EFFECTS OF FRAGMENTATION ON AVIFAUNAL COMPOSITION, DIVERSITY AND FLUCTUATING ASYMMETRY IN THE EASTERN MAU FOREST: A CASE STUDY OF RIVER NJORO WATERSHED, KENYA

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DECLARATION

This Thesis is my original work and has not been submitted for a degree in any other university.

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This Thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

I dedicate this piece of work to my family; my fellow ornithologists; and to the memory of the late Maurice Mugode of National Museums of Kenya.

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ABSTRACT

Fragmentation and its effects on avifauna is a study that was conducted in upper River Njoro watershed covering about 280km^2. The watershed is under threat from increasing human activities that have led to rapid changes in land cover and deterioration of environmental and habitat conditions for birds. These include replacement of indigenous trees with exotic types, clearing of riparian vegetation, cultivation of river banks, deforestation and forest fragmentation. The study's main objective was examination of effects of forest fragmentation and environmental degradation on composition, diversity and fluctuating asymmetry of avifauna in natural and plantation forest fragments in the River Njoro watershed. Mist netting was used as the method of data collection. Length of sampling time per station depended on rate of capture. Captured birds were ringed and studied with detailed data recorded in Ringing Book. Statistical and descriptive analyses were performed using windows based MINITAB (Version 13.1) software. Diversity Indices were calculated for different forest fragments and data subjected to Analysis of Variance and F-test. A total of 238 individual birds from 49 species, 17 Families and 4 Orders were captured. Results show that larger continuous forest fragments have more birds and higher diversity than smaller ones, forest generalist birds are more than forest specialist birds, natural forest fragments have a higher diversity of birds than plantation forests ($P<0.05$), fluctuating asymmetry was, however, not observed in the birds. Based on these key findings, several conclusions are made. These include a difference in composition of birds between the forest fragments, a significant difference in diversity of birds between natural forest fragments and plantation forest fragments and environmental degradation has not caused significant genetic stress in the avifauna of River Njoro watershed since fluctuating asymmetry was not observed. The study recommends; that forest policies on plantation establishment be reviewed by Kenya Forest Service and all stakeholders to discourage establishment of monoculture plantations in the midst of natural forests, that a similar study is carried out during the dry season to capture weather variations, that regular monitoring of environmental conditions and birds be carried out to monitor trends, and lastly, long term research on genetics of birds be carried out in the watershed to serve as early warning signals and thus provide guidance on informed management decisions.

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CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Since the development of agriculture, natural vegetation cover of every continent has been extensively modified (Taku, 2000) resulting to extensive removal of native vegetation, and leave fragmented patches across the landscape (Tompkins and Kotiaho, 2002). This process is commonly known as habitat fragmentation, a process which brings about climatical changes that include temporal and spatial patterns of temperature, and precipitation that influence natural ecosystems (Brown *et al.,* 1982). After fragmentation some of the biota within the remnant areas is influenced and changes seen in behaviour, morphology and distribution. In extreme cases, species that are incapable of adapting to the changes are either forced to migrate or they die and eventually get extirpated (Wiens, 1989).

Habitat fragmentation is defined as the process by which large, continuous habitat blocks become subdivided into smaller, more or less isolated fragments (Lund, 2006). Studies of the effects of habitat fragmentation on spatial structure and genetic variation of populations across a variety of taxa continue to identify dispersal as a key process in both population regulation and spatial distribution (Mladenoff *et al.*, 1993). In birds, effects of such habitat and climatic changes are expressed in altered morphological formations, a manifestation of genetic alteration (Anciaes and Marini, 2000). This manifestation is measured by an index of condition called Fluctuating Asymmetry (Krissman, 2006).

Fluctuating asymmetry is described by Tomkins and Kotiaho (2002) as the deviation from perfect bilateral symmetry caused by environmental stresses, developmental instability and genetic problems during development. The condition also refers to small random deviations from perfect symmetry in bilaterally paired structures. It reflects an organism's ability to cope with genetic and environmental stress during development. The use of Fluctuating Asymmetry as an indicator of such stresses is based on the assumption that perfect symmetry is a priori expectation for the ideal state of bilateral structures (Leary and Allendorf, 1989). Fluctuating asymmetry has been used as an indicator of individual quality in studies of natural and sexual selection and as a bio-indicator tool for environmental monitoring and conservation biology (Bradley, 1980).

Eastern Mau Forest has been heavily and destructively logged and degraded (Ngugi *et al.,* 2005), and as reported by Shivoga *et al.,* (2003), this has drastically altered the ecosystem. Since the changes are not happening in isolation, they affect all the other players in the tropical forest ecosystem. As this continues, the functions of the ecosystem are impaired, with concomitance ecosystem imbalances and declines in biodiversity. In Kenya, threatened biodiversity extends well beyond the currently gazetted protected areas (Bennun and Njoroge, 1999). Indeed, Important Birds Areas (IBAs) (places of international significance for the conservation of birds at the global, regional or sub regional level) designated in Kenya, so far cover most of these protected areas and some substantial area outside. Mau forest complex is one such IBA. According to Bennun and Njoroge (1999) the forest holds one of the richest examples of a central East African montane avifauna and 72% of the Kenya's Afrotropical Highland biome species.

River Njoro watershed which covers the eastern escarpment of Mau is one of the parts in the Mau Forest Complex that has been extensively degraded and fragmented (KFWG, 2001). The watershed area under forest progressively declined from 47% in 1970 to about 15% in 1998 (SAPS, 2002). Between 1986 and 2005, the watershed lost 10% and 9% of indigenous and plantation forests, respectively (Baldyga *et al.*, 2004). Despite all these changes, very little is known on the present status of birds in Eastern Mau forest and more particularly in River Njoro watershed. Bird communities play major roles in the functioning of ecosystems and are very sensitive to slight environmental changes. Changes in general character of vegetation cover of a given region almost inevitably would be followed by changes in bird distribution.

This study was undertaken in upper River Njoro watershed of Eastern Mau forest with the principal aim of studying the relationships between environmental stress (fragmentation and degradation) and genetic stress (fluctuating Asymmetry) in birds. Afro tropical forest bird species in fragmented landscape manifested environmental stress in morphometric differentiation. Furthermore the study gave an estimate of the density and population structure of the forest dependent birds in upper River Njoro watershed.

1.2 Statement of the Problem

River Njoro watershed is part of the Mau forest complex, which is one of the five major water towers for Kenya. Mau Forest complex has five main Forest Reserves; Eastern Mau (66,000ha), Western Mau (22,700ha), South-western Mau (84,000ha), Trans Mara (34,400ha), and Ol Pusimoru (17,200ha). The forest complex covers a substantial area of the south-western highlands of Kenya, and represents the largest remaining near-continuous block of montane indigenous forest in East Africa (Bennun and Njoroge, 1999). Mau Forest Complex generally has a rich highland bird community, characteristic of the central Kenya highlands (Bennun and Njoroge, 1999). It is designated as an Important Bird Area since it has global and regional significance in birds conservation. This is proven by the fact that Mau complex is categorized among the richest examples of Central East African montane avifauna (Fishpool, 1996). Further to this, forty-nine of the Kenya's 67 Afrotropical Highland biome species are known to occur in Mau, making 72% of Kenya's Afro-tropical Highland biome species (Bennun and Njoroge, 1999).

The forest also harbours eight species of birds that are Vulnerable and Regionally Threatened. These are Ayre's Hawk Eagle, African Crowned Eagle, African Grass Owl, Cape Eagle Owl, Red-chested Owlet, Least Honey guide, Grey-winged Robin, and Purple-throated Cuckoo-shrike. The Hartlaub's Turaco is endemic in Mau escarpment while Hunter's Cisticola and Jackson's Francolin are restricted-range species in the complex forest (Zimmerman *et al.*, 1996). In spite of this, the forest and its rich biodiversity are threatened by human interference. As reported by Bennun and Njoroge (1999), among the most vulnerable parts of Mau Forest for bird conservation, are the high montane forests on the Eastern Mau. This is where River Njoro watershed is located.

Eastern Mau forest as a whole and River Njoro watershed in particular is under threat from increasing human activities that have led to rapid changes in land cover and deterioration of environmental and habitat condition. The major degrading activities include replacement of indigenous tree species with exotic types, clearing of riparian vegetation, cultivation of river banks, deforestation and forest fragmentation. The increasing human population in the watershed translates to a greater need for agricultural produce and settlement land. About two-thirds of the river's drainage basin is already used for agricultural purposes, mainly for intensive small-scale cultivation (WWF, 1998). The remaining forest mainly along the river bank has also been fragmented into small forest parcels.

The environmental degradation in Eastern Mau Forest is a threat to biodiversity and subsequent loss including birds' species. To prevent the undesired loss, intervention to control the degradation is necessary. To ensure interventions have the desired outcome, it is indispensable to establish the current status of the biodiversity which would serve as the beginning point for measuring any impacts of the intervention and establishing trends. Prior to this study, not much was known about birds in River Njoro watershed. Research work on biotic communities carried out previously in the watershed focused on composition, abundance and distribution of aquatic macro-invertebrates, fish, frogs, phytoplankton, and zooplankton, (Milbrink, 1977; Vareschi, 1979, 1982; Vareschi and Vareschi, 1984; Vareschi and Jacobs, 1984; Kairu, 1994; Leichtfried and Shivoga, 1995; Bretschko, 1995 and 1996; and Shivoga, 1999a, b, c, d). None of the studies focused on birds.

This study therefore was conducted to establish baseline status of birds with the main objective being to examine the effects of forest fragmentation and environmental degradation on composition, diversity, and fluctuating asymmetry of avifauna in upper River Njoro watershed. The research focused on birds in the fragmented forest blocks using mist nets and ringing procedures, compared and contrasted the status of birds for the different fragments. The guiding objectives were as outlined below.

1.3 The General Objective

The general objective of this study was to provide a clear and broad understanding of the effects of forest fragmentation and environmental degradation on composition, diversity, and fluctuating asymmetry of avifauna in upper River Njoro watershed

1.4 Specific Objectives

The main objective was broken down into specific objectives namely;

(i) To determine the composition of avifauna in each forest fragment in River Njoro watershed

(ii) To assess the diversity of avifauna in both plantation and natural forest fragments in River Njoro watershed

(iii) To measure fluctuating asymmetry of avifauna in River Njoro watershed

1.5 Hypothesis

The following hypotheses guided the study:

H_0: There is no difference in composition of the avifauna found in the various forest fragments in River Njoro watershed

H_0: There is no difference in the diversity of avifauna found in plantation forest compared to those in natural forest in River Njoro watershed

H_0: There is no fluctuating asymmetry in avifauna of River Njoro watershed

1.6 Justification and Significance of the Study

Birds are an integral component of the ecosystem since they serve many important functions, including: control of insect and rodent population, distribution of seeds and pollination of flowers that leads to forest conservation, food sources for bird predators, scavenge carcasses and recycle nutrients back into the earth. Ecosystems such as forests provide us with food, medicines and important raw materials. Humans depend on these ecosystems for survival because they keep the climate stable, oxygenate the air and transform pollutants into nutrients. Birds play an important role in the effective functioning of these systems.

Birds live in a variety of habitats; their conservation highlights the diversity of different habitats and is critical to the richness and diversity of the planet. Birds occupy a higher position in the food chain and are therefore good indicators of the general state of our biodiversity. Extirpation of birds is an indicator that something is wrong with the local environment and that action needs to be taken to restore the affected environment. Birds are also indicators of climate change; their behaviour and disappearance are a response to change in the prevailing environment. Driscoll (2013) describes birds as having a psychosocial significance to humans and states that, "birds feed our spirits, marking for us the passage of seasons, moving us to create art and poetry, inspiring us to flight and reminding us that we are not only on, but of, this earth". Many people derive great pleasure, fulfilment and inspiration from watching birds and listening to them.

Given the importance of birds, effects of the observed fragmentation and habitat degradation in River Njoro watershed needed investigation. The finding of this study will lead to information and decisions that will lead to conservation of biodiversity. This study is justified because it forms a beginning point for further conservation work in River Njoro watershed.

1.7 Scope, Limitations, Assumptions and Challenges,

1. The scope of this study was birds that can be captured by mist netting. As such, it did not focus on breeding and nestlings of the birds studied. The birds that were captured by the mist net formed the sample used for analysis and conclusion.
2. Mist netting as the main data collection tool is limited to the extent that it does not capture birds that soar high above the height of the net which would be about five meters from the ground.
3. The study did not study effects of climate change on the birds' densities and composition. It assumed that all the observed trends are attributed to fragmentation
4. The study assumed that any observed fluctuating asymmetry is brought about by environmental stress that originates from habitat fragmentation. It did not consider other sources of environmental stress including pollution from agrochemicals used in the surrounding agricultural land.
5. This study did not consider effects of other factors related to urbanisation, land use and land use change and human settlements in specificity other that it brings about fragmentation.
6. The study was carried out during the day therefore may have not captured nocturnal birds

1.8 Operationalization of Terms

The list below has definitions of key terms described in the context of this study.

Avifauna: The term has two words in one, *fauna* refering to organisms in Kingdom Animalia and *aves* which is another name for all animals in the birds' branch so avifauna refers to all birds' species. The term has been used to generate other terms e.g. Avitourism, refereeing to the ecotourism that focuses on bird watching. In this study Avaifauna refers to birds' species and individuals observed in the watershed. This is the main subject of study.

Composition: refers to species found in the ecosystem and their characteristics including age, sex, and population structure. Composition in this study focuses on characteristics in terms of age (adult, juvenile, breeding), sex (male and female) and forest dependency.

Diversity: refers to the unique collection of bird species in a unique ecosystem setting that probably cannot be replicated and that cannot be moved to another site because of the environmental drivers. The term in this study is used to describe the total variety of bird species living in River Njoro watershed.

Fluctuating Asymmetry (FA): the differences observed in the sizes of a pair of limbs/tarsi of individual birds. It is a measure of condition of individual birds' morphological formation following exposure to environmental stress (in this case forest fragmentation) which in turn affects the genetic formation. The observed difference could be between the two parts of the pair and/or the standard measurements for the species in question. This study uses the term to refer to any difference in the length of tarsus of an individual bird resulting from any cause.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter examines the previous work that has been done globally, regionally and nationally in the fields of forest fragmentation, birds' composition, diversity, abundance and fluctuating asymmetry. It also looks at comparisons that have been done between natural forests and plantation forests. This chapter also describes the birds of Mau forest complex showing the significance of the forest to birds. It further explains the theories that surround habitat fragmentation and using the literature reviewed it shows the conceptual framework behind this study.

2.2 Forest Fragmentation

Forest fragmentation, the process of breaking up large continuous forest patches into several smaller pieces (Forman and Godron, 1986; Riitters 2002), is caused by many factors, including clearing forest for roads or development. It is a result of human activities such as logging, conversion of landscapes to agricultural land, overgrazing, mining, urban development, roads, water harvesting reservoirs, water diversion, among others (Hunter, 1996; Noss and Cooperrider, 1994; Reed *et al.*, 1996). Forest fire might also contribute in fragmenting and degrading landscapes (Mladenoff *et al.*, 1993).

Continued fragmentation can lead to deforestation. As reported by Mehaffey (2001), human land uses tend to expand over time, so forests that share a high proportion of their borders with anthropogenic uses (urban or agriculture) are at higher risk of further degradation than forests that share a high proportion of their borders with non-forest and natural land cover (wetland, grassland or shrub land).

Fragmentation has become a central issue in ecological studies as it is detrimental for biodiversity across landscapes (Jomaa *et al.*, 2007). Fragmentation threatens forest resources throughout the world, and remains one of the serious causes of biodiversity depletion (Di Castri and Younès, 1995; Hunter, 1996). Smaller forest patches get more susceptible to external disturbances than larger ones (Diamond, 1975; Nilsson and Grelsson, 1995).

Forest fragmentation combined with habitat loss (Jomaa *et al.*, 2007) has become one of the most important causes behind the loss of biodiversity in Africa during the last decades (Lens, *et al.*, 1999; Anciaes and Marini, 2000). Although there are several mechanisms by which these processes can threaten the persistence of forest bird populations, isolation between forest remnants may play a major role especially for species with poor dispersal capacity (Lens *et al*., 2002), such as under-storey insectivorous species (Lens *et al.*, 1999).

Habitat fragmentation is a major cause of species (or population) extinctions. It may interrupt gene flow, affect population size and promote inbreeding (Knick and Rotenberry, 1995). Studies have shown that forest clearance affects habitat selection and movements of birds (Simberloff, 1986; Wiens, 1989), decreased food supplies, nest site availability, increase nest predation and parasitism. Habitat destruction, fragmentation and loss are actually the overriding problems facing Kenya's Important Bird/Biodiversity Areas (Bennun and Njoroge, 1999).

Forest fragmentation and disruption in the continuity of forest habitat is also hypothesized to be a major cause of population decline for some forest bird species (Lens, *et al.*, 1999). This is because fragmentation reduces nesting (reproductive) success (Knick and Rotenberry, 2002). All other factors held constant, brooding success is highly dependent on nesting.

2.3 Characteristics of Natural and Plantation Forest

Although forest is classified primarily by trees, a forest ecosystem is defined intrinsically with additional species such as fungi (Evans and Turnbull, 2004). These plant communities presently cover approximately 9.4% of the Earth's surface (or 30% of total land area) in many different regions and function as habitat for organisms (Lund, 2006), hydrologic flow modulators, and soil conservers, constituting one of the most important aspects of the Earth's Biosphere (Stamets, 2005).

According to The National Forest and Nature Agency Denmark (1994), natural forest starts off from the original forest cover, i.e. a forest reproduced naturally. Natural forests can be more or less influenced by culture, e.g. by logging or regeneration techniques, but the forests must not have been subject to regeneration by sowing or planting (Kirby *et al*., 1984).

Natural forest might be managed to some degree, or be unmanaged (untouched, non-intervention forest, strict forest reserve). After an adequate amount of time ranging 30 years on without intervention, such a forest might develop some of the basic structures of a virgin forest and be considered as "virgin-like natural forest" (Tanninen *et al*., 1994). It is, however, not practical considering there is always something happening in the forest, either forestry operations including cutting, planting, thinning, pruning or indirect manipulation by grazing, air pollution, hindering immigration and spreading of natural species. This influences the kind and amount of dominant species in a landscape (Møller, 2000). A forest cannot be viewed in isolation since it is an integral part of the surrounding landscape. Similarly, the nature of a forest is affected by the dynamics of former activities that took place in the landscape, especially in non-intervention systems.

Principal characteristics of natural forests and key elements of native ecosystems include complexity, structure and diversity. Kirby *et al*., (1984) describe such ecosystems as forest remnant comprising indigenous species of plants (i.e. plant species which are native to a specified area or region in the country). They further explain that forest may include naturalized species (i.e. exotic species introduced into or naturally colonized in a region so as to appear native or wild), provided they are not sufficiently abundant or physiognomically dominant so as to alter the general character of the original forest. According to Evans and Turnbull (2004), natural forest includes: unaltered virgin upland and lowland indigenous forest, indigenous forest which has been slightly or significantly modified by human activity but which retains part or most of the general composition or character of the original forest, or indigenous forest which is being managed or exploited primarily for the commercial production of wood.

Plantation forests on the other hand, are forest areas lacking most of the principal characteristics and key elements of native ecosystems (Lund, 2006) which result from the human activities of planting, sowing or intensive silvicultural treatments. Plantations of trees are typically grown as an even-aged monoculture for timber production (Hartono, 2002). They are also sometimes known as "man-made forests" or "tree farms", though this latter term more typically refers to specialist tree nurseries which produce the seedlings used to create plantations

(Kirby *et al.*, 1984). More generally, a plantation is forest land where trees are grown for commercial use, most often in a planted forest, but may also be in a naturally regenerated forest.

Plantation forests are generally intended for the production of timber and pulpwood. They increase the total area of forest worldwide though they are commonly mono-specific and/or composed of introduced tree species (Zobel, *et al.,* 1987). Plantation ecosystems are not generally important as habitats for native biodiversity (Stamets, 2005) but they can be managed in ways that enhance their biodiversity protection functions. In addition they are important providers of ecosystem services such as maintaining nutrient capital, protecting watersheds and soil structure as well as storing carbon (Nambiar *et al.,* 1999). They may also play an important role in alleviating pressure on natural forests for timber and fuel wood production.

The Kyoto Protocol (2005) proposes to encourage the use of plantations to reduce carbon dioxide levels. This idea is being challenged by some scientists however, on the grounds that the sequestered carbon is eventually released after harvest (Sedjo, 2001). The Australian National plantation blueprint gives facts about plantation forests and carbon sequestration, and argues that they have positive contributions to carbon sequestration (Thompson, 2008).

2.4 Birds' Composition

Birds' composition in any given area is determined by several factors including the geological factors, ecological factors and microclimate. This section elaborates on that.

2.4.1 Geographic distribution of birds

Geology, evolution, physical barriers, and mobility are factors that account for birds' distribution. Significantly also, ecological conditions account for birds' species distribution since the tolerate levels for different species differ (Tyne and Berger, 1976). Out of the more than 9600 species of birds in the world (Birdlife/COC, 1999 and Urban *et al.,* 1996), no two have exactly the same distribution, if we exclude a few species confined to small islands. Yet many species have distributions that coincide to a considerable extent. Biome, a "climax" vegetation area is another method for analyzing distribution of animals and plants, for example coniferous forest, prairie grassland, and its animal inhabitants (Perrins and Middleton, 1985). Each zoogeographical zone or region has its characteristic birds which include endemic species. For example, African endemic families include Mouse birds and Turacos. However, a few species of world avifauna, for example the Barn owl (*Tyto alba*), largely ignore these zonal restrictions (Brown *et al.*, 1982).

2.4.2 Ecological factors influencing bird distribution

Despite the high mobility of birds with the chief advantage being their capacity to exploit diverse habitats, birds show a surprising variety of adaptations to their various conditions of existence (Fanshawe and Bennun, 1991). Several factors are responsible for these interrelations between birds and their environments, namely; abiotic (soil, water, climate and light) and biotic (plants and animals). Their adaptations to these varying ecological factors account for their temporal and spatial distribution (Tyne and Berger, 1976; Klein *et al.,* 1995; Juricica *et al.*, 2004; Hernández *et al.*, 2012; Xiaoxu *et al.,* 2012).

The local topography, drainage and soil types result in mosaic vegetation types and consequently bird communities (Pitelka 1941; Palmer 1991; Brown *et al.* 1982; Sombroeck 1982). Plants and different vegetation types are of ecological importance to birds, not only as sources of food but also for nesting materials and sites, lookout posts, singing stations, roosting sites and protective cover (Wiens, 1989). According to Taku (2000), plants satisfy psychological needs in birds (safety, cleanliness, good nesting sites, roasting sites), but food is of primary importance. Plant distribution, therefore, plays a major role in determining the distribution of bird species.

Despite plants being the major sources of food for birds, whatever a bird's feeding adaptations and habits may be, it must live in those regions where its preferred foods are found. A considerable degree of co-evolution exists between birds, their nutritional needs, and the quantity and quality of available fruit (Wiens, 1989). Vegetation is the main source of nesting material or nesting site for birds. Some bird species show pronounced preferences for specific vegetation types as nesting site (Robbins *et al.,* 1986), which could be hayfield, grass, conifers, deciduous trees or dense woods e.g. Larks are likely to build their nest in a meadow with short grass.

Intra-specific competition is the keenest competition that occurs between birds of the same species due to the identity of their requirements (Wiens, 1989). This leads to the establishment of territories which is a competition-reducing mechanism and a factor contributing to the temporal and spatial distribution of bird populations. Inter-specific competition exists between different species and can be lessened if two or more species require different things from the same environment. Each species is thus encouraged to seek out its optimum habitat. Bennun *et al.,* (2000) vividly demonstrate habitat stratification in a rainforest: the canopies which constitute the location of most flowers and fruits harbour the many brilliantly coloured birds such as the parrots, macows, trogons and turacos. Midway to the ground into the under-storey of small trees, large shrubs, lianas and epiphytes, with relatively subdued light and warm humid quiet air occur the flycatchers, woodpeckers and other insectivorous species. On the forest floor with relatively little vegetation because of the perpetual gloom, are found the dull coloured ant eater birds and robins. By avoiding much of the competition for food, nesting sites and territories (Wiens, 1989), the different species or higher category of birds distribute and adapt themselves to these different strata (Juricica *et al.,* (2004).

Habitats are varied since they are distinct vegetation types based on the amount and kind of plants that constitute them. Every major habitat presents special conditions of life and usually peculiar problems of existence for birds living there (Robbins *et al.,* 1986). Birds occupying a given habitat, as a rule, are adapted to exploit these conditions and to meet their needs sufficiently well (Wiens, 1989). The resources and challenges presented by different habitats also account for the distribution of avian species.

2.4.3 Microclimate and distribution of organisms

A microclimate is a small but distinctly different climate within a larger area, hence it is climatic condition in a relatively small area, within a few feet above and below the Earth's surface and within canopies of vegetation. Microclimates are affected by factors such as temperature, humidity, wind and turbulence, dew, frost, heat balance, evaporation, the nature of the soil and vegetation, the local topography, latitude, elevation, and season. For example, valleys and hills classically have their own climates, due to a variety of factors that cause their weather to be different from the more general weather in the region. A microclimate can offer an opportunity as a small growing region for crops that cannot thrive in the broader area (Horace, 1958).

A microclimate exerts considerable influence over the functioning of forest ecosystems (Chen *et al.*, 1999), with direct influences on processes as diverse as soil respiration, nutrient cycling, plant regeneration and invertebrate mortality rates (Smith and Johnson, 2004; Laurance *et al.*, 2002). Within forests, microclimate conditions are buffered from the macroclimatic conditions immediately adjacent to and above forests, having lower annual and seasonal variability reflected in warmer minimum temperatures and cooler maximum temperatures (Didham and Lawton, 1999). Forest fragmentation, and the creation of forest edges, exposes parts of the forest environment to external climatic conditions, reducing the ability of a forest to buffer its internal microclimate from those more extreme macroclimate conditions. Ewers and Banks-Leite (2013) observed that altered microclimate conditions near forest edges are routinely reported from forests around the world.

Within a climatic belt, zone or locality, local variations may occur in certain environmental conditions (Pitelka, 1941). Those small scale local variations form a microclimate. Different microclimates provide suitable conditions for different sets of living organisms, and they may account for distribution of organisms in a locality. Environmental factors regulate the occurrence and distribution of organisms. Shivoga (1999a) reported that disparities between faunal communities of temporal and nearby permanent streams are related apparently to system-specific differences in the physicochemical and biological environments.

2.5 Birds in Mau Forest

The Mau forest complex is one of the five major water towers for Kenya. It is in Rift Valley province and is 270,300ha of which 224,300ha is gazetted forest and 46,000ha ungazetted (KFWG, 2001). The forest complex covers a substantial area of the south-western highlands of Kenya, and probably represents the largest remaining near-continuous block of montane indigenous forest in East Africa (Bennun and Njoroge, 1999). The forest cloak the western slopes, and part of the crest, of the Mau Escarpment, a block of raised land that forms the western wall of the Gregory Rift Valley. According to Kenya Forest Working Group (KFWG) 2001, Mau Forest complex has five main Forest Reserves; Eastern Mau (66,000ha), Western

Mau (22,700), South-western Mau (84,000ha), Transmara (34,400ha), and Ol Pusimoru (17,200ha). A sixth large block, the Maasai Mau (46,000ha) is as yet ungazetted. Large areas of the Western and Eastern Mau have been fragmented and converted to plantation forest.

Mau Forest Complex has a rich highland bird community, characteristic of the central Kenya highlands (Bennun and Njoroge, 1999). It is designated an Important Bird Area since it has global and regional significance in birds conservation. This is proven by the fact that Mau complex is categorized among the richest examples of Central East African montane avifauna (Fishpool, 1996). Further to this, forty-nine of the Kenya's 67 Afrotropical Highland biome bird species are known to occur in Mau making 72% of Kenya's Afro-tropical Highland biome species. The forest also harbours eight species of birds that are Vulnerable and Regionally Threatened (namely: Ayre's Hawk Eagle, African Crowned Eagle, African Grass Owl, Cape Eagle Owl, Red-chested Owlet, Least Honey guide, Grey-winged Robin, and Purple-throated Cuckoo-shrike). The Hartlaub's Turaco (a huge forest bird) is endemic in Mau escarpment while Hunter's Cisticola and Jackson's Francolin are Restricted-range species in the complex forest (Zimmerman *et al.*, 1996).

The forest and its rich biodiversity are however threatened by fragmentation. As reported by Bennun and Njoroge (1999), among the most vulnerable parts of Mau Forest for bird conservation are the high montane forests on the eastern rim. This is where River Njoro Watershed is located. The more open, destructively logged forest holds good populations of many highland species, but densities of forest-specialist birds are relatively low (BirdLife International, 2007).

The main conservation problem in the Mau is increasing pressure on productive land from an expanding population which has brought about wavy fragmentation patterns. This fragmentation and degradation continues to affect the endemic and vulnerable bird species.

2.6 Birds' Diversity

2.6.1 Biological Diversity (Biodiversity)

Biological diversity is simply the great variety of life. As defined by the Convention Biological Diversity, CBD (1992), it is the unique collection of organisms (the genes they contain and the species they form) in a unique ecosystem setting that probably cannot be replicated and that cannot be moved to another site because of the environmental drivers. The term is also used to describe the total variety of living organisms (plants, animals, fungi and microbes) that exist on the planet. In her classic book on measuring biodiversity, Magurran (2004) defined diversity in three levels;

Alpha diversity – the diversity within a particular area or ecosystem

Beta diversity - the change in diversity between ecosystems

Gamma diversity - the overall diversity in a landscape comprised of several ecosystems.

This study deals with the diversity within Eastern Mau Ecosystem at Alpha diversity level. Magurran (2004) further explains that diversity can be quantified in many different ways. The two main factors taken into account when measuring diversity are "richness" and "evenness". Richness is a measure of the number of different kinds of organisms present in a particular area. For example, species richness is the number of different species present in an area. However, diversity depends not only on richness, but also on evenness (Dalgleish and Woods, 2007). Evenness compares the similarity of the population size of each of the species present in an area.

Richness is measured by the number of species per sample. The more species present in a sample, the 'richer' the sample. Species richness as a measure on its own, takes no account of the number of individuals of each species present (Magurran, 2004). It gives as much weight to those species which have very few individuals as to those which have many individuals. Thus, one daisy, for instance, has as much influence on the richness of an area as 1000 buttercups.

Evenness is a measure of the relative abundance of the different species making up the richness of an area (Dalgleish and Woods, 2007). To give an example, one might have sampled two different fields for wildflowers. The sample from the first field consists of 300 daisies, 335 dandelions and 365 buttercups. The sample from the second field comprises 20 daisies, 49 dandelions and 931 buttercups (Table 1). Both samples have the same richness (3 species) and the same total number of individuals (1000). However, the first sample has more evenness than the second. This is because the total number of individuals in the sample is quite evenly distributed between the three species. In the second sample, most of the individuals are buttercups, with only a few daisies and dandelions present. Sample 2 is therefore considered to be less diverse than sample 1.

Table 1: Demonstration of species richness and evenness in a flower field

	Numbers of individuals	
Flower Species	**Sample 1**	**Sample 2**
Daisy	300	20
Dandelion	335	49
Buttercup	365	931
Total	1000	1000

A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance (Fisher, 1956). As species richness and evenness increase, so does diversity.

In ecology, a diversity index is a statistic which is intended to measure the biodiversity of an ecosystem (Magurran 2004). More generally as explained by Fisher (1954), diversity indices can be used to assess the diversity of any population in which each member belongs to a unique species. Magurran (2004), further warns that estimators for diversity indices are likely to be biased, so caution is advisable when comparing similar values.

2.6.2 Factors affecting Diversity

Biodiversity is distributed heterogeneously across the Earth. Some areas teem with biological variation while others are virtually devoid of life and majority fall in between the two extremes (Gaston, 2000). The number of species is determined by the birth, death, immigration and emigration rates of species in an area. These rates in turn are determined by the effects of abiotic and biotic factors which could be intrinsic or extrinsic to the organisms of concern (Gaston and Williams, 1996). These factors act at local and regional scales.

Brown and Lomolino (1998) describe the factors that influence biodiversity of an ecosystem as;

(i) Overexploitation referring to harvesting species more rapidly than populations can replenish themselves or to do so at unsustainable levels,

(ii) Habitat loss and fragmentation due to development, ranching, agriculture and pollution has a huge impact on biodiversity as human populations continue to grow. Deforestation of tropical rainforests has had perhaps the most dramatic effect on biodiversity, both directly in the loss of species in these incredibly diverse ecosystems and indirectly through the increased threat of global warming.

(iii) Invasive Species, Non-native, introduced or alien species which are plants, animals, diseases or other organisms transferred unnaturally from one ecosystem to another, either intentionally or unintentionally. They can pose a threat to biodiversity when they possess adaptations that help them out-compete, prey upon or interbreed with native species in their new ecosystem; and

(iv) Climate Change which is generally more gradual than habitat destruction, but it threatens ecosystem biodiversity because climate strongly influences the kinds of organisms that have adapted to each ecosystem.

The diversity of birds is affected by factors including geographical and ecological. Apparently, there is no place on earth as remote or isolated as to be completely deprived of birdlife (Pitelka, 1941). Over 9600 species of bird presently live on earth (Birdlife/COC, 1999). The majority are confined to certain regions. Very few species such as Peregrine Falcon (*Falco peregrines)*, and Grey Plover (*Pluvialis squatarola)*, are found in all continents and can be considered as cosmopolitan (Taku, 2000). In Africa, as recorded by Clement (2005), there exist 1850 species of birds and none is resident in every part of the continent. With 1089 bird species (Bennun and Njoroge, 1999) Kenya has one of the richest avifauna in Africa. At least six of these (Williams' Lark, Sharpes Longclaw, Hinde's Babbler, Taita Thrush, Tana River Cisticola and Clarke's Weaver) are national endemics (Bennun and Njoroge, 1999). This high species total is due to Kenya's diverse habitats and the presence of four endemic bird areas and six avian biomes (Fishpool, 1996). Kenya is also on a major flyway of Palaearctic migrants, both land- and water-birds, mainly from Eastern Europe, Russia, the Middle East and Siberia (Fanshawe and Bennun, 1991). Around 170 of Kenya's bird species are Palaearctic migrants (11 of them with a local breeding population) and 60 migrate regularly within the Afro-tropics or from Madagascar. Some 335 of Kenya's bird species are found in forests, 230 are entirely forest-dependent, and 110 are 'forest specialists', requiring intact, undisturbed forest habitat (Bennun *et al.*, 2000).

2.6.3 Simpson's Diversity Index

Simpson's Diversity Index is a measure of diversity which takes into account both richness and evenness (Dalgleish and Woods, 2007). It measures the probability that two individual birds randomly selected from a sample will belong to the same species, or some category other than species (Quinn and Keough, 2002). In ecology, it is often used to quantify the biodiversity of a habitat. The formula described below calculates diversity index;

If p_i is the fraction of all organisms which belong to the i-th species, then Simpson diversity index is most commonly defined as the statistic

$$D = \sum_{i=1}^{S} p_i^2. \qquad \text{...1}$$

This quantity was introduced by Edward Hugh Simpson (Quinn and Keough, 2002). If n_i is the number of individuals of species i which are counted, and N is the total number of all individuals counted, then

$$\sum_{i=1}^{S} \frac{n_i(n_i-1)}{N(N-1)} \qquad \text{...2}$$

is an estimator for Simpson's index for sampling without replacement.

Note that $0 \leq D \leq 1$, with values near zero corresponding to highly diverse or heterogeneous ecosystems and values near one corresponding to more homogeneous ecosystems. Biologists who find this confusing sometimes use 1 / D instead; confusingly, this reciprocal quantity is also called Simpson's index. A more sensible response is to redefine Simpson's index as

$$\tilde{D} = 1 - D = 1 - \sum_{i=1}^{S} p_i^2, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

(Called by statisticians the index of diversity), since this quantity has a simple intuitive interpretation (Fisher 1956). It represents the probability that if we randomly choose two individuals, that they will belong to distinct species, this quantity is comparable with the Shannon diversity index, which has an even better theoretical justification as a measure of statistical in homogeneity (Quinn and Keough, 2002). To describe diversity in River Njoro Watershed, this study will use Simpson index because it puts into consideration both the richness and evenness of species.

The Simpson Diversity Index (D) value is always between zero (0) and 1 and is interpreted as the higher the value of D, i.e. the closer it is to 1 the less the diversity and the less the value of D that is the closer it is to zero (0) the higher the diversity. This is the opposite of Diversity Index (D`) which is a reciprocal or $D$`= 1 – D and it value is always between zero (0) and 1. It is interpreted as the higher the value of D` the higher the diversity and the lower the value of $D$` the lower the diversity of the ecosystem in question. In other words the conclusion can be expressed as

$1 \leq D` \leq 0$ meaning values near 1 represent heterogeneity and values near zero (0) represent homogeneity.

2.7 Fluctuating Asymmetry

The deviation from perfect bilateral symmetry (Fluctuating Asymmetry) is caused by environmental stresses, developmental instability and genetic problems during development (Tomkins and Kotiaho, 2002). It is thought that the more perfectly symmetrical an organism is, the better it has been able to handle developmental stress and has more developmental stability (Møller, and Swaddle, 1997). Fluctuating Asymmetry (FA), as discussed by Valen (1962), may be a measure of good-genes that is difficult or impossible to mask or disguise. In breeding therefore, as elaborated by Campo *et al*., **(**2007) and Cadée (2000), mates with low FA should be preferred.

Fluctuating asymmetries in most animals other than human beings are small deviations in the expression of normally bilaterally symmetrical characters associated with developmental instability (Møller and Swaddle, 1997), induced by such factors as population density, temperature extremes, food shortage, pollution, and such. According to Pankakoski (1985), FA is the difference between the Right and Left sides in characters that should otherwise be bilaterally symmetrical, but whose expression is affected by epigenetic stress during development. Forest fragmentation may promote an increase in FA in isolated populations, by either genetic or environmental stress (Lens *et al*., 2002b). Fluctuating Asymmetry may function as a bio-monitor index in conservation biology if increased levels were observed in populations from fragmented habitats.

The small random deviations from perfect symmetry in bilaterally paired structures; is thought to reflect an organism's ability to cope with genetic and environmental stress during development. Fluctuating Asymmetry, therefore, can be used as an indicator of such stresses basing on the assumption that perfect symmetry is a priori expectation for the ideal state of bilateral structures (Leary and Allendorf, 1989). Fluctuating asymmetry has been used as an indicator of individual quality in studies of natural and sexual selection and as a bio-indicator tool for environmental monitoring and conservation biology (Bradley, 1980).

Causes of FA include mutations, inbreeding, homozygosity and poor genetic co-adaptation (Pankakoski, 1985; Anciaes and Marini, 2000; Krissman, 2006). In any given population, the optimal phenotype is promoted by buffering mechanisms that keep inter- and intra-individual variations low (Leary and Allendorf, 1989). A link exists between canalization that controls phenotypic variation, and developmental stability, mostly measured as fluctuating asymmetry of bilateral traits (Palmer and Strobeck, 1986). Both types of variations are associated with the functional importance of a trait, and both are increased by stress of various kinds (Leary and Allendorf, 1989). But there are also several instances of non-congruence (Palmer and Strobeck, 1986).

It can be concluded that developmental stability in birds is partly governed by specific, as yet unknown, molecular processes (Tull and Brussard, 2007). However, bilateral symmetry is an important indicator of freedom from disease, and worthiness for mating (Campo *et al*., 2007).

Facial asymmetries and minor physical anomalies begin to appear early in embryonic development, and can be a sign of instability during this growth (Palmer and Strobeck, 2003). Fluctuating asymmetry (random differences between two sides, as opposed to the deliberate natural asymmetry in some animals) develop throughout the lifespan of the individual and is a sign of the phenotype being subjected to some levels of stress (Kozhara, 1994).

The ability to cope with these pressures is partly reflected in the levels of symmetry. A higher degree of symmetry indicates a better coping system with environmental factors (Tull and Brussard, 2007). During the last decade, the study of fluctuating asymmetry (FA) in relation to different fitness aspects has become a popular issue in evolutionary biology (Anciaes and Marini, 2000). There has been much recent debate in subtle departures from perfect symmetry in bilaterally paired morphological characters, and the extent to which such departure actually reflects aspects of individual quality and fitness (Kozhara, 1994; Lens, *et al*., 2002b; Cadée 2000).

2.8 Theoretical Framework

The study is based on theory of island biogeography that was coined by ecologists Robert MacArthur and E.O. Wilson 1967. The theory says that a larger island will have a greater number of species than a smaller island. For this theory, an 'island' is any ecosystem that is remarkably different from the surrounding area. So, this could refer to an actual island in the ocean, or it may be an oasis that is surrounded by a desert. When trying to understand the species diversity within any of these ecological 'islands,' you will need to consider three main factors. First is **immigration**, which is the number of new species that move to the island. When there is a higher rate of immigration, there will be a higher number of species in the island ecosystem. However, immigration rates tend to slow when species diversity becomes higher on the island because of competition. Next is **emigration**, which is the number of species that leave the island. Emigration produces results opposite of immigration. As more species emigrate, there is lower species diversity on the island, and as fewer species emigrate there will be a higher species diversity. The third factor is **extinction**, which is the number of species on the island that become extinct. Extinction rates are related to the size of the island, the smaller the island, the higher the rate of extinction. This is because larger islands contain more resources and habitats and are thus able to support more life (Wilson and MacArthur, 1967).

The biodiversity hotspots of the globe contain a high degree of endemism and are undergoing gradual loss of habitats (Laurance *et al.,* 2002). Maximum portions of these hotspots are located in tropical forests, which are considered as the most endangered (WWF, 2012). Habitat fragmentation is one of the major causes of the biodiversity loss. Habitats can either disappear completely or they may become degraded and/or fragmented, both processes cause serious impacts on biodiversity as well as ecosystem processes (Brooks *et al.,* 1999). Loss of natural forests and fragmentation of the remaining areas into progressively smaller patches is a significant global trend. The habitat fragmentation occurs in different patterns including patches, waves for instance by urbanization or linear for instance by construction of roads (Kupfer *et al.,* 2006). Figure 1 elaborates the patterns.

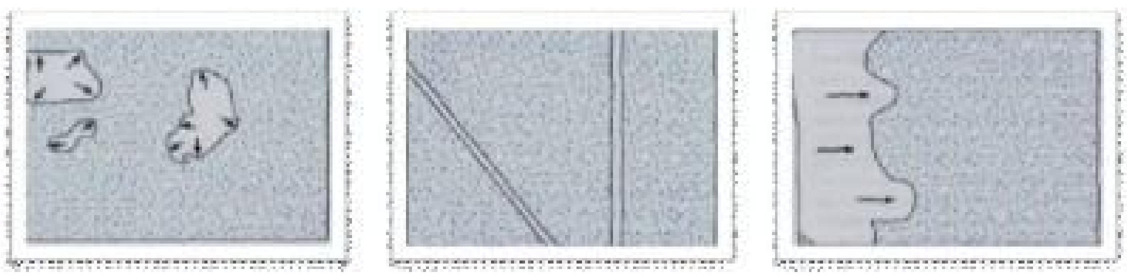

Figure 1: Theoretical fragmentation patterns; patches, linear and waves

Tropical deforestation involves the conversion of continuous forest to the remnant of forest patches set in a matrix of non-forest vegetation. Such manipulation of ecosystems has consequences for biodiversity at both landscape and fragment levels (Kupfer and Franklin, 2009). The altered microclimate becomes unsuitable for certain species by reducing the fragment size further, increasing mortality rates near the edge and reducing recruitment to their populations (Ewers and Banks-Leite, 2013). The tropical forest ecosystem is often characterized by a heavy dependency on mutualistic species interactions for its stability. Many plant species in the tropical forests are reliant on animals as agents of dispersal for either pollen or seeds or both (Fahrig, 2003). In the event that habitat fragmentation causes the extinction of certain important pollinating or seed-dispersing animals, regeneration of rare plant species is severely limited and initiating an extinction vortex (Brooks *et al.,* 1999).

Both population size and species richness decreases as does the habitat abundance. Rare and patchily distributed species requiring a large range or specialist habitats are particularly susceptible to fragmentation (Kupfer and Franklin, 2009). With the decrease of habitat proportion, patch size decreases while between patches increases. Larger patches contain more species than do the small patches. This occurs because small patches experience more extinctions (small populations are more vulnerable to chance events), and receive fewer immigrants (Franklin *et al.,* 2003). Patches that are more remote from the mainland or source population have fewer species because the extinction rate is the same but the immigration rate is lower.

Larger species may have trouble finding habitat to support a home range in heavily fragmented forests. Factors such as fragment size, degree of isolation and time since excision from the continuous forest directly influence the biodiversity of a fragment (Franklin *et al.*, 2003). Species distribution patterns are usually patchy in the tropical forest landscape and this increases the likelihood of certain species being exterminated by fragmentation (Kupfer and Franklin, 2009). As a fragment reduces in size, populations fall below specific levels and extinction ensues. Small populations are more liable to fluctuations which inevitably include local extinctions; as they also tend to suffer from genetic drift and inbreeding (Brooks *et al.,* 1999).

The failure of many animals to move between fragments can also restrict the immigration of plant species when these animals include seed dispersers; gene flow is restricted if they are pollinators. If they do not cross open areas, they are unlikely to utilize fragmented habitats (Fahrig, 2003), so the conservation value of isolated forest patches will diminish. Immigration is an important phenomenon for the maintenance of high local levels of diversity in tropical forests. In isolated fragments the rare species will die out relatively rapidly (Brooks *et al.,* 1999), and not be replaced by other species because of a failure of immigration.

Edge phenomenon in the physical environment may have direct effects on the forest community. Fragment edges are inhospitable to a majority of forest species (Ewers and Banks-Leite, 2013). If certain animal or plant groups are more susceptible to extirpation through fragmentation than others, a change in community structure within the fragment is highly likely, which may ultimately lead to further changes and more extinctions, producing second and higher order effects (Brooks *et al.,* 1999). The deforested matrix of a fragmented landscape is often dominated by alien species, because few of the native species are tolerant of the extremely exposed conditions in the cleared areas (Kupfer *et al.,* 2006).

Habitat fragmentation, introduction of exotic species, and management of exploitable systems tend to decrease species richness and heterogeneity (Fahrig, 2003). The alteration of land use pattern results in fragmentation of habitats, ecosystems and landscapes in most parts of the world. Different studies show that all our natural old forests have become critically fragmented to the point where they are considered unlikely to maintain rich level of biodiversity, nor support viable populations of natural and native species of flora and fauna (Kupfer and Franklin, 2009). Encroachment, clear felling, illegal logging, lopping, shifting cultivation, zhum cultivation, urbanization, industrialization, agro-forestation, land use change and agricultural expansions are the major causes of forest fragmentations.

Abundant species has become occasional, occasional become rare, rare become very rare and very rare become extinct (Brooks *et al.,* 1999). The species composition of communities is seldom in a state of equilibrium. Natural disturbances, such as storms, insect plagues, floods or fires influence species diversity and maintain a high level of spatial heterogeneity. The effect of disturbance depends on the intensity of the disturbance and resilience of the system (Aber, 1998). When the magnitude of disturbance becomes too high for the system to recover, the system may collapse with irreversible consequences.

Disturbance caused by human activities, such as deforestation, leads to fragmentation of habitats. Due to fragmentation, patches of habitat are created resulting in disturbed population dynamics (Fahrig, 2003). Species with different morphological traits may respond to fragmentation in different ways. These traits are products of evolutionary history after adaptations to certain conditions. Therefore, morphological traits can be linked to habitat characteristics. As elaborated by Brooks, *et al.,* (1999), several traits may be of importance; such as wing morphology of volant animals and colonization and reproduction characteristics.

Research found a strong correlation between habitat characteristics and the characteristics of bat echolocation patterns (Kupfer and Franklin, 2009).

This study considers the fragmentation that has taken place in the watershed which is both linear and waves, and examines the effects it could have on birds. The forest has been fragmented and degraded; the theory shows that, these changes in habitat conditions affect biodiversity in dynamic ways. Forest birds get affected by fragmentation, the effects start showing in developmental traits that can easily be picked in symmetrical morphology. The research focused on birds' distribution in the fragments and the fluctuation of the asymmetry in bird tarsus.

2.9 Conceptual Framework

This study was conceptualised from the gap demonstrated in literature review. It was based on the framework of variables that are depended, independent and those that would intervene to ensure the desired status (See Table 2).

2.9.1 Independent variables

Deforestation, forest fragmentation, forest degradation and encroachment on forest land are the leading anthropogenic processes taking place in Eastern Mau forest and especially along River Njoro. All these alter the form of the forest and the resources therein. These are the drivers that lead to changes in the quality of the habitat hence affecting the biodiversity in this case birds' composition and distribution.

The independent variables are the processes resulting from uncontrolled anthropogenic activities. This in turn will affect distribution, composition, abundance and fluctuating asymmetry of birds, which are the dependent variables, in favour of biodiversity. For instance, if the communities living in River Njoro watershed participate in forest rehabilitation and afforestation programmes, they will reduce grazing which encourages soil erosion and the forest will rebuild. Degradation rate will be controlled and therefore habitat quality improved. This will make the habitat condition better for biodiversity existence and survival. If opening up land for cultivation is stopped, fragmentation will reduce. The forest will regenerate and the small fragments will grow to one continuous block. This will reduce the interruption to birds' distribution and favour development of the birds' population/community in the watershed.

2.9.2 Dependent Variables

Depend variables refer to biodiversity issues that depend on what is happening in the habitat/environment. These include the distribution of bird species in the different parts of the forest including forest edges near cultivated land or glades, deeper inside the canopy forest, riparian forest.

Composition of bird species in the different kinds of forests i.e. natural forest and plantation forest present different habitats. The habitat then harbours different bird species depending on the available resources for roosting, feeding, nesting, protection and predation. The characteristics of these species and numbers are dependent on the condition of the habitat.

Morphology of individual birds is the general physical wellness of the bird. The environment in which a bird lives and grows in affects its morphology. If the environment is degraded, the bird may have some disability. This variable is dependent on the condition of the environment/habitat.

Table 2: Conceptual Framework of the study

Independent variables		Intervening variables		Dependent variables
Environmental / habitat issue		**Policies**		**Biodiversity issues**
• Deforestation		• Participatory forest management (both Government and local communities) put checks and balances on anthropogenic activities		• Distribution of birds
• Forest fragmentation	⇨	• Afforestation and reforestation by local communities and government	⇨	• Composition of bird species
• Forest degradation		• Monitoring of biodiversity by researchers		• Diversity of birds
		• Reduction and control of anthropogenic activities in gazetted forest e.g. grazing, by KFS		• Morphology of individual birds

Source: Derived from Literature Review

CHAPTER THREE

STUDY DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents the study area and methods used in the study. It is divided into various sections dealing with general and detailed description of the study area and study sites, design of the study and methods used to collect, manage and analyse data.

3.2 Study Area

Mau forest complex is one of the five major water towers for Kenya. It is in Rift Valley province and covers 270,300ha of which 224,300ha is gazetted forest and 46,000ha ungazetted (KFWG, 2001). The forest complex covers a substantial area of the south-western highlands of Kenya, and probably represents the largest remaining near-continuous block of montane indigenous forest in East Africa (Bennun and Njoroge, 1999). Mau Forest complex has five main Forest Reserves; Eastern Mau (66,000ha), Western Mau (22,700), South-western Mau (84,000ha), Transmara (34,400ha), and Ol Pusimoru (17,200ha). A sixth large block, the Maasai Mau (46,000ha) is as yet ungazetted.

The focus of the study, River Njoro watershed is in Eastern Mau Block. River Njoro is the main River on the Eastern Mau draining to Lake Nakuru. It is ecologically very significant since it is the main source of fresh water for Lake Nakuru other than the Baharini springs as reported by Shivoga (1999). River Njoro is about 50 km long and has two main streams; Enjoro starting from Logoman and Little Shuru starting at Sigaon (Shivoga *et al.*, 2003). The two streams meet at the middle catchment.

3.2.1 Location

The River Njoro watershed is in Nakuru County in Rift Valley region, and starts from Mau hills, through Njoro Township to Lake Nakuru National Park. It covers an area of about 280km^2 and lies between latitude 0^0 15’ S and 0^0 25’ S and longitude 35^0 05’E and 36^0 05’E. Figure 3 shows the location of the study area in reference to the country and within the Mau Forest Complex (Shivoga *et al.*, 2003). Figure 2 shows the location of the study area and sampling sites.

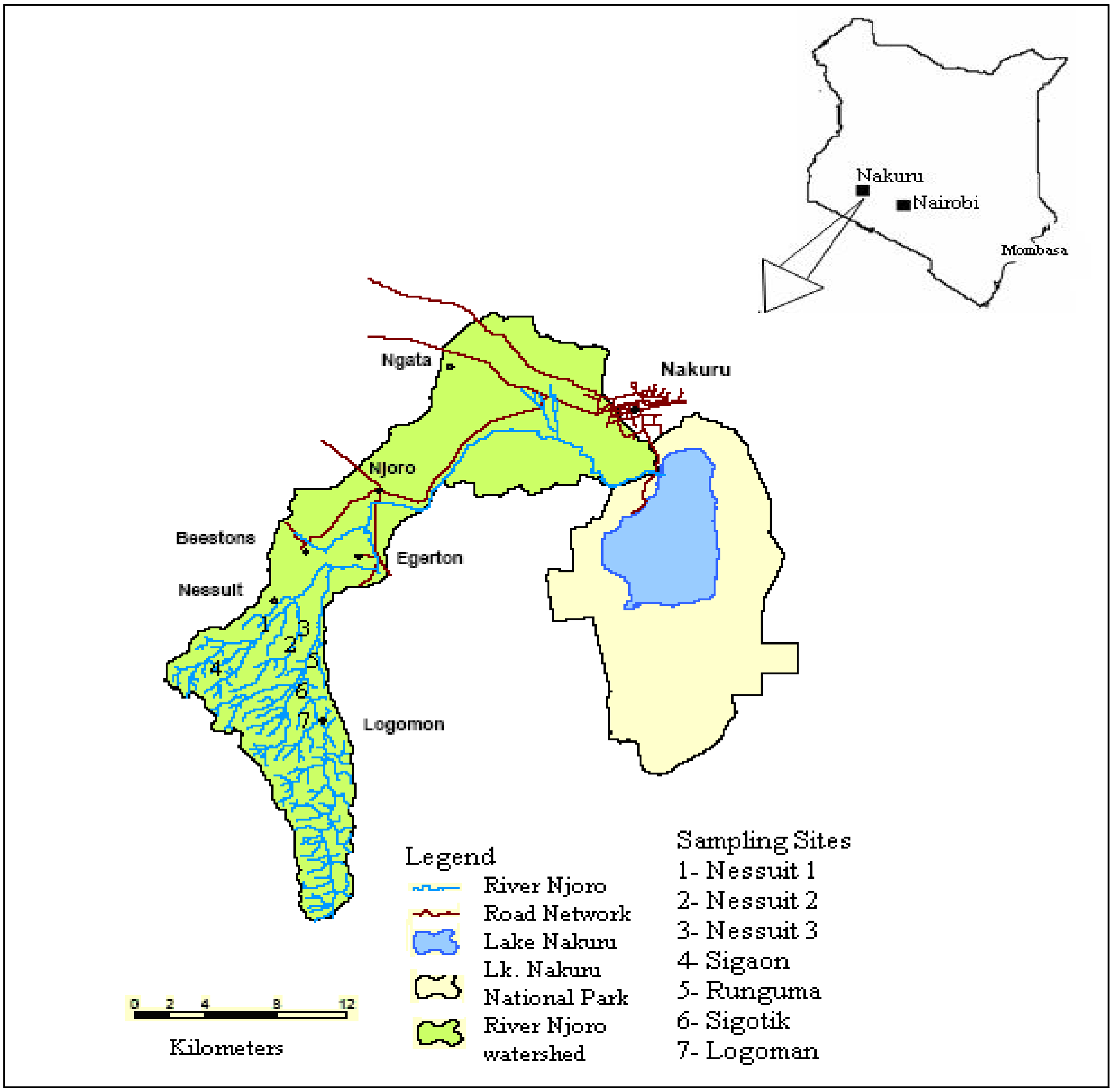

Figure 2: Location of River Njoro watershed and the study sampling sites

Source: Sustainable Management of Rural Watershed Project, 2006

3.2.2 Altitude and Physiography

The River Njoro watershed cuts across six physiographic units (mountains, hills, plateaus, uplands, plains and valleys) with altitude ranging from 1700m to more than 3000m above sea level. The river originates from the Eastern Mau Escarpment at an altitude of over 3000m above sea level, and flows over 50 km through natural and plantation forests, cultivated land, urban centres, and is joined by little Shuru stream at the mid area just above Egerton

University before it eventually empties into Lake Nakuru at 1756m elevation (Shivoga *et. al*, 2003) and Kenya Wildlife Service's brochure.

3.2.3 Climate and Geology

The climatic conditions in the study area range from humid, cool, to fairly warm, and lies within ecological zones I and III receiving an annual rainfall of 750mm - 1200mm. The area is covered by volcanic rocks, ranging in age from Tertiary Quaternary to recent, and Lacustrine and Fluviatile sediments derived directly from them (Sombroeck, 1982).

3.2.4 Soils and Drainage

The soils in the watershed have been developed on pyroclastic rocks of recent volcanoes made up predominantly of agglomerates, sediments, welded tuffs, phonolites on mountains, cidres, pumice, sanidine minerals, basaltic tuffs and black ashes on hills, plateaus, uplands, plains and valleys and alluvium and lacustrine deposits on alluvial and lacustrine plains. In terms of soil type and drainage characteristics; the soils in the study area may be grouped as poorly drained, moderately well drained, well drained to excessively drained, with textures ranging from loam, clay to clay loam and structures in the range of moderately strong to strong (Mainuri, 2005).

More details of the study area and sampling sites are demonstrated by Plates 1and 2.

Plate 1: Natural forest at Logoman: Note the natural glades and forest opening by human interference

(*Photo taken by Faith Milkah, 2006*)

Plate 2: Plantation forest at Ruguma: Note the opening and monoculture of cupressus species (*Photo taken by Faith Milkah 2006*)

3.2 Research Design

The research model on which the samples were taken was Random Effect Design. This is a kind of hierarchical linear model that assumes the dataset being analysed consists of a hierarchy of different levels whose differences relate to that population (Snijders, 2005). In general, a random effect design is efficient, and should be used, if it is assumed that there is normal distribution for the random effects. This depends on whether the units in the design should be regarded as being representative of a population, and the researcher wishes to draw conclusions primarily about the population basing on the observed units (Christensen, 2002).

The individual birds captured in the mist nets and studied, represent different species of forest birds and the different species represent the afromontane biome birds and this in turn represents the tropical birds. The effects of environmental or habitat degradation in Eastern Mau forest is distributed normally among all the individual birds and species in that forest. The individual birds were captured randomly and with equal chance for one bird and another. Mist netting method traps birds into the mist net by chance. No bird is chosen over the other. The individual trapped is considered a representative of the population.

The forest fragments studied are along the two main streams of River Njoro; Enjoro and Little Shuru. Along Enjoro stream there is the main block and source Logoman, then Sigotik and Ruguma plantation fragments. Along Little Shuru which starts at Sigaon there are three fragments Nessuit 1, Nessuit 2 and Nessuit 3. Sigaon and Logoman being large continuous blocks are compared with the smaller fragments that have been separated from them. The fragments were chosen randomly along River Njoro. The only plantation forest along the river was studied for purposes of control and comparison with natural forest.

The study captured all the individual birds that could be captured per site and only considered exhausted if recaptures are over 70%. The study sites were studied in turn, the researchers and tools moved from a site once its exhausted and camps in the next site till it was exhausted.

3.3 Materials and Methods

3.3.1 Avian sampling

Study sites were the existing forest fragments along upper River Njoro. These were Nessuit 1, Nessuit 2, Nessuit 3, Sigotik, Sigaon, and Logoman (Figure 3). Logoman and Sigaon are the main forest blocks with continuous natural forest while the others are small stands of natural forest along River Njoro. Two plantation sites at Ruguma and Logoman were also studied as control since they are adjacent to natural forest and the only plantation forests.

In each site mist nets (Plate 3) were set and opened from 6.30am and operated throughout the day up to 4pm for 21 consecutive days. This was possible largely because of favourable weather. The cool temperatures provided an ambient environment for higher bird activity. Nessuit 1 was sampled four consecutive days, Nessuit 2 two days, Nessuit 3 two days, Sigotik one day, Sigaon 4 days, and Logoman 5 days. The difference in the length of sampling time per station depended on the rate of capture. In the first and second day in most sites, new species and new individuals were captured. After that birds got familiar with the mist net and avoided it so capture rate went down. Where birds don't avoid the mist net, recapturing started to occur at a high rate meaning the site was exhausted. The weather conditions during the study was favourable since most of the day was cool therefore birds were active throughout the day. In Sigotik, sampling was carried out in one day successfully. The site is near the river watering point for livestock and so many people visited the site. On the second day mist nets were interfered with and damaged by people and cows. This challenge affected site maximizing approach.

In the plantation forest, mist nets were set right at the edge of the forest. It was not possible to set up mist nets inside the forest because of the thick density of vegetation structure; trees are close to each other, in straight lines with no undergrowth. Such conditions are not favourable for mist netting since the net must be concealed to some extent from the birds. The Pine plantation forest at Logoman was also not mist-netted for similar reasons. Since mist netting was not possible in plantation fragments, the observation method was used to sample birds in this site.

The netted birds were extracted from the net every 20 minutes and put in bird bags. One by one the birds were removed from the bird bags and studied carefully at the ringing table held on a birders grip (Plates 4 and 5). The first step in the analysis was to identify the bird by common name and age using the size, plumage, shape and other details as guided by the field guide book for Birds of Kenya (Zimmerman *et al.*, 1999). Once identified, the appropriate ring depending on tarsus size was lounged on the left tarsus of the bird. Each ring has serialised identification which is internationally recognised. The bird rings used range from sizes AA, AB, BB, K, and T, the recorded ring numbers with letter R in front of the number means it is a re-trap. Meaning, the bird has already been ringed in the data collection session but captured again (Appendix 3). Ringing was done using ringing tools and all records were put in a ringing book (Plate 4). Once ringed, bird biometrics including length of wing, length of head, length of tarsus, weight, primary and secondary feathers moult, body moult and tail moult were measured before releasing or freeing the bird. Body fat was estimated for female adults and bill and tail lengths for sunbirds were measured as additional parameters.

Plate 3: Open mist nest set at the Sigaon study station

(*Source: Photo taken by Faith Milkah 2006*)

Plate 4: Birds ringing table, ringing tools, ringing book, bird bags and identification guide

(*Source: Photos taken by Faith Milkah 2006*)

Plate 5: African Dusky Flycatcher (*Muscicapa adusta interposita*) held in a birder's grip after it was captured in the mist net during the research

(*Source*: *Photo taken by Faith Milkah 2006*)

To increase precision and minimize error on the length of Right and Left tarsus of the captured birds, length measurements in millimeters were taken by the same person twice, left, right, left, then right again. The measurements were done by team comprised of the researcher; Faith Milkah and three assistants namely; Geoffrey Mwangi, Mary Warui and Maurice Mugode. The mean length of the Right and Left tarsus were then calculated and recorded for further analysis.

Further, general observations were made by the researchers constantly with a view to noting and recording other bird activities in the site. All other birds that were not trapped in the mist net but seen or heard in the sampling site were identified and the bird species name recorded. The weather condition for the mist netting day was recorded since it significantly affects the activity of birds. All birds captured were photographed.

3.3.2 Data analysis

All data collected was transferred from the ringing book at the end of sampling period and entered into a data sheet using Microsoft EXCEL spreadsheet. The software allows management of data and can be exported to any other preferable analysis software. The bird species were further identified to Family and Order levels of classification using avian classification books and the scientific names were also added as well as the international referencing code number given per species (Zimmerman *et al.*, 1999).

Statistical and descriptive analysis for composition, diversity, abundance and fluctuating asymmetry of birds were performed using windows based MINITAB (Version 13.1) a statistical analysis software used for learning about statistics as well as statistical research. The application has the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Pie charts, bar graphs and tables were subsequently used to present the results emerging from the above analyses.

Birds' Diversity for each fragment was converted to Diversity Indices (since true diversity cannot be described by numbers of individuals but rather an index of comparison) using Simpsons Diversity Index (D). This takes into account the richness and evenness of the samples - the number of species present and the abundance of each species. The formula below was used to calculate the diversity index of the sampled fragments.

$$D = \frac{\Sigma\, n(n-1)}{N(N-1)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

n = the total number of individuals of a particular birds species

N = the total number of individuals of all birds species

The value of **D** ranges between 0 and 1. This index is thus interpreted as follows: 0 represents infinite diversity and 1, no diversity. That is, the higher the value of D, the lower the diversity of bird species.

Analysis of variance for Diversity Indices for the different forest fragments was done at 95% significance level to establish the significance of effects of fragmentation on birds' community in River Njoro watershed.

In addition, fluctuating asymmetry for the birds was measured by means of body condition index which was derived from the bio data collected i.e. length of Right and Left tarsus for the various species. All the bird species with a total of four and above individuals from all the sites were used for this analysis. Less than four individuals was too small a sample to subject to statistical analysis. A total of 20 species were subjected to One-way classification Analysis of Variance (ANOVA) at 95% significance level to determine if there was any significant difference between the length of Right and Left tarsus for the various bird species.

The purpose of the analysis of variance was to provide evidence concerning the presence or absence of impacts of environmental degradation on the length of bird tarsus. The source of variation is the length of Right and Left tarsi. Thus, analysis of variance only considers two treatments – mean of Right tarsus and mean of Left tarsus. The number of replications depends on the number of birds sampled for each species subjected under this analysis.

This design is the random effect model since the birds sampled are randomly picked from the population by mist netting. The conclusion is therefore extrapolated to all birds in the population. The calculation model is a linear statistical model:

$$y_{ij} = \mu + t_i + \varepsilon_{ij} \qquad \text{.......... 5}$$

Where;

y_{ij} = the observation of the i^{th} treatment and j^{th} replication
μ = overall mean
t_i = i^{th} treatment effect
ε_{ij} = random error component

The model supposes that there is zero variance between the two treatments.

The data and analyses that were used to test the hypotheses are summarised in Table 3.

Table 3: Data analysis matrix

Objective	**Hypothesis**	**Data**	**Analysis**
To determine the composition of avifauna in each forest fragments in River Njoro watershed	There is no difference in composition of the avifauna found in the various forest fragments in River Njoro watershed	Bird species in each fragment Characteristics of each individual bird	Descriptive analysis using MINITAB
To assess the diversity of avifauna in both plantation and natural forest fragments in River Njoro watershed	There is no difference in the diversity of avifauna found in plantation forest compared to those in natural forest in River Njoro watershed	Number of birds of each species in each fragment	Simpson Diversity Index Analysis of Variance (P-test)
To measure fluctuating asymmetry of avifauna in River Njoro watershed	There is no fluctuating asymmetry in avifauna of River Njoro watershed	Measurement of length of right and left tarsus of each individual bird	Standard deviation Analysis of Variance F-test

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the result of the study and discussions of the results. The chapter is structured in 3 sections following the study objectives: bird composition in different forest fragments; comparison of birds' diversity in plantation and natural forest fragments; and fluctuating asymmetry. The results are presented in tables, graphs, charts and descriptive summaries.

4.2 Bird Composition in different forest fragments in River Njoro watershed

Objective one of this study was to determine the composition of avifauna in each forest fragment in River Njoro watershed. The objective was based on the hypothesis that there is no difference in composition of the avifauna found in the various forest fragments in River Njoro watershed.

Result 1.1 Number of bird species and individuals

The results of this study show that a total of 238 individual birds from 49 different species, 17 Families and 4 Orders were mist netted and ringed. Of the four orders, Passeriformes were the majority comprising 43 species; there were only 3 species of Piciformes and 1 species of Coliiformes and Columbiformes each (Appendix 2).

Logoman sampling site had the highest number of species at 25% followed by Sigaon with 24%. These were followed by Nessuit 3, Nessuit 1, Nessuit 2 and Sigotik with 16%, 14%, 11%, and 10% respectively, (Figure 3 and Appendix 1). The two fragments, Logoman and Sigaon, with the highest number of birds captured are larger and continuous. They are also less disturbed since they are further up in the watershed (Figure 2) and not as easily accessible as the others that are closer to recently opened up settlement areas.

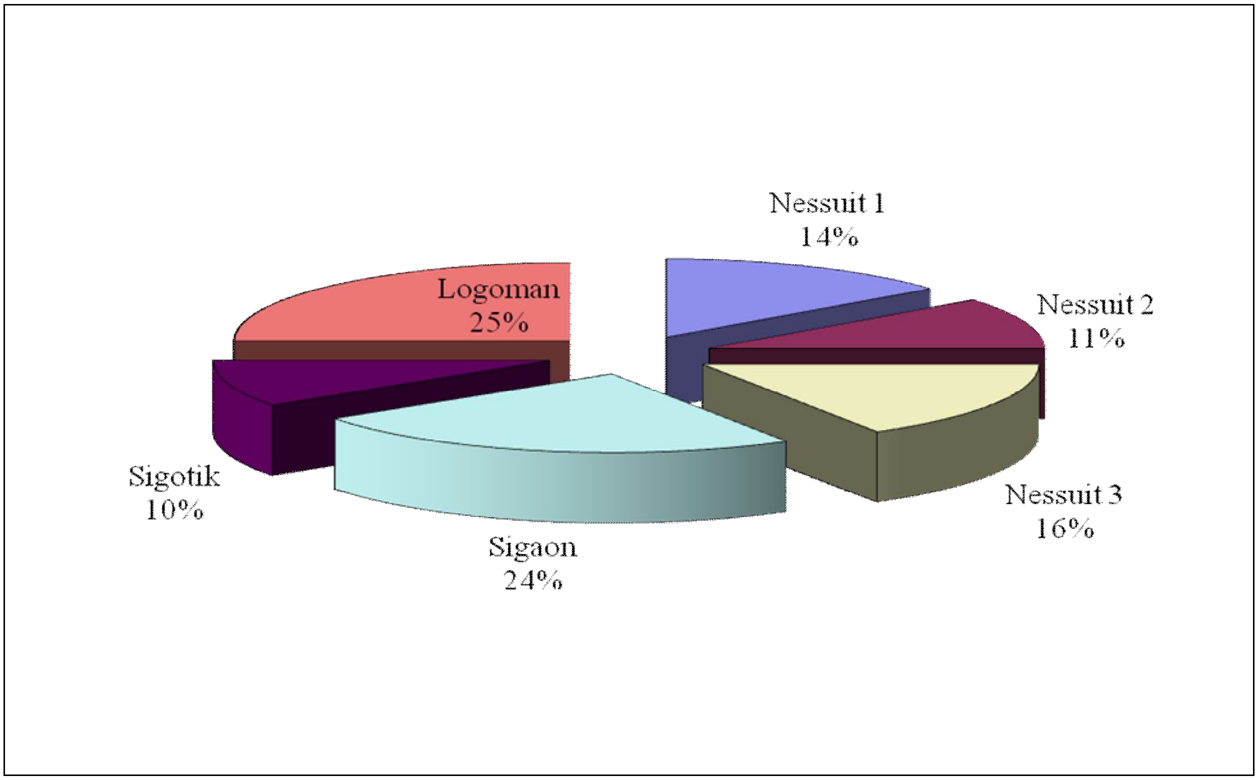

Figure 3: Percentage bird species mist netted in different fragments

The most abundant species of the birds trapped was the Streaky Seedeater *(Serinus s. striolatus)* with 41 individuals and only one re-trap. It is a finch or passerine bird in the Fringillidae family. Seed eaters are common in highland areas above 1300m asl, and are found in gardens and cultivated areas, woodlands edges, health and scrub. They are usually found in pairs of small family groups. Apart from Kenya this species is also found in the following countries; Burundi, Democratic Republic of Congo, Eritrea, Ethiopia, Rwanda, Sudan, Tanzania, Uganda and Zambia (Birdlife International, 2007). Seedeaters are associated with human habitations and open fields where there is plenty of grain seeds. The bird is a colonizer species, and a forest generalist that can comfortably exist in forest edges or non forest habitats. Seed eaters are the most abundant in the study area which could be attributed to opening of forest land for cultivation in addition to the natural glades found in the forest (Birdlife International, 2007). The species would thrive in fragmented habitats since it increases edge surface area.

The second most abundant bird in this study was Montane Greenbul (*Andropadus nigriceps*) with 16 individuals and one re-trap. This species belongs to Pycnonotidae family. It is only found in the continent of Africa. Besides Kenya, the species is also found in Burundi, Democratic Republic of Congo, Malawi, Mozambique, Rwanda, Tanzania, Uganda, and Zambia (Birdlife International, 2007). Greenbuls are common and have a large home range (BirdLife International, 2007). However, its distribution is affected largely by habitat extent and quality, and severe fragmentation. Montane Greenbul as the name suggests is found in high altitude areas and is a forest edge bird. Like the seedeaters, greenbuls thrive in fragmentation. However, this can only be sustained up to some point since the size of the patch is also significant in terms of other required resources for instance territories and food availability (Lens *et al*., 2002a).

According to the results **Nessuit1** recorded 37 individuals from 15 species with the most common species being Mountain Greenbul. **Nessuit 2** recorded 18 individuals from 11 species and the most common species was Yellow-whiskered Greenbul (*Andropadus l. latirostris*). **Nessuit 3** recorded 35 individuals from 17 species and the most common was the Streaky Seedeater followed by Montane White-eye (*Zosterops poliogaster*). **Sigaon** recorded the highest number of individuals; 75 from 25 different species, the most abundant species was also Streaky Seedeater and Montane Greenbul. **Sigotik** is the site that recorded the least number of individual birds trapped, 13 from 10 species, most common species was Black-collared Apalis (*Apalis p. pulchra)*. **Logoman** recorded 60 birds ringed from 26 species, most common species being Streaky Seedeater, Hunters Cisticola (*Cisticola hunteri)* and Common Bulbul (*Pycnonotus barbatus).* The highest total number of individual birds was found in Sigaon at 31% of the entire sample. This was followed by Logoman (25%), Nessuit 1(16%), Nessuit 3 (15%), Nessuit 2 (8%) and Sigotik with 5% (Figure 4).

Nessiut 1, 2, 3 and Sigotik are small fragments of natural forest at the bank of River Njoro and have an advantage of water availability close by. The vegetation strata in these fragments are however not so advanced since there is a lot of interference with the under-storey by livestock accessing the water and human movement into the forest and to the river for abstraction. These patches are surrounded by cultivated land hence there are some bird species that will possibly go to the farms during the day and roost and nest in the forest. In such a case, these birds may therefore have not been captured since mist nets were opened during the day.

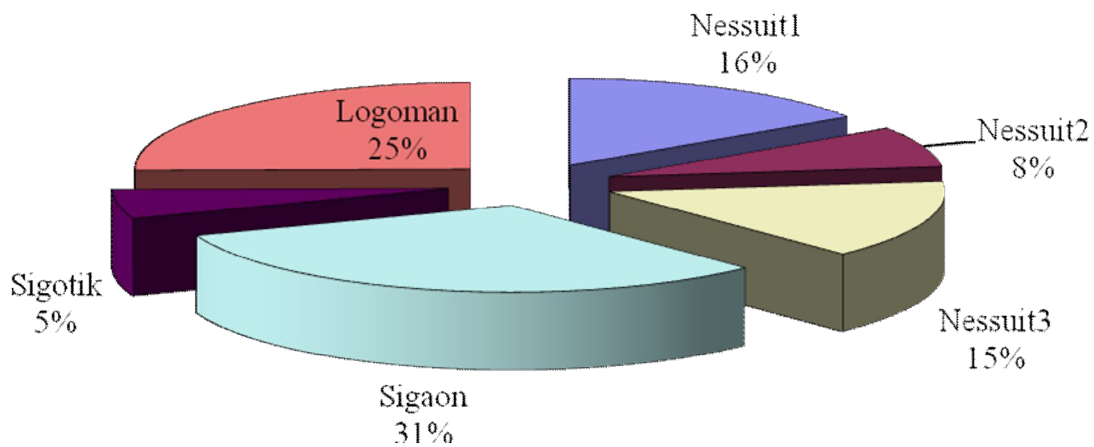

Figure 4: Percentages of total number of birds mist netted in the various fragments

A study on Bronze Sunbird foraging by Mwaura and Hunduma (2001) shows that canopy quality may determine where birds will spend their day. Similarly, a study by Gustafsson *et al.*, (1998) in East Usambara Mountains on under storey birds, shows that forest specialist species tend to avoid linear strips of forest vegetation.

The number of birds species and individuals recorded in Sigotik, Nessuit 1,2 and 3 study sites was low which could be as a result of high intensity of human activity on the undergrowth that reduced the quality of the canopy strata. The birds that possibly roost in these sites may therefore spend their day in other neighbouring habitats and only return to the sites to roost.

Result 1.2 Forest specialists and forest generalists

There were only 94 forest birds out of the 238 birds captured (Figure 5). Forest specialist birds are the 'true' forest birds, characteristic of the interior of undisturbed forest. They may persist in secondary forest and forest patches if their particular ecological requirements are met. Where they do occur away from the interior, they are usually less common and are rarely seen in non-forest habitats. The forest specialist birds can only breed within forests.

Forest generalist birds on the other hand, may occur in undisturbed forest, but are also regularly found in forest strips, edges and gaps. They are likely to be more common in such habitats and in secondary forest than in the interior of intact forest. They also breed within forest. Both forest specialists and forest generalists therefore need forest habitat to breed.

The third category of forest birds is called forest visitors. These are birds which are often recorded in forests, but are not solely dependent upon it. They are almost always more common in non-forest habitats, where they are most likely to breed. In this study, forest visitor birds were considered as forest generalists.

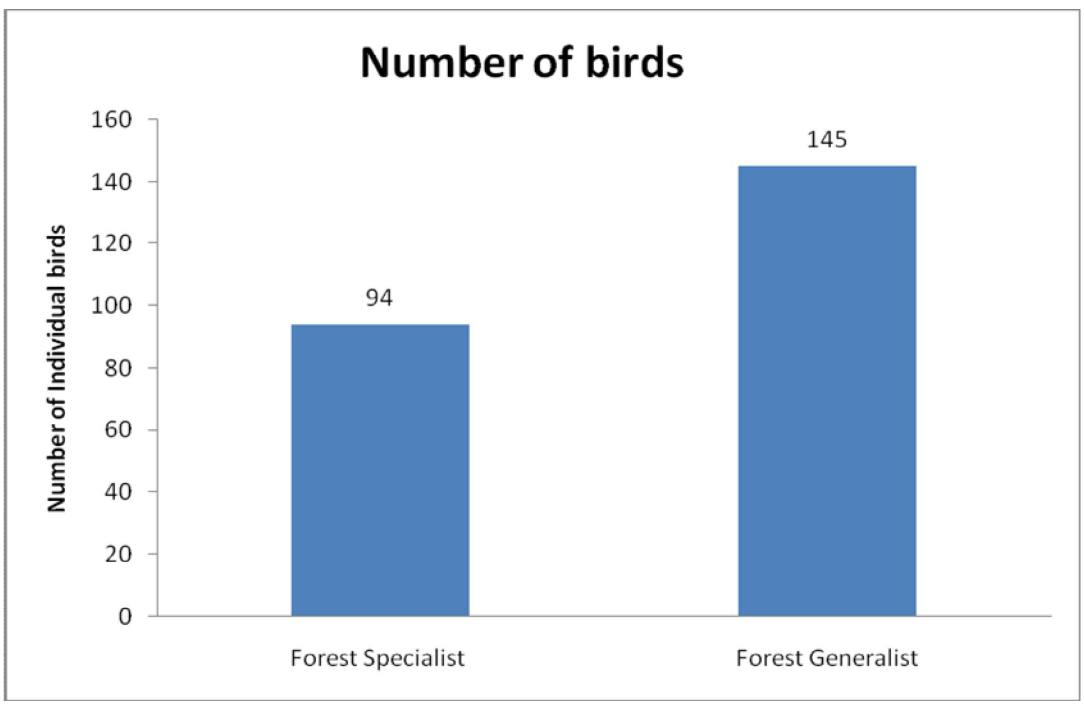

Figure 5: Number of generalist versus forest specialist birds sampled

The recent excision and human settlement in Eastern Mau forest block as noted by BirdLife International (2007) and Omweri *et al.* (2009), have altered the forest characteristic of the forest block. Considering birds high mobility capability, birds of all kinds can now exploit the remaining forest stands from the opened up habitat areas. As discussed in the relevant section of the literature review (see section 2.3b and c), distribution of birds just like other animals is influenced by a wide variety of abiotic and biotic factors, which influence their diversity, density and abundance.

An old ecological theory states that niche-breadth differences among species are the result of an evolutionary trade-off between the ability of species to exploit a range of resources and their capability to use each (McArthur, 1972). Specialist species are known to have lower dispersal abilities (Brouat *et al*., 2004; Tripet *et al*., 2002), are more strongly regulated by intra-specific competition (Dall and Cuthill, 1997), and are less able to cope with environmental stochasticity (Sol *et al*., 2002) than generalist species. Therefore, in disturbed or fragmented forest, the number of forest specialist birds will be on a declining trend while that of generalist bird species will go up.

In Eastern Mau bird species including Blue-spotted Wood Dove, Bronze Sunbird, Doherty's Bush-shrike, Sharpe's Starling, Black-headed Waxbill, Brown Woodland Warbler, Tropical Boubou, Black-throated Wattle-eye, Grey Apalis, Yellow-rumped Tinkerbird, Moustached Green Tinkerbird, African Hill Babbler, Mountain Yellow Warbler, White Starred Robin, Olive Sunbird, Yellow-whiskered Greenbul, Black-collared Apalis and Mountain Greenbul which depend fully on forest resources are affected by fragmentation. Their breeding is particularly affected by degraded forest resources explaining the decreasing diversity noted by Bennun and Njoroge (1999). To safeguard this species and biodiversity as a whole, conservation and sustainable management of Mau Forest complex called upon. Fragmenting the blocks of the montane ecosystem contributes to the observed reducing density of the forest specialist bird species.

Result 1.3 Age

The captured birds were aged in the ringing process and classified as “Adult”, “Fully Grown”, “Immature”, and “Juvenile”. Of the total number captured, nine individuals could not be aged with precision and are recorded as Un-aged.

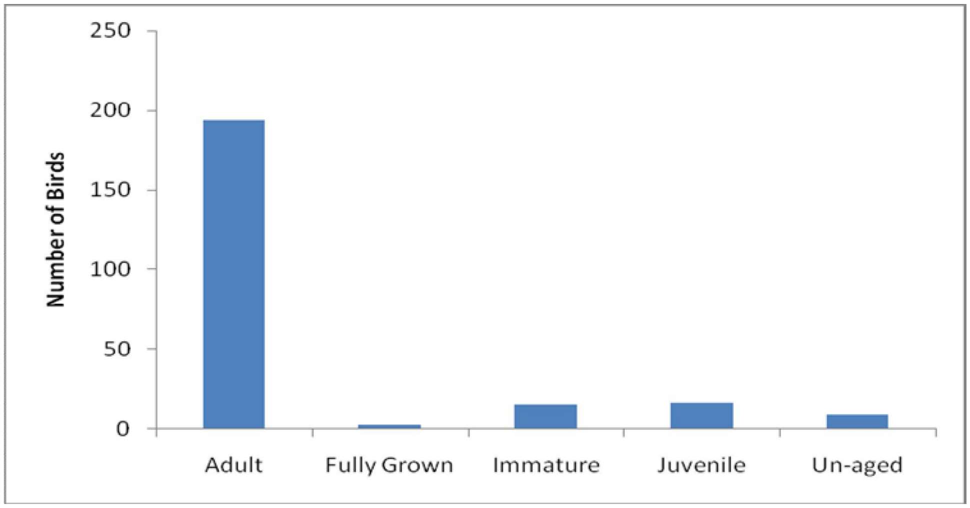

Figure 6: Number and Age of sampled birds

“Adult” referred to breeding age birds; “Fully Grown” referred to almost adult but has not begun breeding; “Immature” referred to almost fully grown but still has characteristics from juvenile stage for example the gale; and “Juvenile” referred to birds that have not developed fully and are straight from the brood. Most of the juveniles looked totally different from the adults in plumage. There were about 80% adults and 7% juveniles of the captured birds (Figure 6). The results imply that the population structure was not balanced. The study was not expected to capture nestlings in this study because the mist netting method only captures flying birds. The number of juveniles and immature birds is low compared to the breeding adult population. This study however does not have adequate data to ascertain the relationship between the number of adults and that of juveniles and immature birds. To make conclusive observations on breeding, prolonged study on the birds for several months and seasons is necessary.

The four parameters used to describe composition of birds in River Njoro Watershed; i) number of birds, ii) number of species, iii) category of birds (forest specialists and generalists), and iv) age of birds have all shown a significant difference between the different fragments. Therefore the null hypothesis “there is no difference in composition of the avifauna found in various forest fragments in River Njoro watershed” is rejected.

4.3 Comparison of diversity of avifauna between plantation and natural forest fragments:

The second objective of this study was to assess the diversity of avifauna in both plantation and natural forest fragments in River Njoro watershed. This objective was based on the hypothesis that there is no difference in the diversity of avifauna found in plantation forest compared to those in natural forest in River Njoro watershed.

Result 2.1 Diversity Index

This study focused on the two plantation forests that existed in the watershed; Ruguma a Cyprus (*Cupressus lucitanica*) plantation and Logoman a Pinus (*Pinus radiate*). The two blocks are surrounded by natural forest and boarded by a strip of open grass (Plate 2). The two blocks are also near streams of water. There were no birds captured at Ruguma and Logoman. The two sites were not suitable for setting mist nets because of the structure of the forest. The trees were low, dense and dark with bare ground and no undergrowth. Despite the challenging structure, the research made effort to locate a concealed positing for setting mist net. After hours of waiting, there were only few warblers flying below the canopy near the edge crossing from the natural forest patches.

According to this study, there was no bird species found in the plantation forest fragments. It was not possible to calculate the diversity index for Ruguma and Logoman plantation fragments without any counts of species and individuals. Diversity of birds in the other forest fragments was computed using the number of species and number of individuals (Table 4). Diversity of Upper River Njoro watershed is an average of 0.071. Logoman (0.043) is the most diverse site while Nessuit 3 (0.086) is the least diverse (Table 4). To arrive at the diversity index shown in Table 4, the number of individuals of every species (n) is used in the calculation with total number of birds per site (N). The lists of species and number of individual birds per site are shown in Appendix 1.

Table 4: Diversity Index of the various sampling sites

Site	**Nessuit1**	**Nessuit2**	**Nessuit3**	**Sigaon**	**Sigotik**	**Logoman**
Number (N)	37	18	35	75	13	60
Diversity Index (D)	0.077	0.085	0.086	0.085	0.051	0.043

Diversity Index with values near zero corresponds to highly diverse or heterogeneous ecosystems while index values near one correspond to more homogeneous ecosystems (Quinn and Keough, 2002). According to the results obtained from this study, the average diversity for the watershed is more towards homogeneous. This suggests that richness may be high but all species are evenly distributed in the watershed. Taking a site account, Logoman with 0.043 index is the most heterogeneous fragment in River Njoro watershed.

Logoman block is continuous with cider tree species among other natural indigenous vegetation with a high altitude of 2700m asl. Besides the pine plantation, there is a recuperating young cyprus patch on one end of the block. The heterogeneous nature of birds population in this block shown by the study can be attributed to the variety of habitat resources available for birds. The young cyprus plantation had more bird life from observation. Most of the birds captured in the natural forest were also observed here. This could be attributed to diverse nature of a regenerating forest. There are weeds, grasses and various plants species growing and regenerating forest is open since the canopies have not formed, hence providing more food including fruits, seeds, nectar, leaves as well as insects for hunting species.

Ngugi *et al.* (2006) explain that existence of a forest does not necessarily suggest there will be more bird species, but rather the harmonious integration of land uses explans the high bird diversity. Quality of the whole landscape and especially the number of different habitats and their spatial arrangement (Pardini, 2005) play a critical role in contributing to the diversity. A modified Qualitative Habitat Suitability Index (QHSI) based on availability of potential bird micro-habitats along the riparian corridors in River Njoro watershed as reported by Ngugi *et al.*, (2006) shows that sites with more micro habitat recorded more numbers of birds and a high diversity.

Plantation forest fragments in River Njoro watershed are abrupt interruptions of the natural forest and consist of one tree species of one age. Contrasting with natural forests of many species of varied ages, the resources available for birds are bound to vary. Evans and Turnbull (2004), explain that monoculture and homogenous nature of plantation forests applies to associated flora and fauna. This has led to claims that plantation forests are biological deserts (Nambiar *et al.*, 1999). Plantation forests in this study recorded no birds species, which agrees with the claims that plantation forests are biological deserts.

To gain further insights on diversity of birds in the study area, analysis of variance was done for Diversity Indices of the different forest fragments at 95% significance level. This analysis elaborates the significance of effects of fragmentation on birds' community in River Njoro watershed. The ANOVA (Table 5) shows a P value of 0.002. This means that a conclusion on the hypothesis under test can be arrived at with 99.998 confidence level. This is high confidence proving that there is a significant difference in birds diversity between plantation and natural forest fragments.

Table 5: Analysis of Variance for diversity index of forest fragments

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	4703	4703	16.38	0.002
Error	10	2871	287		
Total	11	7575			

Based on the foregoing results, the null hypothesis that "there is no difference in diversity of avifauna between plantation and natural forests in River Njoro watershed" is therefore rejected since calculated P-value (0.002) is less than 5% or 0.05 the significance level. According to the findings concerning this objective it is concluded that there is significant difference in birds' diversity between plantation and natural forest blocks in River Njoro watershed.

4.4. Fluctuating Asymmetry

The third objective in this study was to measure the extent to which fragmentation (environmental/habitat degradation) has affected the fluctuating asymmetry of birds in River Njoro watershed. This objective was elucidated by the hypothesis that “there is no fluctuating asymmetry in avifauna of River Njoro watershed”. Fluctuation from perfect symmetry was measured by comparison between the left and right tarsus. If they not measure the same length there is a fluctuation. Therefore a measure of standard deviation is the main factor of consideration for significance.

Result 3.1 Analysis of variance of Left and Right tarsus length of different bird species

Out of the 49 species reported in Result1.1, 20 species were analysed to test for fluctuating asymmetry. The 20 species had a minimum of 4 replications. Mean and Standard Deviation of each tarsus was calculated for all the individuals of the species and an overall mean calculated. Table 6 shows the Means and the Standard Deviation (SD) for each species. Analysis of Variance for each species was calculated and p-value is shown in the summary Table 6. For specific ANOVA for each of the birds species, refer to Appendix 4.

Table 6: Mean and Standard Deviation of the Right and Left Tarsus of Birds

Bird Species	Mean and SD of Right Tarsus	Mean and SD of Left Tarsus	p-value
1. African Citril	17.067±0.894	17.033±0.77	0.946
2. African Hill Babbler	26.600±0.376	26.550±0.403	0.844
3. Baglafecht weaver	27.575 ±0.413	27.613 ±0.357	0.895
4. Black Collared Apalis	24.933 ±0.905	24.942 ±0.984	0.983
5. Cape Robin Chat	34.038 ±1.389	34.037 ± 1.341	1.000
6. Common Bulbul	26.850 ±0.644	26.838 ±0.621	0.979
7. Eastern Double-Collared Sunbird	19.861±0.494	19.739±0.509	0.612
8. Grosbeak weaver	23.875±0.437	23.775±0.634	0.804
9. Hunters Cisticola	28.607±3.769	28.564±3.810	0.983
10. Montane White-eye	20.706±0.671	20.669±0.762	0.918
11. Mountain Greenbul	28.047±0.653	27.977±0.647	0.770
12. Mountain Yellow Warbler	25.713±0.912	25.463±1.249	0.757
13. Moustached Green Tinkerbird	17.438±0.317	17.300±0.235	0.512
14. Olive Sunbird	19.629±0.830	19.479±0.748	0.729

15. Olive Thrush	37.470±1.302	37.540±1.361	0.936
16. Streaky Seedeater	24.296±1.014	24.338±0.983	0.854
17. Tacazze sunbird	21.440±0.912	21.410±0.888	0.959
18. White Starred Robin	28.814±2.794	28.854±2.866	0.971
19. White-eyed Slaty flycatcher	27.120±1.232	27.110±1.124	0.990
20. Yellow Whiskered Greenbul	25.133±1.432	25.361±1.048	0.705

The *P-test* for the 20 species shows that the p-value for each species is more than 0.05. This suggests that there is no significant difference in the mean of the Right Tarsus and that of the Left Tarsus of the birds species under investigation. This could imply that fragmentation in River Njoro watershed and the environmental degradation in the watershed have not significantly affected the morphology of the birds in question and therefore Fluctuating Asymmetry has not been observed in avifauna of the watershed.

The obtained *P-values* (Table 6) only give confidence of 0% - 48% to reject the hypothesis. These are low levels implying that there is no confidence to reject the null hypothesis. On the basis of the results obtained, the hypothesis stating "there is no fluctuating asymmetry in avifauna of River Njoro watershed" is accepted.

To gain further insight on fluctuating asymmetry of birds in River Njoro watershed, F-test was carried out, a summary of the results in Table 7.

Table 7: Analysis of Variance summary of F values

Bird Species	**Numerator, denominator Degrees of freedom**	**F -cal**	**F-tab at 5%**
1. African Citril	1,10	0.00	4.96
2. African Hill Babbler	1,8	0.04	5.32
3. Baglafecht weaver	1,6	0.02	5.99
4. Black Collared Apalis	1,22	0.00	4.30
5. Cape Robin Chat	1,14	0.00	4.60
6. Common Bulbul	1,6	0.00	5.99
7. Eastern Double-Collared Sunbird	1,16	0.27	4.49
8. Grosbeak weaver	1,6	0.07	5.99
9. Hunters Cisticola	1,12	0.00	4.75
10. Montane White-eye	1,14	0.01	4.60

11. Mountain Greenbul	1,28	0.09	4.20
12. Mountain Yellow Warbler	1,6	0.1	5.99
13. Moustached Green Tinkerbird	1,6	0.49	5.99
14. Olive Sunbird	1,12	0.13	4.75
15. Olive Thrush	1,8	0.01	5.32
16. Streaky Seedeater	1,78	0.03	4.00
17. Tacazze sunbird	1,8	0.01	5.32
18. White Starred Robin	1,26	0.00	4.23
19. White-eyed Slaty flycatcher	1,8	0.00	5.32
20. Yellow Whiskered Greenbul	1,16	0.15	4.49

For all the 20 birds species, *F-calculated* value is less than the *F-tabulated* value suggesting there is no significant variation between the mean lengths of Right and Left tarsus hence the null hypothesis: “there is no fluctuating asymmetry in avifauna of River Njoro watershed” is accepted in all the cases. In other words, environmental degradation has not caused significant genetic stress in avifauna of River Njoro watershed and the conclusion according to the findings concerning this objective, is that environmental degradation in Eastern Mau Forest has not caused significant genetic stress in the avifauna of River Njoro watershed.

Both *P and F- tests* show that there is no significant variation between the length of the Left and the Right tarsus of the birds sampled in River Njoro watershed. Even though this study does not show significant variations between Right and Left tarsus of the sampled bird species, there could be other ways that birds in Eastern Mau Forest have been affected by the environmental stress they have been exposed to. Indeed various studies (Bytebier, 2001, Lens and Dongen, 1999, Lauga and Joachim, 1992) show that bird populations in most degraded forest fragments were exposed to increased levels of environmental stress.

CHAPTER FIVE

SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Key Findings

The main objective of this study was to examine the effects of forest fragmentation and environmental degradation on composition, diversity and fluctuating asymmetry of avifauna in upper River Njoro watershed. The study achieved the set specific objectives which are; (i) to determine the composition of avifauna in each forest fragment in River Njoro watershed (ii) to evaluate the diversity of avifauna in both plantation and natural forest fragments in River Njoro watershed (iii) to measure fluctuating asymmetry of avifauna in River Njoro watershed. The key findings in this study are that (i) larger continuous forest fragments have more birds and more species than smaller ones; Forest generalist birds are more in the fragments than forest specialist birds; 80% of birds studied are breeding adults; (ii) natural forest fragments have a higher diversity of birds than plantation forests; (iii) there was no morphologically evident effects of fragmentation and environmental degradation in the asymmetry of birds.

5.2 Conclusions

Based on the key findings, this study has shown that there is a difference in the composition of birds between the forest fragments. Forest fragmentation has therefore affected the distribution of forest bird species in River Njoro watershed

Secondly, the study has shown that there is a significant difference in diversity of birds between natural forest fragments and plantation forest fragments. Natural forests have more diverse resources therefore can support varied bird species, at the same time sustain more numbers. Plantation forest on the other hand, being a monoculture has less diverse resources limiting the variety and number of birds' species it can support.

Thirdly, this study has shown that there is no fluctuation in the asymmetry of birds in the watershed. Theoretically, environmental degradation, for instance, fragmentation causes environmental stress to birds as well as biodiversity in the ecosystem. Birds respond to this stress genetically which manifests morphologically as fluctuating asymmetry. However it is important to note that these effects manifest over time since they are passed on genetically.

5.3 Recommendations

Following the findings and conclusions of this study, the following recommendations are therefore made;

5.3.1 Policy Recommendations

1. The composition of birds in the different forest fragments is clearly affected by the size of the fragment. It is recommended that initiatives to rejoin the separated fragments in Eastern Mau Forest be embraced by all stakeholders. The recommendations by the Mau Task Force (RoK, 2009) on conservation of the forest should be implemented. As a first step towards joining the fragmented blocks, protection of River Njoro banks and riparian vegetation should be a collective effort by NGOs, private sector, communities and relevant government ministries and agencies including Ministry of Agriculture, Ministry of Livestock, Ministry of Water and Irrigation, Kenya Forest Service, National Environmental Management Authority, Egerton University and Kenya Agricultural Research Institute Njoro centre and Nakuru County Government among other relevant stakeholders working with Community Based Groups including Njoro Water Resource Users Association and Community Forest Association.

2. Given the significant difference between birds in plantation and natural forests, forest policies on establishment of plantation forests should be reviewed to discourage establishment of monoculture plantations in the midst of natural forests. This is because the plantation causes an abrupt break in the habitat and hence it creates patchiness.

3. Since morphological manifestation of environmental stress in biodiversity builds over time, biodiversity conservation policies based on ecosystems, need to be harmonised to concert effort on habitat protection unlike the current policies that separate forest from wildlife and from water and from other natural resources. It will have more impact to take ecosystem conservation approach which will protect and conserve all diversity in the given ecosystem.

5.3.2 Recommendations on areas for further research

1. This study was carried out in a cold rainy season. It is therefore recommended that a similar study is carried out in the watershed in a dry season since seasonality affects the composition and diversity of birds in a given area.

2. This study is the first of its kind in the watershed. It is therefore recommended that regular monitoring of environmental conditions and their possible effects on the ecosystem be carried out. This will show trends that can serve as early warning signals and thus provide guidance on management decisions.

3. Regular bird ringing should be carried out in the study area since data of the ringed birds is universally accessed and can be used to establish trends of the movement of birds to and from the ecosystem. The bird ringing that this study did was the first in the watershed, regular bird ringing will capture new populations in the catchment.

4. Given the significant difference shown in birds' diversity between the plantation and natural forest fragments, effects of separating population pockets should be investigated for the biodiversity populations that have experienced fragmentation of Eastern Mau Forest.

5. As a follow up on fluctuating asymmetry study, it is recommended that research on genetics of specific bird species in River Njoro watershed be carried out. This will reveal any defects caused by habitat degradation that has not yet manifested in the length of tarsus studied.

6. Similarly other underlying factors that could cause environmental stress to birds and biodiversity including pollution by agrochemicals and climate change need further research.

7. This study has shown trends in avifauna's composition and diversity following the environmental processes going on in Mau. What is happening to birds in the ecosystem can be used to infer to what is happening to other biodiversity in terms of effects of environmental degradation. Birds can therefore be used as indicators of ecosystem health.

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APPENDICES

Appendix 1: Bird composition in the various forest fragments of Eastern Mau forest

Birds' Name	Nessuit 1	Nessuit 2	Nessuit 3	Sigaon	Sigotik	Logoman	Total
Abbssianian Crimsonwing	1	1					2
African Citril			1	4		1	6
African Dusky Flycatcher				1	1		2
African Hill Babbler	2	1		1		1	5
Baglafetch Weaver			2	1		1	4
Black-billed Weaver	1		1				2
Black-collared Apalis	3		2	2	3	2	12
Black-headed Waxbill				2			2
Black-throated Wattle-eye	1			1		1	3
Blue-spotted Wood Dove				1			1
Bronze Sunbird			1				1
Brown Woodland Warbler	1				1		2
Cape Robin-Chat			3	1		4	8
Cardinal Woodpecker	1						1
Cinnamon Bracken Warbler			1	1	1		3
Common Bulbul						5	5
Common Fiscal						2	2
Common Waxbill				1			1
Doherty's Bush-shrike						1	1
Eastern Double-collared sunbird				4	2	3	9
Golden-winged Sunbird		1				1	2
Green-headed Sunbird		1					1
Grey Apalis					1	2	3
Grey-headed Negrofinch	2						2
Grosbeak Weaver				3		1	4
Hunter's Cisticola			1			6	7
Montane White-eye			4	4		4	12
Mountain Greenbul	7	2		7			16
Mountain Yellow Warbler				4		1	5
Moustached Green Tinkerbird				2		2	4
Northern Double-collared Sunbird		1					1
Olive Sunbird	2	1		4			7
Olive Thrush			1	3		1	5
Purple Grenadier			1				1
Sharpe's Starling				1			1
Speckled Mousebird		1				2	3
Streaky Seedeater	5		9	19	1	7	41
Tacazze Sunbird	2			2		2	6
Tropical Boubou			1			1	2
Variable Sunbird			1				1
White-eyed Slaty Flycatcher				2		3	5
White-starred Robin	5	2		3	1	4	15
White-tailed Crested Flycatcher		2					2
Yellow Bishop			3				3

Yellow-bellied Waxbill					1		1
Yellow-crowned Canary				1		1	2
Yellow-rumped Tinkerbird	1		1			1	3
Yellow-whiskered Greenbul	3	5	2		1		11
	37	18	35	75	13	60	238

Appendix 2: List of the bird species captured and observed in the study

SPECIES (Common Name)	*Scientific Name*	Family	Order
Abbssianian Crimsonwing	*Cryptospiza salvadorii kilimensis*	Estrildidae	Passeriformes
African Citril	*Serinus citrinelloides*	Ploceidae	Passeriformes
African Dusky Flycatcher	*Muscicapa adusta interposita*	Muscicapidae	Passeriformes
African Hill Babbler	*Pseudoalcippe a. abyssinica*	Timaliidae	Passeriformes
Baglafetch Weaver	*Ploceus baglafecht*	Ploceidae	Passeriformes
Black-billed Weaver	*Ploceus melanogaster stephanophorus*	Ploceidae	Passeriformes
Black-collared Apalis	*Apalis p. pulchra*	Sylviidae	Passeriformes
Black-headed Waxbill	*Estrilda atricapilla graueri*	Estrildidae	Passeriformes
Black-throated Wattle-eye	*Platysteria p. peltata*	Platysteiridae	Passeriformes
Blue-spotted Wood Dove	*Turtur afer*	Columbidae	Columbiformes
Bronze Sunbird	*Nectarinia k. kilimensis*	Nectariniidae	Passeriformes
Brown Woodland Warbler	*Phylloscopus trochilus*	Sylviidae	Passeriformes
Cape Robin-Chat	*Cossypha caffra iolaema*	Turdidae	Passeriformes
Cardinal Woodpecker	*Dendropicos fuscescens*	Picidae	Piciformes
Cinnamon Bracken Warbler	*Bradypterus carpalis*	Sylviidae	Passeriformes
Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	Passeriformes
Common Fiscal	*Lanius collaris humeralis*	Prionopidae	Passeriformes
Common Waxbill	*Estrilda astrild*	Estrildidae	Passeriformes
Doherty's Bush-shrike	*Malaconotus dohertyi*	Malaconotidae	Passeriformes
Eastern Double-collared sunbird	*Nectarinia mediocris*	Nectariniidae	Passeriformes
Golden-winged Sunbird	*Nectarinia reichenowi*	Nectariniidae	Passeriformes
Green-headed Sunbird	*Nectarinia verticalis viridisplendens*	Nectariniidae	Passeriformes
Grey Apalis	*Apalis c. cinerea*	Sylviidae	Passeriformes
Grey-headed Negrofinch	*Nigrita canicapilla schistacea*	Estrildidae	Passeriformes
Grosbeak Weaver	*Amblyospiza albifrons*	Ploceidae	Passeriformes
Hunter's Cisticola	*Cisticola hunteri*	Sylviidae	Passeriformes
Montane White-eye	*Zosterops poliogaster*	Platysteiridae	Passeriformes
Mountain Greenbul	*Andropadus nigriceps*	Pycnonotidae	Passeriformes
Mountain Yellow Warbler	*Chloropeta similis*	Sylviidae	Passeriformes
Moustached Green Tinkerbird	*Pogoniulus leucomystax*	Capitonidae	Piciformes
Northern Double-collared Sunbird	*Nectarinia preussi kikuyuensis*	Nectariniidae	Passeriformes
Olive Sunbird	*Nectarinia olivacea*	Nectariniidae	Passeriformes
Olive Thrush	*Turdus olivaceus*	Turdidae	Passeriformes
Purple Grenadier	*Uraeginthus ianthinogaster*	Estrildidae	Passeriformes
Sharpe's Starling	*Cinnyricinclus sharpii*	Sturnidae	Passeriformes
Speckled Mousebird	*Colius striatus*	Coliidae	Coliiformes
Streaky Seedeater	*Serinus s. striolatus*	Fringillidae	Passeriformes
Tacazze Sunbird	*Nectarinia tacazze jacksoni*	Nectariniidae	Passeriformes
Tropical Boubou	*Lanirius aethiopicus*	Malaconotidae	Passeriformes
Variable Sunbird	*Nectarinia venusta*	Nectariniidae	Passeriformes
White-eyed Slaty Flycatcher	*Melaenornis fischeri*	Muscicapidae	Passeriformes
White-starred Robin	*Pogonocichla stellata*	Turdidae	Passeriformes
White-tailed Crested Flycatcher	*Trochocercus albonotatus*	Muscicapidae	Passeriformes
Yellow Bishop	*Euplectes capensis crassirostris*	Ploceidae	Passeriformes
Yellow-bellied Waxbill	*Estrilda quartinia kilimensis*	Estrildidae	Passeriformes
Yellow-crowned Canary	*Serinus canicollis flavivertex*	Fringillidae	Passeriformes
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	Capitonidae	Piciformes
Yellow-whiskered Greenbul	*Andropadus l. latirostris*	Pycnonotidae	Passeriformes

Appendix 3: Catalogue of Ring Numbers of all the ringed birds and International Reference Code of the species

RING NO	International Ref. Code	SPECIES (Common Name)	*Scientific Name*
AA15001	705	Mountain Greenbul	*Andropadus nigriceps*
AA15002	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15003	705	Mountain Greenbul	*Andropadus nigriceps*
AA15004	705	Mountain Greenbul	*Andropadus nigriceps*
AA15005	705	Mountain Greenbul	*Andropadus nigriceps*
AA15006	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15007	705	Mountain Greenbul	*Andropadus nigriceps*
AA15008	705	Mountain Greenbul	*Andropadus nigriceps*
AA15009	1211	Black-billed Weaver	*Ploceus melanogaster stephanophorus*
AA15010	610	Cardinal Woodpecker	*dendropicos fuscescens*
AA15011	705	Mountain Greenbul	*Andropadus nigriceps*
AA15012	705	Mountain Greenbul	*Andropadus nigriceps*
AA15013	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15014	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15015	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15016	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15017	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15018	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15019	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15020	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15021	1205	Baglafecht Weaver	*Ploceus baglafecht*
AA15022	1211	Black-billed Weaver	*Ploeceus melanogaster stephanophorous*
AA15023	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15024	1205	Baglafecht Weaver	*Ploceus baglafecht*
AA15025	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
AA15026	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15027	1205	Baglafecht Weaver	*Ploceus baglafecht*
AA15028	933	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
AA15029	933	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
AA15030	705	Mountain Greenbul	*Andropadus nigriceps*
AA15031	705	Mountain Greenbul	*Andropadus nigriceps*
AA15032	1203	Grosbeak Weaver	*Amblyospiza albifrons*
AA15033	1203	Grosbeak Weaver	*Amblyospiza albifrons*
AA15034	1123	Sharpe's Starling	*Cinnyricinclus sharpii*
AA15035	705	Mountain Greenbul	*Andropadus nigriceps*
AA15036	1203	Grosbeak Weaver	*Amblyospiza albifrons*
AA15037	705	Mountain Greenbul	*Andropadus nigriceps*
AA15038	705	Mountain Greenbul	*Andropadus nigriceps*
AA15039	705	Mountain Greenbul	*Andropadus nigriceps*
AA15040	705	Mountain Greenbul	*Andropadus nigriceps*
AA15041	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15042	1055	Doherty's Bush-shrike	*Malaconotus dohertyi*
AA15043	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15044	1203	Grosbeak Weaver	*Amblyospiza albifrons*

AA15045	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15046	933	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
AA15047	769	Cape Robin-Chat	*Cossypha caffra iolaema*
AA15048	933	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
AA15049	933	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
AA15050	729	Common Bulbul	*Pycnonotus barbatus*
AA15051	1043	Common Fiscal	*Lanius collaris humeralis*
AA15052	1205	Baglafetch Weaver	*Ploceus baglafecht*
AA15053	1043	Common Fiscal	*Lanius collaris humeralis*
AA15054	729	Common Bulbul	*Pycnonotus barbatus*
AA15055	729	Common Bulbul	*Pycnonotus barbatus*
AA15056	729	Common Bulbul	*Pycnonotus barbatus*
AA15057	729	Common Bulbul	*Pycnonotus barbatus*
AB2301	816	Olive Thrush	*Turdus olivaceus*
AB2302	1004	Tropical Boubou	*Lanirius aethiopicus*
AB2303	816	Olive Thrush	*Turdus olivaceus*
AB2304	816	Olive Thrush	*Turdus olivaceus*
AB2305	816	Olive Thrush	*Turdus olivaceus*
AB2306	1004	Tropical Boubou	*Lanirius aethiopicus*
AB2307	816	Olive Thrush	*Turdus olivaceus*
AB5802	358	Blue-spotted Wood Dove	*Turtur afer*
BB5801	459	Speckled Mousebird	*Colius striatus*
BB5803	459	Speckled Mousebird	*Colius striatus*
BB5804	459	Speckled Mousebird	*Colius striatus*
K45001	1343	Streaky Seedeater	*Serinus s. striolatus*
K45002	1343	Streaky Seedeater	*Serinus s. striolatus*
K45003	898	Hunter's Cisticola	*Cisticola hunteri*
K45004	892	Mountain Yellow Warbler	*Chloropeta similis*
K45005	898	Hunter's Cisticola	*Cisticola hunteri*
K45006	898	Hunter's Cisticola	*Cisticola hunteri*
K54044	1343	Streaky Seedeater	*Serinus s. striolatus*
K54045	884	Cinnamon Bracken Warbler	*Bradypterus carpalis*
K58001	1020	Black-throated Wattle-eye	*Platysteria p. peltata*
K58002	756	White Starred Robin	*Pogonocichla stellata*
K58003	1143	Olive Sunbird	*Nectarinia olivacea*
K58004	756	White Starred Robin	*Pogonocichla stellata*
K58005	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
K58006	1143	Olive Sunbird	*Nectarinia olivacea*
K58007	737	African Hill Babbler	*Pseudoalcippe a. abyssinica*
K58008	756	White Starred Robin	*Pogonocichla stellata*
K58009	737	African Hill Babbler	*Pseudoalcippe a. abyssinica*
K58010	1343	Streaky seedeater	*Serinus s. striolatus*
K58011	1343	Streaky Seedeater	*Serinus s. striolatus*
K58012	1343	Streaky Seedeater	*Serinus s. striolatus*
K58013	1343	Streaky Seedeater	*Serinus s. striolatus*
K58014	1343	Streaky Seedeater	*Serinus s. striolatus*
K58015	563	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*
K58016	756	White Starred Robin	*Pogonocichla stellata*
K58018	1269	Grey-headed Negrofinch	*Nigrita canicapilla schistacea*
K58019	1269	Grey-headed Negrofinch	*Nigrita canicapilla schistacea*

K58020	756	White-starred Robin	*Pogonocichla stellata*
K58021	756	White starred Robin	*Pogonocichla stellata*
K58022	1143	Olive Sunbird	*Nectarinia olivacea*
K58023	737	African Hill Babbler	*Pseudoalcippe a. abyssinica*
K58024	756	White Starred Robin	*Pogonocichla stellata*
K58025	1279	Abbyssinian Crimsonwing	*Cryptospiza salvadorii kilimensis*
K58026	1180	Golden-winged Sunbird	*Nectarinia reichenowi*
K58027	1146	Green-headed Sunbird	*Nectarinia verticalis viridisplendens*
K58028	884	Cinnamon Bracken Warbler	*Bradypterus carpalis*
K58029	1258	Yellow Bishop	*Euplectes capensis crassirostris*
K58030	1343	Streaky Seedeater	*Serinus s. striolatus*
K58031	1343	Streaky Seedeater	*Serinus s. striolatus*
K58032	1343	Streaky Seedeater	*Serinus s. striolatus*
K58033	1343	Streaky Seedeater	*Serinus s. striolatus*
K58034	1343	Streaky Seedeater	*Serinus s. striolatus*
K58035	1343	Streaky Seedeater	*Serinus s. striolatus*
K58036	1333	African Citril	*Serinus citrinelloides*
K58037	1179	Bronze Sunbird	*Nectarinia k. kilimensis*
K58038	1343	Streaky Seedeater	*Serinus s. striolatus*
K58039	1258	Yellow Bishop	*Euplectes capensis crassirostris*
K58040	563	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*
K58041	1343	Streaky Seedeater	*Serinus s. striolatus*
K58042	898	Hunter's Cisticola	*Cisticola hunteri*
K58043	756	White-starred Robin	*Pogonocichla stellata*
K58046	1343	Streaky Seedeater	*Serinus s. striolatus*
K58047	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
K58048	756	White-starred Robin	*Pogonocichla stellata*
K58049	892	Mountain Yellow Warbler	*Chloropeta similis*
K58050	756	White-starred Robin	*Pogonocichla stellata*
K58051	1343	Streaky Seedeater	*Serinus s. striolatus*
K58052	1343	Streaky Seedeater	*Serinus s. striolatus*
K58053	1343	Streaky Seedeater	*Serinus s. striolatus*
K58054	1343	Streaky Seedeater	*Serinus s. striolatus*
K58055	1020	Black-throated Wattle-eye	*Platysteria p. peltata*
K58056	1343	Streaky Seedeater	*Serinus s. striolatus*
K58057	1343	Streaky Seedeater	*Serinus s. striolatus*
K58058	1343	Streaky Seedeater	*Serinus s. striolatus*
K58059	1343	Streaky Seedeater	*Serinus s. striolatus*
K58060	756	White-starred Robin	*Pogonocichla stellata*
K58061	1343	Streaky Seedeater	*Serinus s. striolatus*
K58062	884	Cinnamon Bracken Warbler	*Bradypterus carpalis*
K58063	1343	Streaky Seedeater	*Serinus s. striolatus*
K58064	1343	Streaky Seedeater	*Serinus s. striolatus*
K58065	1143	Olive Sunbird	*Nectarinia olivacea*
K58066	892	Mountain Yellow Warbler	*Chloropeta similis*
K58067	1333	African Citril	*Serinus citrinelloides*
K58068	1343	Streaky Seedeater	*Serinus s. striolatus*
K58069	1333	African Citril	*Serinus citrinelloides*
K58070	1333	African Citril	*Serinus citrinelloides*
K58071	1343	Streaky Seedeater	*Serinus s. striolatus*

K58072	1343	Streaky Seedeater	*Serinus s. striolatus*
K58073	1343	Streaky Seedeater	*Serinus s. striolatus*
K58074	737	African Hill Babbler	*Pseudoalcippe a. abyssinica*
K58075	1143	Olive Sunbird	*Nectarinia olivacea*
K58076	892	Mountain Yellow Warbler	*Chloropeta similis*
K58077	1333	African Citril	*Serinus citrinelloides*
K58078	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
K58079	1343	Streaky Seedeater	*Serinus s. striolatus*
K58080	1343	Streaky Seedeater	*Serinus s. striolatus*
K58081	1180	Golden-winged Sunbird	*Nectarinia reichenowi*
K58082	756	White-starred Robin	*Pogonocichla stellata*
K58083	756	White-starred Robin	*Pogonocichla stellata*
K58085	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
K58086	961	Black-throated Wattle-eye	*Platysteria p. peltata*
K58087	737	African Hill Babbler	*Pseudoalcippe a. abyssinica*
K58088	898	Hunter's Cisticola	*Cisticola hunteri*
K58089	756	White-starred Robin	*Pogonocichla stellata*
K58090	898	Hunter's Cisticola	*Cisticola hunteri*
K58091	898	Hunter's Cisticola	*Cisticola hunteri*
K58092	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
K58093	1343	Streaky Seedeater	*Serinus s. striolatus*
K58094	1333	African Citril	*Serinus citrinelloides*
K58095	1343	Streaky Seedeater	*Serinus s. striolatus*
K58096	1343	Streaky Seedeater	*Serinus s. striolatus*
K58097	1343	Streaky Seedeater	*Serinus s. striolatus*
K58098	1180	Golden-winged Sunbird	*Nectarinia reichenowi*
K58099	756	White-starred Robin	*Pogonocichla stellata*
K58100	1343	Streaky Seedeater	*Serinus s. striolatus*
RAA15001	705	Mountain Greenbul	*Andropadus nigriceps*
RAA15002	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
RAA15014	702	Yellow-whiskered Greenbul	*Andropadus l. latirostris*
RK58005	1177	Tacazze Sunbird	*Nectarinia tacazze jacksoni*
RK58049	892	Mountain Yellow Warbler	*Chloropeta similis*
RK58051	1343	Streaky Seedeater	*Serinus s. striolatus*
RT49207	970	White-tailed Crested Flycatcher	*Trochocercus albonotatus*
RT49208	950	Black-collared Apalis	*Apalis p. pulchra*
RT49226	1305	Black-headed Waxbill	*Estrilda atricapilla graueri*
RT49235	982	Montane White-eye	*Zosterops poliogaster*
RT49245	1132	Montane White-eye	*Zosterops poliogaster*
RT49247	1132	Montane White-eye	*Zosterops poliogaster*
T48211	1152	Variable Sunbird	*Nectarinia venusta*
T49201	950	Black-collared Apalis	*Apalis p. pulchra*
T49202	950	Black-collared Apalis	*Apalis p. pulchra*
T49203	876	Brown Woodland Warbler	*Phylloscopus trochilus*
T49204	1279	Abbssianian Crimsonwing	*Cryptospiza salvadorii kilimensis*
T49205	950	Black-collared Apalis	*Apalis p. pulchra*
T49206	1159	Northern Double-collared Sunbird	*Nectarinia preussi kikuyuensis*
T49207	970	White-tailed Crested Flycatcher	*Trochocercus albonotatus*
T49208	950	Black-collared Apalis	*Apalis p. pulchra*
T49209	1132	Montane White-eye	*Zosterops poliogaster*

T49212	1311	Purple Grenadier	*Uraeginthus ianthinogaster*
T49213	1132	Montane White-eye	*Zosterops poliogaster*
T49214	1132	Montane White-eye	*Zosterops poliogaster*
T49215	1161	Eastern Double-Collored sunbird	*Nectarinia mediocris*
T49216	950	Black-collared Apalis	*Apalis p. pulchra*
T49217	876	Brown Woodland Warbler	*Phylloscopus trochilus*
T49218	1299	Yellow-bellied Waxbill	*Estrilda quartinia kilimensis*
T49219	950	Black-collared Apalis	*Apalis p. pulchra*
T49220	950	Black-collared Apalis	*Apalis p. pulchra*
T49221	936	African Dusky Flycatcher	*Muscicapa adusta interposita*
T49222	1161	Eastern Double-Collored sunbird	*Nectarinia mediocris*
T49223	945	Grey Apalis	*Apalis c. cinerea*
T49225	1132	Montane White-eye	*Zosterops poliogaster*
T49226	1305	Black-headed Waxbill	*Estrilda atricapilla graueri*
T49227	1161	Eastern Double-Collored sunbird	*Nectarinia mediocris*
T49228	1161	Eastern Double-collared sunbird	*Nectarinia mediocris*
T49229	950	Black-collared Apalis	*Apalis p. pulchra*
T49230	1161	Eastern Double-collared-Sunbird	*Nectarinia mediocris*
T49231	950	Black-collared Apalis	*Apalis p. pulchra*
T49232	1303	Common Waxbill	*Estrilda astrild*
T49233	982	Montane White-eye	*Zosterops poliogaster*
T49234	560	Moustached Green Tinkerbird	*Pogoniulus leucomystax*
T49235	982	Montane White-eye	*Zosterops poliogaster*
T49236	1332	Yellow-crowned Canary	*Serinus canicollis flavivertex*
T49237	831	African Dusky Flycatcher	*Muscicapa adusta interposita*
T49238	560	Moustached Green Tinkerbird	*Pogoniulus leucomystax*
T49239	1143	Olive Sunbird	*Nectarinia olivacea*
T49240	1143	Olive Sunbird	*Nectarinia olivacea*
T49241	1161	Eastern Double-collared-Sunbird	*Nectarinia mediocris*
T49242	1161	Eastern Double-collared-Sunbird	*Nectarinia mediocris*
T49244	950	Black-collared Apalis	*Apalis p. pulchra*
T49245	1132	Montane White-eye	*Zosterops poliogaster*
T49246	950	Black-collared Apalis	*Apalis p. pulchra*
T49247	1132	Montane White-eye	*Zosterops poliogaster*
T49248	945	Grey Apalis	*Apalis c. cinerea*
T49249	945	Grey Apalis	*Apalis c. cinerea*
T49250	548	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*
T49251	1161	Eastern Double-collared-Sunbird	*Nectarinia mediocris*
T49252	551	Moustached Green Tinkerbird	*Pogoniulus leucomystax*
T49253	1161	Eastern Double-collared-Sunbird	*Nectarinia mediocris*
T49254	1332	Yellow-crowned Canary	*Serinus canicollis flavivertex*
T49343	560	Moustached Green Tinkerbird	*Pogoniulus leucomystax*
T49510	1132	Montane White-eye	*Zosterops poliogaster*

Appendix 4: Analysis of Variance for Sampled Birds Species

Analysis of variance for African Citril Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.003	0.03	0.00	0.946
Error	10	6.962	0.696		
Total	11	6.965			

Analysis of variance for African Hill Babbler Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.006	0.006	0.04	0.844
Error	8	1.215	0.152		
Total	9	1.221			

Analysis of variance for Baglafecht Weaver Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.003	0.003	0.02	0.895
Error	6	0.894	0.149		
Total	7	0.897			

Analysis of variance for Black Collared Apalis Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.000	0.000	0.00	0.983
Error	22	19.661	0.894		
Total	23	19.661			

Analysis of variance for Cape Robin Chat Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.00	0.00	0.00	1.000
Error	14	26.10	1.86		
Total	15	26.10			

Analysis of variance for Common Bulbul Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.000	0.000	0.00	0.979
Error	6	2.402	0.400		
Total	7	2.402			

Analysis of variance for Eastern Double-Collared Sunbird Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.067	0.067	0.27	0.612
Error	16	4.028	0.252		
Total	17	4.095			

Analysis of variance for Grosbeak Weaver Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.020	0.020	0.07	0.804
Error	6	1.780	0.297		
Total	7	1.800			

Analysis of variance for Hunters Cisticola Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.000	0.000	0.00	0.983
Error	12	172.3	14.4		
Total	13	172.3			

Analysis of variance for Montane White-eye Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.006	0.006	0.01	0.918
Error	14	7.207	0.515		
Total	15	7.212			

Analysis of variance for Mountain Greenbul Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.037	0.037	0.09	0.770
Error	28	11.837	0.423		
Total	29	11.873			

Analysis of variance for Mountain Yellow Warbler Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.13	0.13	0.10	0.757
Error	6	7.17	1.20		
Total	7	7.30			

Analysis of variance for Moustached Green Tinkerbird Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.0378	0.0378	0.49	0.512
Error	6	0.4669	0.0778		
Total	7	0.5047			

Analysis of variance for Olive Sunbird Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.079	0.079	0.13	0.729
Error	12	7.489	0.624		
Total	13	7.567			

Analysis of variance for Olive Thrush Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.01	0.01	0.01	0.936
Error	8	14.19	1.77		
Total	9	14.21			

Analysis of variance for Streaky Seedeater Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.034	0.034	0.03	0.854
Error	78	77.776	0.997		
Total	79	77.810			

Analysis of variance for Tacazze Sunbird Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.002	0.002	0.00	0.959
Error	8	6.479	0.810		
Total	9	6.481			

Analysis of variance for White Starred Robin Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.01	0.01	0.00	0.971
Error	26	208.21	8.01		
Total	27	208.23			

Analysis of variance for White-eyed Slaty Flycatcher Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.00	0.00	0.00	0.990
Error	8	11.12	1.39		
Total	9	11.13			

Analysis of variance for Yellow Whiskered Greenbul Right and Left Tarsus

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ration	P Value
Factor	1	0.23	0.23	0.15	0.705
Error	16	25.20	1.57		
Total	17	25.43			