INFLUENCE OF VEGETATION TYPE AND STRUCTURE ON FOREST BIRD COMMUNITY COMPOSITION AT NANYUKI FOREST BLOCK, WESTERN MT. KENYA

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DECLARATION

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To my wife Eunice Wairimu and daughter Wanjiku Njuki.

ABSTRACT

This study investigated the influence of vegetation cover type and structure on composition and abundance of avian foraging and forest-dependence guilds at Nanyuki Forest Block, western Mt. Kenya. The study was conducted within and around Nanyuki Forest Block of the larger Mt. Kenya Forest in Central Kenya Using point counts, bird communities were assessed in natural forest, plantation forest and farmlands in a forest-agricultural landscape of the western Mt. Kenya ecosystem. Compared to farmlands and plantation forest, natural forest had the highest avian species richness as well as relative abundance of all except one avian foraging and one forest-dependence guild: granivores and non-forest species. Bird relative abundance and species richness related positively with vegetation structural diversity. Due to low structural diversity, plantation forest had the lowest species richness and relative abundance of all avian guilds, while farmlands only had high abundance of non-forest and granivorous species, avian guilds that often occur in open habitats or on forest edges. Conversely, specialist forest-dependent species mainly occurred in the structurally complex natural forest, and may prove especially vulnerable to forest loss. This underscores the importance of natural forests and the risk posed by replacing these with plantation forests in the conservation of forest biodiversity. Clearance of natural forest for establishment of plantation forest should be avoided since this leads to loss of forest specialized species and loss of species diversity and richness of birds, and possibly other taxa. At the same time farmers should be encouraged to plant indigenous tree species in the farms to attract ecological services provided by birds e.g. pollination, pest control and seed dispersal.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Forests are important ecosystems because of their immense contribution to national economies and the livelihoods of local communities. Globally, tropical rainforests are declining at an alarming rate due to human-induced habitat loss (Myers, 1992). Anthropogenic habitat modification in the tropics has generated intense concerns because these regions suffer the highest rates of forest loss, fragmentation, and degradation (FAO, 2010) with the decline of global forest cover being a major threat to biodiversity (Sala, 2000) and ecosystem services (Mulwa, Katrin & Matthias, 2012).

In East Africa, expansion of crop and livestock farming has changed vegetation cover from natural vegetation forms to ever-expanding agro-ecosystems. This trend of forest conversion is likely to continue given the needs of an ever rapidly expanding human population and economies of many tropical countries (Kalya, Amina & Senarathge, 2014). Therefore, with declining natural habitats due to intermittent human pressure and the fact that only a small percentage of land in East Africa is protected by parks (Norton-Griffiths & Said, 2010), biodiversity conservation in the region must be integrated into agricultural landscapes (Smith, 2015). Yet, there is a need of information on the suitability of human-modified habitats in sustaining biodiversity. Such information is important in understanding roles and effects of human-modified landscapes that serve dual purposes of maintaining biodiversity and sustaining livelihoods of local communities (Dendi, Satoru, Tadashi & Kazuhiko, 2013). It is particularly important to determine under which conditions and to what extent agro-ecosystems can compensate for the destruction and fragmentation of natural habitats (Laube, Breitbach, & Gaese, 2008). This information could form the scientific basis for managing such human-modified landscapes for biodiversity conservation, especially species that provide ecosystem services such as seed dispersal, plant pollination and pest control. With over 1089 bird species, Kenya has one of the richest avifauna in Africa (Bennun & Njoroge, 1999). Seven species, namely William's Lark (*Mirafra Williamsi)*, Sharpe's Long claw (*Macronyx sharpei*), Hindi's Babbler (*Turdoides hindei),* Taita Thrush (*Turduss olivaceus helleri*), Taita Apalis (*Apalis thoracica fuscigularis*), Tana River Cisticola (*Cisticola restrictus*) and Clarke's Weaver (*Ploceus golandi*)) are endemic to Kenya. Out of the seven endemic species, four are forest dependent species.

Kenya's natural highland forests are recognized for their importance as sites of high biodiversity in terms of both fauna and flora. For instance, Mt. Kenya Forest is one of the 62 Kenyan Important Bird and Biodiversity Areas (IBAs) recognized under Birdlife International as a priority sites for conservation (Bennun & Njoroge, 1999). The forest at Mt. Kenya has a rich montane bird fauna (BirdLife International, 2015). This forest is also one of the largest and commercially important forest areas in Kenya and is considered to be among the highest priority forests for national conservation (Wass, 1995). However, like many other forests in the country, Mt. Kenya Forest is facing enormous pressure from anthropogenic activities leading to changes in vegetation structure and vegetation cover. Consequently, many sections of the forest have been converted to open woodlands, farmlands and plantation forests.

1.2 Significance of the study

Although a few studies exploring various aspects of biodiversity have been conducted at Mt Kenya (Musila, *et al.,* 2009; Ndegwa, 2014), little is known of the impacts of human-induced changes on vegetation structure and cover on birds. Yet detailed knowledge of how birds use such a human-modified landscape is needed to develop effective conservation strategies. Additionally, it is important to understand anthropogenic impacts on the occurrence of avian functional groups because functional groups strongly determine ecosystem functioning (Mulwa *et al.,* 2012). Birds play pivotal ecological roles both in forest and farmland ecosystems, notably pollination, seed dispersal and pest control (Sekercioglu, 2006; Whelan, Wenny, & Marquis, 2008; Mulwa *et al.,* 2012), this makes birds good indicators of ecosystem health.

1.3 Problem Statement

Mount Kenya forest is facing enormous pressure from anthropogenic activities (encroachment, clear felling and selective logging) which have led to substantial loss of forest cover leading to landscapes dominated by farmlands, and settlement areas. Additionally, some of the natural forests within the Mt. Kenya ecosystem have been converted to landscapes dominated by human use mostly land intensively used for agriculture and plantation forests. It's important we understand the influence of forest cover loss on forest on birds. Understanding the influence of forest cover loss on abundance of functional groups of birds at a landscape level is useful in management planning from a conservation and ecosystem-service perspective. This information may have implications on how farmlands and plantation forests can be managed for the benefit of retaining forest birds. However, little is known regarding the suitability of farmlands and plantation forests for maintaining forest birds.

1.4 General objective

The goal of this study was to assess the overall avian community composition in Nanyuki forest block of Mt Kenya Forest and investigate the influence of vegetation cover type and structure on composition of avian feeding and forest-dependence guilds in that area.

1.5 Specific objectives

1. To assess overall avian species diversity and abundance at Nanyuki forest block, western Mount Kenya
2. To determine influence of vegetation cover type on overall bird species richness and abundance of avian foraging and forest dependence guilds.
3. To determine influence of vegetation structure on birds species richness and abundance of avian foraging and forest dependence guilds.

1.6 Research hypothesis

Objective 1

- Overall avian species richness and abundance does not significantly differ within Nanyuki forest block, western mount Kenya

Objective 2

- The abundance of avian forest dependence and foraging guilds in the natural forest does not significantly differ from those in the farmlands and plantation forest
- Bird species richness in the natural forest does not significantly differ from that in the farmlands and plantation forest

Objective 3

- The abundance of avian forest dependence and feeding guilds does not significantly differ with vegetation vertical heterogeneity
- The abundance of avian forest dependence and feeding guilds does not significantly differ with density of woody plants.
- Bird species richness does not significantly differ with density of woody plants.
- Bird species richness does not significantly differ with vegetation vertical heterogeneity.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effects of forest loss on birds

Global forest destruction has increased dramatically in the last few decades (Farwing, Sajita & Böhning, 2008). This destruction is more profound in the tropics where most natural forests have been converted to farmlands and plantation forests to meet the ever growing demand for resources (FAO, 2012). According to Kalya *et al*. (2014), most of the tropical forests, which contain a large proportion of the world's biological diversity, are still being cleared for agricultural purposes and for the timber industry. Rural areas, with high human population density, are particularly prone to forest loss (Wright, 2005).

Conversion of natural forests to plantation forests and farmlands negatively affects the rich biodiversity associated with forest ecosystems (Lupatini, Jacques & Antoniolli, 2012; Kalya *et al.*, 2014), and this is largely because most plantations and farmlands have exotic tree species which greatly differ with indigenous forests in composition and structure, leading to different ecological processes and functional outcomes (Davis, Jacob & Dumroese, 2012; Kalya *et al*., 2014). Consequently, the loss of habitats used by wildlife for shelter and as breeding and feeding grounds has become a major problem (Azman *et al.*, 2011). Habitat loss has serious deleterious effects on wildlife and in some cases has driven some species to extinction (Myers, Mittermeier, Fonseca & Kent, 2000).

In natural forests, deforestation causes changes in animal feeding guilds because of alterations in the structure of the food web. Secondly, deforestation leads to reduction in diversity of fruit trees (Harris & Pimm, 2004). This decrease produces changes in the distribution of feeding guilds (Gray, Baldauf, Mayhew & Hill, 2007), with forest-dependent being adversely affected compared to forest generalists and edge species (Sekercioglu, 2002).

In general, habitat loss, especially the conversion of tropical forests into farmlands, settlements and urban development, is the main driver of the biodiversity loss (Donald, 2004; Foley, Asner, Barfod, & Bonan, 2005). Natural forests are also lost when they are replaced with monocultures of plantation forests, which result in the simplification of vegetation structure and composition (Sekercioglu, 2002; Kalya *et al.,* 2014). Plantation forests have fewer resources such as roosting, sheltering and nesting sites for birds and other fauna and, as a rule, have lower species richness and diversity (Zurita, Rey, Varela & Bellocq, 2006; Kalya *et al*., 2014). Only species that are capable of using a wide range of habitats have the capability to persist in the human-altered portions of landscape (Andren, 1994). Indeed, many studies have demonstrated higher bird species richness and diversity in native forests compared to exotic monocultures such as eucalyptus and conifer plantations (Sekercioglu, 2002; Barlow *et al.*, 2007).

Studies of avian feeding guilds in different habitats resulting from land conversion have not been conducted (Gray *et al.,* 2007; Azman *et al*., 2011). Such studies are crucial for understanding the complexity of ecosystem structure and for providing updated information on each type of habitat in the ecosystem (Azman *et al.*, 2011).

2.2 Forest as a habitat for birds

According to Unite Nation Environmental Program (2011) and Birdlife International (2013), world's forests play an important role in maintaining fundamental ecological processes, such as water regulation, and carbon storage as well, as providing livelihoods and supporting economic growth. Forests are among the most diverse and complex ecosystems in the world, providing a habitat for a multitude of flora and fauna (Farzam, 2015). In fact forests are home to about 80% of the world's terrestrial biodiversity, including majority of the bird fauna (Birdlife International, 2012; Ozanne, Anhuf, Boulter & Keller, 2003). Birds are found across all major habitat types but forests are the most important habitat for threatened birds, supporting 77% of species, with 27% in shrub land, 16% in inland wetlands and 16% in grasslands (BirdLife International, 2012). In Kenya, native forests support 299 of the country's 1079 species of birds, forests also provide refuge to 50% of Kenya's 71 threatened bird species (Mutuku, 2007).

2.3 Influence of vegetation structure on avian diversity

Complex vegetation structure and floristic composition heterogeneity increase niche diversity which in turn increases avian diversity (Diaz, 2005). The potential of tropical farmlands for sustaining bird biodiversity, including forest birds, can be influenced by habitat structure and the distance from the nearest remnant forest patches (Laube *et al.*, 2008). In studies conducted in Spain to investigate effects of forest type and forest structure on bird communities by Diaz, (2005) and Jankowski, Merkord, and Rios, (2012) demonstrated that vegetation structure in an important determinant of avian diversity. In Philippines Posa and Sodhi (2006) demonstrated the importance of vegetation structure and especially canopy cover (60% or more) for the existence of many forest bird species. This is consistent with recent studies in Kenya by Mulwa *et al*. (2012) and Ndang'ang'a, Githiru and Njoroge (2013) that showed a strong positive influence on overall avian species richness and species diversity by vegetation structure. Changes in vegetation structure, especially vegetation heterogeneity has a significant effect on abundance and richness of tropical forest birds. The increase in the number of vertical strata in a habitat allows coexistence of greater variety of bird species that have adapted to utilize each of the vertical strata (Kalya *et al*., 2014). As a result changes in vegetation structure will easily affect abundance and richness of forest birds (Sekercioglu, 2002). Laube *et al*. (2008) investigated the effect of habitat structure and the distance from the nearest forest on the bird community in farmland near Kakamega Forest, Kenya and found out that high vertical vegetation heterogeneity and a large number of woody plant individuals were related to high species richness of forest and shrub-land birds, whereas open-country birds avoided such areas.

2.4 Ecosystem services provided by birds

In forest landscapes, birds are considered valuable indicators of the health of fragmented forest patches, as their distribution and community composition is usually strongly linked to the quantity (e.g., patch area) or quality (e.g., plant composition) of forest habitat (Moonen & Bàrberi, 2008). Consequently, being highly mobile, birds respond rapidly to fluctuations in habitat conditions and their diversity and distribution vary both in space and cover making them good indictors of ecosystem change over time (White, Ernest, Adler, Hurlbert & Lyons, 2010; Mulwa *et al.,* 2012). Birds play important ecological roles through their foraging behavior such as insect pest control and seed dispersal (Ndang’ang’a, 2013). Up to 90% of all tree species in tropical forests are dispersed by frugivorous animals, including birds (Tabarelli & Peres, 2002). Birds also act as mobile links that transfer energy both within and among ecosystems (Lundberg &

Moberg, 2003; Ndang’ang’a, 2013) that are crucial for maintaining ecosystem function and resilience (Nyström & Folke, 2001; Ndang’ang’a, 2013). The link between ecosystem functioning and biodiversity loss depends on the range of functional roles of species, rather than species identity because different species can perform similar ecological roles (Petchey & Gaston, 2006), better referred to as functional guilds (Ndang’ang’a, 2013; Petersen, Christensen, Farlk, Jensen & Ouambama, 2008). Good examples are frugivores, which perform critical roles in ecosystem function through fruit and seed dispersal and regeneration of tropical forests (Şekercioğlu, 2006; Şekercioğlu, Daily, & Ehrlich, 2004). In Kenya, Githiru, Bennun & Lens, (2002) demonstrated that many tropical rainforest plant species decline in fragments due to loss of dispersers such as large frugivores. Insectivores also perform major ecological role in pest control, a study by Hooks, Panday and Johnson, (2003) revealed that insectivorous birds are very important in pest control which in turn reduces crop damage.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

Mount Kenya is an extinct volcano and the second highest mountain in Africa after Kilimanjaro in Tanzania. The study was conducted within and around Nanyuki Forest Block of the larger Mt. Kenya Forest in Central Kenya. Mount Kenya forest covers a total area of 260,000 ha while Nanyuki Forest Block covers a total of 9,855 ha, but with various eco-types (Table 1). Nanyuki Forest Block Forest lies within Latitude 0^{0}03'N and Longitude 37^{0}09'E and at an altitude of 2309 - 2387 m above sea level.

Table 1: Area of different vegetation types at Nanyuki Forest Block

Cover type	Area
Plantation Forest	1227
Indigenous Forest	365
Bush Land	938
Bamboo Forest	1897
Grass Land	4203
Other	1224
Total	**9854**

Source: KFS 2010

Mount Kenya forest is a World Heritage Site and an Important Bird Area (IBA) recognized by Birdlife International as a priority site for conservation (Bennun & Njoroge, 1999). The area has a typical equatorial mountain climate with very cold nights but fairly hot during daytime (Hedberg, 1969). Mount Kenya is an important water catchment area since the area not only has snow covered peaks but also very high rainfall. The area has two distinct dry and wet seasons, with long rains falling from March to June and short rains from October to December. Average annual precipitation ranges from 2,300 mm on the south eastern slopes to 900 mm in the north (KWS, 1996). Temperatures span a wide range, which varies with the changing altitude and season. Diurnal wind circulation is strong: down slope winds blow from evening through the night to mid-morning, drawing in persistent cloud (Allan, 1991).

The habitat around Mount Kenya is a mix of rainforest, bamboo (*Arundinaria alpina*), open woodland, scrub, Afroalpine moorland as well as the high altitude rock peaks. Mount Kenya has a rich montane avifauna (Birdlife International, 2013). It has a number of globally and regionally threatened species, but it is also home to the Lesser Kestrel, (*Falco naumanni*, a passage migrant on the moorland), the Purple-throated Cuckoo-shrike (*Campephaga quiscalina*) and is one of the few remaining areas in Kenya where the Lammergeier (*Gypaetus barbatus*) can still be seen. The area also supports other rare and threatened bird species such as African green Ibis (*Bostrychia olivacea)* (a rare resident); Lammergeier (*Gypaetus barbatus)*, Ayres's Hawk-Eagle (*Hieraaetus ayresii)* (a rare resident); African crowned Eagle (*Stephanoaetus coronatus)*; African grass Owl (*Tyto capensis)*; Cape Eagle-Owl (*Bubo capensis)*; Purple-Throated Cuckoo-Shrike (*Campephaga quiscalina*) (uncommon in montane forest); and Lond-Tailed Widowbird (*Euplectes progne)* (status uncertain). The rare and little-known race *graueri* of African long-eared Owl (*Asio abyssinicus)* has been recorded from the forest at high altitude. Scarlet-Tufted Malachite Sunbird (*Nectarinia johnstoni)* is particularly common in the moorland. A side from the nearby Nyambeni Hills, Mt. Kenya is also the only Kenyan site for Kenrick's Starling (*Poeoptera kenricki)*. Mammals of conservation interest in Mt. Kenya ecosystem include the four rare or threatened species; African elephant (*Loxodonta africana*), Leopard (*Panthera pardus*), Giant forest hog (*Hylochoerus meinertzhageni*) and Black fronted duiker (*Cephalophus nigrifronshooki*).

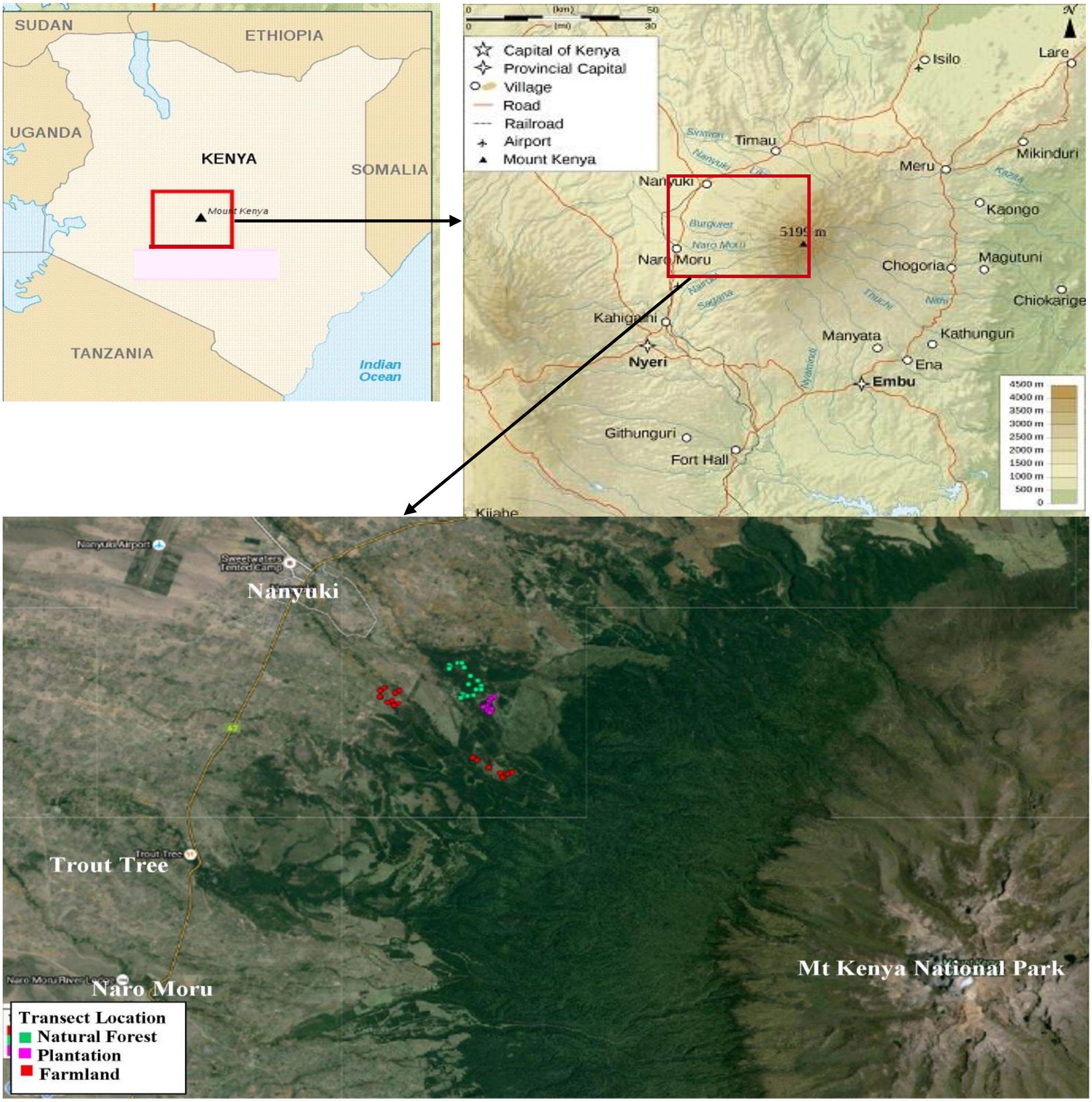

Figure 1. Map of the study area.

3.2 Study design

The study was conducted between December 2013 and December 2014. Data on birds and vegetation structure were collected in three distinct habitat types: representing differences in land-use intensity and vegetation structural heterogeneity: natural forest, plantation forest, and farmland. The farmlands were composed of small-scale subsistence mixed crop farms, with patches of fallow land, isolated trees, bushes and hedgerows. Natural forest sites were undisturbed dense montane forest characterized by canopy tree species such Red Cedar (*Juniperus procera)* growing to over 30 m, Podo (*Podocarpus falcatus)* with heights of up to 45 meters and the olive trees (*Olea africana)*. The dominant shrubs included *Toddalia asiatica, Rhus natalensis* and *Trichocladus ellipticus.* The plantation forest was characterized by Cypress (Family Cupressaceae) plantations.

Using a stratified random sampling design, ten transects were established within each of the three habitat types (natural forest, plantation forest and farmland) in the study area. Five replicate point count plots were established along each transect, each 200 m away from the other. In total there were 50 point count plots per study plot and 150 point count plots in the whole study area. The geographical coordinates of each point count were recorded using a GPS receiver (Garmin eTrex Summit). Sampling was done twice at each point count plot, once in dry season (August and September) and once in wet season (April, March and may).

3.3 Bird community sampling

Birds were counted using the standard point count method as described by Bibby, Burgess, Hill, and Mustoe, (2000). On arriving at the point count station, birds were allowed time to settle for one minute. All birds seen or heard within the 30-m radius plot were then recorded for a period of 10 minutes. The counts were conducted between 0600hrs and 1100hrs on fair weather days. Recorded birds were then classified into functional guilds according to habitat and diet preferences. Classification into habitat-preference guilds was guided by the forest-dependence classification of Bennun *et al*. (1996) where birds were classified as follows. 'Forest Specialist' (FF) species are true forest birds, characteristic of the interior of undisturbed forest. They are rarely seen in non-forest habitats. 'Forest Generalist' (F) species may occur in undisturbed forest but are also regularly found in forest strips, edges and gaps. They are likely to be commoner there and in secondary forest than in the interior of intact forest. Breeding is typically within forest. 'Forest Visitor' (f) species are often recorded in forest, but are not dependent upon it. They are almost always more common in non-forest habitats, where they are mostly likely to breed.

Diet classification for African birds was used to group birds according to their diet (Kissling, Rahbek, Böhning, 2007) where Up to three 'major' and three 'minor' diets taken by every species are listed and this was used as a basis for placing all recorded bird species into seven foraging guilds. Only the 'major' diets were used in placing birds into feeding functional guilds classifications according to Gray *et al*. (2007): carnivores (vertebrates), nectarivores (nectar) frugivores (fruits), granivores (seeds), omnivores, herbivores (vegetable materials, e.g. leaves, shoots, roots, flowers and bulbs). These were further adapted following Ndang'ang'a (2013).

3.4 Vegetation structure sampling

To quantify vegetation structure of within each point count plot, two variables were recorded: number of woody plant species and vertical vegetation heterogeneity. Number of woody plant individuals was the number of tree and shrub individuals above 2 m height within a 0.03 ha (10 m radius) circular plot (James & Warmer, 1982). Vertical vegetation heterogeneity within each plot was obtained by estimating plant cover over the whole study plot to the nearest 5% at heights of 0, 1, 2, 4, 8 and 16 m. Vertical vegetation heterogeneity was then defined as the diversity of vegetation layers using the Shannon–Wiener Diversity Index (Bibby *et al.*, 2000). The distribution of Vertical vegetation heterogeneity of vegetation was calculated as follows;

$H' = -\sum p_i \ln p_i$ Where H' is the index of diversity and p_i is the proportion of total percentage cover for all layers belonging to the i^{th} layer. The higher the H' value the higher the vegetation cover.

3.5 Data treatment and analyses

Prior to analyses, variables were examined for deviations from normality using the Shapiro–Wilks' test. Data were transformed using loge(x + 1) if they were not normally distributed or heteroscedastic. To assess the completeness of point counts, species accumulation curves were plotted for all habitat types. All means are presented ± SE. Bird species diversity was calculated using the Shannon–Wiener Index (Bibby *et al.*, 2000) while bird species richness was expressed as the mean number of species per point count plot (Bibby *et al.*, 2000). Bird abundance was expressed as the mean number of birds per point count plot, for all birds and for the respective foraging and forest dependence guilds. To determine the influence of vegetation cover type on bird community composition, one way analysis of variance (ANOVA) was conducted by comparing the means of bird community composition variables between the three land use types. Avian properties used are: species richness, overall abundance, abundance of respective forest-dependence and foraging guilds. To determine the influence of vegetation structure (vertical heterogeneity and density of tree/shrub species) on bird community composition, simple linear regressions were calculated for the following respective bird community composition variables: species richness, overall abundance, abundance of respective forest-dependence and foraging guilds. These analyses were carried out using Statistical Package for Social Sciences 16.0 (SPSS, USA).

CHAPTER FOUR

4.0 RESULTS

4.1 Overall species richness, diversity abundance and species accumulation

A total of 1902 individual birds belonging to 90 species were recorded across all point plots and seasons. Higher bird abundance per point count was recorded in natural forest as compared to farmlands and plantation forest (Table 2). Natural forest had the highest number of species (77), followed by farmlands with 59 species while plantation forest had 19 avian species recorded (Table 2). All species accumulation graphs reached an asymptote indicating that the sampling was exhaustive and further sampling could not add new species (Figure 2)

Table 2: Bird species richness and Shannon's diversity (H) Index at three land use types sites on the western side of Mt Kenya forest.

Habitat type	**Total Individuals**	**Total Species**	Shannon-Wiener Index (*H*)
Farmlands	314	59	3.54
Natural Forest	539	77	3.88
Plantation forest	145	19	2.41

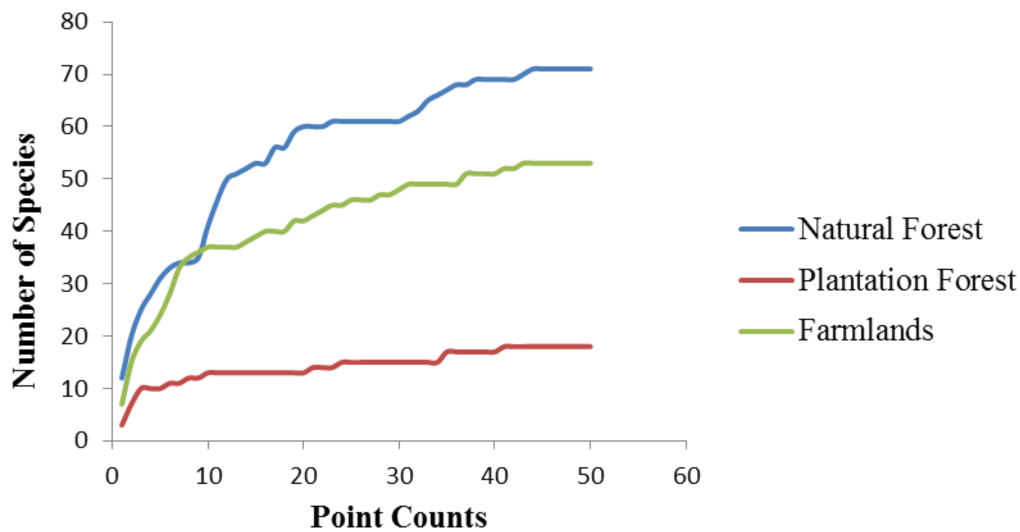

Figure 2: Species accumulation rates for birds at Nanyuki Forest Block, Western Mount Kenya: December 2013 – December 2014

4.2 Influence of vegetation cover type on abundance of avian forest dependence guilds

There was a significant difference in abundance of generalist ($F_{2,\ 147}$ =56.17 P = 0.000), non-forest ($F_{2,\ 147}$ =9.79, P = 0.001), forest specialist ($F_{2,147}$ = 52.45, P = 0.001), and forest visitor species ($F_{2,\ 147}$ = 20.51, P = 0.000) among the three vegetation cover types. Significant differences were further analyzed using post hoc Tukey's HSD test at 95% confidence level (Table 3).

Table 3: Tukey's HDS test significant results

Dependent Variable	Habitat Type	Habitat type	Significance level.
Forest Generalists	Natural Forest	Plantation Forest	0.000
		Farmland	0.000
	Plantation Forest	Natural Forest	0.000
		Farmland	0.003
Non Forest Species	Natural Forest	Farmland	0.001
	Plantation Forest	Farmland	0.000
Forest Specialists	Natural Forest	Plantation Forest	0.000
		Farmland	0.000
Forest Visitors	Natural Forest	Plantation Forest	0.000
	Plantation Forest	Farmland	0.000

The abundance of forest specialist and generalist species was highest in the natural forest, while non-forest species showed highest abundance in the farmlands (Figure 2). Plantation forest had low abundance for all forest-dependence guilds (Figure 2).

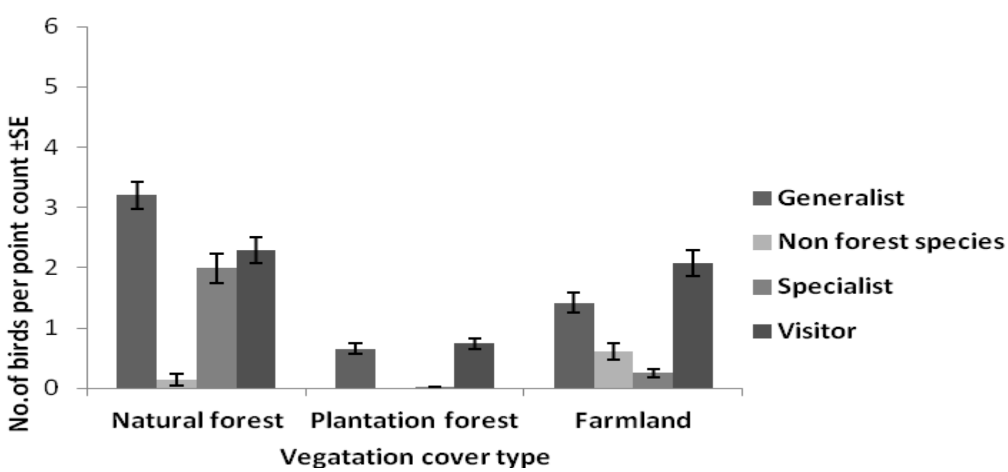

Figure 3: Influence of vegetation cover type on abundance of different avian forest dependent guilds

4.3 Influence of vegetation cover type on abundance of avian feeding guilds

There was a significant difference in abundance of frugivores ($F_{2,147}$ =34.33, P= 0.000), omnivores ($F_{2,147}$ =34.41, P = 0.000), granivores ($F_{2,147}$ =3.73, P = 0.026), insectivores ($F_{2,147}$ = 33.22, P = 0.000) and nectarivores ($F_{2,147}$ =3.22, P = 0.043) between the three vegetation cover types. Significant differences were further analyzed using post hoc Tukey's HSD test at 95% confidence level (table 4).

Table 4: Tukey's HDS test significant results

Feeding Guilds	Habitat type	Habitat Type	Significance level.
Frugivores	Natural Forest	Plantation Forest	0.000
		Farmland	0.000
	Plantation Forest	Farmland	0.019
Insectivore	Natural Forest	Plantation Forest	0.000
		Farmland	0.000
Nectarivore	Natural Forest	Plantation Forest	0.041
Omnivore	Natural Forest	Plantation Forest	0.000
		Farmland	0.000

Natural forest had the highest abundance of frugivores, omnivores, insectivores and nectarivores, whereas farmlands and plantations had the highest abundance of granivores and lowest abundance of all avian foraging guilds, respectively (Figure 3).

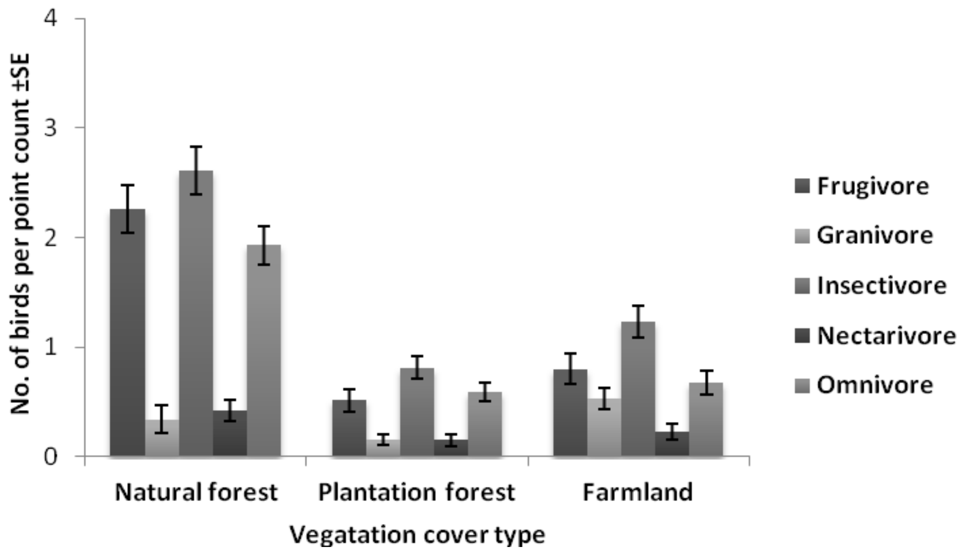

Figure 4: Influence of vegetation cover type on abundance of avian feeding guilds

4.4 Influence of vegetation cover type on bird species richness

There was a significant difference in species richness (number of species per point count plot) between the three vegetation cover types ($F_{2,\ 147} = 35.29$, $P = 0.000$), with natural forest recording the highest species richness and plantation forests the lowest.

4.5 Influence of vegetation vertical heterogeneity on abundance of avian forest dependence guilds

A simple linear regression showed a significant regression equation in forest specialist, generalist and non-forest species. However, there was no significant regression equation in forest visitors and non-forest birds (Table 5).

Table 5: Relationship between vertical vegetation heterogeneity (independent variable) and avian forest dependence guild categories.

Forest Dependence Category	**DF**	***F***	***P* ***	**R^2**
Specialist	1,148	34.36	**0.000**	0.188
Generalist	1,148	10.02	**0.002**	0.063
Forest visitor	1,148	0.06	0.811	0.000
Non forest	1,148	1.75	0.188	0.012

P* values for regressions that were significant are in **bold

4.6 Influence of vertical vegetation heterogeneity on abundance of different avian feeding guilds

Univariate linear regressions analysis showed abundance of frugivores, insectivores, and omnivores significantly related with vertical heterogeneity whereas granivores and nectarivores were not (Table 6)

Table 6: Simple linear regression outputs on the influence of vertical vegetation heterogeneity (independent variable) on the abundance of respective avian foraging guilds

Dependent variable	**DF**	***F* value**	***P* value***	**R^2**
Frugivores abundance	1,148	30.56	**0.000**	0.71
Insectivores abundance	1,148	25.99	**0.000**	0.15
Granivores abundance	1,148	0.03	0.855	0.00
Nectarivore abundance	1,148	1.84	0.177	0.02
Omnivores abundance	1,148	30.17	**0.000**	0.15

* Significant *P* values for regressions are indicated in **bold**

4.7 Influence of vertical vegetation heterogeneity on overall bird species richness and abundance.

There was a significant relationship between vertical vegetation heterogeneity and overall bird species richness ($F_{1,148}$ = 110.27, $P < 0.002$, $R^2 = 0.065$) and overall bird abundance ($F_{1,148}$=11.32, $P = 0.001$, R^2 =0.071).

4.8 Influence of tree density on abundance of avian forest dependence guilds

Based on woody plant density, significant relationships were found between woody plant and abundances of forest specialists ($F_{1,\ 148}$ = 72.19, P = 0.000; R^2= 0.329) and generalists ($F_{1,\ 148}$ = 46.22, p = 0.000, R^2= 0.239). However, relationships of forest visitors ($F_{1,\ 148}$ = 2.96, P = .0.87, R^2 = 0.020) and non-forest species ($F_{1,\ 148}$ = 3.300, P = 0.071, R^2 = 0.022) were not significant (Figure 4)

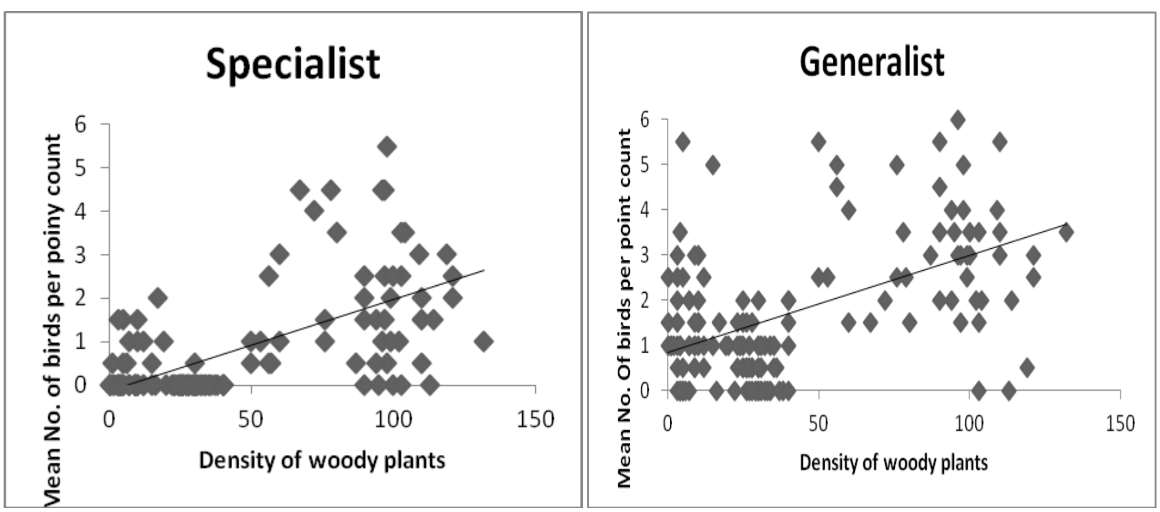

Figure 5: Influence of tree density on abundance of avian forest dependence guilds.

4.9 Influence of tree density on abundance of avian feeding guilds

Significant relationships were found between tree density and abundances of frugivores ($F_{1,148}$= 38.04, P = 0.000, R^2= 0.208), insectivores ($F_{1,148}$ = 41.14, P = 0.000, R^2 = 0.219), omnivores $F_{1,148}$ = 64.332, P = 0.000, R^2 = 0.304) and nectarivores ($F_{1,148}$ = 4.56, P = 0.034, R^2 = 0.03). However the relationship for granivores ($F_{1, 148}$ = 0.124, P = .0.725, R^2 = 0.001) was not significant.

4.10 Influence of tree density on avian species richness

Significant relationship was found between overall bird species richness ($F_{1,148}$ = 62.76, P =.0.000, R^2 = 0.299) and density of trees

CHAPTER FIVE

5.0 DISCUSSIONS

All species accumulation graphs reached an asymptote indicating that the sampling was exhaustive and further sampling could not add new species. Consistent with other studies elsewhere, for example in Argentina (Zurita *et al*., 2006), Uganda (Sekercioglu, 2002), Tanzania (Werema & Howell, 2016) and Kenya (Farwing *et al.*, 2008), plantation forests supported much lower bird abundance, species richness and diversity than natural forests and farmlands. This can be attributed to their simple vegetation structural complexity as demonstrated by their low vertical vegetation heterogeneity and low tree species richness. Thus, compared to natural forests, plantation forests provided far less nesting and foraging resources for birds. The regular distribution of trees in plantation forests and loss of structural components of old-growth forests (such as old living trees, logs and snags) reduce richness and change the composition of bird communities in plantation forests (Mazurek & Zielinski, 2004). However, plantation forests can still be valuable for enhancing indigenous biodiversity by enabling connectivity between two or more natural forest patches (Werema & Howell, 2016). They can also buffer edges between natural forests and non-forest lands, and like other forest types, play a role in reducing global warming by acting as carbon sinks (Hartley, 2002). They also relieve timber demands from natural forests since they produce much more fiber on a much smaller land base (Hartley, 2002). In order to enhance the structural complexity and thus the diversity of birds and other fauna in plantation forests, some of the measures suggested by Hartley (2002) could be taken, including thinning some plantations earlier and heavier than normal, to stimulate or maintain a diverse understory plant community and leaving sections of plantations un-thinned to create a mosaic of relatively open areas and dense thickets.

Like with the plantation forests, bird abundance, species richness and diversity in farmlands was lower compared to natural forests, and can also be explained by the lower vegetation structural heterogeneity (Zurita *et al.*, 2006) in farmlands. Agricultural habitats vary in terms of their vegetation complexity and, therefore, in their ability to harbour forest biodiversity (Naidoo, 2004). In some montane regions of Eastern Africa, complex agricultural landscapes have been observed to have had higher species diversity than natural forests (Naidoo, 2004; Laube *et al.*, 2008). However many studies in the tropics that compare the avifauna between forested and agricultural areas have generally shown that forested areas contain more species than agricultural areas (Thiollay, 1995; Daily, Ehrlich & Sanchez, 2001, Naidoo, 2004; Waltert, Mardiastutu & Mühlenberg, 2004; Seavy, 2009), like in this study. This shows that the farmlands in western Mt Kenya have low vegetation complexity possibly attributable to reduced tree cover. As recommended by Ndang'ang'a *et al.* (2013) the vegetation structural richness of these farmlands that were originally covered by forest may be enhanced through inclusion of non-crop woody habitat elements, e.g. live fences, field margins, and planting of indigenous trees dotted across landscape or on a line along fences (hedge rows).

Vegetation structural complexity, assessed using vertical vegetation heterogeneity and wood plant density, positively influenced the abundance of forest specialist and forest generalist species, as well as the abundance frugivores, insectivores and omnivores. Again this demonstrates that high vegetation structural complexity contributed to the observed high abundance of the two forest-dependence and three feeding guilds in the natural forest.

In fact forest modification and fragmentation is known to result in declines of frugivores and insectivores and an increase in granivores (Sodhi , Liow, & Bazzaz, 2008). The decline or loss of fruits in the farmlands could have resulted in the reduced frugivore abundance. This could in turn lead to disrupted avian-mediated seed dispersal thus preventing colonization and persistence of certain frugivores in this disturbed habitat (Sodhi *et al.*, 2008). Insectivores are adversely affected by pesticides insectivores, as does the lack of leaf litter and low vegetation diversity in agriculture (Sodhi *et al*., 2008), and it is possible that the same factors led to the observed low abundance of insectivores in the farmlands. Similar to Ndang'ang'a *et al.* (2013) the high abundance of granivores in farmlands could be attributed to increasing food (seed) resources associated with farmlands. Substantial amounts of weed seeds grains are held in cultivations and fallow providing food especially for seedeaters, canaries, doves, sparrows and weavers, and farmland are a source of grains/seeds from crops (Ndang'ang'a *et al*., 2013).

The observed decline in bird richness in farmlands was related to species dependency on forested habitats, where forest-dependent species are the most sensitive to the replacement of natural forests (Sekercioglu, 2002; Lindenmayer, Mclntryreb & Fischer, 2003; Petit & Petit, 2003). Most forest-dependent species recorded in my study were found only in the natural forest, whereas bird communities in farmlands were composed mainly of forest-generalist and non-forest species. Low density trees and woody plants in farmland had a strong positive influence on number of birds in farmland due to reduced cover and food resources. Similar findings were recorded in Kakamega forest (Laube *et al.,* 2008). These findings are in line with previous studies that show lower species richness and abundance in plantation forest areas than in natural forests (Sekercioglu, 2002; Waltert, Bobo, Saing, Fermon, Hlenberg, 2005). In a number of studies vegetation structure in plantation forests differed strongly from natural forests explaining differences in bird assemblages (e.g. Sekercioglu, 2002; Sodhi *et al*., 2004; Zurita *et al.*, 2006).

Vegetation cover type also greatly influenced occurrence of avian feeding guilds. Forest specialists (e.g. frugivores and nectrinavores) avoided human-modified cover types, with farmlands being preferred by generalist species (e.g. granivores) and plantation forests being suitable for only a small number of non-forest species. Therefore, levels of forest dependence may be considered a useful tool for predicting species sensitivity to vegetation cover type (Sekercioglu, 2002; Lindenmayer *et al.,* 2003; Petit & Petit, 2003; Zurita *et al.*, 2006; Faria, Laps, Baumgarten, Cetra, 2006; Farwing *et al.,* 2008). In this study, natural forest recorded the highest number of forest specialists because it was heterogeneous and structurally more complex, hence providing more diverse nesting and foraging resources than locally uniform areas (Sekercioglu, 2002). Conversely, it was likely that forest specialists were negatively affected by the more open and less complex farmlands and the highly homogeneous tree distribution in plantation forest with fewer resources for nesting, feeding and protection from predators.

This study also revealed that natural forest had the highest abundance of insectivorous avian species compared to other feeding guilds. Insectivores are very sensitive to habitat modification (Sekercioglu *et al.,* 2002; Tscharntke *et al.,* 2008). In contrast, granivore bird species were more abundant on farmlands than any other feeding guild. This could be attributable to availability of food resources associated with farmlands since substantial amounts of weed-seed grains are held in cultivations and fallow lands that may provide food especially for seed eaters, canaries, doves, sparrows and weavers (Ndang'ang'a, 2013). This is in agreement with a study by Gray *et al.* (2007), which found that richness and abundance of insectivores and granivores tend to decrease and increase, respectively, in response to human-induced disturbance. This study demonstrated that farmlands and plantation forests were highly disturbed with lower vertical stratification and low tree species diversity compared to the natural forest (Rother, 2009), and hence recorded more granivores that utilize such disturbed environments Gray *et al*. (2007).

A large proportion of birds (*ca.* 88%) recorded in this study are forest dependent species including 26 forest generalists, 36 forests visitors and 17 forest specialist species. The rest were non forest species and only 11 species of these were recorded. Increasing vertical vegetation heterogeneity and tree density positively influenced relative abundance of all avian forest dependence and foraging guilds. On the other hand non-forest, forest visitor and granivorous species did not show a clear relationship with vertical vegetation heterogeneity. This corresponds with a study at Kakamega forest by Laube *et al.* (2008), which demonstrated a non-linear relationship between generalist species and vertical vegetation heterogeneity. Indeed, Laube *et al.* (2008) concluded that non-forest birds avoid areas with high vertical heterogeneity and many woody plants species. In general, generalist guilds in this study were not affected by human disturbance because they depend on more open habitats usually associated with human activities. For modified ecosystems such as farmlands to sustain forest biodiversity, including birds, the maintenance of a high density of woody plants and high vertical and horizontal heterogeneity is crucial (Laube *et al*., 2008; Mulwa *et al.,* 2012).

Comparison of forest-dependent birds between natural forest, farmlands, plantation forest demonstrated that forest species were more abundant in the natural forest, which had higher tree density and more diverse vegetation structure. This result conforms to the conclusion of Azman *et al*. (2011) in bird structure in different habitat types, that bird diversity is higher in areas to high vegetation diversity such as primary and secondary forests. According to Pearman (2002), variation in vegetation structure may affect the distribution of bird foraging guilds. Frugivores, insectivores and omnivores increased with vertical vegetation heterogeneity and number of trees natural forest.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Findings obtained from this study indicated that the exotic plantation and farmlands supported less forest bird species richness and diversity than natural forest. Therefore, the conversion of tropical forests to farmlands and plantation forests leads to substantial decline in forest bird and especially of the specialized feeding guilds such as insectivores and frugivores. This underscores the importance of the protection of remnant natural forests for the conservation forest biodiversity.

6.1 Recommendations

From the findings of this study, a lot need to be done to enhance protection the remaining natural forest especially highland forest for the protection of forest birds. My recommendations are as follows:

1. More study should be carried out within the study area on impacts of vegetation cover and structure on non-bird taxa for comparisons purposes.
2. There is need for studies to be carried out on impacts of conversion of natural forests to human-modified covers on ecosystem services provided by birds
3. Clearance of natural forest for establishment of plantation forest should be avoided since this leads to loss of forest specialized species and loss of species diversity and richness of birds, and possibly other taxa.

4. Farmers should be encouraged to plant indigenous tree species in the farms to attract ecological services provided by birds e.g. pollination, pest control and seed dispersal.

REFERENCES

Allan, I. (1991). *Guide to Mt. Kenya and Kilimanjaro.* Nairobi: The Mountain Club of Kenya

Andren, H. (1994). Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review *Oikos 71, 355-366.*

Azman, N. M., Latip, N. S. A., Sah, S. A. M., Akil, M. A. M. M., Shafie, N. J., & Khairuddin, N. L. (2011).. Avian Diversity and Feeding Guilds in a Secondary Forest, an Oil Palm Plantation and a Paddy Field in Riparian Areas of the Kerian River Basin, Perak, Malaysia. *Tropical Life Sciences Research* 22, 2- 45.

Barlow, J., Gardner, T.A., Araujo, I.S., A´ vila-Pires, T.C., Bonaldo, A.B., Costa, J.E., Esposito, M.C., Ferreira, L.V., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite, R.N., Lo-Man Hung, N.F., Malcom, J.R., Martins, M.B., Mestre, L.A.M., Miranda-Santos, R., Nunes-Gutjahr, A.L., Overal, W.L., Peters, S.L., Ribeiro-Junior, M.A., da Silva, M.N.F., da Silva Motta & C., Peres, C.A. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. U.S.A. *Proceedings* of the *National Academy* of *Sciences 104, 18555–18560.*

Bennun, L. A. & Njoroge, P. (1999). Important bird areas of Kenya. *East Africa Natural History Scopus, pp*. 318.

Bennun, L.A., Dranzoa, C. & Pomeroy, D. (1996). The forest birds of Kenya and Uganda. *East Africa Natural History* 85, 23–48

Bibby, C. J, Burgess, N.D, Hill, D.A. Mustoe, S.H. (2000). *Bird census techniques.* London: Academic Press.

BirdLife International. (2012). Threatened birds occur in all habitats, but the majorities are found in forest. Cambridge, UK: Birdlife International.

Birdlife International. (2013). State of the world's birds: indicators for our changing world. Cambridge, UK: Birdlife International.

BirdLife International. (2015). Important Bird Areas factsheet: Mount Kenya, Cambridge, UK: Birdlife International.

Daily, G. C., Ehrlich, P. R. & Sanchez-Azofeifa, G. A. (2001). Countryside biogeography: use of human-dominated habitats by the avifauna of southern Costa Rica. *Ecological Applications*, 11, 1–13.

Davis, A.S., Jacobs, D.F., & Dumroese, R.K. (2012). Challenging a paradigm: Toward integrating indigenous species into tropical plantation forestry. Forest Landscape Restoration. *Springer* 293-298.

Dendi M., Satoru. O., Tadashi, M. & Kazuhiko, T. (2013). Effects of habitat type, vegetation structure, and proximity to forest on birds species richness in a forest-agricultural landscape of West Java, Indonesia. *Impact Factor* 1.37; DOI: 10.1007/s10457-013-9633-x

Dıaz, L. (2005). Influences of forest type and forest structure on bird Communities in oak and pine woodlands in Spain. *Forest Ecology and Management* 223, 54–65.

Donald, P. F. (2004). Biodiversity impacts of some agricultural commodity production systems. *Journal of Conservation Biology* 18, 17–38.

East Africa Natural History Society. (2009). *Check-list of the birds of Kenya* (4th edn). Nairobi: Nature Kenya - East Africa Natural History Society.

Faria, D., Laps, R.R., Baumgarten, J., Cetra, M., (2006). Bat and birds assemblages from forests and shade cocoa plantations in two contrasting landscape in Atlantic forest of southern Bahia. *Journal of Brazil Biodiversity Conservation*. 15, 587–612.

Farwing, N., Sajita, N., Böhning-Gaese, K., (2008). Conservation value of forest plantation for bird communities in western Kenya. *Forest Ecology Management* 255, 3885-3892.

Farzam Tavankar, (2015). Woody species diversity in natural juniperus stands in Northwest of Iran. *Journal of Biodiversity and Environmental Sciences* 6, 268-275

Foley J.A, R, Asner G.P, Barford C, Bonan G, et al. (2005). Global consequences of land use. *Science* 309, 570–574.

Food and Agriculture Organization. (2010). *Global Forest Resources Assessment 2010*, Food and Agriculture Organization of the United Nations, Rome, Italy

Food and Agriculture Organization. (2012). *State of the world's forest 2012*, Food and Agriculture Organization of the United Nations, Rome, Italy

Githiru, M., Bennun, L., Lens, L., (2002). Regeneration patterns among bird-dispersed plants in a fragmented Afrotropical forest, South-East Kenya. *Journal of Tropical Ecology* 18, 143–149

Gray, M.A., Baldauf, S.L., Mayhew, P.J., Hill, J.K. (2007). The response of avian feeding guilds to tropical forest disturbance. *Journal of Conservation Biology* 21, 133–141.

Greenberg, R., Bichier, P., Angon, A.C., Reitsma, R., (1997). Bird populations in shade and sun coffee plantations in central Guatemala. *Journal of Conservation Biology* 11, 448–459.

Harris, GM and Pimm, SL, (2004). Bird species' tolerance of secondary forest habitats and its effects on extinction, *Journal of Conservation Biology* 1607-1616, ISSN 0888-8892.

Hartley, M. (2002). Rationale and methods for conserving biodiversity in plantation forests. *Forest Ecology and Management* 155, 81–95

Hedberg, O. (1969). Evolution and speciation in a tropical high Mountain flora. *Biological Journal of the Linnean Society* 1, 135–148.

Heikkinen, R. K., Luoto, M., Virkkala, R. & Rainio, K. (2004). Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in an agricultural-forest mosaic. *Journal of Applied Ecology*, 41, 824–835.

Hooks, C. R. R., Pandey, R. R. & Johnson, M. W. (2003). Impact of avian and arthropod predation of Lepidopteran caterpillar densities and plant productivity in an ephemeral agro ecosystem. *Ecological Entomology* 28, 522–532.

Hughes, J. B, Daily GC, Ehrlich PR (2002). Conservation of tropical forest birds in countryside habitats. *Journal of Ecology Letter* 121–129.

James, F. C & Wamwer. (1982). Relationships between temperate forest bird communities and vegetation structure. *Ecology*, 63, 159-171

Jankowski, J. E, Merkord, C. L, Rios W.F. (2012). The relationship of tropical bird communities to tree species composition and vegetation structure along an Andean elevation gradient. *Journal of Biogeography* 40, 950-962.

Kalya Subasinghe, Amila, P., Senarathge, R. Weerawardhena, (2014). The impact of forest conversion on bird communities in the northern flank of the Knuckles Moutain Forest Range, Sri Lanka. *Journal of Asia-Pacific Biodivers*ity 367-373

Kenya Forestry Service. (2010). *Nanyuki Forest Station Management plan 2011-2015*. Kenya Forestry Service, Nairobi, Kenya

Kenya Forestry Service. (2015). History of forestry in Kenya. Retrieved March 3, 2015 from http://www.kenyaforestservice.org

Kenya Wildlife Service. (1996). Nomination Forms for Maasai Mara World Heritage Site, Mt. Kenya World Heritage Site and Sibiloi World Heritage Site. Nairobi, Kenya, Kenya Wildlife Service,.

Kissling, W. D, Rahbek C., Böhning-Gaese K. (2007). Food plant diversity as broad-scale determinant of avian frugivore richness. *Royal Society* 274, 799–808.

Laube, I., Breitbach, N. & Bohning, G. K. (2008). Avian diversity in a Kenyan agroecosystem: effects of habitat structure and proximity to forest. *Journal of Ornithology, 149), 181-91*

Lindenmayer, D.B., McIntryreb, S., Fischer, J., (2003). Birds in eucalypt and pine forests: landscape alteration and its implications for research models of faunal habitat use. *Biology Conservation* 110, 45–53.

Lundberg, J. and Moberg, F. (2003). Mobile link organisms and ecosystem function Ecosystems *DOI*: 10.1007/s 10021-002-0150-4

Lupatini, M., Jacques R. J., Antoniolli Z.I. (2012). Land use change and soil type are drivers of fungal and archaeal communities in the Pampa biome. *World Journal Microbiology and Biotechnology* 29, 223-233.

MacArthur, R. H. & MacArthur, J. W. (1961). On bird species diversity. *Ecology* 42, 594– 598.

Mazurek, M. J., Zielinski, W. J., (2004). Individual legacy trees influence vertebrate wildlife diversity in commercial forests. *Jounal of Forest Ecology and Management*. 193, 321–334.

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being: Island Press, Washington, D.C., USA.

Moonen, A.C & Bàrberi, P. (2008). Functional biodiversity: an agroecosystem approach. *Jounal of Agriculture, Ecosystems & Environment* 127, 7–21.

Mulwa, R. K., Katrin, B. & Matthias, S. (2012). High Bird Species Diversity in Structurally Heterogeneous Farmland in Western Kenya. *Biotropica 44, 801–809.*

Musila, W., Githiru M., Kanga M. E, Warui, C., Njoroge P., Gikungu M.,Mbau J., Nyingi D., Malombe I., Kibet S., Nyaga J. (2009). Mt. Kenya Forest Biodiversity Assessment Technical Report. Kenya Forests Working Group, Nairobi.

Mutuku, M.J (2007). The effects of habitat change on the avifauna of Mount Marsabit forest, unpublished Masters of Science. Thesis. University of Nairobi, School of Biological Science.

Myers, N. (1992). The primary source: tropical forests and our future. W. W. Norton & Company, New York.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G.A.B., Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Science* 403, 853–858.

Naidoo, R. (2004). Species richness and community composition of songbirds in atropical forest-agricultural landscape. *Animal Conservation, 7, 93–105*.

Ndang'ang'a, P. K. (2013). The composition and ecological function of birds in the agricultural landscape of Nyandarua, Central Kenya. P.H.D. Dissertation. Kenya: Jomo Kenyatta University of Agriculture and Technology. DOI: 10.13140/2.1.3930.3360

Ndang'ang'a, P. K., Githiru, M., Njoroge, J. B. M. (2013) Vegetation composition and structure influences bird species community assemblage in the highland agricultural landscape of Nyandarua, Kenya. *Ostrich: Journal of African Ornithology,* 84, 171-179.

Ndegwa, S. W. (2014). Bird community response to disturbance in a secondary forest in Eastern Kenya. Masterarbeit. Technische Universität Dresden, Dresden/Tharandt. Internationale Forst- und Holzwirtschaft.

Norton-Griffiths, M., & Said M. (2010). The future for wildlife on Kenya's rangelands: an economic perspective. *Blackwell Publishing Ltd, West* Sussex, UK, Pages 367-392

Nyström, M. & Folke, C. (2001). Spatial resilience of coral reefs. *Ecosystems, 4, 5- 40*

Ozanne, C.H.P., Anhuf, D., Boulter, Keller S.L. (2003). Biodiversity meets the atmosphere: A Global view of forest canopies. *Science* 301, 183-186

Pearman, P. B. (2002). The scale of community structure: Habitat variation and avian guilds in tropical forest understory. *Ecological Monographs 72*, 19–39.

Petchey, O. L, Gaston K. J (2006). Functional diversity: back to basics and looking forward. *Ecological Letters 9, 741−758*

Petersen, B. S., Christensen, K. D., Falk, K., Jensen, F. P. & Ouambama, Z. (2008). Abdim’s Stork Ciconia abdimii exploitation of Senegalese grasshopper Oedaleus senegalensis in south-eastern Niger. *Water birds 31, 159–168*.

Petit, L. J., & Petit, D. R. (2003). Evaluating the importance of human-modified lands for Neotropical bird conservation. *Journal of Conservation Biology 17, 687–694*.

Posa, M.R.C & Sodhi N.S. (2006). Effects of anthropogenic land use on forest birds and butterflies in Subic Bay, Philippines. *Journal of Biology Conservation 129, 256-270.*

Rainer, W. B. (1996), Destruction and Management of Mt. Kenya's Forest. *Journal of the Human Environment 25, 314-317.*

Rother, D.C., Rodrigues, R.R., Pizo, M.A., (2009). Effects of bamboo stand on seed rain and seed limitation in a rainforest. *Forest Ecology Management 257, 885–892.*

Sala, O.E. (2000). Global biodiversity for the year 2000. *Science 287: 1770-1774*

Seavy, N. E. (2009). Bird use of banana plantations adjacent to Kibale national park, Uganda: evaluating the conservation value of a matrix habitat. *Journal of East African Natural History 98*, 211–222.

Sekercioglu, C. H. (2002). Effects of forestry practices on vegetation structure and bird community of Kibale National Park, Uganda. *Journal of Biological Conservation* 107, 229–240.

Sekercioglu, C. H. (2006). Increasing awareness of avian ecological function. *Trends in Ecology and Evolution 21*, 464–471.

Sekercioglu, Ç. H., Daily, G. C. & Ehrlich, P. R. (2004). Ecosystem consequences of bird declines. *Proceedings of the National Academy of Sciences*, *101*(52), 18042–18047.

Smith, C. (2015). Bird communities in sun and shade coffee farms in Kenya. Unpublished Master of Science in Natural Resources. Thesis. Humboldt: Humboldt State University

Sodhi, N.S., Liow, L.H., Bazzaz, F.A., (2004). Avian extinctions from tropical and subtropical forests. *ecosystems.35.112202.130209*

Tabarelli, M., & Peres, C.A. (2002). Abiotic and vertebrate seed dispersal in the Brazilian Atlantic forest: Implications for forest regeneration. *Journal of Biological Conservation*, 106, 165–176.

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M. & Jeltsch, F. (2004). Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *Journal of Biogeography* 31: 79–92.

Thiollay, J. M. (1995). The role of traditional agro forest in the conservation of rain forest bird diversity in Sumatra. *Journal Conservation Biology,* 9: 335–353.

Tian Gao, Marcus Hedblom, Tobias Emilsson & Anders Busse Nielsen (2014). The roles of forest stand structure as biodiversity indicator. *Forest Ecology and Management* 330 (2014) 82–93

Tscharntke, T., Sekercioglu, C. H., Dietsch, T. V., Sodhi, N. S, Hoehn & P. Tylianakis, J.M(2008). Landscape constraints on functional diversity of birds and insects in tropical agroecosystems. *Ecology* 89: 944–951.

United Nation Environment Program. (2011). Emerging perspectives of forest biodiversity. Nairobi, United Nation Environment Program.

Waltert, M., Bobo, S.K., Saing, N.M., Fermon, H.,Mu¨ hlenberg, M., (2005). From forest to farmland: habitat effects on Afrotropical forest bird diversity. *Journal of Agricultural and Biological Science* 15, 1351–1366.

Waltert, M., Mardiastuti, A. & Mühlenberg, M. (2004). Effects of land use on bird species richness in Sulawesi, Indonesia. *Journal Conservation Biology*, 5, 1339–1346.

Wass, P. (1995). Kenya's Indigenous Forest: Status, Management and conservation. IUCN, Nairobi, Kenya.

Werema, C. & Howell, K. (2016). Seasonal variation in diversity and abundance of under storey birds in Bunduki Forest Reserve, Tanzania: evaluating the conservation value of a plantation forest. *Ostrich* 87, 89-93

Whelan, C. J., Wenny, D. G. & Marquis, R. J. (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences*, 1134, 25–60.

White, E. P., Ernest, S. K. M., Adler, P. B., Hurlbert, A. H. & Lyons, S. K. (2010) Integrating spatial and temporal approaches to understanding species richness. *Philosophical Transactions of the Royal Society of London Series B* 365, 3633–

Wright, S. J. (2005). Tropical forests in a changing environment. *Trends in Ecology & Evolution* 20, 553–560.

Zimmerman, D. A., Turner, D. A. & Pearson, D. J. (1996). *Birds of Kenya and Northern Tanzania*. South Africa. Russel Friedman Books, Halfway House.

Zurita, G.A., Rey, N., Varela, D.M., Villagra, M., Bellocq, M.I. (2006). Conversion of the Atlantic forest into native and exotic tree plantations: effects on bird communities from the local and regional perspectives. *Forest Ecology Management* 235, 164–173.

APPENDICES

Appendix 1

Record of bird’s and relative abundance in different cover types indicating their forest dependence guild and foraging guilds within Nanyuki forest Block of Mt. Kenya forest, December 2013-december 2014. Bird names are arranged taxonomically and allocated numbers following EANHS (2009); Foraging guilds are assigned based on major food items described by Kissling *et al*. (2007).

			#Relative abundance				
***EANHS no.**	**Common name**	***Scientific name***	**Farmlands**	**Natural forest**	**Plantation**	**Forest-dependence guild**	**Foraging guild**
51	Black-headed Heron	*Ardea melanocephala*	0.02	0	0	Non forest	Omnivore
62	Hadada Ibis	*Bostrychia hagadesh*	0	0.08	0	visitor	Insectivore
139	Moutain Buzzard	*Buteo oreophilus*	0	0.04	0	Specialist	Carnivore
284	Crowned Plover	*Vanellus coronatus*	0.04	0	0	non forest	Insectivore
354	African Green Pigeon	*Treron calvus*	0	0.32	0	generalist	Frugivore
365	Olive Pigeon	*Columba arquatrix*	0	0.04	0	Specialist	Omnivore
369	Lemon Dove	*Columba larvata*	0	0	0	Specialist	Granivore
370	Red-eyed Dove	*Streptopelia semitorquata*	0.16	0.1	0	visitor	Granivore
373	Ring-necked Dove	*Streptopelia capicola*	0.3	0	0	visitor	Granivore
376	Dusky Turtle Dove	*Streptopelia lugens*	0.02	0.12	0	visitor	Granivore
380	Red-fronted Parrot	*Poicephalus gulielmi*	0.24	1.38	0	Specialist	Frugivore
398	Hartlaub's Turaco	*Turaco hartlaubi*	0.14	0.54	0.02	Specialist	Frugivore

409	Red-chested Cuckoo	*Cuculus solitarius*	0	0.08	0	generalist	Insectivore
409	Red-chested Cuckoo	*Cuculus solitarius*	0.02	0	0	generalist	Insectivore
417	African Emerald Cuckoo	*Chrysococcy cupreus*	0	0.02	0	generalist	Insectivore
419	Klaas's Cuckoo	*Chrysococcy klaas*	0.02	0.12	0	visitor	Insectivore
449	Montane Nightjar	*Caprimulgus poliocephalus*	0	0.02	0.08	generalist	Insectivore
480	Speckled Mousebird	*Colius striatus*	0.38	0.22	0.26	visitor	Frugivore
482	Bar-tailed Trogon	*Apaloderma vittatum*	0	0.32	0	Specialist	Insectivore
514	Cinnamon-chested bee-eater	*Merops oreobates*	0.12	0.14	0	generalist	Insectivore
543	Crowned Hornbill	*Tockus alboterminatus*	0	0.16	0	visitor	Omnivore
549	Silvery-Cheeked Hornbill	*Bycanistes brevis*	0	0.26	0	generalist	Frugivore
565	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	0	0.34	0	generalist	Frugivore
587	Greater Honeyguide	*Indicator indicator*	0.02	0.12	0	visitor	Insectivore
588	Lesser Honeyguide	*Indicator minor*	0	0.06	0	visitor	Insectivore
606	Fine-banded Woodpecker	*Campethera tullbergi*	0	0.08	0	Specialist	Insectivore
610	Cardinal Woodpecker	*Dendropicos fuscescens*	0	0.12	0.04	visitor	Insectivore
672	Black Saw-wing	*Psalidoprocne holomelas*	0.18	0.3	0	visitor	Insectivore
702	Yellow-whiskered Greenbul	*Andropadus latirostris*	0.12	1.66	0	generalist	Omnivore
703	Slender-billed Greenbul	*Andropadus gracilirostris*	0	0.1	0	generalist	Frugivore
705	Mountain Greenbul	*Andropadus nigriceps*	0.02	0.14	0	Specialist	Frugivore
713	Cabanis's Greenbul	*phyllastrephus cabanisi*	0.02	0.1	0	Specialist	Omnivore
729	Common Bulbul	*Pycnonotus barbatus*	0.76	0.72	0.3	visitor	Frugivore
729	Common Fiscal	*Lanius collaris*	0.32	0.04	0	non forest species	Insectivore

737	African Hill Babbler	*Pseudoalcippe abysinica*	0	0.32	0	generalist	Insectivore
738	Black-lored Babbler	*Tortoises sharpei*	0	0.1	0	visitor	Insectivore
746	Rufous Chatterer	*Tortoises rubiginosa*	0.1	0	0	non forest species	Insectivore
751	Mountain Illadopsis	*Illadopsis pyrrhoptera*	0	0.04	0	Specialist	Granivore
756	White-Starred Robin	*Pogonocichla stellata*	0	0.38	0	generalist	Omnivore
769	Cape Robin-Chat	*Cossypha caffra*	0.28	0.12	0.08	visitor	Omnivore
771	Ruppell's Robin-Chat	*Cossypha semirufa*	0.16	0.16	0	generalist	Omnivore
794	Common Stonechat	*Saxicola torquata*	0.16	0	0	non forest species	Insectivore
807	Northern Ant-eater Chat	*Myrmecocichla aethiops*	0.02	0	0	non forest species	Insectivore
816	Olive Thrush	*Torus olivaceus*	0.96	0.7	0.42	generalist	Omnivore
831	African Dusky Flycatcher	*Muscicapa adusta*	0.22	0.18	0.6	generalist	Insectivore
840	White-eyed Slaty Flycatcher	*Melaenornis fischeri*	0.26	0.34	0.2	generalist	Insectivore
843	Southern Black Flycatcher	*Melaenornis pammelaina*	0	0.04	0	Specialist	Frugivore
876	Brown Woodland Warbler	*Phylloscopus umbrovirens*	0	0.1	0	generalist	Insectivore
898	Hunter's Cisticola	*Cisticola hunteri*	0.16	0.1	0.02	generalist	Insectivore
933	Grey-backed Camaroptera	*Camaroptera brachyura*	0.06	0.2	0.02	visitor	Insectivore
936	Yellow-breasted Apalis	*Apalis flavida*	0	0.02	0	visitor	Insectivore
940	Chestnut-throated Apalis	*Apalis porphyrolaema*	0.08	0.18	0	generalist	Insectivore
945	Grey Apalis	*Apalis cinerea*	0.04	0.16	0	Specialist	Insectivore
948	Black-throated Apalis	*Apalis jacksoni*	0	0.14	0	Specialist	Insectivore
950	Black-collared	*Apalis pulchra*	0	0.08	0	generalist	Insectivore

	Apalis						
957	Grey-capped Wabbler	*Eminia lepida*	0.04	0.04	0	visitor	Insectivore
990	White-bellied Tit	*Parus albiventris*	0	0.32	0	visitor	Insectivore
1007	African Paradise Flycatcher	*Tersiphone viridis*	0.2	0.38	0.14	visitor	Insectivore
1013	Chin-spot Batis	*Batis molitor*	0.12	0.1	0	visitor	Insectivore
1020	Black-throated Wattle-eye	*platysteira peltata*	0	0.14	0	generalist	Insectivore
1048	Brown-crowned Tchagra	*Tchagra australis*	0	0	0	visitor	Insectivore
1064	Tropical Boubou	*Laniarius aethiopicus*	0.08	0.26	0.24	visitor	Insectivore
1072	Black-backed Puffback	*Dryoscopus gambensis*	0.02	0.08	0	generalist	Insectivore
1076	Black Cuckoo-Shrike	*Campephaga flava*	0	0.02	0	visitor	Insectivore
1080	Grey Cuckoo-Shrike	*Coracina caesia*	0	0.24	0	Specialist	Insectivore
1087	Black-headed Oriole	*Oriolus larvatus*	0	0.08	0	visitor	Frugivore
1088	Montane Oriole	*Oriolus percivali*	0.04	0.14	0	Specialist	Insectivore
1088	Montane White-eye	*Zosterops poliogaster*	0.26	0.54	0	generalist	Omnivore
1121	Violet-backed Starling	*Cinnyricinclus leucogaster*	0.34	0.14	0.06	visitor	Frugivore
1140	Collared Sunbird	*Hedydipna collaris*	0.1	0.24	0	generalist	Frugivore
1146	Green-headed Sunbird	*Cyanomitra verticalis*	0.06	0.16	0	generalist	Nectarivore
1149	Amethyst Sunbird	*Chalcomitra amethystina*	0.08	0.04	0	visitor	Nectarivore
1152	Variable Sunbird	*Cinnyris venustus+*	0.24	0.16	0.08	visitor	Nectarivore
1161	Eastern Double-collared Sunbird	*Cinnyris mediocris*	0	0.14	0	generalist	Nectarivore

1161	Northern Double-collared Sunbird	*Nectarinia preussi*	0.14	0	0	generalist	Nectarivore
1179	Bronze Sunbird	*Nectarinia kilimensis*	0.22	0.16	0.02	visitor	Nectarivore
1180	Golden-winged Sunbird	*Drepanorhynchus reichenowi*	0	0.18	0	visitor	Nectarivore
1185	Rufous Sparrow	*Passer rufocinctus*	0.04	0	0	non forest species	Insectivore
1203	Grosbeak Weaver	*Ambloyospiza albifrons*	0.2	0	0	visitor	Granivore
1205	Baglafecht Weaver	*Ploceus baglafecht*	0.2	0.08	0	visitor	Insectivore
1210	Spectacled Weaver	*Ploceus ocularis*	0	0	0	visitor	Insectivore
1240	Brown-capped Weaver	*Ploceus insignis*	0	0.08	0	Specialist	Insectivore
1262	Red-collared Widowbird	*Euplectes ardens*	0.1	0	0	non-forest	Granivore
1309	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	0	0.2	0	non forest species	Granivore
1311	Purple Grenadier	*Granatina ianthinogaster*	0.06	0.04	0	non forest species	Granivore
1318	Bronze Mannikin	*Spermestes cucullatus*	0.48	0	0	non forest species	Granivore
1333	African Citril	*serinus citrinelloides*	0.18	0.06	0	visitor	Granivore
1337	Brimstone Canary	*Serinus sulphuratus*	0.04	0	0	visitor	Granivore
1343	Streaky Seedeater	*Serinus striolatus*	0.18	0	0	visitor	Insectivore
1344	Thick-billed Seedeater	*serinus burtoni*	0	0.12	0	Specialist	Granivore
1354	Golden-breasted Bunting	*Emberiza flaviventris*	0	0	0.24	visitor	Omnivore