which makes such species vulnerable to the extent of even becoming extinct over time in relation to narrow elevation bands (Arbor & Road, 2008; Brooks, Lens, Barnes, & Barnes, 2010; T. M. Brooks et al., 2002; Carothers et al., 1996)

Species may move along a gradient due to changes in temperature (Popy *et al.*, 2010). This is more obvious to bird species in the temperate regions but birds in the tropics do not have a huge band in terms of temperature changes and that may force a species to move to higher elevation to survive (Forero-Medina et al., 2011). Endothermy may provide birds with some flexibility to temperature changes and allow them to move less than expected. Instead of being directly dependent on temperature, birds may be responding to gradual changes in the nature of the habitat or availability of food resources, and presence of competitors. If so, this has important implications for estimates of mountaintop extinctions from climate change (Forero-Medina *et al.*, 2011).

The Taita Hills of south-eastern Kenya are an ancient mountain massif forming the northernmost reach of the Eastern Arc Mountains range, one of 34 global biodiversity hotspots (Mittermeier *et al.*, 2004). The tiny forest remnants of the Taita Hills and Mt Kasigau boast a remarkable amount of endemic biodiversity, including plants, vertebrates and invertebrates (Burgess *et al.*, 2007), but the survival of these species is threatened by a rapidly expanding human population (Luca Borghesio et al., 2010; Bytebier, 2001).

Mt Kasigau is the most northeastern mountain in the Eastern Arc and coastal forests biodiversity hot spot according to Myers *et al*., 2000 (T. M. Brooks et al., 2002; Mulwa, Bennun, Ogol, & Lens, 2007). These ancient crystalline mountains have a high species richness and, compared with other hot spot locations, the highest concentration of endemic species and among the highest degree of habitat fragmentation and loss (Newmark 2002). Perhaps because of the mountain's isolation and the very rigorous climb to its summit (one thousand meters in about two kilometers).

2.7 Biodiversity Importance

Common carnivores are the wild dog *Lycaon pictus*, lion *Panthera leo*, leopard *Panthera pardus*, cheetah *Acinonyx jubatus*, and spotted hyena *Crocuta crocuta*; Grevy's zebra *Equus grevyi*, African Elephant *Loxodonta Africana*, Martial Eagle, African Crowned Eagle, Bateleur, Lappet-faced Vulture, African White-backed Vulture and the Secretary bird *Sagitarrius serpentarius.* An endemic bird species Taita White-eye *Zosterops poliogater* is found in the montane forest part of the mountain (Freund & Bird, 2013)

2.8 Summary and Gaps in Knowledge

Several studies have been undertaken on Mt Kasigau especially to document it's vegetation but not much on birds and elevation gradient and how it affects all biota(Medley & Kalibo, 2005). Studies done on birds indicate Mt Kasigau as a strong endemism zone and hosts critical populations of Taita White-eye *Zosterops silvanus* in the fragmented forests of Taita Hills and Mount Kasigau, Kenya (Mulwa *et al.*, 2007).

Species may respond to a warming climate by moving to higher latitudes or elevations. Shifts in geographic ranges are common responses in temperate regions but not so for the tropics (Jetz et al., 2007). For the tropics, latitudinal temperature gradients are shallow; the only escape for species may be to move to higher elevations. There are a few data to suggest that they do, yet the greatest loss of species from climatic disruption may be for Tropical Montane Species (Forero-Medina *et al.,* 2011).

As global warming brings changes in temperature, altered moisture and precipitation, more extreme weather and a generally more variable climate, birds from the Arctic to the Antarctic are already responding (Malhi *et al.,* 2010). Literature reviewed shows

that very little is known about effects of weather and elevation gradient shift on birds of Mt Kasigau and this study will shed light on what happens when we observe such changes (Freund & Bird, 2013).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives information on the research methodology that was used in this study. They include; research design, study area, target population, sampling procedure, sampling methods, and data collection methods and instruments and data analysis.

3.2 Research Design

The *ex-post facto* type of research design was used for this study. It can be described as a pre-experimental type of design, which is quantitative and longitudinal in nature as it involved monitoring the trends in biodiversity (plants and birds) on Mount Kasigau over a long period of time. The design was found to be appropriate for this study, in that the dependent variable bird species composition and diversity had already occurred and no manipulation was needed. Plant and bird species data was collected in the dry and wet season every year starting from 2011 to 2019 in order to monitor the trends in bird and plant species diversity.

The *ex-post facto* design or the causal comparative design attempts to trace the effects that have already occurred to a probable cause. It tries to establish the influence of the independent variables on the dependent variable. It is applicable to environment and natural resource management especially with phenomena that are not easy to enact in an experiment such as pollution effects, radiation effects, drought, and rain on living organisms. It is easy to study these phenomena after they have occurred. It is a basic design for determining cause-and-effect relationships between variables. Causal-comparative research is different from experimental research in that you do not

manipulate the independent variable since it has already occurred, and as already indicated, you cannot control it.

3.3 Research Site

The geographical location of Mt Kasigau occurs in the Taita Taveta District and Coast Province in southeast Kenya (38◦39_E and 3◦30_S), in a corridor of private and communal lands between Tsavo East and West national parks. It is the most northeastern mountain in the Eastern Arc and coastal forests biodiversity hot spot (Myers et al., 2000). These ancient crystalline mountains have high species richness and, compared with other hotspot locations, the highest concentration of endemic species richness and among the highest degree of habitat fragmentation and loss (Newmark, 2002).

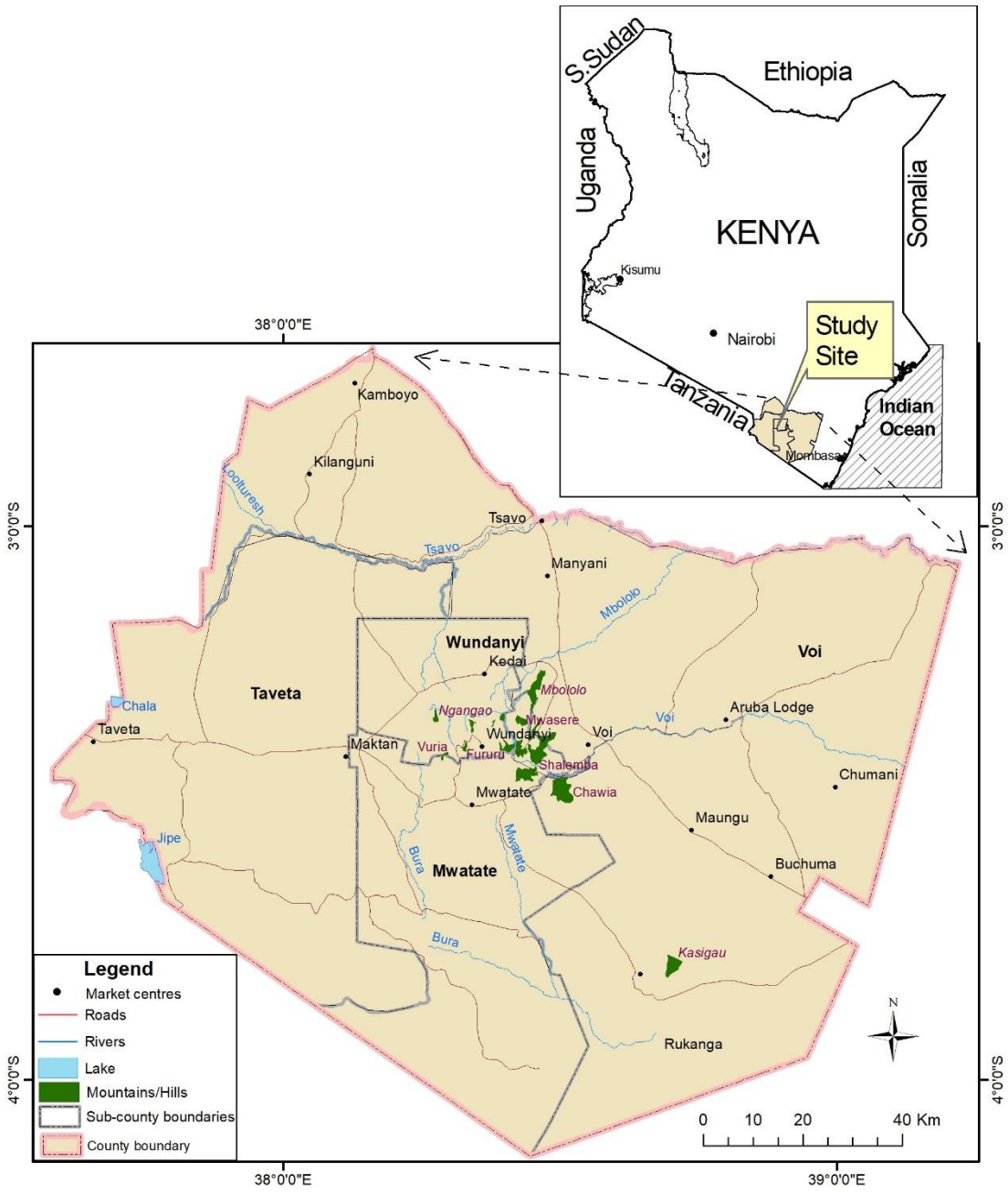


Figure 3.1: Map of the Study area, showing the location of Mt Kasigau in relation to other hills in Taita-Taveta County

Mt Kasigau rises in elevation from about 550m in the surrounding bushland to a height of 1641m. With the increase in elevation, there is a significant drop in temperature and thus an increase in rainfall. The temperature drops because the air is getting thinner and the rains increase because the mountain captures moisture from the clouds that come in from the Indian Ocean coast (Medley & Kalibo, 2005).

3.3.1 Climate

The climate in the Kasigau Area is semi-arid, with average annual rainfall in the 300-500 mm range. There are no permanent water sources. Though irregular and prone to fail, rains typically occur seasonally twice a year, in November and April, known as the grass rains and the long rains, respectively. Rainfall follows a bimodal pattern alternated with a long (June–14 September) and a short (February) dry period (Lehouck *et al.*, 2009). Moist forest in the Taita Hills depends on cloud precipitation brought in by southeast trade winds originating from the Indian Ocean (Aerts *et al*., 2011)

3.3.2 Hydrology and Drainage

The mountain rises steeply from 600 to 1641m in less than 2 km, and captures enough atmospheric moisture from the Indian Ocean to sustain evergreen forest above 1000 m. There are no permanent water sources around the mountain. Moisture captured from the Montane forest top is harvested from catchments at the base of the mountain (Kalibo & Medley, 2007).

3.3.3 Floristic Description of the Study Site

The vegetation has been stratified into three main regimes:

Montane Forest: On the hill slopes, there exist fragments of montane forest, similar in vegetation composition to the cloud forest fragments of the Taita Hills (Wilder *et al.*, 2000)

Dryland Forest: Most of the Project Area is comprised of Acacia-Commiphora Dryland Forest, where the dominant species include: *Acacia tortilis*, *A. nilotica*, *A. bussei*, *Commiphora africana*, *C. campestris*, and *C. confusa*. Few emergent hardwoods include *Terminalia spinosa*, *Melia volkensii*, and *Boscia coriacea.*

Savannah Grassland: At the lowest elevations, the Dryland Forest transitions to patches of grassland and open shrubs with the occasional *Acacia zanzibarica* (Freund & Bird, 2013).

3.3.4 Geology and Soils

Tropical forests on the ancient crystalline Eastern Arc mountain system of Tanzania and Kenya are probably the oldest remaining forests in East Africa and an important biogeographic link between the tropical forests of central Africa, the Indian Ocean coast, and the much younger volcanic mountains of the Rift Valley (Lovett and Wasser, 1993). Mt Kasigau has 203 ha of gazetted evergreen forest under the protection of the Kenya Forest Department.

3.4 Target Population

The study targets two populations on Mont Kasigau in Taita-Taveta County, these include: (i) the total bird population found in all elevations of the mountain, (ii) and the population of woody plant species found in all elevations of the mountain.

3.5 Study Sample

3.5.1 Study Sample Size

The size of the bird sample was all the bird species that were caught in the mist nets in the four designated areas along the altitudinal transect during the data collection period. The captured birds were ringed and subsequent recaptures were noted. Any movement along the altitudinal transect were also noted. The size of the woody plant sample was all the tree species found along the altitudinal gradient within the four study areas on the mountain.

3.5.2 Sampling Procedure

Stratified random sampling procedure was used. The mountain was divided into four strata based on altitude and vegetation types, these included:

(i) Bushland vegetation types at altitude range of 850-1104m

(ii) Woodland vegetation type at altitude range of 1105-1327m

(iii) Evergreen forest vegetation type at altitude range of 1328-1546m

(iv) Mountain cloud forest vegetation at altitude range of 1547-1641m

In each stratum the sampling transects for the woody plants and the mist nets for sampling bird species were placed at random. The map (Figure 3.1) illustrates the placement of the mist nets from the lowest point at 850 m ASL to the highest transect at 1,641 m a.s.l.



Figure 3.1: Four sites where mist nets for capturing birds were erected (in green pins) and 20 sites where vegetation data were collected (in pink pins) along the Mt Kasigau elevational gradient

3.6 Data Collection

The following data for plants and birds were collected during this study, these included: species diversity, species composition, species richness, cover.

3.6.1 Data Collection Instruments

The following equipment were used:

i. Mist nets (3 by 12m) and bird bags.
ii. Rings engraved with numbers.
iii. Assorted ringing equipment for collecting biometric data on each bird (ringing pliers, wing measuring rules, calipers, weighing instrument, cyclic pliers).
iv. GPS units for geo-location.
v. Camera for taking photos of bird species caught.
vi. Ringing book for data collection and guide books for identification.



Figure 3.1: An Assortment of equipment used in Bird Ringing studies

3.6.2 Pilot Testing of Research Equipment

Mist nets were set up on Marasi Hills near Mount Kasigau to ensure all are in order and calibrated. This will ensure that trouble-shooting will happen to enable the team to forestall any challenges in the field. The lowest transect within Mt Kasigau forest with 10 mist nets set up. This was used to ensure the equipment is calibrated well.

3.6.3 Instrument Reliability

All equipment to be used such as mist nets, ringing pliers, weighing balances, measuring rulers will be well calibrated in advance to avoid their failure and thus collect inaccurate data.

3.6.4 Instrument Validity

The study shall ensure that the equipment used is not harmful to birds and it passes the standards set aside for such equipment in use for bird trapping. Mist nets will be sourced legally and guarded jealously so as not to fall into hands of people who can misuse them.

3.6.5 Data Collection Procedure

Mist-netting is one of the most commonly used method for capturing birds. However, in most countries the use of mist nets is strictly controlled, and a national permit is required to either buy or use mist-nets (De Beer et al., 2001). It involved trapping birds using fine nets, normally about three meters high and up to 18m long. They are also available in different mesh size and strand thickness. When placed against a dark background the nets are almost invisible from the side. The nets are erected between two poles (see Figure 3.3) and, for day-time, netting is placed in suitable sites for birds.

The nets were placed in four transects within the four different vegetation types, which were marked using altitude ranges (are set Birds trapped using fine nets, for birds. During the experiment, the mist-net effort will be a constant of 25, 12-meter nets, which will be opened for 6 hours between 6:00 am and 12:00 pm in all 4 transects.

Bird Ringing is a mark-release method for marking an individual bird uniquely, so it can be differentiated from a population of other similar birds (Hightower, Gilbert, Hightower, Gilbert, & Gilbert, 2016). A bird is fitted with a light-weight metal ring (normally aluminum) that fits the size of its leg. The ring is marked with the address of the regional ringing scheme and a number that together make the ring unique – and therefore there will be no other ring in the world like it (De Beer, Lockwood, Raijmakers, Oschadleus, & Underhill, 2001). We trap birds using fine nets, normally about three meters high and 12m long each. When placed against a dark background the nets are almost invisible from the side. The nets are erected between two poles and, for day-time, netting is placed in sites suitable for birds. During the data collection period mist-net effort will be a constant of 25, 12-meter nets, which shall be opened for 6 hours between 6:00 am and 12:00 pm for each transect. Other parameters measured were the weather condition, altitude, time nets operated, date and the temperature.



Figure 3.2 Mist nets set up for catching birds

3.7 Bird Survey

Bird surveys were conducted in June and July 2018, at 30-point count stations (15 each in the four vegetation types and altitudinal differences). The timing of field visits was between 06:00 to 10:00 hr when birds were more active. Point count method described by Bibby et al. (2000) was used to survey birds. Birds seen or heard were recorded within a radius of 100 m using binocular (Nikon Monarch 3, 10 x 8 m). At each point count station, we observed birds for 5 minutes. Point count stations were spaced 100 m apart to avoid multiple counting, and this was measured using GPS (Garmin 76 CSx). The nomenclature for bird species follows Borrow and Demey (2014).

Secondary Data Collection

Data collected between October 2011 and January 2015 will be used to compare what effect weather variability and seasonality (wet and dry season) will have on ringed birds in the Mt Kasigau ecosystem. During that expedition, mist-nets were placed in the four ecotones and we shall maintain the same transects so that the data can be comparable.

3.8 Ethical Considerations

The researcher will apply for a permit from National Commission for Science Technology and Innovation (NACOSTI) to conduct research and adhere to the set standards for handling birds as provided for from Ringing Scheme of East Africa (RSEA).

All the team members handling the birds are highly and rigorously trained and their standing in the Ornithology section is unquestionable. No unethical experiments will be performed on birds and will adhere to the rules and regulations laid down by the RSEA whose mandate is to regulate who is authorized to ring or not.

3.9 Data Analysis

Data will be analyzed using descriptive (means, median, mode) and inferential statistics. Bird diversity was determined using Shannon-Weiner diversity index. To minimize the effect of multiple counts, the average number of birds counted was taken for each site and for each bird species after the two months data was collected. Diversity t-test was used to compare bird species diversity between the four-habitat areas. The level of significance was set at $p < 0.05$. Sorensen's similarity index was used to measure the extent of similarity between the two sites (Magurran, 2004) as follows:

$$Cs = 2c/a + b$$

Where Cs is the SØrensen's index of similarity, a is the number of species in the bushland, b is the number of species in the woodland, and c is the number of species common to both areas.

Species richness for each site was determined by counting the number of bird species recorded from each wetland area. Relative abundance of bird species was calculated according to Rais et al. (2013), using the formula below;

$$\text{Relative Abundance} = \frac{\text{Abundance of a bird species}}{\text{Total abundance of all bird species}} \; x\, 100$$

Paleontological statistical package (PAST version 2.17, Hammer et al. 2001) was used for the analyses.

$\sum$= s i 1 H' = - pi log pi

methods including; T-test, ANOVA and Chi-square and DISTANCE. Data will be input in Excel spreadsheet which will be used as an analysis aid program. Data will be presented in graphical and pie-charts presentations to be used to give meaning to the assumptions of gradient shifts by birds.

To assess species diversity and distribution along elevation gradient, the study will use T-test and ANOVA for analysis.

To assess bird species and their altitudinal distributions and patterns of abundance, observations along the transect and calls will be analyzed using DISTANCE.

To correlate climatic variability, elevation and altitudinal movements and dispersal, temperature and rainfall measurement will be analyzed using ANOVA

Jaccard's similarity index will be used to analyze the similarity indices of bird communities from different habitat types while the diversity index will be used to

compare species compositions of the different habitat types from the mist netting data. The Jaccard index is conceptually a percentage of how many objects two sets have in common out of how many objects they have total (Jaccard, King, Donuts, & Ingredient, n.d.).

Nets will be monitored while also in-between recording all species seen and heard during the session. The study shall mark and release all individuals caught and hope to recapture them as re-traps at the consequent capture session. The mark and recapture method involve marking several individuals in a natural population, returning them to that population, and subsequently recapturing some of them as a basis for estimating the size of the population at the time of marking and releasing. Perhaps the most popular is the Jolly-Seber method (Hightower *et al.,* 2016) which requires capturing and marking of animals at regular time intervals.

Animals, marked and released each time, should have different marks so that it is possible to distinguish between individuals marked on different dates. Algorithm is given in Southwood (1978). $\frac{m}{n} = \frac{M}{N}$

Population size can be found as: $N = nM/m$ ("Lincoln Index," n.d.).

The following conditions should be met:

(i) No immigration, emigration, births or deaths between the release and recapture times.

(ii) The probabilities of being caught are equal for all individuals (including marked ones).

(iii) Marks (or tags) are not lost and are always recognizable.

It is based on the principle that if a proportion of the population was marked in some way, returned to the original population and then, after complete mixing, a second sample was taken, the proportion of marked individuals in the second sample would be the same as was marked initially in the total population.

Species will be categorized ecologically following Bennun & Fanshawe (1997). These categories are as follows: FF - Forest Specialists (requires an intact forest), F - Forest Generalists and f – Forest Visitors. Bird communities e.g. the FF in case of forests, are good indicators of changes that are taking place in the environment and are therefore a crucial tool for conservation (Bennun & Fanshawe 1997).

Species diversity was calculated using the Shannon-Weiner (H') Diversity Index as proposed by Shannon (1948), which was chosen because of its ability of providing both the estimate in terms of abundance and evenness and does not favor some species over others as all species are counted according to frequencies as follows;

$H' = - \sum pi \ln pi - - - i$

Where i is the proportion of the plant species relative to the total number of species (pi) multiply by the natural logarithm of this proportion (ln pi) and the final product multiply by -1. $S = \sum n - - - ii$

Table 3.1: Data Analysis Summary Table

Study Objective	Variables	Data collected	Type of Analysis
To determine woody plant species composition along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya.	Plant species name,	Plant species	Species composition list per stratum,
To determine bird species composition along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya.	Bird species composition, altitude	Birds trapped in mist nets	Species composition per stratum
To assess bird species diversity along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya.	Bird species diversity	Bird species per stratum	Shannon and Wiener function (H') of diversity
To assess trends in bird species diversity in relation to spatial and temporal dimensions on Mount Kasigau in Taita-Taveta County, South East Kenya.	Bird species diversity	Bird species per stratum, secondary data	Shannon and Wiener function (H') of diversity, Correlation

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter presents results and their interpretation on the factors affecting bird composition and diversity in Mount Kasigau in Taita-Taveta County, Kenya. The chapter is divided into the following sections: (i) woody plant species composition on Mount Kasigau, (ii) bird species composition on mount Kasigau, (iii) bird species diversity on mount Kasigau, (iv) bird species diversity in relation to spatial and temporal dimensions,

4.2 Woody Plant Species Composition on Mount Kasigau

The first objective was to determine the plant species composition along the altitudinal gradient on Mount Kasigau. The plant species that were found on Mount Kasigau within the different ecotypes (bushland, woodland, evergreen forest, and montane cloud forest), the type of plant growth habit (whether tree, shrub or climber), plant family were noted during the data collection period. The data were then analysed and is presented in a Table (Table 6.1 in Appendix C).

The study recorded 84 plant species belonging to 36 families as shown in Table 4.1. The relative abundance of plant species ranges from 1.2 to 11.9. Plant families that were highly represented in the study area were Euphorbiaceae and Fabaceae both with a relative abundance of 11.9 followed by Rubiaceae (8.3), and Apocynaceae (6).

Table 4.1: Woody Plant Families and Number of Species Represented and their Relative Abundance on Mount Kasigau

Family	Number of Species	Relative Abundance
Acanthaceae	1	1.2
Achariaceae	1	1.2
Anacardiaceae	4	4.8
Apocynaceae	5	6
Araliaceae,	1	1.2
Asparagaceae	2	2.4
Asteraceae	1	1.2
Boraginaceae	1	1.2
Burseraceae	3	3.6
Capparaceae	1	1.2
Celastraceae	2	2.4
Clusiaceae	1	1.2
Combretaceae,	3	3.6
Convolvulaceae	1	1.2
Dracaenaceae /Asparagaceae	1	1.2
Ebenaceae	3	3.6
Euphorbiaceae	10	11.9
Fabaceae	10	11.9
Malvaceae	4	4.8
Melastomataceae	1	1.2
Meliaceae	1	1.2
Monimiaceae	1	1.2
Myricaceae	3	3.6
Olacaceae	2	2.4
Piperaceae	1	1.2
Rhamnaceae,	1	1.2
Rhizophoraceae	2	2.4
Rubiaceae	7	8.3
Salicaceae	1	1.2
Sapindaceae	2	2.4
Sapotaceae.	2	2.4
Sterculiaceae	1	1.2
Stilbaceae	1	1.2
Thymelaeaceae	1	1.2
Urticaceae	1	1.2
Vitaceae	1	1.2
36	84	100

4.3 Woody Plant Species along an Elevational Gradient on Mount Kasigau

The main woody plant species within each of the four different types of vegetation found along the elevation gradient of Mount Kasigau were determined these included: the lower bushland layer, the woodland layer, evergreen forest and the montane cloud forest.

4.3.1 Woody Plant Species Composition within the Bushland Ecotype (Altitude 850-1104m) on Mount Kasigau

The woody plant species identified in the lower stratum were noted and are presented in a species composition Table 4.2.

Table 4.2: Woody Plant Species Composition in the Bushland (Altitude Range 850-1104m)

Family	Woody Plant Species	Growth Habit	n	Relative Abundance
Acanthaceae	*Ruttya fruticosa*	Shrub	1	2.08
Anacardiaceae	*Lannea shweinfurthii*	Tree	1	2.08
Apocynaceae	*Hollarrhea pubescens*	Tree	1	2.08
Araliaceae	*Cussonia spicata*	Tree	1	2.1
Asparagacceae	*Asparagus racemosa*	Climber	2	4.17
Asparagacceae	*Asparagus asparacoedis*	Climber	-	-
Boraginaceae	*Bourreria teitensis*	Tree	1	2.08
Burseraceae	*Commiphora baluensis*	Tree	2	4.17
Burseraceae	*Commiphora confusa*	Tree	-	-
Combretaceae	*Combretum exalatum*	Shrub	2	4.17
Capparaceae	*Maerua angolense*	Shrub	1	2.08
Combretaceae	*Terminalia brownii*	Tree	-	-
Convolvulaceae	*Ipomea kituiensis*	Climber	1	2.08
Ebenaceae	*Diospyros consolatae*	Shrub	2	4.17
Ebenaceae	*Euclear divinorum*	Tree	-	-
Euphorbiaceae	*Euphorbia quinquecostata*	Tree	5	10.42
Euphorbiaceae	*Croton pseudopuchellus*	Shrub	-	-
Euphorbiaceae	*Euphorbia tenuispinosa*	Shrub	-	-
Euphorbiaceae	*Euphorbia tirucalli*	Tree	-	-
Euphorbiaceae	*Euphorbia candelabrum*	Tree	-	-
Fabaceae	*Acacia hockii*	Tree	8	16.67
Fabaceae	*Acacia mellifera*	Tree	-	-
Fabaceae	*Acacia brevispica*	Shrub	-	-

Fabaceae	*Acacia nilotica*	Tree	-	-
Fabaceae	*Acacia senegal*	Tree	-	-
Fabaceae	*Acacia etbaica*	Tree	-	-
Fabaceae	*Dalbergia hetoriphylla*	Shrub	-	-
Fabaceae	*Lonchocarpus eriocalyx*	Tree	-	-
Malvaceae	*Grewia bicola*	Shrub	4	8.33
Malvaceae	*Grewia mollis*	Shrub	-	-
Malvaceae	*Dombeya kirkii*	Shrub	-	0.00
Malvaceae	*Grewia forbesii*	Shrub	-	0.00
Olacaceae	*Vipris trifoliata*	Shrub	2	4.17
Oleaceae	*Olea africana*	Tree	-	-
Rhamnaceae	*Ziziphus mucronata*	Tree	1	2.08
Rhizophoraceae	*Cassipourea celestroides*	Tree	1	2.08
Rubiaceae	*Cantenaregum nilotica*	Shrub	4	8.33
Rubiaceae	*Hymenodictyon pervifolium*	Shrub	-	-
Rubiaceae	*Psydrax schimperiana*	Tree	-	-
Rubiaceae	*Coptosperma graveolens*	Shrub	-	-
Sapindaceae	*Allophylus rubifolius*	Shrub	2	4.17
Sapindaceae	*Haplocoelum foliolosum*	Tree	-	-
Sapotaceae	*Manilkara sulcata*	Tree	1	2.08
Thymelaeceae	*Gnidia latifolia*	Shrub	1	2.08
Urticaceae	*Obetia radula*	Shrub	1	2.08
Vitaceae	*Cissus rotundifolia*	Climber	1	2.08
Vabenaceae	*Premna oligotricha*	Shrub	1	2.08
?	*Brendelia teitensis*	Shrub	1	2.08
23			48	100.

The bushland vegetation type found on the lower altitudes of the mountain consisted of trees, shrubs and climbers. In total 48 species, belonging to 23 families were recorded in this vegetation type (Table 4.2). The relative abundance of the woody plant species ranged from 2.08 to 16.67. The family with the highest relative abundance was Fabaceae (16.67) followed by Euphorbiaceae (10.42). The woody plant species richness was 48. This vegetation type had higher species richness than the other three vegetation types found on Mount Kasigau.

4.3.2 Woody Plant Species in the Woodland Ecotype (Altitude 1105-1327m)

The woodland vegetation on Mount Kasigau was found to have tall trees up to 20m in height with an open canopy cover of more than 20 percent. Bushes and shrubs dominate the ground layer. The common woody plant species identified in the stratum were noted and are presented in a species composition Table 4.3.

Table 4.3: Plant Species Composition in the woodland Altitude Range 1105-1327m

Family	Woody Plant Species	Growth Habit	n	
Anacardiaceae	*Rhus natalensis*	Shrub	3	11.1
Anacardiaceae	*Rhus vulgaris*	Shrub		
Anacardiaceae	*Lannea schweinfirthii*	Tree		
Apocynaceae	*Acocanthera oppositifolia*	Tree	3	11.1
Apocynaceae	*Carissa edulis*	Shrub		
Apocynaceae	*Carissa tetramera*	Shrub		
Araliaceae	*Cussonia spicata*	Tree	1	3.7
Asteraceae	*Brachylaena huillensis*	Tree	1	3.7
Burseraceae	*Commiphora baluensis*	Tree	2	7.4
Burseraceae	*Commiphora zimermanii*	Tree		
Celastraceae	*Elaeodendron shweinfurthianum*	Tree	2	7.4
Celastraceae	*Mystroxylon aethopicum*	Tree		
Combretaceae	*Combretum exalatum*	Shrub	2	7.4
Combretaceae	*Combretum molle*	Tree		
Euphorbiaceae	*Croton pseudopuchelus*	Shrub	6	22.2
Euphorbiaceae	*Croton dichogamus*	Shrub		
Euphorbiaceae	*Euphobia bussei*	Tree		
Euphorbiaceae	*Suregada zanzibarensis*	Tree		
Euphorbiaceae	*Euphorbia candelabrum*	Tree		
Euphorbiaceae	*Synadenium compactum*	Tree		
Fabaceae	*Albizia zimmermanii*	Tree	1	3.7
Malvaceae	*Dombeya kirkii*	Tree	1	3.7
Olacaceae	*Olea africana*	Tree	1	3.7
Rubiaceae	*Cathium mombazense*	Shrub	1	3.7
Salicaceae	*Ludia mauritiana*	Tree	1	3.7
Sapotaceae	*Manilkara spicata*	Tree	1	3.7
Thymelacaceae	*Gnidia latifolia*	Shrub	1	3.7
15			27	100

The woodland vegetation type found at elevations between 1105 to 1327m of the mountain consisted of trees, shrubs and climbers. In total 27 species, belonging to 15 families were recorded in this vegetation type (Table 4.3). The relative abundance of the woody plant species ranged from 3.70 to 22.22. The family with the highest relative abundance was Euphorbiaceae (22.22) followed by Burseraceae, Celastraceae and Combretaceae all with a relative abundance of 7.4). The woody plant species richness was 27.

4.3.3 Woody Plant Species in the Evergreen Forest Ecotype (Altitude 1328-1546m) on Mount Kasigau

The species composition of the evergreen forest was determined and is recorded in Table 4.4.

Table 4.4: Families of Plants found on Mount Kasigau at Altitude 1328-1546m

Family	Woody Plant species	Growth habit	n	
Achariaceae	*Rawsonia lucida*	Tree	1	5.6
Anacardiaceae	*Sorindeia madagascariensis*	Tree	1	5.6
Apocynaceae	*Tarbanaemontana stapfiana*	Tree	1	5.6
Asparagaceae	*Dracaena steudneri*	Tree	1	5.6
Clusiaceae	*Garcinia volkensii*	Tree	1	5.6
Ebenaceae	*Diospyros natalensis*	Shrub	1	5.6
Euphorbiaceae	*Euphorbia engleri*	Tree	1	5.6
Fabaceae	*Newtonia buchananii*	Tree	1	5.6
Melastomataceae	*Memecylon greenwayii*	Tree	1	5.6
Monimiaceae	*Xymalos monospora*	Tree	1	5.6
Myrtaceae	*Syzygium guineense*	Tree	1	5.6
Olacaceae	*Strambosia scheffleri*	Tree	1	5.6
Piperaceae	*Piper capense*	Shrub	1	5.6
Rhizophoraceae	*Cassipourea gummiflua*	Tree	1	5.6
Rubiaceae	*Psychotria teitensis*	Tree	1	5.6
Sterculiaceae	*Cola greenwayii*	Tree	1	5.6
Stilbaceae	*Nuxia congesta*	Tree	1	5.6
?	*Ochna hostii*	Tree	1	5.6
17			18	100

The Evergreen forest vegetation type found at elevations between 1328 to 1546m of the mountain consisted of trees, shrubs and climbers. In total 18 species, belonging to 17 families were recorded in this vegetation type (Table 4.4). The relative abundance of the woody plant species was 5.6. All the families found in this vegetation type were equally represented. The woody plant species richness was 18.

4.3.4 Plant Species found on the Montane Cloud Forest (Altitude 1547-1640m) on Mount Kasigau

The montane cloud forest is characteristic with endemic woody plant species. The different trees and shrubs were identified and are presented in Table 4.5.

Table 4.5: Trees and Shrubs Growing on the Montane Cloud Forest on Mount Kasigau (Altitude 1547-1640m)

Family	Woody Plant Species	Growth Habit	*n*	
Anacardiaceae	*Sorindeia madagascariensis*	Tree	1	6.7
Apocynaceae	*Tarbanaemontana stapfiana*	Tree	1	6.7
Asparagaceae	*Dracaena steudneri*	Shrub	1	6.7
Ebenaceae	*Diospyros natalensis*	Shrub	1	6.7
Fabaceae	*Newtonia buchananii*	Tree	1	6.7
Meliaceae	*Turraea holstii*	Tree	1	6.7
Monimiaceae	*Xymalos monospora*	Tree	1	6.7
Myrtaceae	*Morrella salicifolia*	Tree	2	13.3
Myrtaceae	*Syzygium micklethwaitii*	Tree	-	-
Olacaceae	*Strambosia scheffleri*	Tree	1	6.7
Piperaceae	*Piper capense*	Shrub	1	6.7
Rubiaceae	*Psychotria lauracea*	Tree	2	13.3
Rubiaceae	*Chassalia piarvifolia*	Tree	-	-
?	*Ocha hostii*	Tree	1	6.7
?	*Puridiantha paucinervis*	Tree	1	6.7
			15	100.0

The montane cloud forest vegetation type found at elevations between 1547 to 1640m of the mountain consisted of trees, shrubs and climbers. In total 15 species, belonging to 13 families were recorded in this vegetation type (Table 4.5). The relative abundance of the woody plant species ranged between 6.7 and 13.3. The families with highest

relative abundance were Rubiaceae and Myrtaceae all with a relative abundance of 13.3. The woody plant species richness was 15.

4.4 Bird Species Composition along the Altitudinal Gradient on Mount Kasigau

The second objective of this study was to determine bird species composition along the altitudinal gradient on mount Kasigau. The altitude was divided into four strata, as follows: stratum 1 bushland altitude range from 850-1,104m, stratum 2 woodland with an altitude range form 1,105-1,327, stratum 3 evergreen forest with an altitude range from 1,328-1,546), and stratum 4 montane forest with an altitude range from 1,547-1,640.

The bird species list was developed from the data collected during three data collection session in 2019. The surveys were conducted in January (dry period), June (after the wet period) and in September (dry/wet period). The birds were captured using a mist-net they were then identified, their vital characteristics measured, ringed and then released.

The bird species composition list for each of the stratum was developed showing the following: the family, foraging behaviour, preferred habitat, and IUCN listing. In total, 53 bird species belonging to 31 families were recorded on Mount Kasigau (Table xxx in Appendix xxx). The relative abundance of bird species was calculated and is presented in Table 4.6. The relative abundance of bird species ranges from 1.9 to 11.3. There were bird families that had higher representation than others, these included; Muscicapidae (11.3), and Pycnonotidae (9.4).

Table 4.6: Bird Families and Number of Species Recorded on Mount Kasigau

Family	Number of Bird Species	Relative Abundance
Accipitridae	2	3.8
Alcedinidae	1	1.9
Caprimulgidae	1	1.9
Cisticolidae	1	1.9
Columbidae	3	5.7
Coraciidae	1	1.9
Cuculidae	2	3.8
Estrildidae	3	5.7
Fringillidae	1	1.9
Indicatoridae	1	1.9
Lybiidae	2	3.8
Macrosphenidae	1	1.9
Malaconotidae	3	5.7
Monarchidae	1	1.9
Monarchidae	1	1.9
Motacillidae	2	3.8
Muscicapidae	6	11.3
Nectariniidae	3	5.7
Nicatoridae	1	1.9
Numididae	1	1.9
Phylloscopidae	1	1.9
Picidae	1	1.9
Platysteiridae	2	3.8
Ploceidae	1	1.9
Pycnonotidae	5	9.4
Strigidae	1	1.9
Sylviidae	1	1.9
Trogonidae	1	1.9
Vangidae	2	3.8
Zosteropidae	1	1.9
31	53	100.0

4.5 Bird Species Diversity in relation to Altitude on Mount Kasigau

The third objective of this study was to assess bird species diversity along an altitudinal gradient on Mount Kasigau in Taita-Taveta County, South East Kenya. Data was collected from sampling points located within the four habitat types identified along the different elevations on the study area.

4.5.1 Bird Species Diversity within the Bushland Habitat (Altitude Range 850-1104m)

The bird species biodiversity (*H'*) for the bushland habitat was determined and the results are presented in Table 4.7.

Table 4.7: Species Diversity of Birds found within Altitude Range 850-1104m with Bushland Vegetation on Mount Kasigau

Family	Species	Scientific Name	n	H'
Cisticolidae	Grey-backed Camaroptera	*Camaroptera brachyura*	1	-0.161
Columbidae	Tambourine Dove	*Turtur tympanistria*	1	-0.161
Estrildidae	Peters's Twinspot	*Hypargos niveoguttatus*	1	-0.161
Malaconotidae	Black-backed puffback	*Tchagra jamesi*	3	-0.299
Monarchidaae	African Paradise Flycatcher	*Trochocercus cyanomelus*	1	-0.161
Monarchidae	Blue-mantled Crested Flycatcher	*Trochocercus cyanomelas*	1	-0.161
Muscicapidae	Bearded Scrub Robin	*Cossypha natalensis*	2	-0.244
Muscicapidae	Red-capped Robin Chat	*Cossypha natalensis*	3	-0.299
Nectariniidae	Collared sunbird	*Hedydipina collaris*	3	-0.299
Nicatoridae	Eastern Nicator	*Nicator gularis*	1	-0.161
Pycnonotidae	Zanzibar Greenbul	*Andropadus importunus*	1	-0.161
9			18	-2.264

The results (Table 4.7) indicate that this habitat had in total 18 species belonging to nine (9) families. The species diversity was found to be (*H'*= -2.264). Relative abundance of bird species ranged from 0.24 to 10.78. The species with the highest

relative abundance were Black-backed puffback (*Tchagra jamesi),* Red-capped Robin Chat (*Cossypha natalensis)* and collared sunbird *(Hedydipina collaris)* all with a relative abundance of 0.167.

4.5.2 Bird Species Diversity within the Woodland Habitat at 1105-1327m Elevation

The bird species biodiversity (*H'*) for the woodland vegetation type was determined and the results are presented in Table 4.8.

Table 4.8: Birds found in the Woodland Vegetation Type and their Diversity on Mount Kasigau (Altitude range 1005-1327)

Family	Species	Scientific Name	n	H'
Cisticolidae	Grey-backed Camaroptera	*Camaroptera brachyura*	3	-0.239
Estrildidae	Peters's Twinspot	*Hypargos niveoguttaus*	1	-0.119
Lybiidae	Spot-Flanked Barbet	*Tricholaema lacrymosa*	1	-0.119
Malaconotidae	Tropical Boubou	*Laniarius aethiopicus*	2	-0.189
Malaconotidae	Black-backed Puffback	*Dryoscopus cubla*	1	-0.119
Monarchidae	Blue-mantled Crested Flycatcher	*Trochocercus cyanomelas*	1	-0.119
Muscicapidae	White-starred Robin	*Pogonocichla stellata*	7	-0.347
Muscicapidae	Red-capped Robin Chat	*Cossypha natalensis*	5	-0.308
Muscicapidae	Bearded Scrub Robin	*Cercotrichas quandrivirgata*	4	-0.278
Nectariniidae	Collared sunbird	*Hedydipna collaris*	2	-0.189
Nectariniidae	Olive Sunbird	*Cynomitra olivacea*	1	-0.119
7			28	-2.144

The results (Table 4.8) indicate that the woodland habitat had in total 28 species belonging to seven (7) families. The species diversity was found to be (*H'*= -2.144). Relative abundance of bird species ranged from 3.6 to 25. The species with the highest

relative abundance were white-starred robin chat *(Pogonocichla stellata*) with 25, red-capped Robin Chat (*Cossypha natalensis)* with 17.9, and Bearded Scrub Robin (*Cercotrichas quandrivirgata*) with 14.3.

4.5.3 Bird Species Diversity within the Evergreen Forest Habitat at Altitude 1328-1546m

The bird species biodiversity (*H'*) for the evergreen forest habitat was determined and the results are presented in Table 4.9.

Table 4.9: Bird Species Diversity found on Mount Kasigau's Evergreen Forest at Altitude 1328-1546m

Family	species		n	H'
Columbidae	Lemon dove	*Aplopelia larvata*	1	-0.230
Estrildidae	Green-backed Twinspot	*Mandingoa nitidula*	1	-0.230
Indicatoridae	Lesser Honeyguide	*Indicator minor*	1	-0.230
Muscicapidae	Red-capped Robin Chat	*Cossypha natalensis*	1	-0.230
Muscicapidae	White-starred Robin	*Pogonocichla stellata*	4	-0.367
Nectariniidae	Olive Sunbird	*Cynomitra olivacea*	1	-0.230
Zosteropidae	Montane White-eye	*Zosterops p. silvanus*	1	-0.230
6			10	-1.748

The results (Table 4.9) indicate that the evergreen forest habitat had in total 10 species belonging to six (6) families. The species diversity was found to be (*H'*= -1.748). Relative abundance of bird species ranged from 10 to 40. The species with the highest relative abundance were white-starred robin (*Pogonocichla stellata)* with a relative abundance of 40.

4.5.4 Bird Species Diversity within the Montane Cloud Forest Habitat (Altitude 1547-1640m)

The bird species biodiversity (*H'*) for the montane cloud forest habitat was determined and the results are presented in Table 4.10.

Table 4.10: Bird Species Diversity found on Mount Kasigau's Montane Cloud Forest (Altitude 1547-1640m)

	Species		n	H'
Estrildidae	Green-backed Twinspot	*Mandingoa nitidula*	2	-0.115
Muscicapidae	White-starred Robin	*Pogonocichla stellata*	23	-0.367
Muscicapidae	Red-capped Robin Chat	*Cossypha natalensis*	8	-0.271
Numididae	Crested Guineafowl	*Guttera pucherani*	1	-0.069
Pycnonotidae	Cabanis's Greenbul	*Phyllastrephus strepitans*	15	-0.348
Zosteropidae	Montane White-eye	*Zosterops p. silvanus*	10	-0.301
5			43	-1.471

The results (Table 4.10) indicate that the evergreen forest habitat had in total 43 species belonging to five (5) families. The species diversity was found to be (*H'*= -1.471). Relative abundance of bird species ranged from 1.7 to 25. The species with the highest relative abundance were white-starred robin (*Pogonocichla stellata)* with a relative abundance of 25, this a forest dependent species.

4.5.5 Comparison of Bird Species Diversity along an Altitudinal Gradient on Mount Kasigau

A comparison was done of the bird species diversity, species richness and number of families how they vary with increase in altitude, the results are presented in Table 4.11.

Table 4.11: Variation in Bird Species Diversity, Species Richness and Number of Families with increase in Altitude

	Elevation			
Variable	**850-1104m**	**1105-1327m**	**1328-1546m**	**1547-1640m**
Species Diversity (H')	-2.264	-2.144	-1.748	-1.471
Species Richness	18	28	10	43
Number of Families	9	7	6	5

The results (Table 4.11) show that bird species diversity progressively decreased with increase in altitude ranging from (H'=-2.264) in the lower elevations to (H'= -1.471) in the highest elevation. It was also noted that with increase in altitude the proportion of tree-nesting insectivorous species increased, whereas tree nesting frugivorous birds decreased and omnivores stayed about the same. In addition, the proportion of predatory birds decreased, while the proportion of ground-living birds such as Crested Guineafowl *Guttera pucherani* increased with elevation. These changes were explained in terms of decreasing food resources, especially of fruit and small vertebrates, with increasing altitude (Kikkawa and Williams, 1971).

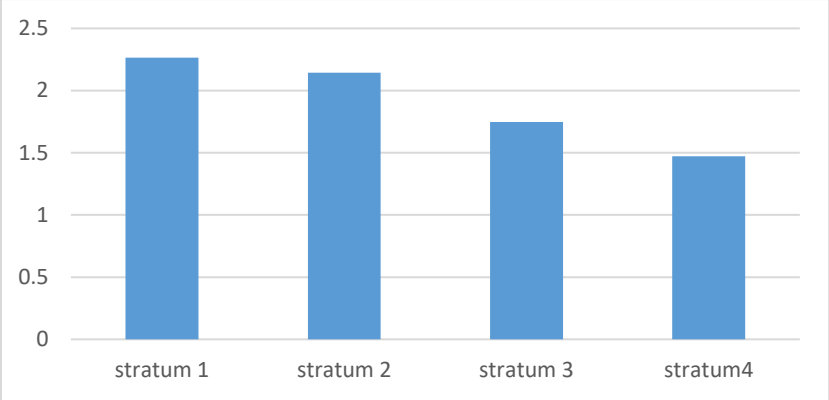


Figure 4.1: Comparison of Bird Species Diversity within the four Strata. Stratum 1 (bushland), stratum 2 (woodland), stratum 3 (evergreen forest) stratum 4 (montane cloud forest).

Figure 4.1 shows the progressively decreasing bird species diversity as the elevation increases, the higher elevations had lower bird diversities compared to the lower elevations. The vegetation structure also showed variations in bird diversities, the bushland had higher diversities compared to woodland, evergreen forest and montane cloud forest and these difference were significant statistically.

4.6 Assessment of Trends of Bird Species Diversity Using Spatial and Temporal Dimensions

The fourth objective of this study was to assess trends in bird species diversity in relation to spatial and temporal dimensions on Mount Kasigau in Taita-Taveta County, South East Kenya.

Temporal dimensions were assessed by looking at bird species diversity over a period of six years starting from 2011 to 2019 (a three year gap in the data for the period starting from 2016 to 2018 exists). Spatial dimensions were examined by looking at the trends in bird species diversity within the four sites designated by the ecotypes as follows: site 1: bushland, site 2 woodlands, site 3 evergreen forest, and site 4 montane Forest. The results of this assessment is shown in Table 4.12.

Table 4.12: Spatial and Temporal Dimensions of Bird Species Diversity on Mount Kasigau in Taita-Taveta County

Year	s1	s2	s3	s4	Total	Mean
2011	2.217	2.570	1.684	1.375	7.846	-1.962
2012	2.721	2.854	2.499	1.515	9.589	-2.397
2013	2.966	2.650	2.027	1.331	8.974	-2.244
2014	2.602	2.481	2.065	1.693	8.841	2.210
2015	2.003	1.414	1.835	1.280	6.532	1.633
2019	2.264	2.364	1.748	1.471	7.847	1.962
Total	14.773	14.333	11.858	8.665		12.407
Mean	2.462	2.389	1.976	1.444		2.068

s1=site 1 (bushland), s2=site 2 (woodland), s3=site 3 (evergreen forest), s4= (montane forest)

Table 4.12 shows means for species diversity (H') for the six years studied and ranged between -1.962 and -2.397, while the means for the different vegetation types ranged between -1.444 and -2.462. The diversity index (H') ranges between 1 and 3, where below one is low and above 2 is high). These differences were statistically significant.

4.6.1 Temporal Dimension of Bird Species Diversity on Mount Kasigau

Bird species diversities varied significantly ($p <. 05$) in the six (6) years studied. The maximum occurred in 2012 and the minimum occurred in 2015 as is shown in Figure 4.2.

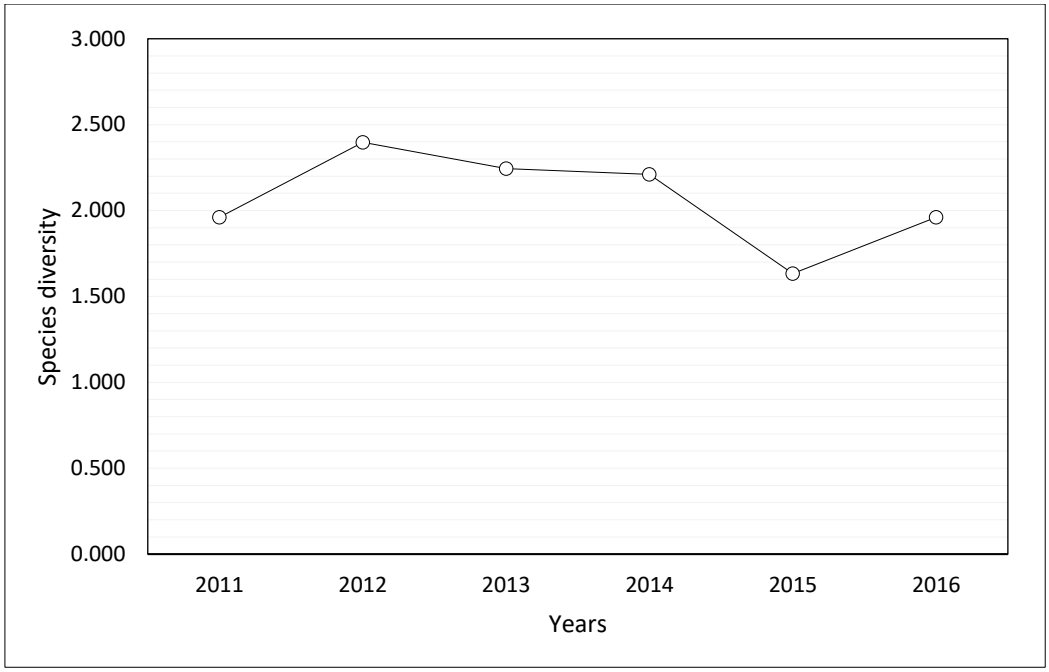


Figure 4.2: Trends in species diversity on mount Kasigau (2011-2019)

The bird species diversity on Mount Kasigau varied over the seven (7) years of study. The highest species diversity on the mountain occurred in 2012 and the lowest occurred in 2015.

4.6.2 Spatial dimensions of Bird Species Diversity on Mount Kasigau

The trends in bird species diversity for the seven (7) years (2011-2016) four vegetation sites (bushland, woodland, evergreen forest, and montane forest). The results are shown in Figure 4.3.

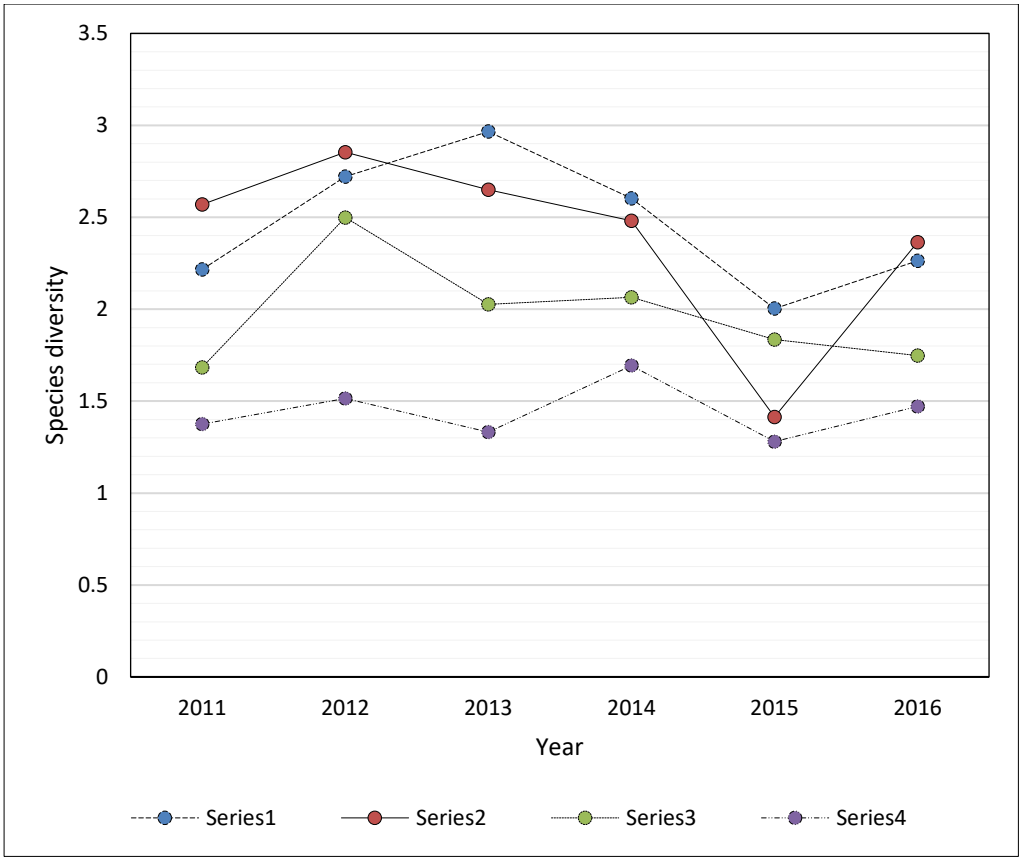


Figure 4.3: Trends in Bird Species Diversity for the Four Sites (s1 bushland, s2 woodland, s3 evergreen forest, s4 montane forest) on Mount Kasigau between 2011 and 2019.

The results (Figure 4.3) show a marked variation of the bird species diversity within the different vegetation types on Mount Kasigau, The montane forest had the lowest bird species diversity compared to the other three. The bushland area had the highest bird species diversity compared to the other three vegetation types fond on Mount Kasigau. All the vegetation types showed a marked drop in bird species diversity in 2015, which rose again in 2016. These variations could be associated with the climatic which would affect the availability of food.

4.6.3 Assessing influence of Annual Rainfall Distribution on Bird Diversity on Mount Kasigau in Taita-Taveta County

The spatial and temporal differences found to exist in Mount Kasigau prompted the need to investigate the underlying causes of these differences. The annual rainfall distribution for the six years of study was assessed and then correlated with the bird species diversity to determine any existing relationships.

The annual rainfall distribution for the area surrounding Mount Kasigau for the study period (2011-2019) was analysed and the results are recorded in Appendix E. The mean monthly rainfall for the surrounding area is presented as Figure 4.4. The data reveals a bimodal type of rainfall, with two peaks one in April and another one in November and a long dry period from June to September. The mean annual rainfall for the study period was 55.1 mm, which was higher than the long term mean of the area (45.8 mm).

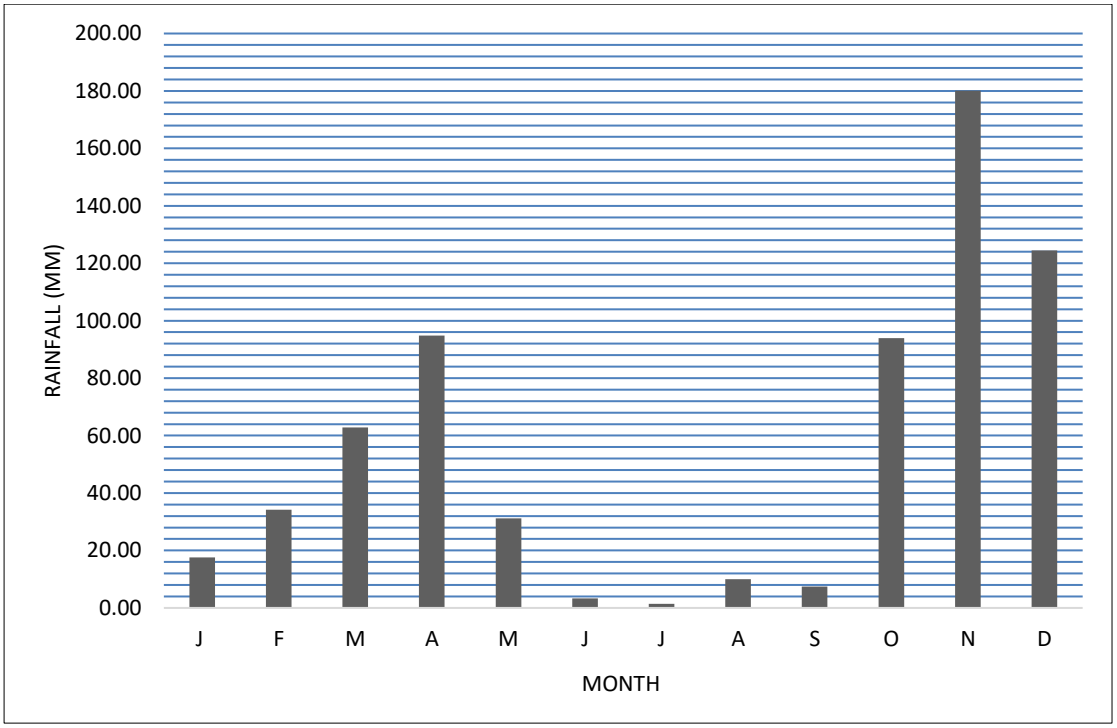


Figure 4.4: Monthly mean rainfall for the surrounding area of Mount Kasigau

The rainfall data taken during the study period was compared to a long term mean and a graph (Figure 4.4) was produced. The rainfall for the study period was above the mean, with an exception of year 2015.

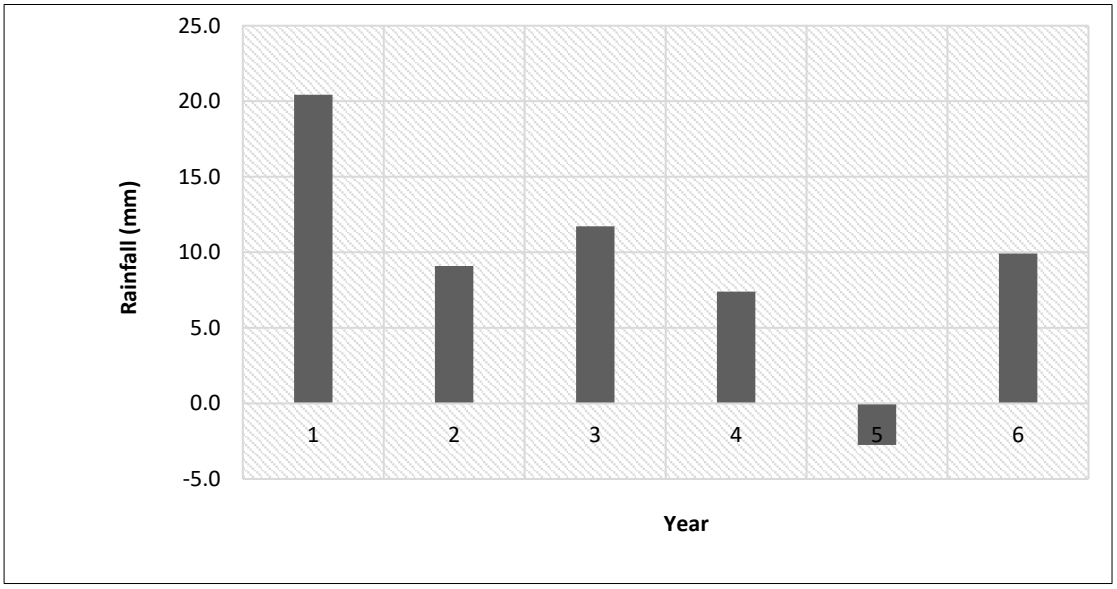


Figure 4.5: showing annual rainfall deviation from a long term mean for period of study

The correlation between annual rainfall and the bird species diversity was determined using Pearson correlation coefficient and the results are shown in Table 4.13.

Table 4.13: Correlation between Annual Rainfall Distribution and Bird Species Diversity

Pearson correlation (r)	p	n
0.401	0.216	6

The results (Table 4.13) that there were no significant correlations between the annual rainfall distribution and the bird species diversity on mount Kasigau in Taita-Taveta. This concludes that the differences shown in the bird species diversity were not statistically significant ($p > 0.05$) related to the distribution of rainfall in the surrounding areas.

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATION

5.1 Introduction

This chapter presents the summary of the findings, their discussion, conclusions and recommendations.

5.2 Discussion

The study findings for this study are discussed based on the specific objectives stated in section 1.4 of this thesis.

5.2.1 Bird Habitat Factors along an Altitudinal Gradient on Mount Kasigau

Bird habitat factors on Mount Kasigau were analysed based on the variation of woody plant species along the environmental gradient of altitude. The study determined that woody plant species varied within the four habitat structures (bushland, woodland, evergreen forest and montane forest) identified in this study, this classification is described by Pratt and Gwynne (1977).

The mountain is exceptionally rich with plants species whose growth range is restricted to the mountain compared to the surrounding savannah area, Lovett (1998) described these type of ecosystems as unique and the importance of the plant species composition when he surveyed the Eastern Arc Mountains of East Africa. The forests of Eastern Arc Mountains also include the coastal forests of Kenya and Tanzania, covering a variety of altitudinal gradients and climatic zones (Myers, Mittermeier, Mittermeier, da Fonseca & Kent, 2000). Mount Kasigau and Taita Hills are tropical montane cloud-forests forming the northernmost outlier of the Eastern Arc Mountains of Tanzania and south-east Kenya (CI and ICIPE, 2003). The vegetation is characteristic of tropical montane cloud forests (TMCFs) found in raised lowland areas (Bussmann, 2002).

The montane cloud forest harbours several endemic plant species and bird species. Endemic plant species include: native coffee (*Coffea fadenii*); and *Milletia oblata*, *Ceropegia verticillata* and several other plants also endemic to the eastern arc mountains. (Chase, M.W., Thijs, K.W., Kamau, P. & Fay, M.F. 2013)

Typical indicator tree species for this fragment are Chrysophyllum gorungosanum Engl., Coffea fadenii, Cynometra sp., Heinsenia diervilleoides K.Schum., Sorindeia madagascariensis DC. and Strychnos mitis S.Moore. such as *Xymalos monospora*, *Rapanea melanophloeos*, and *Syzygium guineense*, which are associated with low levels of disturbance (Omoro, Pellikka, & Rogers, 2010)

The dominant and adaptable tree species i.e. Macaranga conglomerata, Albizia gummifera, Syzygium guineense, Xymalos monospora, Tabernaemontana stapfiana and Maesa lanceolata (Wekesaa, Maranga, Kiruib, Muturi, Gathara, 2018).

The area has been experiencing a forest cover change over the years due anthropogenic influences; in some areas the forest cover has increase due to afforestation, while in some areas they have decreased due to deforestation has taken place (Wekesa, Kirui, Maranga, & Muturi, 2020).

The study findings show that the plant species composition decreased with increase in elevation across the altitudinal gradient, a fact that was confirmed by Aerts, Thijs, Lehouck, Beentje, Bytebier, Matthysen, Gulinck., Lens, and Muys (2011) study of the area. This is a common phenomenon with tropical montane cloud forests, and can be related to climate (rainfall and temperature) which tend to be different from other tropical montane forests. Cloud forests are found to be wetter (by 184 mm year−1 on

average), cooler (by 4.2 C on average), and less seasonally variable than other montane forests (Jarvis & Mulligan, 2011). The Hills experience lower temperatures of 18.2˚C compared to the lower zones that have an average temperature of 24.6˚C (Republic of Kenya, 2013). The average relative humidity is 79% and 83% for the lower zones and the Hills respectively (Republic of Kenya, 2013). The climate of the TMCFs has been shown to influence the structure of these forests (Ribeiro, Santana, & Carvalho, 2018).

Factors other than climate have been shown to affect ($p<.05$) the distribution and abundance of most abundant species and less abundant in the Taita hills ecosystem, these factors include: distance from the forest edge, soil pH, electrical conductivity, nitrogen, and potassium (Omoro, Laiho, Starr & Pellikka, 2011; Wekesaa, Maranga, Kiruib, Muturi, Gathara, 2018).

Long term studies of more than 10 years are recommended in order to able to collect enough data to specifically determine (i) quantify population dynamics and compare it to that expected from environmental or demographic variance; (ii) quantify long-term trends in species richness and functional diversity; (iii) test whether there have been directional changes in the functional composition of the forest though time and the population changes that are responsible for these changes; and (iv) place these long-term results into the context of the successional and climatic history of the forest (Swenson, Hulshof, Katabuchi, & Enquist, 2020).

5.2.2 Bird Species Composition along an Altitudinal Gradient on Mount Kasigau in Taita-Taveta County

Bird species composition along the environmental gradient of elevation on Mount Kasigau was found to vary with height, with more species being concentrated on the lower altitudes than the higher ones. This phenomenon was associated with two main factors: the bird feeding habits (whether a bird was and habitat preference (whether the bird was a generalist or a forest dependent/specialist). Bird-habitat relationships are important and can be used to indicate bird population changes as habitat of an area changes due to changes in management or other human activities (Bibby et al., 2000). Habitat factors include vegetation, topography, climate, and hydrological status. Bibby et al., (2000) listed eleven (11) habitat variables that can be recorded for use in bird studies, these included vegetation attributes (such as height, density, heterogeneity, species diversity, communities, grassland or lay) soils, litter, and environment.

The following bird species have been recorded as endemic to the Taita hills forest and Mount Kasigau, they include: Taita White-eye *Zosterus silvanus,* Taita Thrush *Turdus helleri,* and Taita Apalis *Apalis fuscigularis,* African violet *Saintpaulia teitensis,* Sagalla Caecilian *Boulengerula niedeni,* White-tailed Crested Flycatcher *Trochocerus albonotatus,* Black-fronted Bush-Shrike *Malaconotus nigrifrons* and Four-coloured Bush-Shrike *M. quadricolo* (Brooks et al., 1998; Lens, Barnes, Barnes, Kihuria, & Wilder, 1998; Mulwa, Bennun, Ogol, & Lens, 2007).

Forest dependent species, species that rely on the forest resources can be used as model species to help formulate general conservation guidelines, were found on the montane cloud forest, these included White-starred Robin *Pogonocichla stellata* (Githiru & Lens, 2004).

5.2.3 Bird Species Diversity along an Altitudinal Gradient on Mount Kasigau in Taita-Taveta County

Bird species diversity along the environmental gradient of altitude was analysed in this study and it was realized that the bird diversity varied greatly within the four habitat types (Bushland, woodland, evergreen forest and montane forest) that were recognized on Mount Kasigau. Bird species diversity was found to vary significantly among the different habitat types represented on the mountain, generally the lower altitudes had higher bird species diversity than the higher elevations and the diversity decreased progressively from bushland, woodland, evergreen forest and finally the montane forest. Species diversify and the number of species for most taxa decline as the elevation increases within a tropical forest context (Bellis et al., 2009; Carothers et al., 1996). Species become fewer but more specialized in the higher echelons of a forest system and more diverse and generalist feeders in the lower echelons of the same forest system (Luca Borghesio, Samba, Githiru, Bennun, & Norris, 2010; Githiru & Lens, 2005; Sanders & Rahbek, 2012). Though changes in species diversity and composition along an elevational gradient with various distinct ecotones are well known, it is less well understood how and why species' distribution patterns occur as they do (Bellis et al., 2009; Oiselle & Rica, 2001; Şekercioğlu, Primack, & Wormworth, 2012).

5.2.4 Trends in Bird Species Diversity in relation to Spatial and Temporal Dimensions on Mount Kasigau in Taita-Taveta County

Bird species diversity varied significantly temporally and spatially on Mount Kasigau in Taita-Taveta County. Temporally the bird diversity had a decreasing trend from year 2011 to 2019, while spatially the trend decreased steadily from the lower elevations to the higher elevations. There is evidence in literature to show that these changes do occur. Adler, White, Lauenroth, Kaufman, Rassweiler, and Rusak, (2005) gave evidence of these relationships and referred to them as Species-time –area relationships

(STAR). They also referred the temporal relationships as Species-time relationships (STR) and spatial dimensions as Species-Area relationships (SAR). STAR provides a tool for scaling species richness and diversity across time and space, for comparing the relative rates of species turnover in space and time at different scales of sampling, and for rigorous testing of mechanisms proposed to drive community dynamics (Adler et al. 2005).

Our results show that the SAR and STR are not separate relationships but two dimensions of one unified (Adler et al. 2005). The changes in the temporal dimensions can be related to climatic factors affecting the habitat of the birds

5.3 Summary of Main Findings

Bird habitat factors on Mount Kasigau were analysed based on the variation of woody plant species along the environmental gradient of altitude. The study determined that woody plant species varied within the four habitat structures (bushland, woodland, evergreen forest and montane forest) identified in this study,

Bird species composition along the environmental gradient of elevation on Mount Kasigau was found to vary with height, with more species being concentrated on the lower altitudes than the higher ones. This phenomenon

Bird species diversity along the environmental gradient of altitude was analysed in this study and it was realized that the bird diversity varied greatly within the four habitat types (Bushland, woodland, evergreen forest and montane forest) that were recognized on Mount Kasigau.

Bird species diversity varied significantly temporally and spatially on Mount Kasigau in Taita-Taveta County. Temporally the bird diversity had a decreasing trend from year 2011 to 2019, while spatially the trend decreased steadily from the lower elevations to the higher elevations.

5.4 Conclusion

The following conclusions were made from the study:

(i) Four habitat areas were recognized to exist on Mount Kasigau in Taita-Taveta county, these included: bushland in the lower elevations, woodland, evergreen forest and montane cloud forest on the higher elevation. Woody plant species varied within the four habitats.

(ii) Bird species composition varied significantly along the elevational gradient on Mount Kasigau in Taita-Taveta County

(iii) Bird species diversity on Mount Kasigau in Taita-Taveta County, significantly decreased with increasing elevation.

(iv) Temporal and spatial variations in bird species diversity were observed to occur on Mount Kasigau in Taita-Taveta County, but these variations were not statistically related to rainfall distribution in the surrounding areas.

5.4 Recommendations

Bird species diversity and composition on Mount Kasigau, which is a tropical montane cloud forest can be enhanced by having a comprehensive conservation management plan, involving all the stakeholders, the county leadership, community, and non-governmental organizations involved in bird life. The plan will address conservation of all key ecosystem resources, the birds, the plant, soil and tourism. Specifically the following are recommendations that can be done:

(i) Manage the ecological resources using nature based solutions (NbS)

(ii) Improve on the quality (species composition) of the forests by afforestation using endemic species.

(iii) Reducing poaching of birds and cutting of trees by educating the communities living around the mountain of the importance of the birds in their localty.

(iv) Developing ecotourism facilities and encouraging ecotourism within the Mount Kasigau ecosystem.

5.5 Recommendations for Further studies

The following are recommended to be done for further research within the Mount Kasigau ecosystem:

(a). Target to continue long term data collection using the present six year data used in this study as the baseline for future trend studies.

(b). Determine bird species diversity in relation to the changing climatic regime on Mount Kasigau.

(c). Determine plant species diversity in relation to soil and climatic differences.

(d). Quantify the influence on anthropogenic factors on the bird diversity on Mount Kasigau.

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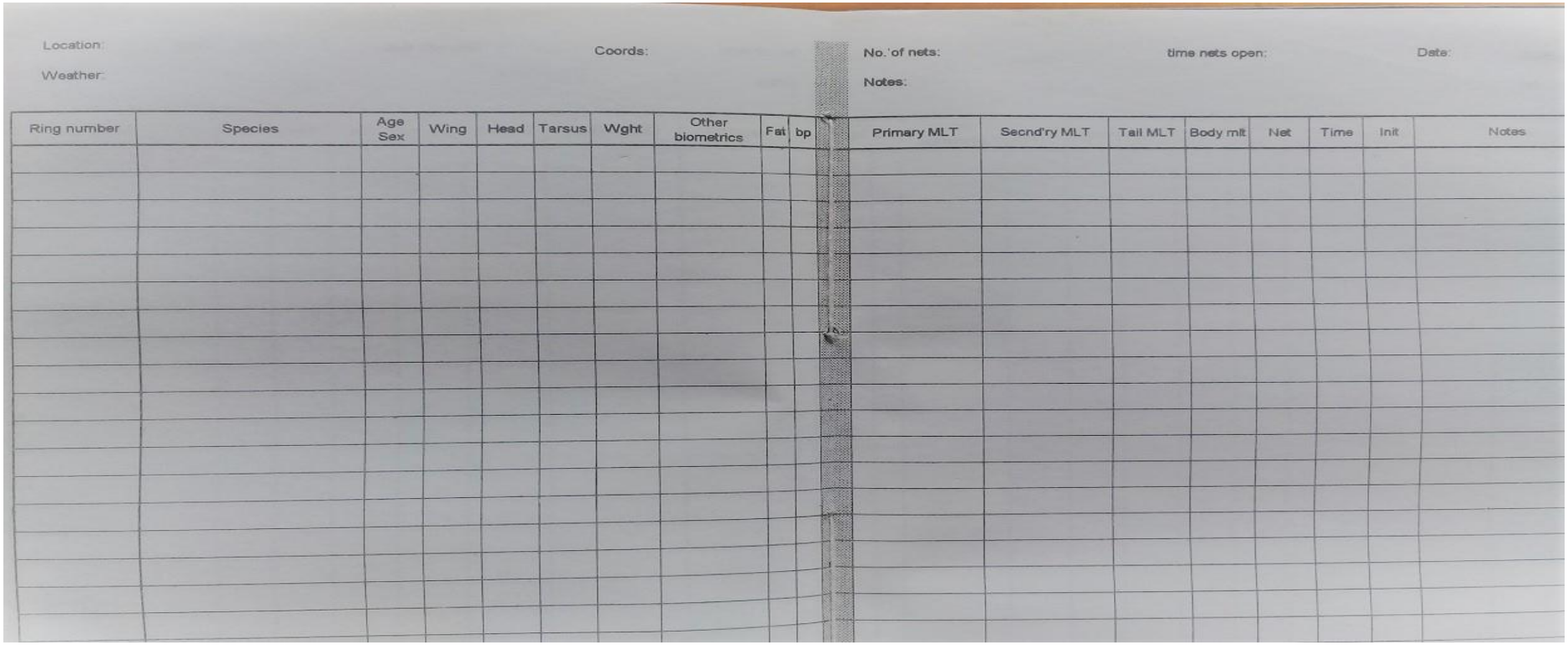
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APPENDICES

Appendix A: Datasheet: Specimen of the Data Collection Sheets



Location: Coords: No.'of nets: time nets open: Date:

Weather: Notes:

Ring number	Species	Age Sex	Wing	Head	Tarsus	Wght	Other biometrics	Fat	bp	Primary MLT	Secnd'ry MLT	Tail MLT	Body mlt	Net	Time	Init	Notes

Figure 1.1 Sample of the Datasheet to be used

Appendix B: Vegetation Sampling Sheet

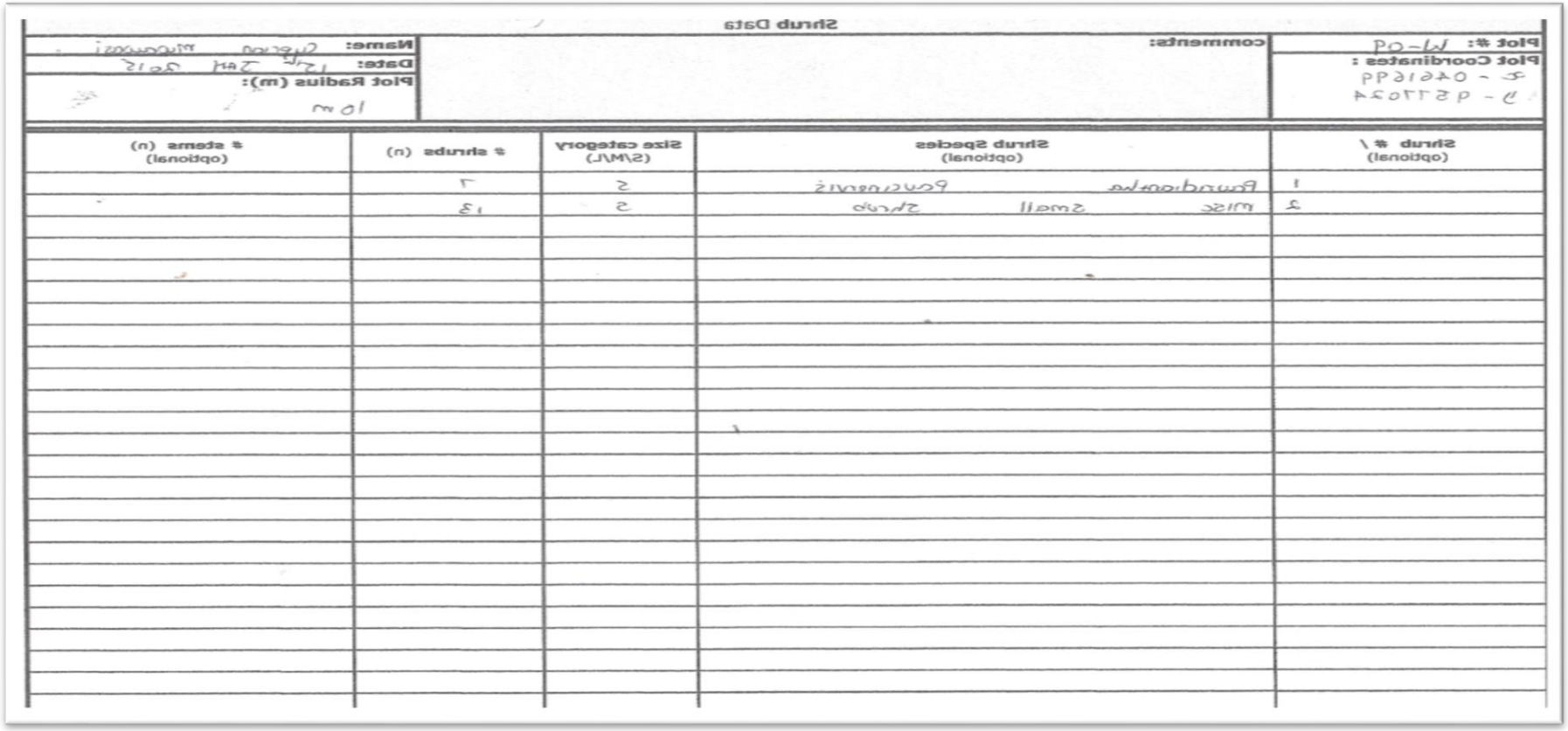


Figure 1.2 Vegetation sampling datasheet

Appendix C: Field Research Data

Table 6.1: Families and Plant Species found on Mount Kasigau

Family	Tree and Shrub Species	PT	Site 1 850 – 1104 m	Site 2 1104 – 1327 m	Site 3 1104 – 1327 m	Site 4 1547 – 1640 m
	Brendelia teitensis	S	X			
	Ocha hostii	T			X	X
	Premna olligotricha	S	X			
	Puridiantha paucinervis	T				X
Anacardiaceae	*Sorindeia madagascariensis*	T			X	X
Olacaceae	*Strombosia scheffleri*	T			X	X
	Vipris trifoliata	S	X			
Acanthaceae	*Ruttya fruticosa*	S	X			
Achariaceae	*Rawsonia lucida*	T			X	
Anacardiaceae	*Lannea schweinfurthii*	T		X		
Anacardiaceae	*Lannea shweinfurthii*	T	X			
Anacardiaceae	*Rhus natalensis*	S		X		
Anacardiaceae	*Rhus vulgaris*	S		X		
Apocynaceae	*Acokanthera oppositifolia*	T		X		
Apocynaceae	*Carrisa edulis*	S		X		
Apocynaceae	*Carrisa tetramera*	S		X		
Apocynaceae	*Holarrhena pubescens*	T	X			
Apocynaceae, Rauvolfioideae	*Tabernaemontana steffiana*	T			X	X
Araliaceae,	*Cussonia spicata*	T	X	X		
Asparagaceae	*Asparagus asparacoedis*	C	X			
Asparagaceae	*Asparagus racemosa*	C	X			
Asteraceae	*Brachylaena huillensis*	T		X		
Boraginaceae	*Bourreria teitensis*	T	X			
Burseraceae	*Commiphora baluensis*	T	X	X		

Burseraceae	*Commiphora confusa*	T	X			
Burseraceae	*Commiphora zimermanii*	T		X		
Capparaceae	*Maerua angolense*	S	X			
Celastraceae	*Elaeodendron shweinfurthianum*	T		X		
Celastraceae	*Mystroxylon aethopicum*	T		X		
Clusiaceae	*Garcinia volkensii*	T			X	
Combretaceae,	*Terminalia brownii*	T	X			
Combretaceae.	*Combretum exalatum*	S	X	X		
Combretaceae.	*Combretum molle*	T		X		
Convolvulaceae	*Ipomea kituiensis*	C	X			
Dracaenaceae Asparagaceae,	*Dracaena steudneri*	S			X	X
Ebenaceae	*Diospyros consolatae*	S	X			
Ebenaceae	*Diospyros natalensis*	S			X	X
Ebenaceae	*Euclea divinorum*	T	X			
Euphorbiaceae	*Croton dichogamus*	S		X		
Euphorbiaceae	*Croton pseudopuchellus*	S	X	X		
Euphorbiaceae	*Euphobia bussei*	T		X		
Euphorbiaceae	*Euphorbia candelabrum*	T	X	X		
Euphorbiaceae	*Euphorbia engleri*	T			X	
Euphorbiaceae	*Euphorbia quinquecostata*	T	X			
Euphorbiaceae	*Euphorbia tenuispinosa*	S	X			
Euphorbiaceae	*Euphorbia tirucalli*	T	X			
Euphorbiaceae	*Suregada zanzibariensis*	T		X		
Euphorbiaceae	*Synadenium compactum*	T		X		
Fabaceae	*Acacia brevispica*	S	X			
Fabaceae	*Acacia etbaica*	T	X			
Fabaceae	*Acacia hockii*	T	X			
Fabaceae	*Acacia mellifera*	T	X			
Fabaceae	*Acacia nilotica*	T	X			
Fabaceae	*Acacia senegal*	T	X			

Fabaceae	*Albizia zimmermannii*	T		X		
Fabaceae,	*Dalbergia hetoriphylla*	S	X			
Fabaceae.	*Lonchocarpus eriocalyx*	T	X			
Fabaceae.	*Newtonia buchananii*	T			X	X
Malvaceae	*Dombeya kirkii*	S	X	X		
Malvaceae	*Grewia bicolor*	S	X			
Malvaceae	*Grewia forbesii*	S	X			
Malvaceae	*Grewia mollis*	S	X			
Melastomataceae	*Memecylon greenwayii*	T			X	
Meliaceae	*Turraea holstii*	T				X
Monimiaceae	*Xymalos monospora*	T			X	X
Myricaceae	*Morrella salicifolia*	T				X
Myrtaceae	*Syzygium guineense*	T			X	
Myrtaceae	*Syzygium micklethwaitii*	T				X
Oleaceae	*Olea africana*	T	X	X		
Piperaceae	*Piper capense*	S			X	X
Rhamnaceae	*Ziziphus mucronata*	T	X			
Rhizophoraceae	*Cassipourea celastroides*	T	X			
Rhizophoraceae	*Cassipourea gummiflua*	T			X	
Rubiaceae	*Catunaregam nilotica*	S	X			
Rubiaceae	*Chassalia parvifolia*	T				X
Rubiaceae	*Coptosperma graveolens*	S	X			
Rubiaceae	*Hymenodictyon parvifolium*	S	X			
Rubiaceae	*Psychotria lauracea*	T			X	X
Rubiaceae	*Psydrax schimperiana*	T	X			
Rubiaceae •	*Cathium mombazense*	S		X		
Salicaceae	*Ludia mauritiana*	T		X		
Sapindaceae	*Allophylus rubifolius*	S	X			

Sapindaceae	*Haplocoelum foliolosum*	T	X			
Sapotaceae.	*Manilkara spicata*	T		X		
Sapotaceae.	*Manilkara sulcata*	T	X			
Sterculiaceae	*Cola greenwayi*	T			X	
Stilbaceae	*Nuxia congesta*	T			X	
Thymelaeaceae	*Gnidia latifolia*	S	X	X		
Urticaceae	*Obetia radula*	S	X			
Vitaceae	*Cissus rotundifolia*	C	X			
		91				

PT= Plant Type, T=Tree, S=Shrub, C=Climber,
Site 1=Bushland, Site 2= Woodland, Site 3=Evergreen Forest, site 4= Montane Forest

Table 6.2: Families, Feeding Guild, Migration Status and IUCN Status of Birds on Mount Kasigau

Family	**Common name**	***Scientific name***	**Feeding guild**	**Forest dep**	**Migration**	**IUCN status**
Accipitridae	African Goshawk	*Accipiter tachiro*	Raptor	F		LC
Accipitridae	Little Sparrowhawk	*Accipiter minullus*	Raptor	f		LC
Alcedinidae	African Pygmy Kingfisher	*Ceyx pictus*	Sallying Insectivore	f	am	LC
Caprimulgidae	Plain Nightjar	*Caprimulgus inornatus*	Sallying Insectivore		AM, pm	LC
Cisticolidae	Grey-backed Camaroptera	*Camaroptera brachyura*	Insectivore	f		LC
Columbidae	Lemon Dove	*Aplopelia larvata*	Gramnivore	FF		LC
Columbidae	Emerald-spotted Wood Dove	*Turtur chalcospilos*	Gramnivore			LC
Columbidae	Tambourine Dove	*Turtur tympanistria*	Gramnivore	F		LC
Coraciidae	Eurasian Roller	*Coracias garrulus*			PM	NT
Cuculidae	Common (Eurasian) Cuckoo	*cuculus clamosus*	Gramnivore		PM	LC
Cuculidae	African Emerald Cuckoo	*Chrysococcyx cupreus*	Insectivore	F		LC

Family	**Common name**	***Scientific name***	**Feeding guild**	**Forest dep**	**Migration**	**IUCN status**
Estrildidae	Green-backed Twinspot	*Mandingoa nitidula*	Gramnivore	FF		LC
Estrildidae	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	Gramnivore-insectivore			LC
Estrildidae	Peters's Twinspot	*Hypargos niveoguttatus*	Gramnivore			LC
Fringillidae	Jameson's Firefinch	*Lagonosticta rhodopareia*	Gramnivore-insectivore			LC
Indicatoridae	Lesser Honeyguide	*Indicator minor*	Insectivore	f		LC
Lybiidae	Red-fronted Tinkerbird	*Pogoniulus pusillus*	Omnivore			LC
Lybiidae	Spot-flanked Barbet	*Tricholaema lacrymosa*	Omnivore			LC
Macrosphenidae	Red-faced Crombec	*Sylvietta whytii*	Insectivore			LC
Malaconotidae	Three-streaked Tchagra	*Tchagra jamesi*	Leaf-gleaning insectivore			LC
Malaconotidae	Black-backed Puffback	*Dryoscopus cubla*	Insectivore			LC
Malaconotidae	Tropical Boubou	*Laniarius aethiopicus*	Leaf-gleaning insectivore	f		LC
Monarchidae	Blue-mantled Crested Flycatcher	*Trochocercus cyanomelas*	Sallying Insectivore			LC
Monarchidae	African Paradise Flycatcher	*Terpsiphone viridis*	Sallying Insectivore	f	am	LC
Motacillidae	Tree Pipit	*Anthus trivialis*	Insectivore	f	PM	LC
Motacillidae	Striped Pipit	*Anthus lineiventris*	Insectivore			LC
Muscicapidae	White-starred Robin	*Pogonocichla stellata*	Frugivore-Insectivore			LC

Family	**Common name**	***Scientific name***	**Feeding guild**	**Forest dep**	**Migration**	**IUCN status**
Muscicapidae	Common Nightingale	*Luscinia megarhynchos*	Frugivore-Insectivore		PM	LC
Muscicapidae	Red-capped Robin Chat	*Cossypha natalensis*	Frugivore-Insectivore	f	am	LC
Muscicapidae	Bearded Scrub Robin	*Cercotrichas quadrivirgata*	Frugivore-Insectivore			LC
Muscicapidae	Spotted Flycatcher	*Muscicapa striata*	Sallying Insectivore		PM	LC
Muscicapidae	Ashy Flycatcher	*Muscicapa caerulescens*	Sallying Insectivore	F		LC
Nectariniidae	Collared Sunbird	*Hedydipna collaris*	Nectarivore-Insectivore	F		LC
Nectariniidae	Olive Sunbird	*Cynomitra olivacea*	Nectarivore	FF		LC
Nectariniidae	Amethyst Sunbird	*Chalcomitra amethystina*	Nectarivore	f		LC
Nicatoridae	Eastern Nicator	*Nicator gularis*	Insectivore			LC
Numididae	Crested Guineafowl	*Guttera pucherani*	Insectivore	F		LC
Phylloscopidae	Willow Warbler	*Phylloscopus trochilus*	Insectivore	f	PM	LC
Picidae	Nubian Woodpecker	*Campethera nubica*	Bark-gleaning Insectivore			LC
Platysteiridae	Chin-spot Batis	*Batis molitor*	Insectivore			LC
Platysteiridae	Black-headed Batis	*Batis minor*	Insectivore			LC

Family	**Common name**	***Scientific name***	**Feeding guild**	**Forest dep**	**Migration**	**IUCN status**
Ploceidae	Lesser Masked Weaver	*Ploceus intermedius*	Gramnivore-insectivore			LC
Pycnonotidae	Common Bulbul	*Pycnonotus barbatus*	Insectivore	f		LC
Pycnonotidae	Zanzibar Greenbul	*Andropadus importunus*	Frugivore-Insectivore			LC
Pycnonotidae	Yellow-bellied Greenbul	*Chlorocichla flaviventris*	Frugivore-Insectivore			LC
Pycnonotidae	Northern Brownbul	*Phyllastrephus strepitans*	Frugivore-Insectivore	F		LC
Pycnonotidae	Cabanis's Greenbul	*Phyllastrephus cabanisi*	Frugivore-Insectivore	FF		LC
Strigidae	Eurasian Scops Owl	*Otus scops*	Raptor		PM	LC
Sylviidae	Common Whitethroat	*Sylvia communis*	Frugivore-Insectivore		PM	LC
Trogonidae	Narina Trogon	*Apaloderma narina*	carnivore-insectivore	F		LC
Vangidae	White-crested Helmetshrike	*Prionops plumatus*	Insectivore		am	LC
Vangidae	Retz's Helmetshrike	*Prionops retzii*	Insectivore			LC
Zosteropidae	Montane White-eye	*Zosterops p. silvanus*	Insectivore			LC

FD forest dependent

Appendix D: Rainfall Distribution for the Study Area

Year	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL	MEAN
2011	1.6	34.5	78.0	33.8	53.1	0.0	0.0	0.0	19.7	208.8	305.1	60.2	794.7	66.2
2012	7.1	2.6	22.1	189.2	2.0	0.5	0.0	26.7	2.6	16.0	260.1	129.8	658.6	54.9
2013	26.9	1.5	144.3	120.9	8.1	0.0	3.8	0.5	2.5	33.0	79.5	269.0	690.2	57.5
2014	2.6	100.1	94.0	65.0	13.2	7.1	3.6	7.1	19.6	112.8	94.5	118.9	638.3	53.2
2015	1.0	3.6	38.1	129.3	43.7	11.9	0.0	1.3	0.5	62.5	151.6	73.2	516.7	43.1
2019	66.0	62.7	0.5	31.0	66.8	0.0	1.0	24.1	0.0	130.6	190.0	95.8	668.6	55.7
TOTAL	105.2	205.0	376.9	569.2	187.0	19.6	8.4	59.7	44.9	563.6	1080.8	746.8		330.6
MEAN	17.5	34.2	62.8	94.9	31.2	3.3	1.4	9.9	7.5	93.9	180.1	124.5		

Appendix E: Field photo taken at Mount Kasigau



Figure 1: Diedrick Cuckoo



Figure 2: Recording data

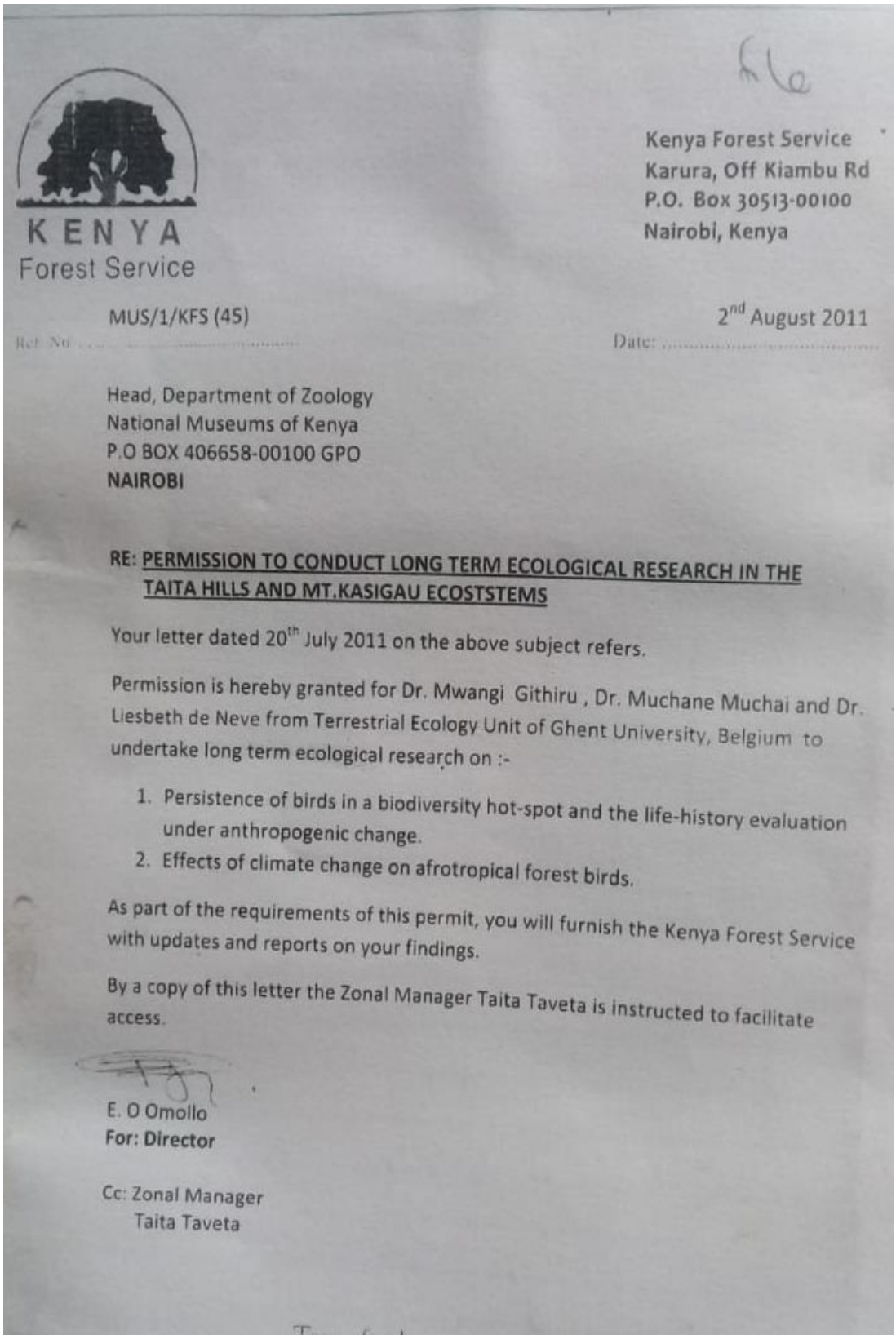


Figure 3: Ringing a bird



Figure 4: Weighing a bird

Appendix F: KFS Research Permit



KENYA
Forest Service

Kenya Forest Service
Karura, Off Kiambu Rd
P.O. Box 30513-00100
Nairobi, Kenya

Ref No MUS/1/KFS (45)

Date: 2nd August 2011

Head, Department of Zoology
National Museums of Kenya
P.O BOX 406658-00100 GPO
NAIROBI

RE: PERMISSION TO CONDUCT LONG TERM ECOLOGICAL RESEARCH IN THE TAITA HILLS AND MT.KASIGAU ECOSTSTEMS

Your letter dated 20th July 2011 on the above subject refers.

Permission is hereby granted for Dr. Mwangi Githiru , Dr. Muchane Muchai and Dr. Liesbeth de Neve from Terrestrial Ecology Unit of Ghent University, Belgium to undertake long term ecological research on :-

1. Persistence of birds in a biodiversity hot-spot and the life-history evaluation under anthropogenic change.
2. Effects of climate change on afrotropical forest birds.

As part of the requirements of this permit, you will furnish the Kenya Forest Service with updates and reports on your findings.

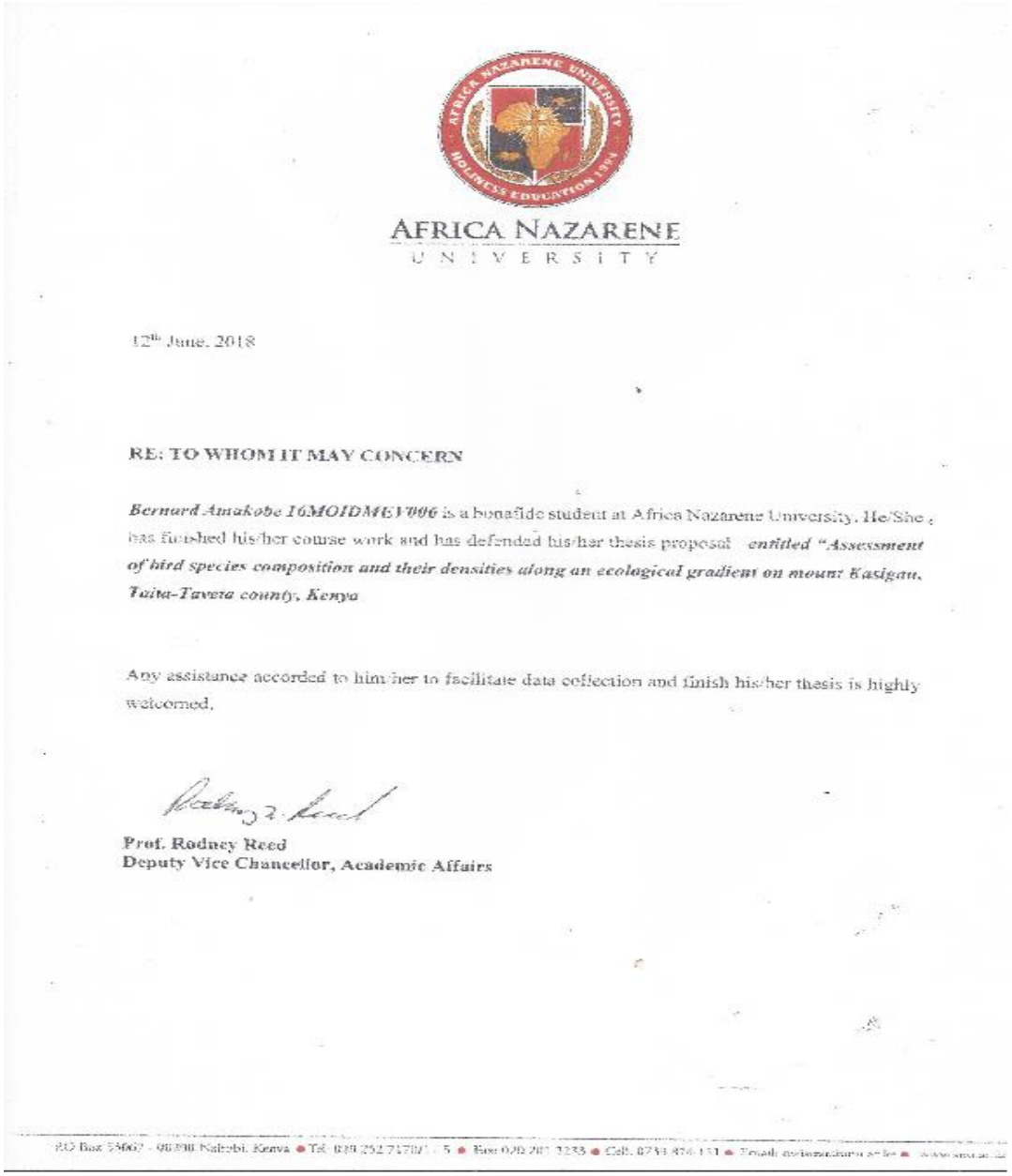
By a copy of this letter the Zonal Manager Taita Taveta is instructed to facilitate access.

E. O Omollo
For: Director

Cc: Zonal Manager
Taita Taveta

Figure 2.1 Research Permits: Specimen of the Research Permit

Appendix G: ANU Research Approval Letter



AFRICA NAZARENE
UNIVERSITY

12th June, 2018

RE: TO WHOM IT MAY CONCERN

Bernard Amakobe 16MOIDME1006 is a bonafide student at Africa Nazarene University. He/She has finished his/her course work and has defended his/her thesis proposal ***entitled "Assessment of bird species composition and their densities along an ecological gradient on mount Kasigau, Taita-Taveta county, Kenya***

Any assistance accorded to him/her to facilitate data collection and finish his/her thesis is highly welcomed.

Prof. Rodney Reed
Deputy Vice Chancellor, Academic Affairs

PO Box 53067 - 00200 Nairobi, Kenya • Tel: 020 252 71787/1 - 5 • Fax: 020 201 3233 • Cell: 0733 874 151 • Email: [illegible] • www.anu.ac.ke

Appendix H: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **593836**

Date of Issue: **20/August/2020**

RESEARCH LICENSE



This is to Certify that Mr.. Bernard Abraham Amakobe of Africa Nazarene University, has been licensed to conduct research in Taita-Taveta on the topic: ASSESSMENT OF BIRD SPECIES COMPOSITION AND THEIR DIVERSITY ALONG AN ELEVATIONAL GRADIENT ON MT KASIGAU, TAITA-TAVETA COUNTY SOUTHEAST KENYA for the period ending : 20/August/2021.

License No: **NACOSTI/P/20/6315**

593836

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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