EFFECTS OF FARMING ACTIVITIES ON BIRD DIVERSITY AND ABUNDANCE IN TRANS-MARA SUB COUNTY KENYA

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DECLARATION

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

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DEDICATION

My special dedication goes to my late father Jason Oyondi for having introduced me to the world of education which has really shaped my life. To My wife Anastasia Ghati, my two children Emmanuel and Blessing for their moral support and to all the people who love to conserve nature for posterity.

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ABBREVIATIONS AND ACRONYMS

RB	-	Resident Breeders
R	-	Resident
M	-	Migrant
GPS	-	Global Positioning System
TSC	-	Timed Species Counts
EACB	-	East African Coastal Biomes
S.E	-	Standard error
ANOVA	-	Analysis of variance

ABSTRACT

Forested habitats are severely threatened in Kenya. Despite their faunal endemism, they have received very little conservation attention. A study on effects of farming activities on bird diversity and abundance was conducted in Trans Mara sub county, kenya from August 2014 to January 2015. Line transect sampling, point counts, time species counts, mist netting and opportunistic observations were used to carry out birds census to determine their abundance and diversity in the cultivated (tea and sugarcane farms) and indigenous forests. Shannon Wiener Diversity index was used to calculate diversity and species richness. Sorenson diversity index was used to determine how the various habitats compared in terms of diversity and abundance. A total of 3792 individuals were observed and recorded in the entire study area. The indigenous forest had the highest density of 6 birds/ha followed by tea farms with 4 birds/ha and sugarcane farms had the least density of 1 bird /ha .140 species of birds were cumulatively recorded in the three habitats. Out of these, 105 species were recorded in the indigenous forests, 64 in tea farms and 49 species in the sugarcane farms. There was a significant difference in bird density in the three habitats (df_1=2, df_2=199, F=7.598, P=0.001). Bird's abundance was highest in the indigenous forest with a mean of 5.72±0.64 birds per hectare, followed by tea farms that had a mean of 3.96±1.23 birds per hectare and lowest abundance was experienced in the sugarcane farms with a mean of 0.91±0.15 birds per hectare and N=119, 46 and 37 respectively. Indigenous forest had the highest diversity of 3.94 while tea farms and sugarcane farms recorded relatively lower diversity of 2.62 and 2.46 respectively. The results of this study demonstrate that human disturbances in natural ecosystems and intensified agricultural systems have adverse effects on birds' diversity and abundance in Trans Mara ecosystem. There is need for frequent bird population monitoring and conservation interventions to ensure their survival in Trans Mara ecosystem.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Species are the elementary units of biological association, and any change in the species diversity may alter to some extent ecosystem functions and services (You *et al*., 2009). Species diversity, species richness and biodiversity are widely used terms (sometimes interchangeably) in ecology and natural resource management.

Species diversity is a function of the number of species present (species richness or number of species) and the evenness with which the individuals are distributed among these species (species evenness, species equitability, or abundance of each species) (Margalef 1958; Lloyd & Ghelardi 1964; Pielou 1966; Spellerberg, 1991). According to (Hamilton, 2005) this definition may be the best one available at the moment. (Hurlbert, 1971) emphasized that the concept of species diversity should be restricted to this extent if it should have any useful meaning.

Ecologists have found species diversity difficult to define and measure and this may in fact reflect the possibility that it is a 'non-concept' (Hurlbert, 1971). In general, there have been two approaches to measuring species diversity, both of which incorporate information on the number of species (species richness) and the relative abundances of individuals within each species (species abundance) (Hamilton, 2005). One method has been to construct mathematical indices broadly known as diversity indices and the other involves comparing observed patterns of species abundance to theoretical species abundance models. Species diversity indices take two aspects of a community into account, namely species richness and evenness or equitability (the distribution of abundance among the species) (Hamilton, 2005). The species richness and composition are important parameters for stability and functioning of an ecosystem, therefore, there is urgent need to protect avian diversity by protecting natural habitat of the area (Luck *et al.*, 2003).

Birds play a significant ecological role in forest ecosystems i.e. pollination, especially of trees with sturdy, brightly coloured flowers (Sutherland, 2000). Frugivorous birds assist in the natural regeneration by dispersing seeds (Holl *et al*. 2000).

Foraging guilds are an important tool for examining changes in species-rich communities because their functional organization can be investigated even if they do not share any species (Terborgh & Robinson, 1986). This is the case when analyzing distribution of birds in various habitats. For example, insectivores of understory or terrestrial microhabitats are rarely resilient to the more severe forms of disturbance (Johns, 1991), and large canopy frugivores, understory insectivores, and forest interior raptors are particularly vulnerable to fragmentation (Johns, 1991; Kattan *et al.,* 1994; Renjifo, 2001; Stratford & Stouffer 1999; Newmark, 2006). Many rainforest understory insectivores are specialists in their foraging techniques, use specific habitats and micro-habitats, are non-migratory and have large territories (Terborgh *et al.,* 1990; Stouffer and Bieregaard, 1995b). Thus, this demonstrates that habitat modification affects bird distribution and that it is trivial to assess the role of feeding guilds on various habitats.

Habitat fragmentation is a paradigm of three main effects: degradation of habitat quality and extent; separation of habitat fragments by anthropogenic matrix (e.g. pasture lands and settlements) and increased intensity of edge effects (Saunders *et al.,* 1991; Forman, 1995). Habitat changes particularly affect less abundant and range-restricted birds, rainforest specialists and altitudinal migrants (Brooks *et al.,* 1999; Raman, 2001). The main effect of habitat fragmentation and degradation is the reduction of population size and an increased vulnerability to extinction (Simberloff, 1994). This exposes risks to many tropical species, as they are less distributed and do not tolerate conditions outside the forest (Turner, 1996).

Habitat loss is the most important single factor threatening bird species with extinction, worldwide (Collar *et al.,* 1994). Within particular African countries, the vast majority of birds are listed as globally threatened as a result of habitat loss and degradation (IUCN 2012, Birdlife international 2014). In East Africa, for example, habitat loss is the primary threat for 28/30 globally threatened species in Tanzania, 21/22 species in Kenya and 9/10

species in Uganda (Collar *et al.,* 1994). Regionally threatened species show similar patterns (Bennun & Njoroge, 1999).

Human beings are transforming the earth's environment and the biological diversity depending on it at an alarming rate. In particular, intensified human pressure on land is leading to evident land degradation (Muchai *et al.,* 2002b). Line transect sampling, point counts, time species counts, mist netting and opportunistic observations were used to carry out birds census to determine their abundance and diversity in the cultivated (tea and sugarcane farms) and indigenous forests. There is need to answer these questions: What is the nature of this decline, and for what types and levels of human activities does it become a cause for concern? What human activities are compatible with biodiversity conservation? Are there critical threshold levels, and how can these be assessed and detected? This research aimed at obtaining preliminary answers to these questions, using birds as an indicator of biodiversity value at a landscape scale. This thesis present data on surveys conducted in agricultural land and natural forests in Keiyan division, Trans Mara sub county Kenya. It attempts to explore what aspects of farmland and natural forests influence bird diversity and therefore, what management prescriptions may be advised to ensure their continuity.

The specific factors causing habitat loss vary from urbanization, loss of wetlands, land fragmentation, loss of forests, invasive species to cater for the expanding needs of an expanding human population. (Lens *et al.,* 1999)

Birds, like all other animals are affected by the structure of their habitat which provides critical microhabitats for different function in their life cycle (Musila, 1998). For example, large areas of pristine or less disturbed habitats are richer in native bird species. Arabuko-Sokoke Forest which covers about 38,200ha of indigenous forest or thicket, for example, hold 25 East African Coastal Biome (EACBs) bird species, while the adjacent Gede Ruins National Monument (covering about 35 ha forest) has 12 (EACBs) (Bennun & Njoroge, 1999). The density, richness and distribution of the bird species in a forest habitat might be influenced by the habitat structure, disturbance and fragmentation. Other factors may

include altitude, levels of predation through hunting and trade by local people or by other animals in the wild.

1.1.1 Habitat Structure

Habitat structure is the gross external appearance of vegetation matter. The appearance is a product of the plant materials which occur in an area. The plant matter is influenced by soil characteristics, climate (rainfall amounts and patterns as well as temperature), altitude, rate and intensity of disturbance. Habitat structure has a strong influence on bird species richness, density, diversity and distribution. The diversity of habitat niches and resources (food, water, cover for protection against predators and weather conditions) provided by a habitat determine the diversity of bird species (Cody, 1981). Additionally, different vegetation types show variation in bird community assemblages. For example, forests supports more bird species than woodlands; while woodland are more rich in species than grasslands (Wilson, 1969), probably due to high habitat heterogeneity and diversity.

1.1.2 Habitat Disturbance

Disturbance is the change in structure of a habitat in a forest. Disturbance mostly occurs through human activities such as selective or commercial logging, pit sawing, vegetation burning, charcoal burning, firewood collection, clearance of vegetation for cultivation, settlements, making trails, roads, or erecting of buildings. Given the needs of expanding human populations and the agricultural economies of many tropical countries, tropical forests will increasingly become fragments in agricultural landscapes (Beier *et al*., 2002).

Birds as group are closely associated with forests, and approximately 30% of the world's species of birds are restricted to tropical forests (either for winter or year-round habitat), and that they would disappear if all tropical forests were lost (Myers, 1992).Therefore, the change in the structure of a forest through disturbance can have serious detrimental effects on avifauna survival. For instance, over half of all threatened bird species and one third of the global bird population considered at risk from habitat disturbance inhabit tropical forests (Birdlife international, 2000; Gaston *et al*., 2003). Specific feeding guilds of birds

are either positively or negatively affected by forest disturbance. For example, frugivores (fruit eating birds) and insectivores (insect feeder) declined after disturbance, whereas granivores (seed eaters) increased (Gray, *et al.*, 2007). The abundance or richness of fruiting plants, for example, is associated with the diversity of frugivorous bird species and their foraging behaviour (Moegenburg & Levey, 2003) and habitat choice (Levey, 1988).

Human activities which selectively remove particular fruiting tree species which support a variety of frugivores might lead to decline in diversity and species richness. For example, insectivorous bird species are often the most species rich and abundant guild in tropical forests (Blake & Loiselle, 2001) and display considerable variation in feeding behaviour. The structural complexity and light regime of the habitat which undergoes considerable change following disturbance, may have important consequences for the search patterns of insectivores (Barlow *et al*., 2002) or different groups of insectivores, such as bark-gleaners or dead-leaf probers (Rosenberg, 1993). Additionally, the removal of the dead wood is detrimental to forest biodiversity, since it affects the density and distribution of cavity nesting bird species due to the decline in quantity of holes and food (Waiyaki, 1995).

1.1.3 Habitat Fragmentation

Fragmentation is the division of a contiguous habitat or ecosystem into two or more different isolated remnant patches. This happens when infrastructure (roads, building, campsites, airstrips, nature trails, transects etc.) encroach on a pristine habitat. This creates ‘islands’ within the habitat matrix, which may negatively affect the survival of animal species in the forest. Birds, population density, distribution and species richness are affected by habitat fragmentation (Donovan & Flather, 2002). This is because fragmentation changes the landscape through loss of original habitat via proliferation of human-dominated habitats and division of the original continuous habitat into isolated remnants patches (Pimm *et al*., 2002).

Isolated patches may become far from one another in a way that they become unreachable by individuals, and thereby lowering the pairing rate (Brooker & Brooker, 2003). Shy or less mobile species might have limited resources in the isolated patch, but be prevented by unsuitable matrix to disperse into the adjacent habitat. Lack of adequate food resources and mates might affect the reproductive capacity of birds. Fragmentation may also affect the availability of critical resources such as food in many ways. According to 'resource concentration hypothesis' (Root, 1973) there is a greater likelihood of critical resources being present in larger habitat patches resulting in higher population growth rates. Therefore, the smaller a patch becomes through increasing edge effects the more likely it will decline in the quality and quantity of resources critical for survival of specific species.

It has been shown that landscape change can result into dramatic changes in predator species assemblages, overall density of predators, and predator pressure on birds and their nests (Bayne & Hobson, 1997). Habitat feature such as cover is used for predatory avoidance by animals. The loss of cover through fragmentation might therefore, expose the prey to many predators, and consequently lead to increased loss of adult, off springs and eggs. Infrastructures such as roads with large traffic volume traversing habitats predispose birds, mammals and other taxonomic groups to accidental kills. Therefore, habitat fragmentation has serious negative effects on habitat quality and consequently avian community composition.

The population declines among farmland birds have coincided with many concurrent changes in agricultural practices which could potentially have acted on casual factors (Fuller *et al*., 1995). The interactions between bird and the agricultural environment are, however, unlikely to be simple. We need to understand such relationships, however, if conservation strategies for farmland birds are to be devised which can be integrated successfully into agricultural policy and practices intensive studies of single species have previously been used successfully to identify those interactions between the species' ecology and the agricultural environment which are casual for population change (Wilson *et al*., 1998), to conduct such studies for each of the large number of species which have declined on farmland would clearly require a large, perhaps prohibitive investment of time

and resources. The result of such studies (or equivalent data) is, however, an essential prerequisite for informed management decision through assessments of conservation priority.

1.2 Statement of the Problem

Human activities such as farming, mining, deforestation, reclamation of wetlands for agriculture and dumping of wastes on various habitats have caused extinction of many species or otherwise threatening many others to extinction. (Collar *et al.*, 1994). Therefore, accurate scientific information on wildlife diversity is critical for informed decision making by the wildlife managers and other stakeholders. Trans Mara sub county habitates quite a number of bird species some of which are found nowhere else in the world. In order to ensure their continuity there is need to determine their diversity, monitor their population and prescribe conservation interventions to ensure that the available avian species remain extant.

1.3 Justification and significance of the study

Birds are an important component of the biotic community of natural ecosystems and have also been used as surrogates of assessing the impact of habitat change. Monitoring species abundance, diversity, habitat preference and correlation between species abundance and habitat provides basic information for determining factors causing population fluctuation of birds. Subsequently, the information helps in formulation of effective conservation and management programmes for threatened and endangered species. Broadly, this study focused on partially filling that gap by 1) documenting the diversity and community composition of the avifauna of a disturbed ecosystem as a result of farming activities and the remnant indigeneous forest; 2) estimating densities of bird species and their respective species richness in different habitats; and 3) investigating effects of farming activities on bird diversity and abundance in Trans Mara sub county, Kenya. Information from this study will serve as a baseline for monitoring future population trends of birds in the study area.

1.4 Hypotheses

1. Bird's abundance is the same in cultivated and natural forest habitats in Trans Mara Sub County.
2. Bird's diversity is the same in cultivated and natural forest habitats in Trans Mara Sub County.

1.5 General Objective

To investigate the impact of farming activities on diversity and abundance of birds in Trans Mara sub county.

1.6 Specific Objectives

1. To determine the avian species richness across different habitat types in Trans Mara sub county.
2. To determine the abundance of various species of birds across different habitat types in Trans Mara sub county.
3. To determine the diversity of birds in the different types of habitats in Trans Mara sub county.

1.7 Scope of the Study

This study focused on the fragmented habitats of Trans Mara sub county Kenya with an intent of finding out the extent of habitat degradation due to farming activities and their possible effects on the existing birds diversity and abundance. Sampling of birds was carried out in August to November, 2014 (short rains), and December to January 2015 (dry season). The study area was stratified into habitats (1) under tea plantations, (2) sugarcane plantations and (3) natural forests. A few limitations ranged from inability to carry out bird census at night to ascertain the presence of any nocturnal birds, common migratory habits of birds may have kept some species away from being observed while some shy and skulking birds may not have been caught during mist netting sessions and therefore escaped observation.

1.8 Chapter Summary

This chapter begun with an introduction that set out the chapter content. It explains in detail the background of the study. The gaps in the study were captured by the statement of the problem. The purpose of the study was defined and its investigation was based on the three objectives posed in the chapter. The significance of the study, scope and limitation of the study were also discussed.

Chapter two is the next chapter and it focused on literature review based on agricultural expansion and its effects on birds' diversity. Further literature was reviewed in line with the three research objectives and each objective was examined in funnel approach from global perspective to local setting. The gaps between what is known and unknown were elicited.

Chapter three focused on research methodology. Sampling design, sampling techniques and samples size were explained in this chapter. it covers; A brief description of the study area, experimental design used to carry out bird census in the study area, description of the criteria for site selection, actual sampling techniques employed to collect data, Bird feeding Guilds considered, and data analysis methods.

Chapter four presented the results, it presents results on birds' abundance, diversity, distribution, richness, species of interest, threats facing various birds, forest dependency on the various categories of birds and feeding guilds observed in the entire study area. Chapter five covered discussion of results and conclusions and possible recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Agriculture expansion into forest land triggers loss of natural habitat, faunal and floral species declines or changes in species composition. For birds, for instance, there could be a loss or interference of nesting and breeding grounds. These negative impacts on biodiversity often translate to a deterioration of the services these biodiversity provide, and that people are dependent upon. As a result, it is very important to regularly take stock of the existing biodiversity and abundance to establish changes overtime in order to assess the impact of these changes.

2.2 Avian species richness

Species richness is the number of different species represented in an ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions.

Species richness is often used as a criterion when assessing the relative conservation values of habitats or landscapes. However, species richness is blind to the identity of the species. An area with many endemic or rare species is generally considered to have higher conservation value than another area where species richness are similar, but all the species are common and widespread.A number of factors are known to affect bird species richness in any ecosystem. They include;

2.2.0 Anthropogenic Habitat Change

Habitat are altered to make way for habitation, which can result in extensive habitat destruction locally and can be a major factor in habitat change when the human population increases (Catterall *et al.,* 1998; Mortberg 2001.The harnessing of hydro-electric power

through dam building and the extraction industries, mining and logging, can lead to the complete removal of the habitat affected (Goodland *et al.*, 1993; Lees & Peres 2006; Wickham *et al.*, 2007). Indirect impacts on habitats include pollution, which can damage habitats through such processes as acid rain, leaching of fertilizers and climate change, which may make the climate of large areas unsuitable to sustain their current habitats or result in the flooding of low-lying areas as sea levels rise (Kappelle *et al*., 1999; Schroter *et al.*, 2005).

Hunting and the introduction of invasive species through human activity can have an impact on wildlife populations and thus affect the habitat by altering grazing and seed-dispersal patterns (Lodge 1993; Wright *et al*., 2007). The conversion of habitat to agriculture is, however, the largest current cause of habitat change by humans, with around one third of the world's exploitable surface now dominated by agriculture (Ormerod & Watkinson 2000). In temperate zones this figure is higher still. It is estimated that about half of all potentially suitable remaining land would be converted to agriculture in developing countries by 2050. Africa, with current high human population increases, will require agricultural changes in order to be self-sufficient for food (Imhoff *et al.*, 2004), indeed, the area of crop land in the developing world has increased by 20% since 1961 whereas developed world cropped land has shrunk, slightly (Green *et al.*, 2005). Therefore the effects of agriculture on biodiversity must be known in order to derive effective policies to limit the damage to current ecosystems.

2.2.1 Farmland as a Habitat for Birds.

On farmland the habitat available has been significantly altered from the natural habitat by human activity and the different bird species present will select for different aspects of this new habitat, depending on the requirements they have evolved for. Bird species may not have evolved entirely in the presence of agriculture on the scale seen today and will select for aspects of the land which resemble the savanna, grassland, forest or wetland they have evolved to exploit (Gill, 2006). The management of farmland in different ways will yield different habitat mosaics suitable for different species. When the natural habitat that has been changed is forest, woodland or savanna, agriculture tends to result in a more

open areas with fewer trees and shrubs (Reid *et al.*, 1997; Soderstrom *et al*., 2003; Marsden *et al*., 2006) and more perennial vegetation, with increased seasonality in the availability of seed and invertebrate food (Critchley *et al*., 2004). Crop fields are sown and harvested every year, during spring and summer in temperate zones and during the wet season in tropical zones, often with a second harvest of a different crop during the winter in temperate zones and the dry season in the tropics (Henderson *et al*., 2004).

The typical farmland birds observed in tropical areas tend to be a mixture of woodland and savanna species and open-country, grassland species, which may not have been present before human disturbance and may have been able to expand their ranges due to agricultural habitat changes (Borrow & Demey 2001; Soderstrom *et al.*, 2003). Forest species may also persist among relict forest patches and riparian forest along water courses. In temperate zones this use of farmland by granivorous, open-country birds, which can make use of cereal grains, has also been noted, although insectivorous, woodland bird species can also persist in farmland by using field borders and woodland remnants (Gregory & Baillie 1998). A mosaic of crop fields, arable land, fallow land, field borders and pockets of woodland may be generated with high levels of year-on-year disturbance, yet conversion to agricultural land still consistently leads to lower habitat heterogeneity (Benton *et al.*, 2003). Agricultural land also tends to have a high input of fertilizers and pesticides which alters the soil quality and chemical make-up, which can influence vegetation and can potentially be toxic to plants and animals (Mader *et al*., 2002).

2.2.2 Farmland Birds and Agricultural Intensification

Since the 1960s the "Green Revolution" has been increasing farming yields, mainly in developed nations, by increasing the total area of crop land, using new technologies such as tractors and combine harvesters to improve efficiency, by the development of new and more effective artificial fertilizers, pesticides and herbicides and by the development of new crop varieties, including genetically-engineered crops (Tilman *et al.*, 2001; Green *et al.*, 2005). This has greatly reduced world hunger, with a doubling of global food-production between 1966 and 2001 (Green *et al.*, 2005), but at an environmental price,

with birds not being immune to the detrimental effects of this change from traditional farming systems to more modern, intensive forms of farming (Fuller *et al.,* 1996; Donald *et al.,* 2006).

2.3 Bird Species Abundance

Species abundance is a component of biodiversity and refers to how common or rare a species is relative to other species in a defined location or community. Species abundances tend to conform to specific patterns that are among the best-known and most-studied patterns in macro ecology. Usually species abundances are described for a single trophic level. Because such species occupy the same trophic level they will potentially or actually compete for similar resources. For example, species abundances might describe all terrestrial birds in a forest community. A number of factors are known to affect bird species abundance in any natural ecosystem

2.3.0 Farmland Birds in the Tropics and in Africa

According to Bird life International's World Bird Data base, farming is the biggest source of threat to bird species listed as threatened, and that this is substantially more important for species in developing than developed countries (Green *et al.,* 2005). Most research on farmland in the tropics has been in the form of comparative studies between more pristine areas and adjacent farmland (Naidoo, 2004), and investigating the effect of adjacent farmland and savanna on populations of birds in fragmented natural habitat (Hughes *et al*., 2002; Matlock *et al.,* 2002; Marsden *et al*., 2006).

2.3.1 Tropical Habitats and Conversion to Agriculture

Hughes *et al.* (2002) surveyed agricultural land adjacent to native forest in Costa Rica and estimated that 46% of bird species native to the region were utilizing agricultural land in some manner, and most used agricultural land for some foraging. They also predicted that removing tall trees and edges from the farmland mosaic would cause a decline in bird richness by approximately 40%. They concluded that tropical agriculture, if managed properly, could contribute to tropical bird conservation. (Naidoo 2004), on the other hand,

found that the management of agricultural land was unlikely to contribute to forest bird conservation in southern Uganda. Naidoo surveyed bird species richness in intact forest, secondary forest and small holder agriculture and found higher diversity in the forest habitats and lower diversity in farmland; in addition species composition was significantly different in farmland and few forest species were utilizing it to a significant level. It was concluded that tree densities would have to be raised to un-realistic levels on small holdings in order to have a positive impact on forest bird populations. (Naidoo 2004). (Marsden *et al*., 2006) studied a forest management area in Papua New Guinea where only 13% of the land was converted for agriculture but there were still low densities of some insectivorous bird species on the converted land. Other studies have assessed the impact of slash-and-burn (Wang & Young 2003) and banana plantations (Matlock *et al.,* 2002) on birds of native forests, but these did not concentrate on farmland as a habitat independent of intact forest.

2.3.2 Birds and Agricultural Gradients in Africa

In Burkina Faso, West Africa, (Soderstrom *et al*., 2003) conducted an investigation into the response of bird communities to human-use land intensification, in particular to the expansion of cultivation. They surveyed birds in areas with different soil types, fallow period lengths and grazing pressures. Vegetation structure was also measured. Avian species richness decreased from cultivation to very old fallows and the bird community was strongly affected by the amount of canopy cover and tree species richness. Nest placement was the most important factor explaining community structure, with shrub nesters benefiting from fallow periods and cavity nesters remaining in intensive farmland with large trees. They concluded that farmland may contain large populations of species of conservation interest in Africa and that more research should be carried out in tropical agricultural landscapes. South Africa is the most developed country in sub-Saharan Africa with a high proportion of intensive agriculture and a number of avian studies there have concentrated on farmland. Higher numbers of bird species were recorded at sites with a mixture of crops compared to less diverse sites in the Aghulas Plains, Southern South Africa (Mangnall & Crowe 2003). For South east South Africa, (Wessels *et al.,* 2003)

integrated land-cover, agricultural potential and species distribution data from different taxa in order to identify potential conflict areas between land transformation and biodiversity conservation. It appeared there was substantial overlap between areas of conservation interest and transformed land, and that policies were needed to promote biodiversity on private farmland. In a parallel to the species-specific research that has taken place in Europe, the ecology and habitat-use of the helmeted guinea fowl, *Numida meleagris*, has been studied on farmland in South Africa (Malan & Benn 1999; Ratcliffe & Crowe 2001).

This indicated that, whilst this species has made extensive use of agricultural habitats for many years, it seems that a reduction in habitat heterogeneity for nesting and cover (Malan & Benn 1999). An increase in the use of pesticides decreasing the availability of arthropod prey and weeds for family groups of helmeted guinea fowl (Ratcliffe & Crowe 2001) has led to a decline in the intensively farmed areas. Threatened bird species which use farmland habitats have been studied in Kenya, including Hinde's Babbler, *Turdoides hindei*, which requires increased thicket cover for increased productivity (Shaw & Masina 2003) and Sharpe's Longclaw, *Macronyx sharpei*, which requires intact grassland, which is under threat by conversion of grazing land to cultivation (Muchai *et al.*, 2002a; Muchai *et al.*, 2002b).

2.4 Bird Species Diversity.

Species diversity is a function of the number of species present (species richness or number of species) and the evenness with which the individuals are distributed among these species (species evenness, species equitability, or abundance of each species) (Margalef 1958; Lloyd & Ghelardi 1964; Pielou 1966; Spellerberg, 1991).

2.4.1 Biodiversity of Farmland

Biodiversity is often used as a measure of the comparative ecological health of habitats, with more diverse communities representing a more desirable habitat from a conservation perspective (Huston 1994; Gaston 1996). Species richness is a relatively easy variable to

study as it only involves the collection of data on which species were present, so it is often used as an indicator of the diversity of a community (Hopton & Mayer 2006; Thomson *et al.,* 2007). Species richness does not, however, take into account other information relevant to diversity involving the number of individuals involved or the biomass of each species. These data can indicate whether the species are distributed equitably or whether there are a small number of common species and the rest are rare. Diversity indices take both of these factors into account, so two areas with the same number of species will have different values depending on the equitability of their distribution, with the more equitable area yielding a higher diversity index (Begon *et al.,* 1996). Both measures of diversity mentioned above miss another aspect of biodiversity, that of the genetic diversity between species. For example, the species data do not distinguish between species of the same or different families, which are more genetically diverse, so could be argued to constitute greater diversity (Gaston, 1996). As habitat changes the number of species may remain similar but the constitution of the avian community may change at a higher taxonomic level (e.g. family).

Alternatively, intraspecific variation may be lost because of intense directional selection on birds in rapidly changing habitats such as farmland, and because of bottle necks, that may not occur in more stable, fragmented habitats such as woodland (Fjeldsa & Lovett 1997). Biodiversity has been found to decrease where agriculture has expanded, with an estimation, based on forecasts of biome conversions, that 27-44% of bird species could be lost to agricultural expansion from Neolithic to 2050 (Teyssedre & Couvet 2007). Increased diversity and species richness have been linked to increased non-cropped elements in an agricultural landscape in the Baltic states (Herzon & O'Hara 2007) and diversity in the agricultural landscape is often positively correlated with taxonomic richness (Bennett *et al.,* 2006). With the higher species richness observed in tropical agricultural land (Mangnall & Crowe 2003; Soderstrom *et al.,* 2003), it is likely that many species are at risk from agricultural expansion in Africa and that focused management may have a large role to play in reducing these potential losses.

2.4.2 Anthropogenic Disturbance and Diversity

Although anthropogenic use of land may result in a complete change in available habitats and ecosystem functions and services, anthropogenic effects may result in new communities of biological importance. The theoretical framework that best describes this is that of succession and disturbance within communities. (Connell, 1978) suggested the intermediate disturbance hypothesis, which states that species diversity will be higher with disturbances of an intermediate frequency and intensity (Connell, 1978).

At a high rate of disturbance the only species which colonize and survive will be those which reach maturity quickly. As the interval between disturbances increases more time is available for the invasion of new species so diversity increases. Under low levels of disturbance, diversity decreases as the most effective competitors for the available limited resources survive at the cost of less-efficient species, thus disturbances interrupt and set back the process of competitive elimination by removing species that are competitively excluding other organisms (Connell, 1978). This suggests that high species diversity could be maintained even under a degree of anthropogenic disturbance, such as agriculture, as long as the disturbance is limited. The challenge is to reach a balance whereby disturbance does not cause significant declines in species diversity.

2.5 Chapter summary

This chapter contains a review of related literature on impacts of human activities on avifaunal population. It explores factors in any natural ecosystem and how they impact on diversity distribution and abundance of birds that depend on various habitats for survival.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This research intended to determine the diversity and bird species abundance in Trans Mara sub county Kenya. This chapter covers, experimental design, study area, site selection, sampling techniques and data analysis.

3.2 Experimental Design

Prior to field surveys, the study area was stratified into habitats (1) under tea plantations, (2) sugarcane plantations and (3) natural forests. A sample area of 5 × 5km square was picked at random from each of the three study areas. Those selected areas were further be sub divided into 1 × 1 km smaller study areas, and a total of 3 transects were laid down randomly within the small study areas. The length of each transect was 1 km and was laid down randomly to cover each kind of habitats.

3.3 Sampling procedure

Line transects was used to sample bird species in the three habitats. Three transects each 1km long were used with the start of each route marked using a GPS. All birds seen within a fixed distance of 0-25m then 25-50m on each side of the transect were recorded. The species, number of birds, perpendicular distance and sighting angle were recorded in datasheets. This method was used to capture data on relative abundance and absolute abundance of birds and it was effective for the extensive, open and uniform habitats in the three habitats.

The time taken for each survey varied depending on the terrain and topography of the study area. Surveys were conducted in the morning hours (6.30 a.m. to 10.30 a.m.) and evening hours (3.30 p.m. to 6.30 p.m.) by a single observer. Observations were carried out with the aid of 8 × 40 binoculars, and field characteristics were noted down on special

ornithological data sheet which included; type of species, number of individuals per species, activity and the micro habitat where the birds were found. The birds were identified using (Zimmerman *et al*., 1996) birds of Kenya and northern Tanzania. Birds noted during the survey were categorized according to their feeding guilds (Insectivore, Nectarinivores, Omnivores, Frugivore, Carnivores, Piscivores, and Granivores).

Three 40-minute Time species counts (TSCs) were conducted on each observation day in the three study areas. Each TSC was separated by at least 1km from the next. This method involved making repeated species lists, on which each species recorded for the first time was positively identified by either sight or sound. For each count, species encountered were recorded and scored according to when they were first recorded to give a 'commonness index' from 4 (1-10minutes) to 1 (31-40 minutes).

Point counts were conducted along each transect at intervals of 200 m. The number of point Counts in each habitat sub-set depended on percentage of its representation in the study area. This kind of data helped in calculating absolute densities as described by (Bibby *et al.*, 2000).

In addition, Mist Netting was done in Nakutu forest to check whether any skulking and secretive species may have been missed. Nets were run between 06:30 – 10:30 hrs. in each sampling day. The length of net lines in each habitat type depended on the percentage representation of each habitat in the study area.

Opportunistic observations were also done during the survey and any bird species seen or heard and identified positively using field guides were recorded. All new sightings were recorded daily.

Sampling of birds was carried out in August to November, 2014 (short rains), December to January 2015 (dry season) to coincide with the contrasting seasons in our study system.Sampling points were set progressively in the three study areas extending from the sugarcane farms, tea farms all the way to the natural forested areas. I endeavored to sample the continuous forest patches at Nakutu to come up with a comprehensive checklist and

numbers of birds that existed in the three study areas in order to determine any differences in diversity and abundance

3.3 Study Area

A six month study was carried out from August 2014 to January 2015 in Trans Mara sub county Kenya. Trans Mara is situated in the south west of the Rift valley (Figure 1) the sub county lies between latitude 0^0 50´ and 1^0 50´ South and longitude 34^0 35´ and $35^0$14´ East. The sub county borders the Republic of Tanzania to the South, Kuria and Migori Sub counties to the West, Gucha South and Bomet Sub counties to the North and Narok Dub county to the East. The Sub county covers an area of about 2,932 km^2 of which the famous Maasai Mara Game Reserve occupies 31km^2.Trans Mara sub county is divided into 5 divisions namely: Kilgoris, Lolgorian, Pirrar, Keiyan and Kirindon. The area is mainly composed of *Themeda* grassland, dwarf shrub and *Acacia drapanolopium* grassland and *Croton* bushes and other woody species interspersed with grassland (stelfox *et al.*, 1986)

The entire Trans Mara Ecosystem has been subject to considerable vegetation changes including domination of dense woodlands and thickets in the Trans Mara Plains due to change in climate, low fire frequency due to recurrent droughts and low animal numbers (Dublin *et al.*, 1990). The Trans Mara naturally supports a mixture of forest and woodland with scattered bushes, but is rapidly being transformed into cultivated land. The main land uses in the area are pastoralism, tourism and agriculture.

This study was conducted in major farmed areas, namely, Keiyan tea farms, Keiyan sugarcane farms, Nakutu forested area and the forested area along Keiyan river of Keiyan Division. Sugarcane farming activities are carried out mainly to feed Sonysugar Company and Trans Mara Sugar Company. Tea is mainly grown to feed Eberege tea factory in the neighbouring Kisii County. Although, some natural forests remain in Nakutu area and along Keiyan river. The farming activities have resulted into major loss of habitats.

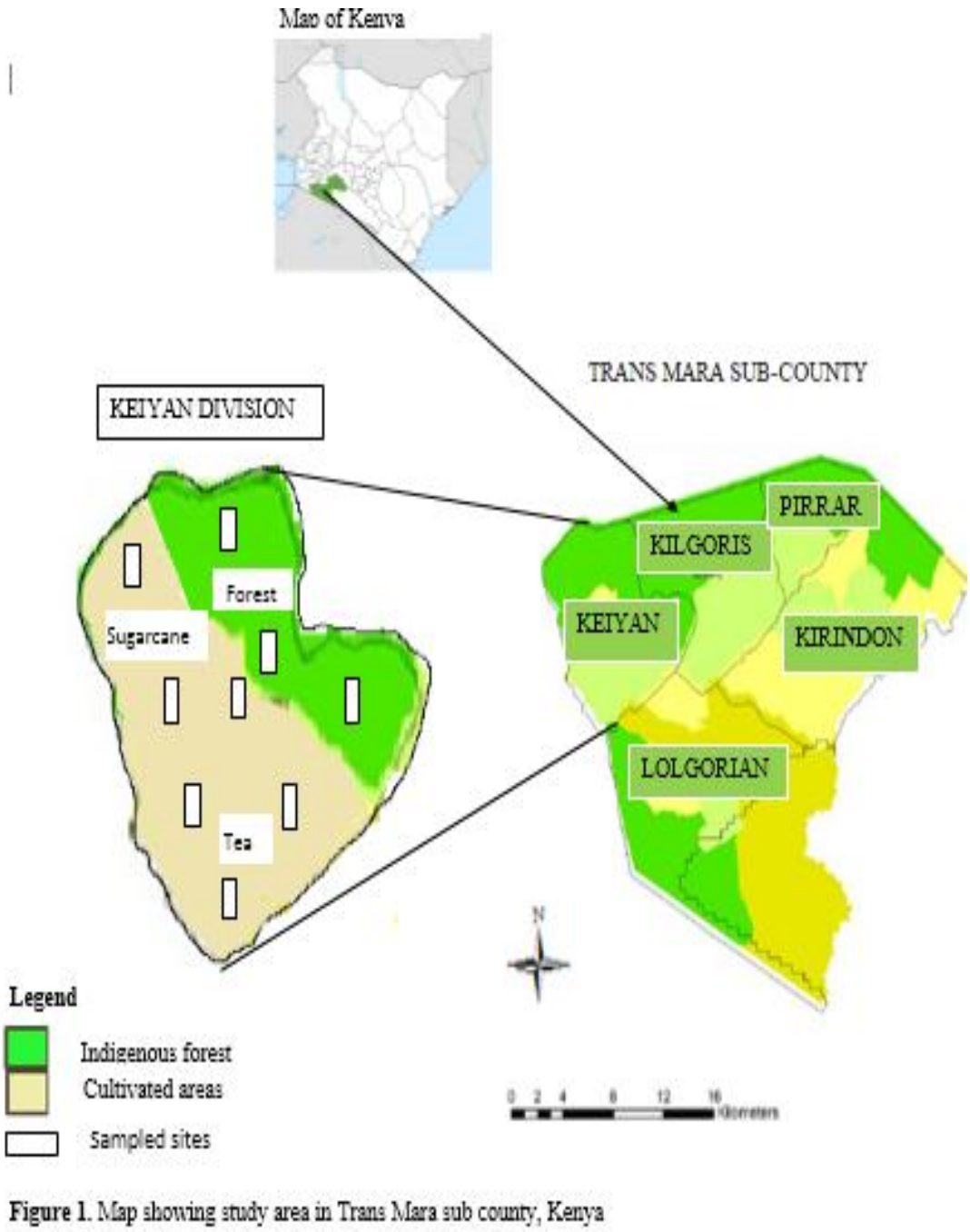

Figure 3.1: Map Showing Study Area in Trans-Mara Sub-County, Kenya

Source; (Author) - 2016

3.4 Site Selection

Sites were chosen based on visual determination of the intensity of agriculture and the extent of scrubland and farmed land in order to cover as wide a range of agricultural intensities as possible as well as naturally forested areas. Initially the area covering Keiyan sugarcane farms and Keiyan tea farms was once a naturally forested area and currently has been cleared for the aforementioned agricultural activities. The area covering Keiyan sugarcane farms and Keiyan tea farms was designated as the main farmed area while Nakutu area was designated as the main forested area including Keiyan riverine forest.

3.5 Sampling techniques

Bird Survey Methods included;

3.5.0 Line transects

Line transects were chosen as sampling units due to the open nature of much of the area (Bibby *et al*. 2000). They line transects were mainly carried out in the tea farms and sugarcane farms due the open nature of much of the area. This involved moving along a pre-determined route and all bird seen or heard were recorded and the perpendicular distance of each to the point of observation (transect) on either side of the line transect noted. The birds seen within the belt transect were counted and the area in hectare determined then the two parameters were combined to calculate density in birds per hectare. (Bibby *et al.,* 2000). The program GPS Utility was used to place transects within each site. Transect walks were conducted between sunrise and 10am, no transects were conducted after this time in order to reduce time of day effects. Sites were chosen randomly to distribute visiting time equally across all transects. Transects were walked so as to complete each within 25 to 30 minutes, depending on the terrain of the specific area. All birds observed were identified and the number in the group recorded. Distance estimations were checked regularly using pacing in order to maintain accuracy. The side of the transect that the bird was recorded was also noted. If birds were in a group, the

distance to the Centre of the group was taken. Birds first seen in the air were identified and counted and noted as flying.

3.5.1 Mist Netting

Mist Netting was done in Nakutu forest to check whether any skulking and secretive species may have been missed. Nets were run between 06:30 – 10:30 hrs in each sampling day. The length of net lines in each habitat type depended on the percentage representation of each habitat in the study area. (Bibby *et al.,* 2000). Since the objective of this study was to list as many birds as possible, standard effort was not applicable i.e. each sub-set of study area was not given an equal effort in terms of net hours (number of hours nets will remain open). Birds caught in mist nets were extracted carefully and identified using an identification guide book, Birds of Kenya and Northern Tanzania by Zimmermann *et al.,* (1996). After taking biometric data, they were then released back to the wild.

3.5.2 Timed Species Counts (TSCs)

Timed species-counts (TSCs) method is ideal for building complete species lists quickly, and to establish the relative abundance of canopy and mid-level bird species. At least five 40-minute TSCs were conducted each day in each of the habitat at the study area. Each TSC was separated by at least 100 m or 10 minutes' walk from the next. This method involves essentially repeated species lists, on which each species is recorded the first time it is positively identified by either sight or sound. For each count, species encountered was recorded and scored according to when they will be first recorded to give a 'commonness index' (4 if in the first ten minutes, 3 if in the next ten minutes, third ten minutes (= 2), fourth ten minutes (= 1); species not recorded during that specific TSC scored a '0'. An average score (TSC Index) was then computed over all counts across the entire study area, which is an index of relative abundance of the species. Relative abundance was calculated by applying the formula; Number of birds of each species/Total number of birds' ×100.To establish distribution patterns, the encounter rate was also computed based on the proportion of all TSCs in which a species was recorded. (Bennun *et al.,* 2002).

3.5.3 Fixed-width point counts

Census stations were marked along a pre-determined line transect at intervals of 200 meters. The observer stood at the Centre of the circle and recorded all birds seen and heard during a set period (10 minutes) allocating each observation to a distance band within a radius of 25 metres. Point counts were conducted along each transect at intervals of 200 m. (Bennun *et al.,* 2002). At every point count there was waiting for one minute (settling-in period) before counting all the birds seen or heard within a 25m radius for the next 9 minutes. The number of birds within the radius of each point count was counted against the total area in hectares to get density in birds per hectare.The number of point Counts in each habitat sub-set depended on percentage of its representation in the study area. This kind of data helped in calculating absolute densities as described by (Bibby *et al.,* 1998).

3.5.4 Opportunistic Observations

The field crew always carried 8 x 40 binoculars during the fieldwork and recorded any species seen or heard and identified positively using an identification guide book, Birds of Kenya and Northern Tanzania by Zimmermann *et al.,* (1996). This method was supplemented by organised bird walks both in early mornings and afternoons to exhaustively search the study area. This involved making observations on target areas such as fruiting and flowering trees besides recognition of calls. Observers also used vantage points to watch sky for raptors and other passing over species. (Bennun *et al.,* 2002).

All new sightings were recorded daily. A curve was plotted from cumulative total number of species seen daily against number of days spent. This curve gave an indication as to whether continued searching would increase the number of species recorded besides showing a near exhaustion of all species. The final species list was compared with known species from this atlas square after Lewis and Pomeroy (1989) and other records from the Department of Ornithology's database.

3.6 Data Analysis

All data were explored preliminarily and in case of significant departure from normal distribution (Zar, 1996), appropriate transformation methods were applied. Specifically data on abundance was first tested for normality and then subject to square root transformation since it was just count data to normalize it then the formula; Number of birds of each species/Total number of birds ×100, was applied to determine relative density.A probability of Type I error of 0.95 ($\alpha = 0.05$ or less) was accepted as significant (unless otherwise noted). The data were analyzed using SPSS program (Nie *et al.,* 2011).

3.6.1 Species accumulation curves modeling

This simple test aimed to inform us how close the total number of species we recorded during the study was to the potential total number of species actually in the study area. Species accumulation curve was prepared using the progressive number of new bird species seen every day from Day 1 to Day 20 of this study. An asymptotic model to the species accumulation curve of observed data was fitted using nonlinear regression procedures (Gaidet *et al.,* 2005).

3.6.2 Bird Species Diversity

Data on avian species diversity in the three habitats was calculated using the **Shannon diversity (H')** index. Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as number of species per sample unit (Whittaker, 1972). The Shannon diversity index (H') was calculated using the following equation.

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

Where: H = the Shannon diversity index, P_i = fraction of the entire population made up of species i, S = numbers of species encountered, ∑ = sum from species 1 to species S.

The Shannon-Wiener index can theoretically range from zero (a community with only one species, which is technically just a "population") to infinity. In practice though, a value of 7 indicates an extremely rich community while values under 1 suggest a community with low diversity. Often values above 1.7 are taken to indicate a relatively diverse community.

Simpson's diversity index for each habitat was calculated using the formula:

$$D=\Sigma ni\ (ni-1)/N\ (N-1),$$

Where; ni= the total number of birds of each individual species and N= total number of birds of all species.

The value of D ranges between 0 and 1. Zero represents infinite diversity and 1 represent no diversity. Since this is not intuitive, D is often subtracted from 1 to give the higher values the higher diversity.

Sorenson's similarity index was used to compare similarity of bird species across the four habitats.

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

Where; a= number of species found in site A, b= number of species in site B and J= number of species shared by the two sites.

3.6.3 Birds Abundance and Species Richness

Relative abundance of a species is the abundance of a species divided by total abundance of all species. It is based on the assumption that the more frequently a species is seen the more abundant it is (Bibby *et al*., 2000). For every habitat, relative abundance of each species was calculated as follows: **Number of birds of each species/Total number of birds' ×100.**

One way ANOVA (Analysis of variance) was used to test the relationship of bird abundance and richness across the three habitats at 5% significance level. Data obtained for number of birds in each habitat was first tested for normality and transformed using square root method since it was count data. Multiple comparison test (Tukey HSD) was used to further establish significant difference between the three habitats. Absolute abundance was further established by getting the number of bird per hectare.

3.6.4 Bird Feeding Guilds

A guild (or ecological guild) is any group of species that exploit the same resources, often in related ways. Guilds are defined according to the locations, the attributes, and the activities of their component species; for example, their mode of feeding, acquiring nutrients, their mobility, and the zones of their habitat that they occupy or otherwise exploit (Simberloff & Dayan, 1991).

Guilds are useful in comparative study of communities. Since it is usually impossible to study all species living in an ecosystem at one, guilds enable us to concentrate on specific groups with specific functional relationships. This is preferable to studying taxonomic groups, within which different species may perform unrelated roles (Simberloff & Dayan, 1991). Birds can be placed into several trophic structures based on their feeding behaviours: insectivores, frugivores, omnivores, carnivores, nectarivores, piscivores and granivores. The type of habitat is a great determinant on these feeding guilds.

3.7 Chapter Summary

This chapter covers; A brief description of the study area, experimental design used to carry out bird census in the study area, description of the criteria for site selection, actual sampling techniques employed to collect data, Bird feeding Guilds considered, and data analysis methods.

CHAPTER FOUR.

RESULTS

4.1 Species Abundance in the Three Study Areas

Based on point count method and line transects, a total of 3792 individuals were observed and recorded in the entire study area. The indigenous forest had the highest abundance with 2736 individuals, followed by tea farms with 721 individual and the sugarcane farms had the least abundance of 335 birds. The cumulative number of birds was higher in the forested area as compared to the tea farms and sugarcane farms. The abundance of each bird species recorded in the three habitats are shown in (Tables 1, 2, 3, 4).

Tea farms

In the tea farms the Fantailed widow bird (*Euplectes axillaris*), had the highest abundance with a density of 38±1.23 birds/Ha, followed by Common waxbill (*Estrilda astrild*), 30±1.23 birds /Ha, Eurasian bee eater (*Merops apiaster*), 27±1.23 birds/Ha and Winding cisticola (*Cisticola galactotes*) 21±1.23birds/Ha. (Table 4.1).

Table 4.1: Bird Species abundance ±SE in the tea farms using point count method List in descending order.

Name of bird	Scientific name	Density (bird/ha) ±SE PC
Fantailed widow bird	*Euplectes axillaris*	38±1.23
Common wax bill	*Estrilda astrild*	31±1.23
Eurasian bee eater	*Merops apiaster*	28±1.23
Winding cisticola	*Cisticola galactotes*	21±1.23

(Full list in appendix 6)

Sugarcane farms

In the Sugarcane farms the Common bulbul (*Pycnonotus barbatus)*, had the highest density of 3±0.15birds/Ha, followed by Common stone chat *(Saxicola torquatus)*, 2.8±0.15 birds /Ha, Eurasian bee eater (*Merops apiaster)*, 2.7±0.15 birds/Ha and Common waxbill (*Estrilda astrild*) 2.6±0.15 birds/Ha. (Table 4.2).

Table 4.2: Bird Species abundance±SE in the sugarcane farms using line transect method

List in descending order.

Name of bird	Scientific name	Density (bird/ha) ±SE PC
Common bulbul	*Pycnonotus barbatus*	3±0.15
Common stone chat	*Saxicola torquatus*	3±0.15
Eurasian bee eater	*Merops apiaster*	3±0.15
Common waxbill	*Estrilda astrild*	3±0.15
Common fiscal	*Lanius collaris*	2±0.15
Baglafecht weaver	*Ploceus baglafecht*	2±0.15
African citril	*Crithagra citrinelloides*	2±0.15
Barn swallow	*Hirundo rustica*	2±0.15
Bronze sunbird	*Nectarinia kilimensis*	2±0.15
Emerald spotted wood Dove	*Turtur chalcospilos*	1±0.15

(Full list in appendix 7)

The Common bulbul (*Pycnonotus barbatus)*, was the most abundant bird in the sugarcane farms and the Purple grenadier *(Granatina ianthinogaster)* was equally quite rare as displayed.

Indigeneous forest

In the indigenous forest the Common bulbul *(Pycnonotus barbatus)*, had the highest density of 45±0.64 birds/Ha, followed by Grey throated barbet *(Gymnobucco bonabartei)*, 32±0.64 birds /Ha, Speckled mouse bird *(Colius striatus)*, 30±0.64 birds/Ha and Double toothed barbet *(Lybius bidentatus)* 28±0.64 birds/Ha. (Table 4.3).

Table 4.3: Bird Species abundance±SE in the indigeneous forest using point count method.

List in descending order.

Name of bird	Scientific name	Density (birds/ha) ±SE
Common bulbul	*Pycnonotus barbatus*	45±0.64
Grey throated barbet	*Gymnobucco bonabartei*	32±0.64
Speckled mouse bird	*Colius striatus*	30±0.64
Double toothed barbet	*Lybius bidentatus*	28±0.64
Barn swallow	*Hirundo rustica*	27±0.64
Bronze sun bird	*Nectarinia kilimensis*	27±0.64
African citril	*Crithagra citrinelloides*	16±0.64
Spectacled weaver bird	*Ploceus ocularis*	16±0.64
African blue fly catcher	*Elminia longicauda*	14±0.64
African goshawk	*Accipiter tachiro*	12±0.64

(Full list in appendix 8)

The common bulbul *(Pycnonotus barbatus)* was the most abundant bird in the indigenous forests and the Red headed weaver *(Anapalectes melanotis)* was quite rare as displayed.

There was a significant difference in bird abundance in the three habitats (ANOVA; (df_1=2, df_2 =199, F=7.598, P=0.001). A further posthoc Tukey's pairwise comparison test showed that Nakutu indigenous forest significantly differed from tea and sugarcane farmlands both having lower birds' abundance as compared to Nakutu indigenous forest.

Bird's abundance was highest in the indigenous forest with a mean of 5.7242±0.64157 birds per hectare, followed by tea farms that had a mean of 3.9556±1.2301 birds per hectare and lowest abundance was experienced in the sugarcane farms with a mean of 0.9054±0.1476 birds per hectare. (Figure 4.1)

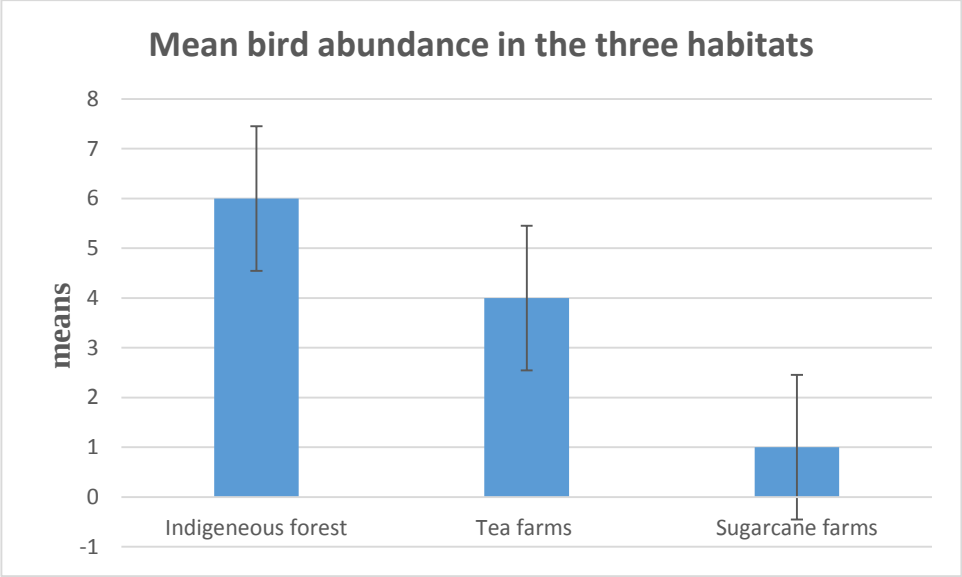

Figure 4.1: Mean bird abundance in the three habitats.

4.1.0 Relative abundance of bird species.

Sugarcane farms

In the Sugarcane farms the Eurasian bee eater (*Merops apiaster*) had the highest relative abundance of 10.71 %, followed by Common stone chat (*Saxicola torquatus*), 8.92%, Fantailed widow bird (*Euplectes axillaris*), 8.92% and Common fiscal (*Lanius collaris*) 8.03 %. (Table 4.4)

Table 4.4: Relative abundance of bird species recorded in sugarcane farms.

List in descending order.

Species name	Scientific name	Relative abundance%
Eurasian bee eater	*Merops apiaster*	10.71
Common stone chat	*Saxicola torquatus*	8.92
Fantailed widow bird	*Euplectes axillaris*	8.92
Common fiscal	*Lanius collaris*	8.03
Common wax bill	*Estrilda astrild*	8.03
Red collared widow bird	*Euplectes ardens*	7.14
Barn swallow	*Hirundo rustica*	6.25
Baglafecht weaver	*Ploceus baglafecht*	5.35
Common bulbul	*Pycnonotus barbatus*	4.46
African citril	*Crithagra citrinelloides*	3.57
Bronze sunbird	*Nectarinia kilimensis*	3.57
Tawny flanked Prinia	*Prinia subflava*	3.57

(Full list in appendix 9)

Tea farms

In the tea farms the Eurasian bee eater (*Merops apiaster*) and Fantailed widow bird (*Euplectes axillaris*), had the highest relative abundance of 10 %, followed by Common bulbul (*Pycnonotus barbatus*), 8.33%, Blue headed Coucal (*Centropus monachus*), 6.67% and Winding Cisticola (*Cisticola galactotes*) 5%. (Table 4.5)

Table 4.5: Relative abundance of bird species recorded in the tea farms.

List in descending order.

Species name	scientific name	Relative abundance in %
Eurasian bee eater	*Merops apiaster*	10
Fan tailed widow bird	*Euplectes axillaris*	10
Common bulbul	*Pycnonotus barbatus*	8.33
Blue headed Coucal	*Centropus monachus*	6.67
Winding Cisticola	*Cisticola galactotes*	6.67
Barn swallow	*Hirundo rustica*	5
Common waxbill	*Estrilda astrild*	5
Red billed fire finch	*Lagonosticta senegala*	5
Baglafecht weaver	*Ploceus baglafecht*	3.33
Cape robin chat	*Cossypha caffra*	3.33
Grey wagtail	*Motacilla cinerea*	3.33
Harlequin quail	*Coturnix delegorguei*	3.33
Red collared widow bird	*Euplectes ardens*	3.33
Sooty chat	*Myrmecocichla nigra*	3.33

(Full list in appendix 10)

Indigeneous forest

In the Indigeneous forest the Common bulbul (*Pycnonotus barbatus*) had the highest relative abundance of 13.40 %, followed by Grey throated barbet (*Gymnobucco bonabartei*), 7.22%, Speckled mouse bird (*Colius striatus*), 6.18% and Double toothed barbet (*Lybius bidentatus*) 5.15%. (Table 4.6)

Table 4.6: Relative abundance of bird species recorded in indigenous forest.

List in descending order.

Species name	scientific name	Relative abundance in %
Common bulbul	*Pycnonotus barbatus*	13.40
Grey throated barbet	*Gymnobucco bonabartei*	7.22
Speckled mouse bird	*Colius striatus*	6.18
Double toothed barbet	*Lybius bidentatus*	5.15
Barn swallow	*Hirundo rustica*	4.12
Bronze sunbird	*Nectarinia kilimensis*	4.12
African citril	*Crithagra citrinelloides*	4.12
Spectacled weaver bird	*Ploceus ocularis*	4.12
African blue fly catcher	*Elminia longicauda*	4.12
African goshawk	*Accipiter tachiro*	4.12
Cape robin chat	*Cossypha caffra*	3.09

(Full list in appendix 11)

There was a significant difference in bird relative abundance in the three habitats (df_1=2 df_2=160, F=19.779, P=0.0001). A further posthoc Turkey's pairwise comparison test showed that Nakutu indigenous forest showed a significant difference from tea and sugarcane farmlands in terms of relative abundance.

Bird's relative abundance was highest in the sugarcane farms with a mean of 4.1617±0.61426 birds per hectare, this was followed by tea farms that had a mean of 3.7044±0.4977 birds per hectare and lowest relative abundance was experienced in Nakutu forest with a mean of 1.5854±0.17956 birds per hectare and N=112, 27 and 24 respectively (Figure 4.2)

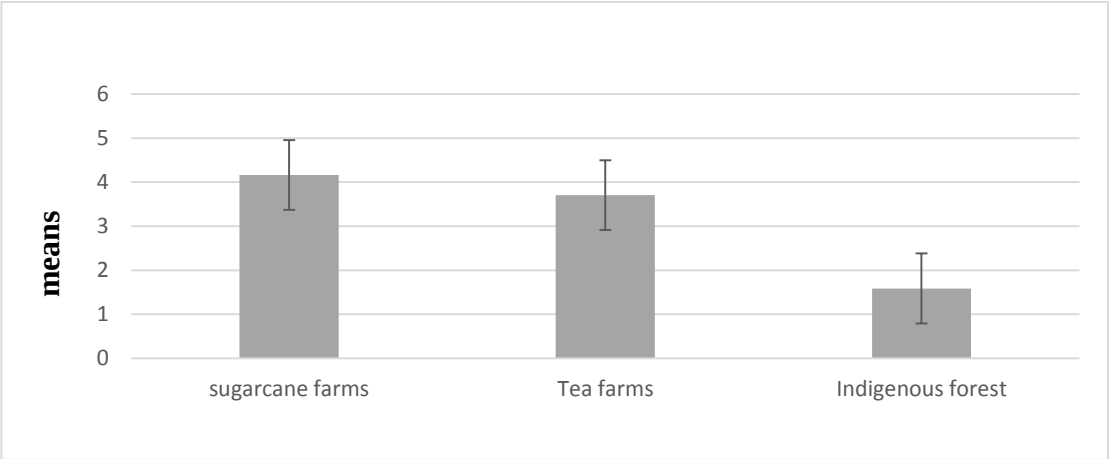

Figure 4.2: Mean Relative Abundance of Birds

4.1.1 Bird Species Dominance using their Relative Abundances.

The Eurasian bee eater was the most dominant bird (10.2%) in the sugarcane farms. Other dominant bird species in the sugarcane farms were; common stone chat, (8.5%), Fan tailed widow bird, (8.5%), common fiscal (8%) common waxbill (8%) and the others were below (6.5%). In the tea farms, the dominant bird species were; Eurasian bee eater (10%), Fan tailed widow bird, (10%), Common Bulbul (8.2%) and blue headed Coucal (6.4%) and other bird species had less than 4.5%.Common Bulbul was the most dominant bird in the indigeneous forest (7.2%). Other dominant bird species in the indigenous forest were; spot flanked barbet (6.2%), yellow Wagtail (6.2%), Cinnamon chested bee eater (5.2%). The remaining bird species had less than 4%.

Sugarcane farms

In the sugarcane farms the Eurasian bee eater was the most abundant while the red eyed dove was the least abundant (Figure 4.3).

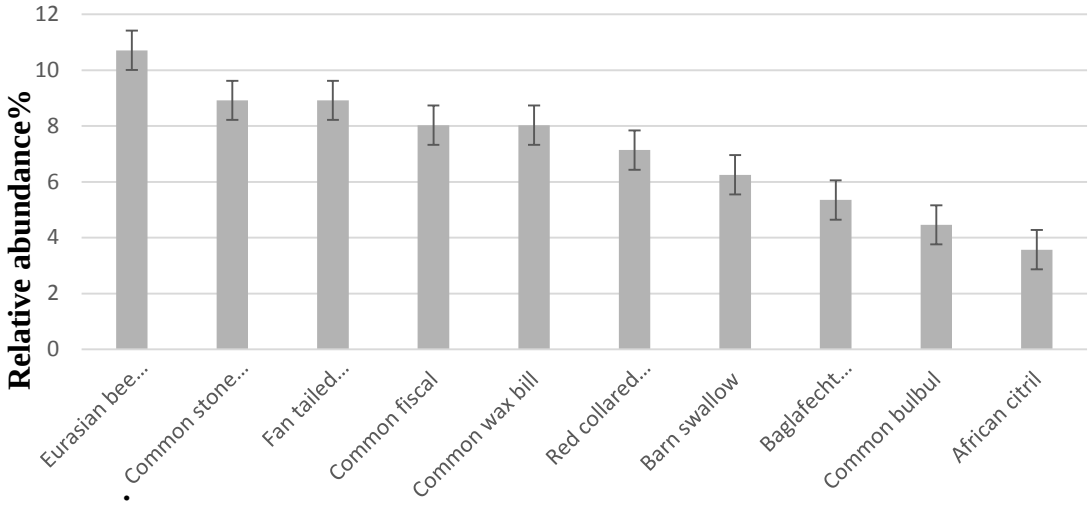

Figure 4.3: Graph showing ten most abundant birds in sugarcane farms

Tea farms;

In the tea farms the Eurasian bee eater is the most abundant with the yellow fronted canary being the least abundant (Figure 4.4).

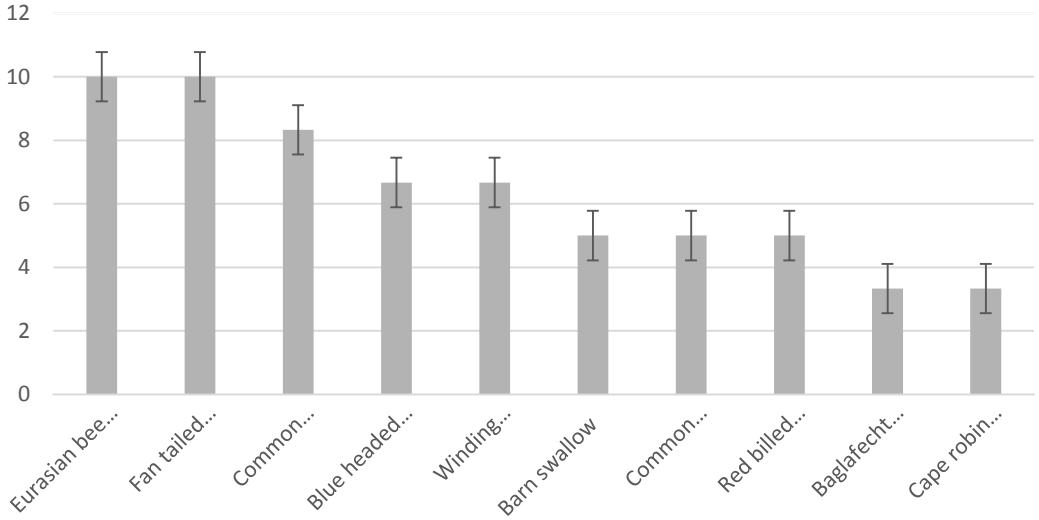

Figure 4.4: Graph showing ten most abundant birds in tea farms.

Indigenous forest

In the indigenous forest the Spot flanked barbet is the most abundant with the Yellow white eye, Cape robin chat, Tambourine dove, Red billed ox pecker, Fan tailed widow bird, Common Drongo, Black cap, were least abundant. (Figure 4.5)

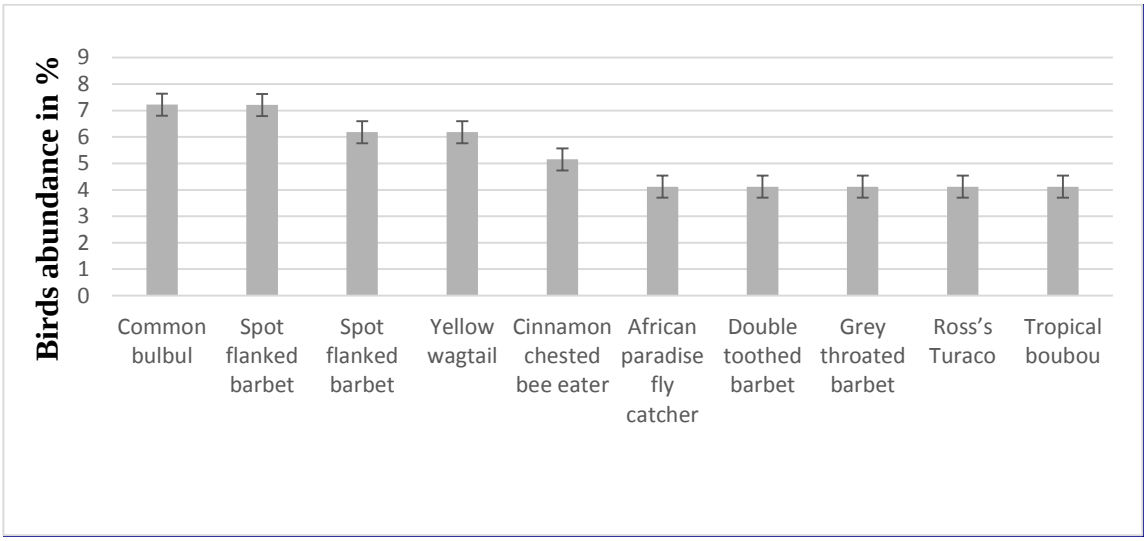

Figure 4.5: Graph showing ten most abundant birds in the indigenous forest.

4.2 Bird's Species Diversity

For the three habitats, H varied from 2.4605 to 3.944. Shannon diversity index was greater in forested areas (H=3.944) than in tea and sugarcane farm areas which had a diversity index of (2.6235 and 2.4605) respectively. Forested area was significantly more diverse, displayed by high numbers of species observed compared to both tea and sugarcane plantations.

There was a significant difference in bird species diversity in the three habitats (ANOVA; df_1 =2, df_2=0.0 F=0.00001, P=0.00001). A further post hoc Turkey's pairwise comparison test showed that the indigenous forest significantly differed from tea and sugarcane farmlands both having lower birds' diversity as compared to the indigenous forest. (Figure 4.6)

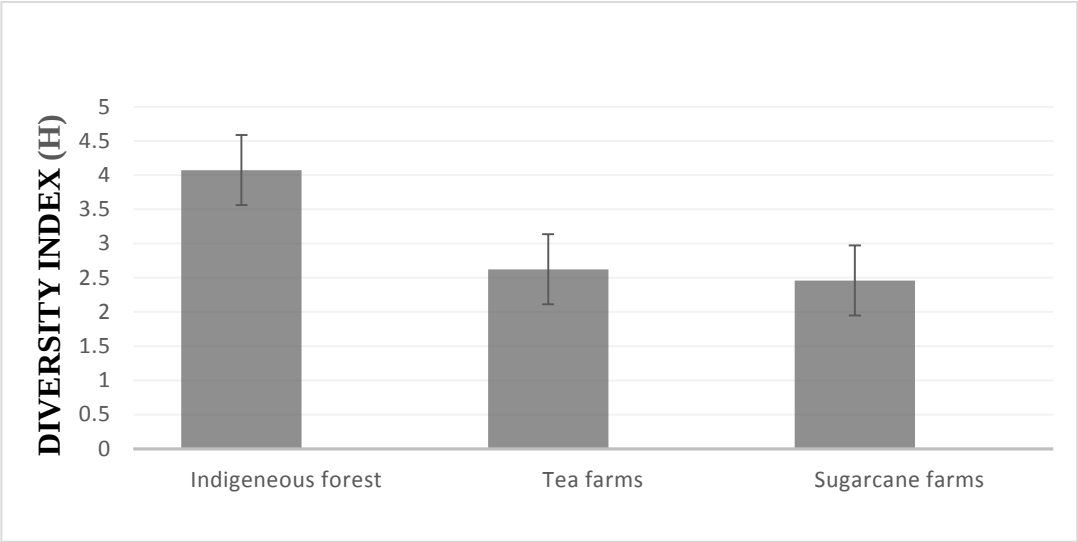

Figure 4.6: Species Diversity of birds across the habitats

From the above diversity index it is clear that indigenous forest had the highest diversity as compared to the cultivated areas.

4.3 Species Distribution across the Three Habitats

Evenness was seen to be greater in forested area than both tea and sugarcane farm. For the three habitats, evenness values are relatively very high (Table 7) on a scale of zero to one, this is significant because it indicates that the three sites vary in term of how the birds are distributed with maximum evenness at forested area as compared to tea and sugarcane farms. Indigenous forest had high bird species variability as compared to low bird species variability in farmlands 4

4.4 Bird Species Richness per Habitat.

Species richness is the number of species present in an area. Bird species richness, were summarized and compared among the three habitats (forested area, tea farms and sugarcane farms). Bird's species richness was calculated by using birds' recorded by TSC.A total of 856 individual birds of 127 species were cumulatively recorded in the three habitats using TSC's, out of these, 105 species were recorded in the indigenous forests,

64 in tea farms and 49 species were recorded in the sugarcane farms. Of the 127 species recorded, 29 species (22.83%) were observed in at least two of the three habitats and a total 32 species (25.20%) were observed across the three sites. Forested area had the highest species richness at 105 species (83%), with a total number of 430 individual birds observed while sugarcane farms had the least number of observed species at 49 bird species. S=105, 64, 49(Table 4.7)

Table 4.7: Bird species richness and distribution in the three habitats.

Habitat	Species richness (S)	Shannon's equitability (E_H)
Sugar cane farms	49	0.6791
Tea farms	64	0.6989
Indigenous forest	105	0.8525

4.4.0 Similarity of bird species richness between different habitats using Sorenson's similarity index

Sorenson's similarity index Cs was used to compare similarity of bird species richness across the three habitats. Sugarcane farms had the highest similarity association with tea farms at 64.78% although the Cs was quite low between indigeneous forest and tea farms at 32.35%.

4.4.1 Species Discovery Curves

This simple test aimed to bring out how close the total numbers of species recorded during the study were to the potential total number of species actually in the study area. The species discovery curves of Keiyan tea farms, Keiyan sugar farms and Nakutu forested areas begun to level off on the 11th ,18th ,17th day respectively where increased searches was unlikely to record new additional species in the three fragments. (Figure 4.7).

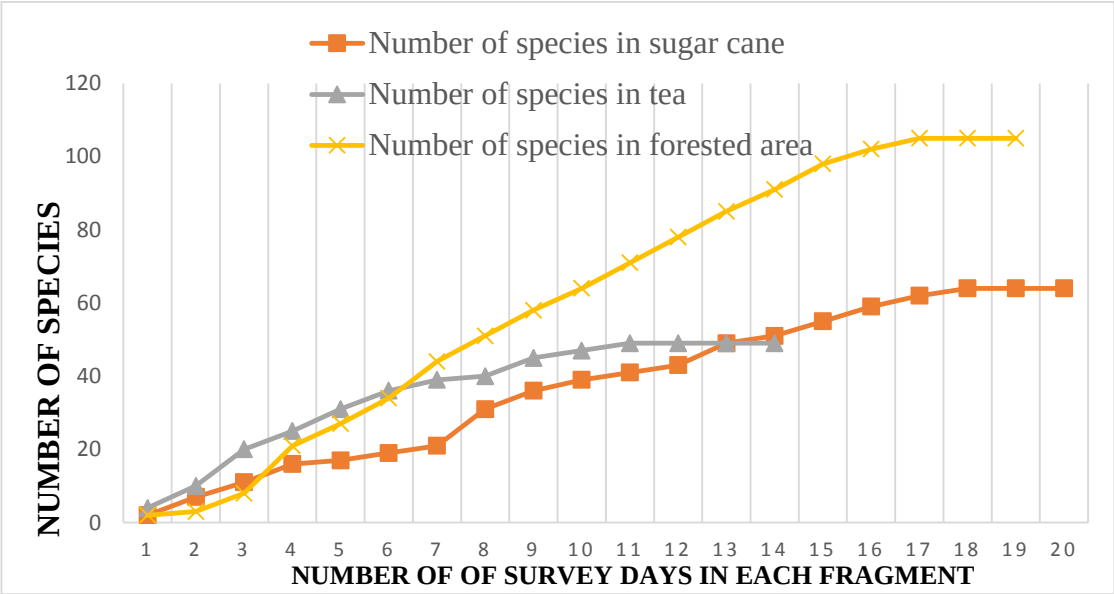

Figure 4.7: Species discovery curves of bird species in Keiyan division

4.4.2 Commonest species based on number of encounters on each habitat.

The common bulbul stood out as the top most common bird seen across the three habitats

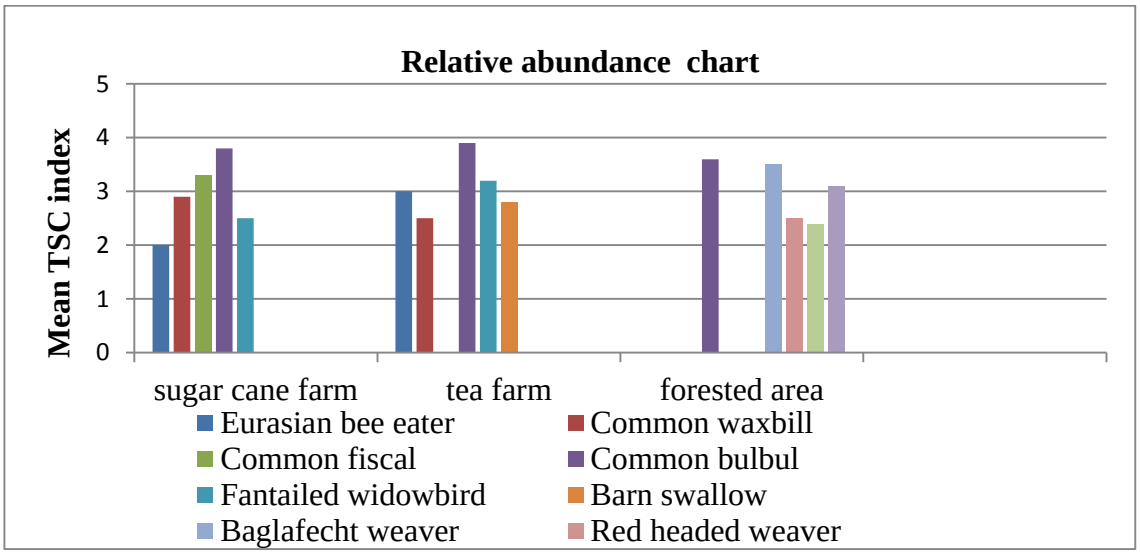

Figure 4.8: Top-5 commonest species based on mean TSC index measures (scale of 1-4)

4.5 Bird's restricted to Particular Habitats

Some bird species were only found in particular habitat during the survey (Table 4.8, 4.9, 4.10,)

Table 4.8: Birds sharing farmed and indigeneous forest habitats

Name of bird	Scientific name
Tawny flanked prinia	*Prinia subflava*
Variable sunbird	*Cinnyris venustus*
Whinchat	*Saxicola rubetra*
Purple banded sunbird	*Cinnyris bifasciatus*

Table 4.9: Birds found in indigeneous forest

Name of bird	Scientific name
Black headed apalis	*Apalis melanocephala*
Cabanis's Greenbul	*Phyllastrephus cabanisi*
Mountain wagtail	*Motacilla clara*
Red headed Malimbe	*Malimbus rubricollis*

Table 4.10: Birds found in farmed areas. (Sugarcane and Tea farms)

Name of bird	Scientific name
Barn swallow	*Hirundo rustica*
Black kite	*Milvus migrans*
Black lored babbler	*Turdoides shapei*
Black shouldered kite	*Elanus caeruleus*
Blue headed coucal	*Centropus monachus*

4.6 Bird species of interest.

Twenty five (25) of the 140 species observed in the entire study area were seen to be biome-characteristic species. In the entire study area there were 14 Afrotropical migrants (8%), 12 Palearctic migrants (7%) and the rest 116 were residents comprising (84%) of total number of species observed. (Figure 4.9)

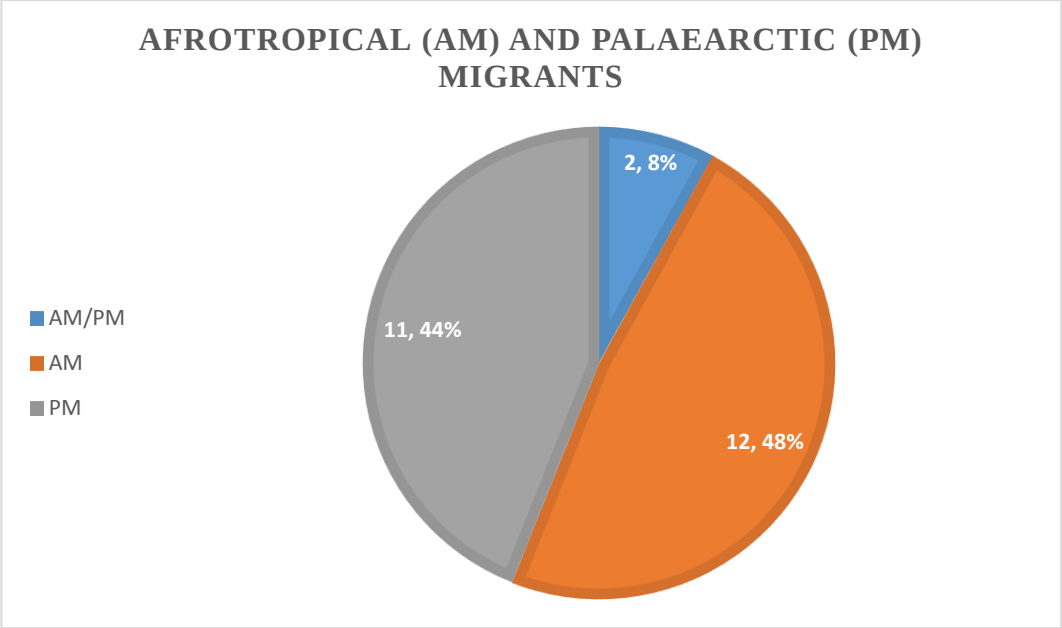

Figure 4.9: Afrotropical (AM) and Palaearctic (PM) Migrants.

(Full list in appendix 12)

4.7 Threat status of birds

Three birds categories were observed in the entire study area of which two were vulnerable that is; the Grey Crowned Crane *Balearica regulorum*, Cape wagtail *Motacilla patensis*, while one was nearly threatened that is; the Martial eagle *Polymaetus bellicossus* and Five birds were identified as endemic namely; African Citril *Crithagra citrinelloides* ,African Dusky Flycatcher *Muscicapa adusta*, Long-tailed Widow bird *Euplectes progne* ,Montane White-eye *Zosterops poliogastrus*,Speckled Mousebird *Colius striatus.*

4.8 Forest dependency

Out of 140 species recorded in all sites, 4 (3%) were forest specialists, 29(21 %) were forest generalists, 42(11 %) were forest visitors and 65(46 %) non forest bird species. The indigeneous forest had the highest numbers of forest specialists. There were more (33 species) forest species (specialist and generalists combined) recorded in indigeneous forest than tea and sugarcane farms combined where only 17 species were recorded. (Figure 4.10)

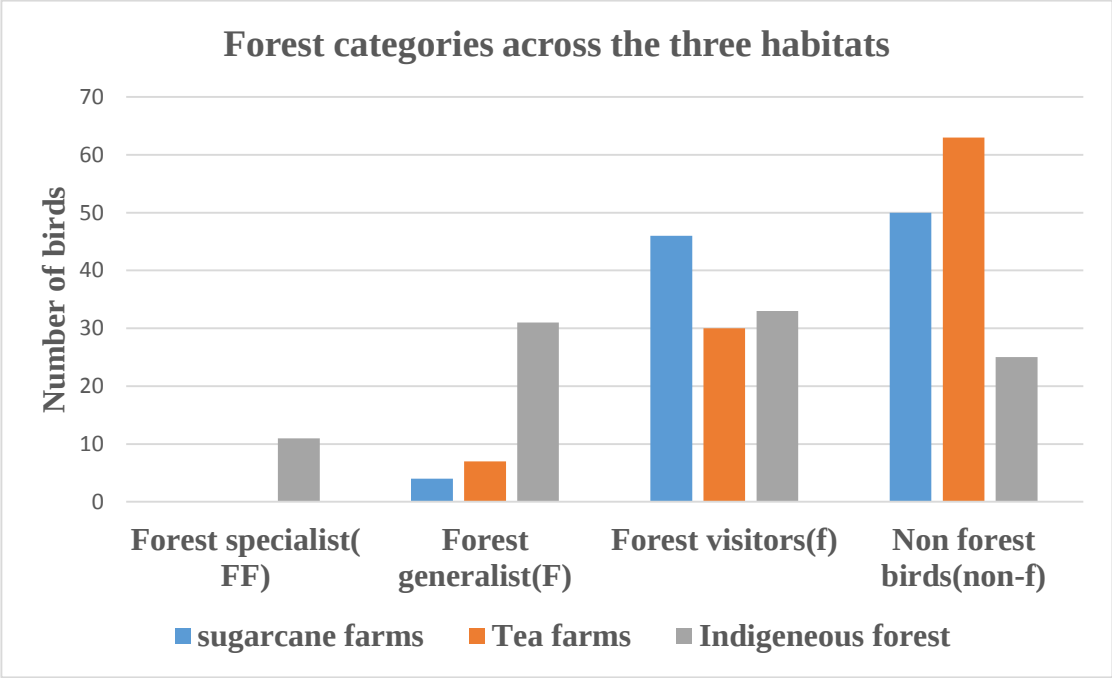

Figure 4.10: Bird forest categories

4.9 Bird Feeding Guilds Compositions4.

The three sites were rich in insectivores representing 45%, followed by Granivores (21%), Frugivore (20%), Raptors (6%), Nectarinivores (4%) molluscivores (2%), and omnivores at (1%). Generally, classification of birds into feeding guild showed that the insectivore dominated the species composition, with omnivore type bird species being the least domineering. (Table 4.11)

Table 4.11: Bird feeding guilds compositions for the three fragments

Feeding guilds	Keiyan tea farm	Keiyan sugarcane farm	Nakutu forest	TOTALS
Insectivore	29	31	50	**110**
Granivore	14	17	20	**51**
Nectarinivore	01	02	09	**12**
Omnivore	01	01	01	**03**
Frugivore	13	12	23	**48**
Raptors	03	06	07	**16**
Molluscivores	02	01	02	**05**
TOTALS	**63**	**70**	**112**	**245**

4.9.1 Chapter Summary

This chapter presents results on birds' abundance, diversity, distribution, richness, species of interest, threats facing various birds, forest dependency on the various categories of birds and feeding guilds observed in the entire study area.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter contains synthesis of the results. It presents summary of the entire work covered during the entire study, discussions on the results, conclusions from the results obtained and gives possible recommendations to mitigate against avian diversity loss due to habitat destruction as observed in the study areas.

5.2 Summary

A study on effects of farming activities on bird diversity and abundance was conducted in various habitats in Trans Mara sub county kenya in August 2014 to January 2015. The study Hypotheses were; Bird's abundance is the same in cultivated and natural forest habitats in Trans Mara Sub County, Bird's diversity is the same in cultivated and natural forest habitats in Trans Mara Sub County. Line transect sampling, point counts, time species counts, mist netting as well as opportunistic observations were used to carry out birds census to determine their abundance and diversity in the cultivated (tea and sugarcane farms) and natural indigenous forested habitats.

This study was based on descriptive research design which included naturalistic observation and surveys. Data analysis was done using SPSS. Shannon Wiener Diversity index was used to calculate diversity and species richness in the three habitats. Sorenson diversity index was used to determine how the various habitats compared in terms of diversity and abundance. Abundance of birds was established by calculating density of birds per hectare. The indigeneous forest had the highest abundance with 2736 individuals, followed by tea farms with 721 individual and the sugarcane farms had the least abundance of 335 birds with 140 species cumulatively recorded in the three habitats. Forested area had the highest species richness at 105 species while sugarcane farms had the least number of 49 bird species. There was a significant difference in bird abundance in the three habitats (df_1=2, df_2 =199, F=7.598, P=0.001). A further posthoc Tukey's

pairwise comparison test showed that the indigenous forest significantly differed from tea and sugarcane farmlands both having lower birds' abundance as compared to the indigenous forest.

Bird's abundance was highest in the indigenous forest with a mean of 5.72±0.64 birds per hectare, followed by tea farms that had a mean of 3.95±1.23 birds per hectare and lowest abundance was experienced in the sugarcane farms with a mean of 0.91±0.15birds per hectare.Indigenous forest had the highest diversity of 3.94 while tea farms and sugarcane farms recorded relatively lower diversity of 2.62 and 2.46 respectively.

5.3 Discussions

The result of this study reveals that the forested areas and its surrounding areas are rich in terms of avifaunal diversity and abundance. It also found that the species diversity, richness, and abundance were less in cultivated areas which are close to human settlement. Three different habitats (indigenous forest, sugarcane farms and tea farms) were surveyed in Keiyan division in Trans Mara Sub County. In this study bird species richness and abundance was highest in the indigenous forest. Species discovery curves based on accumulation of new bird species in each habitat showed that additional surveys may not record new bird species in the entire study area. Insectivorous birds were the dominant guild in all habitats. Habitat destruction was the main detrimental human activity on avifaunal habitats. Re-afforestation and intensification of security patrols in indigenous forest were the most appropriate conservation measures proposed in this study.

5.3.1 Bird Species abundance

The cumulative number of birds was generally high in the forested area as compared to the tea farms and sugarcane farms. This could be as a consequence of habitat degradation in terms of nesting and foraging in the farmed areas. The plants are a source of food for the birds as they produce fruits that birds feed on, nectar for those that feed on nectar and seeds that are eaten by granivores.Besides, birds do their nests on trees to escape from bad weather. Engelen, (2012) determining bird species richness and abundance in different

forest types at Kakamega forest, western Kenya, showed the same results.The loss of habitat therefore through forest clearance and intense noise produced by farmers and farm machinery, as well as constant collection of firewood and building poles from the indigenous forest by local people could have driven many under storey birds away.

5.3.2 Bird species diversity and composition

The overall diversity of the birds was high in the indigenous forest and relatively lower in cultivated areas (tea farms and sugarcane farms), probably due to the frequency of farming activities which were taking place in the farmed areas in comparison to the forested areas. Farming activities are bound to intensify in future unless urgent measures are undertaken to control them because of high demand for construction materials for roads and houses and more land required for farming to take care of the increasing population. Similar results were obtained in Hungary (Jort verhulst *et al.*, 2013) working on relationship between land-use intensity and species richness and abundance of birds. Similar findings by F.B. Munyekenye *et al.*, (2008) & Engelen, (2012) determining bird species richness and abundance in different forest types at Kakamega forest, western Kenya, showed a similar trend.

More vegetation types and microhabitats favoured varieties of bird species in the indigenous forest as opposed to cultivated areas. The higher values in bird diversity observed in indigenous forest can be attributed to the rich vegetative under-storey (mainly composed of *Acanthus sp* and *Solanum mauritianum*) beneath the mature trees. The mid-canopy trees in these forest habitats are rich in mosses, orchids, lianas and other epiphytes which form a good habitat for the lower canopy species. A congruent study indicated similar results in Diversity and richness of bird species in newly formed habitats of Chandoli National Park in Western Ghats, Maharashtra State, India (Abdar mohan Ramchndra, 2013).This clearly indicates that habitat fragmentation and destruction is fatal to avian communities.

5.3.3 Bird species richness

Bird species richness was high in the indigenous forest as compared to the cultivated areas (tea farms and sugarcane farms). This was probably the case because of the small and undisturbed primary habitat of Nakutu and Keiyan riverine forested areas had factors which favoured the survival of birds than habitat conditions in Keiyan sugarcane farm and Keiyan tea farms. Overall, Nakutu and Keiyan riverine forested areas therefore were more important for conservation of avian biodiversity than the other farmed areas. The abundance or richness of fruiting plants, for example, is associated with the diversity of frugivorous bird species and their foraging behaviour (Moegenburg & Levey, 2003) and habitat choice (Levey, 1988). For instance, the indigenous forest had more fruiting trees than the other areas explaining why it had a large population of Turaco's where they could find food (fruits).

Since birds are relatively good indicators of ecosystems health (Furness & Greenwood, 1993), the stability in the species richness in Nakutu and Keiyan riverine forested areas probably, indicate that the habitat condition in the two sites did not undergo serious structural change. However, continuous investigations of the densities of the different specialist bird species over time should be done to monitor population fluctuations. (Leticia diaz, 2006) working on influence of forest types and forest structure on bird communities in oak and pine woodlands in Spain showed similar results as increase in niche diversity also increase avian diversity. The higher the species richness of specialist birds in a forest the healthier the habitat quality (Bennun & Howel, 2002). This is because the specialist birds require less disturbed habitat section for their survival. For instance, the Red headed Malimbe (*Malimbus rubricollis)* was only recorded in the indigenous forest as a forest specialist.

5.3.4 Bird species of interest

Twenty five (25) of the 140 species observed in the entire study area were seen to be biome-characteristic species. In the entire study area there were 14 Afro tropical migrants (8%), 12 Palearctic migrants (7%) and the rest 116 were Residents comprising (84%) of

total number of species observed. The Grey crowned cranes *(Balearica regulorum)*, Cape wagtail *(Motacilla capensis)*, were recorded as globally vulnerable birds while the Martial eagle *(Polemaetus bellicosus)* were recorded as globally nearly threatened in the study area.

This study commenced in late July 2014 and ended in January 2015; a good time to coincide to the time Afro-tropical migrants species are recorded in Kenya which is normally the period between April-October annually (Zimmerman, *et al*., 1996). Other regionally endemic bird species recorded in this survey were; African Citril *Crithagra citrinelloides*, African Dusky Flycatcher *Indicator minor* Long-tailed Widow bird *Euplectes progne*, Montane White-eye *Zosterops poliogastrus and* Speckled Mouse bird *Colius striatus*. Additional bird species can be recorded in the study area using long term surveys which combine different methods in different seasons both day and night (Bibby *et al*., 1998).

5.3.5 Forest dependency categories

The indigeneous forest had the highest numbers of forest specialists. Forest specialists are true forest birds which are characteristic of the interior less-disturbed forest, rarely occurring in non-forest habitat, where they breed (Bennun and Howell, 2002) therefore the indigeneous Forest has a relatively good habitat conditions with low human habitat disturbance. Overally, non forest birds and forest visitors dominated the entire study area, this could be as a consequence of habitat degradation that was driving many birds that depend entirely on the forest for their livelihood.

5.3.6 Bird feeding guilds and distribution

The three sites were rich in insectivores representing 45%, followed by Granivores (21%), Frugivore (20%), Raptors (6%), Nectarinivores (4%) molluscivores (2%), and omnivores at (1%). Generally, classification of birds into feeding guild showed that the insectivore dominated the species composition, with omnivore type bird species being the least domineering. In terms of feeding guilds compositions; insectivores (feeding on insects

and all other invertebrates by sallying, back gleaning etc.) were the most abundant in all the three study areas. (Blake and Loiselle 2001, noted that insectivores are often the most species rich and abundant guild in tropical forests and display considerable variation in feeding behavior.

The abundance of some bird feeding guilds may determine the levels of habitat degradation in a forest. For example, insectivores declined after forest disturbance Gray *et al.*, (2007). The structural complexity and light regime of the habitat which undergoes considerable change following disturbance, may have important consequences for the search patterns of insectivores (Barlow *et al*., 2002) or different groups of insectivores, such as bark gleaners or dead-leaf probers (Rosenberg, 1993). Therefore, habitat disturbance and fragmentation in Keiyan tea and Keiyan sugarcane farms might have led to the decline in abundances of insectivores in these areas. The raptors, frugivores, granivores, nectarinivores and omnivores were represented by few species in the forest and it was difficult to detect a particular pattern. Analysis by Gray, *et al*., (2007) of feeding guilds composition following habitat disturbance indicated that responses of raptors, nectarinivores, and omnivores were less clear. However, Gray, *et al*., (2007), noted that differential responses of some guilds suggested that habitat disturbance affects trophic organization and thus ecosystem functioning.

Additionally, Terborgh *et al*., (1990) and Sodhi *et al*., (2004) have noted that some tropical birds do not range widely, do not disperse far from their natal territory and avoid unsuitable habitat due to physical or behavioural limits. Overally from this study insectivores had a significant difference as the highest proportion across the three habitats with frugivores, granivores, omnivores, nectarivores and raptors showing similar trend in the indigeneous forest. Similar findings by F.B. Munyekenye *et al.*, (2008) and Engelen, (2012) detemining bird species richnesss and abundance in different forest types at Kakamega forest, western Kenya, showed similarity in that the proportion of the guilds observed in different habitats was similar, hence these habitat can support bird species from different guilds.

When the guilds are compared separately in various habitats frugivorous birds had a high proportion in Indigenous forest, this may be attributed to the presence of fruiting trees such as *Ficus thoningii*, *Tabernaemontana stapfiana* among others which produce fruits at the onset of wet season attracting birds such as Double-toothed Barbet *Lybius bidentatus* and Ross's Turaco *Musophaga rossae* to forage. Granivores had a high proportion in Farmlands. High species numbers of granivores in farmlands is likely related to dominance of wild and cultivated grasses (Waltert *et al*., 2005). Nectarivores had almost similar proportion in all the habitats, they are also found in farmlands. Many forest related nectarivores are difficult to detect in the forest canopy due to their small size and thin vocalizations (Waltert *et al*., 2005) and this may have been the reason for low observations in Indigenous forest. Raptors and Omnivores had least proportions across in all habitats and this may be due to changes in bird distributions because of breeding requirements and food availability and this makes classifications more variable (Engelen, 2012) especially in omnivorous birds.

Studies from Asia and the Neotropics on tropical birds specifically by (Gray *et al.*, 2007) found that birds from different feeding guilds respond differently to forest disturbance. Whereas granivorous species increase significantly after disturbance, the abundance of frugivores and insectivores significantly decreased. Declines in the numbers of omnivores, carnivores and nectarivores were also observed, though less outspoken because of regional differences. In another study based on global data (Tscharntke *et al.*, 2008) found similar results for granivores and insectivores, but instead noticed an increase in (small) frugivores and nectarivores with the conversion of forests to agricultural plantations (until a point when disturbance was so severe that also these groups declined). Overall the increase of granivores and the decline of insectivores and large frugivores with forest modification are most strongly supported (Sodhi *et al.*, 2008). The negative impact on insectivores does, however, differ among the various sub-guilds (Dale *et al.*, 2000) and seems most outspoken for species of the understory and large insectivores in general. Birds of the under-storey are thought to be so sensitive to disturbance because of their inability to disperse in a non-forest matrix .Newmark, (1991) and Şekercioğlu *et al.*, (2002).Other studies on birds of East African montane forests from Kenya (Borghesio,

2008; Laube *et al.*, 2008; Mulwa *et al.*, 2012), Uganda (Şekercioğlu, 2002; Naidoo, 2004) and Tanzania (Fjeldså, 1999) also documented a decrease in forest specialists and an increase in overall species numbers with forest disturbance or conversion. The few studies discussing bird functional diversity do, however, note a decline in (several groups of) insectivores Fjeldså, (1999), Şekercioğlu, (2002) and *Mulwa et al.*, (2012) and sometimes also frugivores Borghesio, (2008) and Kirika *et al.*, **(**2008).

5.3.7 Effects of human activities on birds and their habitats

Habitat destruction, cash crop plantation farming and subsistence farming, and hunting of birds were the main human activities directly affecting avian diversity the entire study area. Clearing of the forests for farming by community members bordering the forest affects birds dependent on forests for nesting and foraging such as the Hadada Ibis, Hamerkop and Grey Crowned Crane. Human activities with the greatest impact on the forested habitat were timber extraction, logging, firewood collection and charcoal burning. The most adversely affected habitat by these activities was indigenous forest.

Unemployment of the middle aged people is a significant factor that drives them to exploit the cheaply accessible resources in the forest such as firewood, logging of timber for fencing and construction and grazing of domestic animals in the indigeneous forest. Grazing by cattle in the indigenous forest has led to further opening up of undergrowth vegetation and thickets significantly affecting under-storey and skulking bird species.

5.3.8 Appropriate conservation strategies of birds and their habitats

The main conservation strategies to mitigate detrimental human activities on forest habitats and birds in Trans Mara sub county based on this study was to intensify security patrols in indigenous forest in order to allow regeneration of trees and provide a more suitable habitat for the birds. In farmed areas re-afforestation of open patches using indigenous tree seedlings was identified as a key conservation strategy, this will create more bird nesting sites and food.

5.4 Conclusion

The three study areas are very important sites for avifaunal conservation. Keiyan riverside forest and Nakutu forest were more important for avian conservation because they were richer in forest Specialist, generalist, under storey and globally threatened birds. Keiyan sugarcane farms, Keiyan tea farms were less rich in under storey species. These results indicate that farming and its associated activities are negatively impacting on the diversity and abundance of birds in Trans Mara Sub County. Besides, demand for forest products by local people to meet different household and commercial needs is increasing as the population continue to increase, leading to serious habitat degradation. Trans Mara Sub County is a habitat hosting a high diversity of bird life, which is threatened by impending agricultural intensification. Studies relating to the conservation of wildlife on farmland need to receive higher priority and more resources as farmland area increases in developing countries. Ecologists, social scientists and economists need to cooperate in order to limit the potential effects of farmland expansion and intensification, which include a loss of natural habitat for exploitation, a loss of biodiversity, desertification and the resultant social and ecological upheaval. These challenges will increase in importance as the effects of global warming start to take effect. Studies such as this one will hopefully prove useful in the attempts to develop Kenya more sustainably in the future.

Overall, forest habitat in Trans Mara Sub County is on a declining trend, a situation which could lead to dramatic loss of birds and other existing biodiversity in the near future if not urgently addressed. The study results indicate that further fragmentation and size reduction of forested habitats may result in reduced richness and abundance of bird species in this ecosystem. This emphasizes the need for a management strategy that prevents further fragmentation and size reduction of the natural forests in Trans Mara Sub County. To assist management and preservation of biodiversity of bird species in the area, more research is needed, monitoring bird's populations to ensure they remain extant.

5.5 Recommendations

Trans Mara Forested areas are facing enormous conservation challenges which require urgent attention in order to secure the future of existing biodiversity. The following interventions are proposed;

1. Improved collaboration among the council of elders, Kenya Forest Service, local County administration and National Museums of Kenya to initiate an effective community participatory forest conservation in the forested areas of Trans Mara Sub County.
2. Strengthen the capacity of the local people to actively participate in addressing Environmental problems in and outside the forests through formation of Community Based Organisations (CBOs).
3. Mobilise members of community living around the forests to replant degraded areas with indigenous trees.
4. More extension services on agricultural and forestry issues are needed to increase food productivity and maximisation of yields and reduce pressure on extraction of forests products for sale.
5. Improved enforcement of different legislation on environment such as Forests Act 2005, Government Lands Act (Cap. 280), the Water Act (Cap. 372), Wildlife Conservation and Management Act (as amended in 1989) and Environmental Management and Co-ordination Act (EMCA) 1999 among others by various government institutions in order to save the remaining forests.
6. In the farmland habitat farmers should be encouraged to practice more agro-forestry farming with the focus of planting indigenous trees such as *Croton megalocarpus*, *Bersama abyssinica* and *Syzygium guineense* which provide good habitats for avifauna and will suffice their need for firewood, building and fencing poles hence reduce pressure on forest resources.
7. Community patrols on forested areas to curb deforestation and charcoal burning.

ADDITIONAL RESEARCH

Further research is required to provide missing scientific information to enhance effective conservation of the forest habitats and existing biodiversity as well addressing the welfare of the local people living adjacent to these fragments which includes

a) Determine the amount of poles, timber, and fuel wood extracted from these sites in order to understand the rate at which the forests are getting depleted for local and commercial uses.
b) Produce an updated checklist of other taxonomic groups such as mammals, reptiles, amphibians and invertebrates, and determine whether the forests hold endemics Populations or globally threatened species.
c) Investigate and advice about alternative sources of energy and building materials for household (e.g. solar or energy saving Jikos etc.) use to reduce dependence on extraction of forest products.

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APPENDICES

Appendix 1: List of bird species recorded in the three sites (see legend for initials used)

List of Bird Species	Scientific name	Habitat	Fragment
African blue fly catcher	*Elminia longicauda*	P,CA	NF
African citril	*Crithagra citrinelloides*	P,CA	KT,KS,NF
African dusk fly catcher	*Muscicapa adusta*	P	NF
African goshawk	*Accipiter tachiro*	P	NF
African green pigeon	*Treron calvus*	P,CA	NF, KT
African harrier hawk	*Polyboroides typus*	CA	KT
African paradise fly catcher	*Terpsiphone viridis*	P,CA	NF
African pied wagtail	*Motacilla aguimp*	P,CA	KT,KS,NF
African pygmy kingfisher	*Ceyx pictus*	P	NF
African thrush	*Turdus pelios*	P	NF
African Yellow white eye	*Zosterops senegalensis*	P	NF
Amethyst sunbird	*Chalcomitra amethystina*	CA	KS
Augur buzzard	*Buteo augur*	P,CA	KT,KS,NF
Baglafecht weaver	*Ploceus baglafecht*	P,CA	KT,KS,NF
Barn swallow	*Hirundo rustica*	P,CA	KT,KS,NF
Black and white casqued hornbill	*Bycanistes subcylindricus*	CA	KT
Black billed barbet	*Lubius guifsobarito*	CA	KS
Black cap	*Sylivia atricapilla*	P,CA	KS,NF
Black crowned tchagra	*Tchagra senegala*	P,CA	KS,NF
Black crowned waxbill	*Estrilda nonnula*	CA	KS
Black cuckoo shrike	*Campephaga flava*	P	NF
Black headed apalis	*Apalis melanocephala*	CA	KT

Black headed heron	*Ardea melanocephala*	P,CA	NF,KS
Black headed oriole	*Oriolus larvatus*	P,CA	KT,KS,NF
Black headed weaver	*Ploceus cucullatus*	P,CA	KT,KS,NF
Black kite	*Milvus migrans*	P,CA	KT,KS,NF
Black lored babbler	*Turdoides shapei*	P,CA	KT ,NF
Black shouldered kite	*Elanus caeruleus*	CA	KT
Black throated wattle eye	*Platysteira peltata*	P	NF
Black-headed Batis	*Batis minor*	P	NF
Blue headed coucal	*Centropus monachus*	P,CA	KT,KS,NF
Blue spotted wood dove	*Turtur afer*	P,CA	KT,KS,NF
Bronze mannikins	*spermestes cucullatus*	P,CA	KT,KS,NF
Bronze sunbird	*Nectarinia kilimensis*	P,CA	KT,KS,NF
Brown headed apalis	*Apalis alticola*	CA	KT
Brown headed parrot	*Poicephalus cryptoxanthus*	P,CA	KS,NF
Cabanis's Greenbul	*Phyllastrephus cabanisi*	CA	KS
Cape robin Chat	*Cossypha caffra*	P,CA	KT,KS,NF
Cape wagtail	*Motacilla capensis*	P	NF
Cattle egret	*Bulbulcus ibis*	P,CA	NF,KS
Cinnamon chested bee eater	*Merops oreobates*	P	NF
Collared sunbird	*Hedydipna collaris*	P	NF
Common bulbul	*Pycnonotus barbatus*	P,CA	KT,KS,NF
Common Drongo	*Dicrurus adsimilis*	P	NF
Common fiscal	*Lanius collaris*	P,CA	KT,KS,NF
Common stone chat	*Saxicola torquatus*	P,CA	KT,KS,NF
Common wattle eye	*Platysteira cyanea*	P	NF
Common wax bill	*Estrilda astrild*	P,CA	KT,KS,NF
Compact weaver	*Ploceus superciliosus*	P,CA	KT,KS,NF
Copper sunbird	*Cinnyris cupreus*	P	NF
Double toothed barbet	*Lybius bidentatus*	P	NF

Eastern grey plantain eater	*Crinifer zonurus*	CA	KT
Eastern pale chanting goshawk	*Melierax poliopterus*	P,CA	NF,KS
Emerald spotted wood dove	*Turtur chalcospilos*	P,CA	KT,KS,NF
Eurasian bee eater	*Merops apiaster*	P,CA	KT,KS,NF
Fantailed widow bird	*Euplectes axillaris*	P,CA	KT,KS,NF
Golden breasted bunting	*Emberiza flaviventris*	P,CA	NF,KS
Great sparrow hawk	*Accipiter melanoleucus*	P,CA	NF,KT,KS
Greater blue eared sterling	*Lamprotornis chalybaeus*	P	NF
Green headed sun bird	*Cyanomitra verticalis*	P	NF
Grey backed camaroptera	*Camaroptera brevicaudata*	CA	KT,KS
Grey capped social weaver	*Pseudonegrida arnaudi*	P	NF
Grey capped warbler	*Eminia lepida*	CA	KT,KS
Grey crowned cranes	*Balearica regulorum*	P,CA	KT,KS,NF
Grey headed sparrow	*Passer griseus*	P,CA	NF.KT
Grey throated barbet	*Gymnobucco bonabartei*	P	NF
Grey wagtail	*Motacilla cinerea*	P,CA	NF.KT
Hadada ibis	*Bostrichia hagedash*	P,CA	KT,KS,NF
Harlequin quail	*Coturnix delegorguei*	P,CA	KT,KS,NF
Helmeted guinea fowl	*Numida meleagris*	P,CA	KS,NF
Hilderbrandt's francolin	*Francolinus hilderbrandti*	P	NF
Holubs golden weaver	*Ploceus xanthops*	P	NF
Jacksons golden backed weaver bird	*Ploceus jacksoni*	P,CA	KS,NF
Joyful Greenbul	*Chlorocichla laetissima*	P	NF
Klaas's Cuckoo	*Chrisococcx klaas*	P	NF

Little Greenbul	*Andropadus virens*	P	NF
Little swift	*Apus affinis*	P,CA	NF,KT
Long crested eagle	*Lophaetus occipitalis*	P,CA	NF,KS
Long tailed cisticola	*Cisticola angusticauda*	CA	KT
Marsh tchagrah	*Tchagra minutus*	CA	KS
Martial eagle	*Polemaetus bellicosus*	CA	KS
Montane white eye	*Zosterops poliogastrus*	P	NF
Mountain wagtail	*Motacilla clara*	P	NF
Namaqua doves	*Oena capensis*	CA	KT
Northern ant eater chat	*Myrmecocichla aethiops*	P,CA	NF.KS
Northern double collared sunbird	*Cinnyris reichenowi*	P	NF
Nothern wheat ear	*Oenanthe oenanthe*	CA	KT,KS
Olive bellied sunbird	*Cyanomitra chrolopygius*	P	NF
Pied crow	*Corvus albus*	P,CA	KT,KS,NF
Pied wheatear	*Oenanthe pleschanka*	CA	KT
Pin-tailed whydah	*Vidua macroura*	P,CA	NF,KT
Purple banded sunbird	*Cinnyris bifasciatus*	P	NF
Purple grenadier	*Granatina ianthinogaster*	P,CA	KT,KS,NF
Rattling cisticola	*Cisticola chiniana*	CA	KT
Red billed fire finch	*Lagonosticta senegala*	P,CA	KT,KS,NF
Red billed ox pecker	*Buphagus erhythrorynchus*	P	NF
Red capped robin chat	Cossypha natalensis	P	NF
Red collared widow bird	*Euplectes ardens*	CA	KT
Red eyed dove	*Streptopelia semitorquata*	P,CA	KT,KS,NF
Red faced cisticola	*Cisticola erythrops*	CA	KS,KT

Red fronted tinker bird	*Tricholaema diademata*	P	NF
Red headed malimbe	*Malimbus rubricollis*	P	NF
Red headed weaver	*Anapalectes melanotis*	P,CA	KT,KS,NF
Red shouldered cuckoo shrike	*Campephaga flava*	P	NF
Ring necked dove	*Streptopelia capicola*	P,CA	KT,KS,NF
Ross' s Turaco	*Musophaga rossae*	P	NF
Rosy breasted Longclaw	*Macronyx ameliae*	CA	KT
Scarce swift	*Schoutenapus myoptilus*	P,CA	KT,KS,NF
Singing cisticola	*Cisticola cantans*	CA	KT
Sooty chat	*Myrmecocichla nigra*	P,CA	KT,KS,NF
Southern black fly catcher	*Melaenornis pammellaina*	P	NF
Southern ground hornbill	*Burcovus abyssinicus*	P,CA	NF,KS
Speckled Mouse bird	*Colius striatus*	P,CA	KT,KS,NF
Spectacled weaver bird	*Ploceus ocularis*	P	NF
Speke's weaver	*Ploceus spekei*	CA	KS,KT
Spot flanked barbet	*Tricholaema lacrymosa*	P,CA	NF,KS
Spotted fly catcher	*Muscicapa striata*	P	NF
Streaky seed eater	*Crithagra striolata*	P,CA	KT,KS,NF
Tambourine dove	*Turtur tympanistria*	P,CA	NF,KT
Tawny flanked prinia	*Prinia subflava*	P,CA	KT,KS,NF
Tropical boubou	*Laniarius aethiopicus*	P,CA	KT,KS,NF
Variable sunbird	*Cinnyris venustus*	P	NF
Village weaver	*Ploceus cucullatus*	P	NF
Whin chat	*Saxicola rubetra*	P,CA	KT,KS,NF
White browed coucal	*Centropus superciliosus*	P,CA	KT,KS,NF
White browed robin Chat	*Cossypha heuglini*	CA	NF,KT
White browed scrub robin Chat	*Cercotrichas leucophris*	CA	KT

White eyed slaty fly catcher	*Melaenornis fischeri*	P,CA	KT,KS,NF
White rumped swift	*Apus caffer*	CA	KT
White throated bee eater	*Merops albicollis*	P,CA	NF,KS,KT
White wagtail	*Motacilla alba*	CA	KT
Winding cisticola	*Cisticola galactotes*	CA	KS
Woodland kingfisher	*Halycyon senegalensis*	P	NF
Yellow backed weaver	*Ploceus melanocephalus*	CA	KT
Yellow fronted canary	*Serinus mozambicus*	P,CA	NF,KS
Yellow rumped tinker bird	*Pogonialus bilineatus*	P	NF
Yellow throated leaflove	*Chlorocichla flavicollis*	P	NF
Yellow throated longclaw	*Macronyx croceus*	CA	KS
Yellow wagtail	*Motacilla flava*	P,CA	NF,KS
Yellow whiskered Greenbul	*Andropardus latirostris*	P,CA	NF,KS

Legend: KT-Keiyan tea farm, **KS**-Keiyan sugarcane farm, **NF-** Nakutu Forest **P**-Primary habitat, **CA-** cultivated areas.

Appendix 2: Bird species recorded in the three study areas showing forest category (see legend for initials used).

List of Bird Species	Scientific name	Forest category
African blue fly catcher	*Elminia longicauda*	f
African citril	*Crithagra citrinelloides*	f
African dusk fly catcher	*Muscicapa adusta*	F
African goshawk	*Accipiter tachiro*	Non f
African green pigeon	*Treron calvus*	F
African harrier hawk	*Polyboroides typus*	f
African paradise fly catcher	*Terpsiphone viridis*	f
African pied wagtail	*Motacilla aguimp*	Non F
African pygmy kingfisher	*Ceyx pictus*	f
African thrush	*Turdus pelios*	f
African Yellow white eye	*Zosterops senegalensis*	f
Amethyst sunbird	*Chalcomitra amethystina*	f
Augur buzzard	*Buteo augur*	Non f
Baglafecht weaver	*Ploceus baglafecht*	f
Barn swallow	*Hirundo rustica*	Non f
Black and white casqued hornbill	*Bycanistes subcylindricus*	F
Black billed barbet	*Lubius guifsobarito*	f
Black cap	*Sylivia atricapilla*	F
Black crowned tchagra	*Tchagra senegala*	Non f
Black crowned waxbill	*Estrilda nonnula*	Non f
Black cuckoo shrike	*Campephaga flava*	f
Black headed apalis	*Apalis melanocephala*	FF
Black headed heron	*Ardea melanocephala*	Non f
Black headed oriole	*Oriolus larvatus*	f

Black headed weaver	*Ploceus cucullatus*	F
Black kite	*Milvus migrans*	Non f
Black lored babbler	*Turdoides shapei*	Non f
Black shouldered kite	*Elanus caeruleus*	Non f
Black throated wattle eye	*Platysteira peltata*	F
Black-headed Batis	*Batis minor*	Non f
Blue headed coucal	*Centropus monachus*	Non f
Blue spotted wood dove	*Turtur afer*	f
Bronze mannikins	*spermestes cucullatus*	Non f
Bronze sunbird	*Nectarinia kilimensis*	f
Brown headed apalis	*Apalis alticola*	F
Brown headed parrot	*Poicephalus cryptoxanthus*	F
Cabanis's Greenbul	*Phyllastrephus cabanisi*	FF
Cape robin chat	*Cossypha caffra*	f
Cape wagtail	*Motacilla capensis*	Non f
Cattle egret	*Bulbulcus ibis*	Non f
Cinnamon chested bee eater	*Merops oreobates*	F
Collared sunbird	*Hedydipna collaris*	F
Common bulbul	*Pycnonotus barbatus*	f
Common Drongo	*Dicrurus adsimilis*	Non F
Common fiscal	*Lanius collaris*	Non F
Common stonechat	*Saxicola torquatus*	Non F
Common wattle eye	*Platysteira cyanea*	f
Common wax bill	*Estrilda astrild*	Non F
Compact weaver	*Ploceus superciliosus*	f
Copper sunbird	*Cinnyris cupreus*	f
Double toothed barbet	*Lybius bidentatus*	f
Eastern grey plantain eater	*Crinifer zonurus*	Non f
Eastern pale chanting goshawk	*Melierax poliopterus*	Non f

Emerald spotted wood dove	*Turtur chalcospilos*	f
Eurasian bee eater	*Merops apiaster*	f
Fantailed widow bird	*Euplectes axillaris*	Non f
Golden breasted bunting	*Emberiza flaviventris*	Non f
Great sparrow hawk	*Accipiter melanoleucus*	F
Greater blue eared sterling	*Lamprotornis chalybaeus*	Non f
Green headed sunbird	*Cyanomitra verticalis*	F
Grey backed Camaroptera	*Camaroptera brevicaudata*	F
Grey capped social weaver	*Pseudonegrida arnaudi*	Non f
Grey capped warbler	*Eminia lepida*	f
Grey crowned cranes	*Balearica regulorum*	Non f
Grey headed sparrow	*Passer griseus*	Non f
Grey throated barbet	*Gymnobucco bonabartei*	F
Grey wagtail	*Motacilla cinerea*	F
Hadada ibis	*Bostrichia hagedash*	Non f
Harlequin quail	*Coturnix delegorguei*	Non f
Helmeted guinea fowl	*Numida meleagris*	Non f
Hilderbrandt's francolin	*Francolinus hilderbrandti*	f
Holubs golden weaver	*Ploceus xanthops*	Non f
Jacksons golden backed weaver bird	*Ploceus jacksoni*	Non f
Joyful Greenbul	*Chlorocichla laetissima*	F
Klaas's Cuckoo	*Chrisococcx klaas*	f
Little Greenbul	*Andropadus virens*	F
Little swift	*Apus affinis*	Non f
Long crested eagle	*Lophaetus occipitalis*	f
Long tailed cisticola	*Cisticola angusticauda*	Non f
Marsh tchagrah	*Tchagra minutus*	F

Martial eagle	*Polemaetus bellicosus*	Non f
Montane white eye	*Zosterops poliogastrus*	F
Mountain wagtail	*Motacilla clara*	FF
Namaqua doves	*Oena capensis*	Non f
Northern ant eater chat	*Myrmecocichla aethiops*	Non f
Northern double collared sun bird	*Cinnyris reichenowi*	F
Northern wheat ear	*Oenanthe oenanthe*	Non f
Olive bellied sunbird	*Cyanomitra chrolopygius*	F
Pied crow	*Corvus albus*	Non f
Pied wheatear	*Oenanthe pleschanka*	Non f
Pin-tailed whydah	*Vidua macroura*	Non f
Purple banded sunbird	*Cinnyris bifasciatus*	f
Purple grenadier	*Granatina ianthinogaster*	Non f
Rattling cisticola	*Cisticola chiniana*	Non f
Red billed fire finch	*Lagonosticta senegala*	Non f
Red billed ox pecker	*Buphagus erhythrorynchus*	Non f
Red collared widow bird	*Euplectes ardens*	Non f
Red eyed dove	*Streptopelia semitorquata*	f
Red faced cisticola	*Cisticola erythrops*	Non f
Red fronted tinkerbird	*Tricholaema diademata*	f
Red headed malimbe	*Malimbus rubricollis*	FF
Red headed weaver	*Anapalectes melanotis*	f
Red shouldered cuckoo shrike	*Campephaga flava*	f
Ring necked dove	*Streptopelia capicola*	f
Ross' s Turaco	*Musophaga rossae*	F
Rosy breasted longclaw	*Macronyx ameliae*	Non f
Scarce swift	*Schoutenapus myoptilus*	Non f
Singing cisticola	*Cisticola cantans*	Non f
Sooty chat	*Myrmecocichla nigra*	F

Southern black fly catcher	*Melaenornis pammellaina*	F
Southern ground hornbill	*Burcovus abyssinicus*	Non f
Speckled mouse bird	*Colius striatus*	Non f
Spectacled weaver bird	*Ploceus ocularis*	F
Speke's weaver	*Ploceus spekei*	f
Spot flanked barbet	*Tricholaema lacrymosa*	Non f
Spotted fly catcher	*Muscicapa striata*	f
Streaky seed eater	*Crithagra striolata*	f
Tambourine dove	*Turtur tympanistria*	F
Tawny flanked prinia	*Prinia subflava*	f
Tropical boubou	*Laniarius aethiopicus*	F
Variable sunbird	*Cinnyris venustus*	f
Village weaver	*Ploceus cucullatus*	Non f
Whinchat	*Saxicola rubetra*	f
White browed coucal	*Centropus superciliosus*	Non f
White browed robin chat	*Cossypha heuglini*	f
White browed scrub robin chat	*Cercotrichas leucophris*	f
White eyed slaty fly catcher	*Melaenornis fischeri*	F
White rumped swift	*Apus caffer*	Non f
White throated bee eater	*Merops albicollis*	Non f
White wagtail	*Motacilla alba*	Non f
Winding cisticola	*Cisticola galactotes*	Non f
Woodland kingfisher	*Halycyon senegalensis*	f
Yellow backed weaver	*Ploceus melanocephalus*	Non f
Yellow fronted canary	*Serinus mozambicus*	Non f
Yellow rumped tinker bird	*Pogonialus bilineatus*	F
Yellow throated leaflove	*Chlorocichla flavicollis*	f
Yellow throated longclaw	*Macronyx croceus*	Non f
Yellow wagtail	*Motacilla flava*	Non f

Yellow whiskered Greenbul	*Andropardus latirostris*	F

Legend: FF-Forest Specialist, **F-**Forest generalist, **f-**Forest visitor, **Non f-**Non forest bird.

Appendix 3: Checklist of all bird species seen during the study in the three sites, showing their feeding guild, *threat (*X = *nationally scarce;* NT = *Globally Near-threatened* V=*Vulnerable* LC=*Least concern) and migratory (*AM = *Afrotropical migrant;* PM = *Palaearctic migrant* R=*Resident)*

Family	**Common name**	**Scientific name**	**Migrant status**	**Feeding guild**	**Threat**
Accipitridae	Black kite	*Milvus migrans*	AM,PM	Raptor	LC
Accipitridae	Black shouldered kite	*Elanus caeruleus*	R	Raptor	LC
Accipitridae	Eastern pale chanting goshawk	*Melierax poliopterus*	R	Raptor	LC
Accipitridae	Long crested eagle	*Lophaetus occipitalis*	AM	Raptor	LC
Accipitridae	Martial eagle	*Polemaetus bellicosus*	R	Raptor	NT
Acciptridae	African goshawk	*Accipiter tachiro*	R	Insectivore	LC
Acciptridae	African harrier hawk	*Polyboroides typus*	AM	Raptor	LC
Acciptridae	African thrush	*Turdus pelios*	R	Insectivore	LC
Acciptridae	Augur buzzard	*Buteo augur*	R	Raptor	LC
Acciptridae	Black billed barbet	*Lubius guifsobarito*	AM,PM	Frugivore	LC
Acciptridae	Common wax bill	*Estrilda astrild*	R	Granivore	LC

Alcedinidae	African pied wagtail	*Motacilla aguimp*	AM	Insectivore	LC
Alcedinidae	African pygmy kingfisher	*Ceyx pictus*	AM	Insectivore	LC
Alcedinidae	Woodland kingfisher	*Halycyon senegalensis*	R	Insectivore	LC
Apodidae	Scarce swift	*Schoutenapus myoptilus*	R	Insectivore	LC
Apodidae	White rumped swift	*Apus caffer*	R	Insectivore	LC
Ardeidae	Black headed heron	*Ardea melanocephal a*	R	Insectivore	LC
Buceroditae	Amethyst sunbird	*Chalcomitra amethystina*	R	Nectarinivo re	LC
Buceroditae	Black and white casqued hornbill	*Bycanistes subcylindricus*		Frugivore	LC
Bucorvidae	Southern ground hornbill	*Burcovus abyssinicus*	R	Frugivore	LC
Campephagidae	Black cuckoo shrike	*Campephaga flava*	AM	Insectivore	LC
campephagidae	Red shouldered	*Campephaga flava*	R	Insectivore	LC

	cuckoo shrike				
capitonidae	Bronze mannikins	*spermestes cucullatus*	R	Granivore	LC
Capitonidae	Cattle egret	*Bulbulcus ibis*	AM	Insectivore	LC
Capitonidae	Double toothed barbet	*Lybius bidentatus*	R	Frugivore	LC
Capitonidae	Grey throated barbet	*Gymnobucco bonabartei*	R	Frugivore	LC
Capitonidae	Red fronted tinker bird	*Poginiulus pusillus*	R	Insectivore	LC
Capitonidae	Spot flanked barbet	*Tricholaema lacrymosa*	R	Insectivore	LC
Capitonidae	Yellow rumped tinker bird	*Pogonialus bilineatus*	R	Insectivore	LC
Cisticolidae	Black headed apalis	*Apalis melanocephal a*	R	Insectivore	LC
Cisticolidae	Brown headed apalis	*Apalis alticola*	R	Insectivore	LC
Cisticolidae	Grey backed camaroptera	*Camaroptera brevicaudata*	R	Nectarinivo re	LC
Cisticolidae	Long tailed cisticola	*Cisticola angusticauda*	R	Insectivore	LC
Cisticolidae	Rattling cisticola	*Cisticola chiniana*	R	Insectivore	LC

Cisticolidae	Red faced cisticola	*Cisticola erythrops*	R	Insectivore	LC
Cisticolidae	Singing cisticola	*Cisticola cantans*	R	Insectivore	LC
Cisticolidae	Tawny flanked prinia	*Prinia subflava*	R	Insectivore	LC
Cisticolidae	Winding cisticola	*Cisticola galactotes*	R	Insectivore	LC
Coliidae	Speckled Mouse bird	*Colius striatus*	R	Frugivore	LC
columbidae	African green pigeon	*Treron calvus*	R	Frugivore	LC
Columbidae	Black crowned waxbill	*Estrilda nonnula*	R	Granivore	LC
Columbidae	Blue spotted wood dove	*Turtur afer*	R	Frugivore	LC
Columbidae	Grey capped warbler	*Eminia lepida*	R	Insectivore	LC
Columbidae	Namaqua doves	*Oena capensis*	R	Frugivore	LC
Columbidae	Red eyed dove	*Streptopelia semitorquata*	R	Frugivore	LC
Columbidae	Ring necked dove	*Streptopelia capicola*	R	Frugivore	LC
columbidae	Tambourine dove	*Turtur tympanistria*	R	Frugivore	LC

Corvidae	Emerald spotted wood dove	*Turtur chalcospilos*	R	Frugivore	LC
Corvidae	Pied crow	*Corvus albus*	R	Omnivore	LC
Cuculidae	Black crowned tchagra	*Tchagra senegala*	R	Insectivore	LC
Cuculidae	Blue headed coucal	*Centropus monachus*	R	Insectivore	LC
Cuculidae	Klaas's Cuckoo	*Chrisococcx klaas*	R	Insectivore	LC
Cuculidae	White browed coucal	*Centropus superciliosus*	R	Insectivore	LC
Dicruridae	Common Drongo	*Dicrurus adsimilis*	R	Frugivore	LC
Emberizidae	Golden breasted bunting	*Emberiza flaviventris*	R	Insectivore	LC
Estrildidae	Purple grenadier	*Granatina ianthinogaster*	R	Granivore	LC
Estrildidae	Red billed fire finch	*Lagonosticta senegala*	R	Granivore	LC
Fringillidae	African citril	*Crithagra citrinelloides*	R	Insectivore	LC
Fringillidae	Streaky seed eater	*Crithagra striolata*	R	Granivore	LC
Fringillidae	Yellow fronted canary	*Serinus mozambicus*	R	Granivore	LC

Laniidae	Common fiscal	*Lanius collaris*	R	Insectivore	LC
Malaconotidae	Marsh tchagrah	*Tchagra minutus*	R	Insectivore	LC
Malaconotidae	Tropical boubou	*Laniarius aethiopicus*	R	Insectivore	LC
Meropidae	Bronze sunbird	*Nectarinia kilimensis*	PM	Nectarinivore	LC
Meropidae	Eurasian bee eater	*Merops apiaster*	PM	Insectivore	LC
Meropidae	Little swift	*Apus affinis*	AM	Insectivore	LC
Meropidae	White throated bee eater	*Merops albicollis*	AM	Insectivore	LC
Motacillidae	Cape wagtail	*Motacilla capensis*	R	Insectivore	V
Motacillidae	Grey wagtail	*Motacilla cinerea*	R	Insectivore	LC
Motacillidae	Mountain wagtail	*Motacilla clara*	R	Insectivore	LC
Motacillidae	Rosy breasted longclaw	*Macronyx ameliae*	R	Insectivore	LC
Motacillidae	White wagtail	*Motacilla alba*	PM	Insectivore	LC
Motacillidae	Yellow throated longclaw	*Macronyx croceus*	R	Insectivore	LC
Motacillidae	Yellow wagtail	*Motacilla flava*	PM	Insectivore	LC

Muscicapidae	African blue fly catcher	*Elminia longicauda*	R	Insectivore	LC
Muscicapidae	African dusk fly catcher	*Muscicapa adusta*	R	Insectivore	LC
Muscicapidae	African paradise fly catcher	*Terpsiphone viridis*	AM	Insectivore	LC
Muscicapidae	Northern wheat ear	*Oenanthe oenanthe*	PM	Insectivore	LC
Muscicapidae	Pied wheatear	*Oenanthe pleschanka*	PM	Insectivore	LC
Muscicapidae	Red capped robin chat	*Cossypha natalensis*	AM	Insectivore	LC
Muscicapidae	Southern black fly catcher	*Melaenornis pammellaina*	R	Insectivore	LC
Muscicapidae	Spotted fly catcher	*Muscicapa striata*	PM	Insectivore	LC
Muscicapidae	White eyed slaty fly catcher	*Melaenornis fischeri*	R	Insectivore	LC
Musophagidae	Eastern grey plantain eater	*Crinifer zonurus*	R	Frugivore	LC
Musophagidae	Grey crowned cranes	*Balearica regulorum*	R	Molluscivore	V
Musophagidae	Ross' s Turaco	*Musophaga rossae*	R	Frugivore	LC

Nectariniidae	Collared sunbird	*Hedydipna collaris*	AM	Nectarinivore	LC
Nectariniidae	Copper sunbird	*Cinnyris cupreus*	R	Nectarinivore	LC
Nectariniidae	Green headed sunbird	*Cyanomitra verticalis*	R	Nectarinivore	LC
Nectariniidae	Northern double collared sun bird	*Cinnyris reichenowi*	R	Nectarinivore	LC
Nectariniidae	Olive bellied sunbird	*Cyanomitra chrolopygius*	R	Nectarinivore	LC
Nectariniidae	Purple banded sunbird	*Cinnyris bifasciatus*	R	Nectarinivore	LC
Nectariniidae	Variable sunbird	*Cinnyris venustus*	R	Nectarinivore	LC
Numididae	Helmeted guinea fowl	*Numida meleagris*	R	Granivore	LC
Oriolidae	Barn swallow	*Hirundo rustica*	PM	Insectivore	LC
Oriolidae	Black headed oriole	*Oriolus larvatus*	R	Frugivore	LC
Passeridae	Great sparrow hawk	*Accipiter melanoleucus*	R	Frugivore	LC
Passeridae	Grey headed sparrow	*Passer griseus*	R	Granivore	LC

Phasianidae	Harlequin quail	*Coturnix delegorguei*	R	Granivore	LC
Phasianidae	Hilderbrandt ’s francolin	*Francolinus hilderbrandti*	R	Granivore	LC
Platysteiridae	Black throated wattle eye	*Platysteira peltata*	R	Insectivore	LC
Platysteiridae	Black-headed Batis	*Batis minor*	R	Insectivore	LC
Platysteiridae	Common wattle eye	*Platysteira cyanea*	R	Insectivore	LC
Ploceidae	Baglafecht weaver	*Ploceus baglafecht*	AM	Granivore	LC
Ploceidae	Black headed village weaver	*Ploceus cucullatus*	R	Granivore	LC
ploceidae	Compact weaver	*Ploceus superciliosus*	R	Granivore	LC
Ploceidae	Fantailed widow bird	*Euplectes axillaris*	R	Granivore	LC
Ploceidae	Grey capped social weaver	*Pseudonegrid a arnaudi*	R	Granivore	LC
Ploceidae	Holubs golden weaver	*Ploceus xanthops*	R	Granivore	LC
Ploceidae	Jacksons golden	*Ploceus jacksoni*	R	Granivore	LC

	backed weaver bird				
Ploceidae	Red collared widow bird	*Euplectes ardens*	R	Granivore	LC
Ploceidae	Red headed Malimbe	*Malimbus rubricollis*	R	Granivore	LC
Ploceidae	Red headed weaver	*Anapalectes melanotis*	R	Granivore	LC
Ploceidae	Spectacled weaver bird	*Ploceus ocularis*	R	Granivore	LC
Ploceidae	Speke's weaver	*Ploceus spekei*	R	Granivore	LC
Ploceidae	Village weaver	*Ploceus cucullatus*	R	Granivore	LC
Ploceidae	Yellow backed weaver	*Ploceus melanocephalus*	R	Granivore	LC
Psittacidae	Brown headed parrot	*Poicephalus cryptoxanthus*	R	Frugivore	LC
Pycnonotidae	Common bulbul	*Pycnonotus barbatus*	R	Frugivore	LC
Pycnonotidae	Joyful Greenbul	*Chlorocichla laetissima*	R	Frugivore	LC
Pycnonotidae	Little Greenbul	*Andropadus virens*	R	Frugivore	LC
Pycnonotidae	Yellow throated leaflove	*Chlorocichla flavicollis*	R	Frugivore	LC

Pycnonotidae	Yellow whiskered Greenbul	*Andropardus latirostris*	R	Frugivore	LC
pycononotidae	Cabanis's greenbul	*Phyllastrephus cabanisi*	R	Frugivore	LC
Sturnidae	Greater blue-eared sterling	*Lamprotornis chalybaeus*	R	Raptor	LC
Sturnidae	Red billed ox pecker	*Buphagus erhythrorynch us*	R	Insectivore	LC
Syliviidae	Black cap	*Sylivia atricapilla*	PM	Insectivore	LC
Threskiornithid ae	Cinnamon chested bee eater	*Merops oreobates*		Insectivore	LC
Threskiornithid ae	Hadada ibis	*Bostrichia hagedash*	R	Molluscivor e	LC
Timaliidae	Black lored babbler	*Turdoides shapei*	PM	Insectivore	LC
Turdidae	Common stone chat	*Saxicola torquatus*	R	Insectivore	LC
Turdidae	Northern ant eater chat	*Myrmecocichl a aethiops*	R	Insectivore	LC
Turdidae	Sooty chat	*Myrmecocichl a nigra*	R	Insectivore	LC
Turdidae	Whin chat	*Saxicola rubetra*	PM	Insectivore	LC

Turdidae	White browed robin chat	*Cossypha heuglini*	R	Insectivore	LC
Turdidae	White browed scrub robin chat	*Cercotrichas leucophris*	R	Insectivore	LC
Turdidae	Cape robin chat	*Cossypha caffra*	R	Insectivore	LC
Viduidae	Pin-tailed whydah	*Vidua macroura*	R	Granivore	LC
Zosteropidae	African Yellow white eye	*Zosterops senegalensis*	R	Insectivore	LC
Zosteropidae	Montane white eye	*Zosterops poliogastrus*	R	Insectivore	LC

Appendix 4: Photo galleries of farming activities and sampling procedures in keiyan division

Photo 1: Degraded areas around the forest fragments

Photo 2.Part of Keiyan sugarcane farm

Photo 3.Part of Keiyan tea farm

Photo 4.Mist netting in Nakutu forest

Appendix 5: Photo galleries of some of the birds caught and observed in the study area

Photo 1; Black cuckoo shrike (*Campephaga flava*)-Nakutu forest

Photo 2; African pygmy kingfisher (*Ceyx pictus*)-Nakutu forest

Photo 3; Little Greenbul (*Andropadus virens*)-Nakutu forest

Photo 4; Montane white eye (*Zosterops poliogastrus*)-Nakutu forest

Photo5; Cape robin chat (*Cossypha caffra*)-Keiyan tea farm

Photo 6; Collared sunbird (*Hedydipna collaris*)-Nakutu forest

Photo 7; Northern double collared sunbird (*Cinnyris reichenowi*) (male)

Nakutu forest

Photo 8; Nothern double collared sunbird (*Cinnyris reichenowi*) (female)

Photo 9; Grey backed Camaroptera (*Camaroptera brevicaudata*)-Nakutu forest

Photo 10; Black cap (*Sylivia atricapilla*)-Nakutu fores

Photo 11; Tambourine dove (*Turtur tympanistria*)-Nakutu fores

Photo 12; Yellow whiskered Greenbul (*Andropardus latirostris*)-Nakutu for

Photo 13; Variable sun bird (*Cinnyris venustus*)-Nakutu fo

Photo14; Green headed sunbird (*Cyanomitra verticalis*)-Nakutu forest

Appendix 6; Bird species abundance in the tea farms using point count method. List in descending order.

Name of bird	Scientific name	Density (bird/ha)PC
Fantailed widow bird	*Euplectes axillaris*	38
Common wax bill	*Estrilda astrild*	31
Eurasian bee eater	*Merops apiaster*	28
Winding cisticola	*Cisticola galactotes*	21
Common bulbul	*Pycnonotus barbatus*	9
Barn swallow	*Hirundo rustica*	7
Baglafecht weaver	*Ploceus baglafecht*	5
Sooty chat	*Myrmecocichla nigra*	4
Harlequin quail	*Coturnix delegorguei*	4
Common stone chat	*Saxicola torquatus*	4
Red billed fire finch	*Lagonosticta senegala*	3
Yellow wagtail	*Motacilla flava*	3
Bronze manikins	*spermestes cucullatus*	2
Cape robin chat	*Cossypha caffra*	2
Bronze sunbird	*Nectarinia kilimensis*	2
Common fiscal	*Lanius collaris*	2
Blue headed coucal	*Centropus monachus*	2
Grey crowned cranes	*Balearica regulorum*	2
African citril	*Crithagra citrinelloides*	1

Brown headed apalis	*Apalis alticola*	1
Hadada ibis	*Bostrichia hagedash*	1
Whin chat	*Saxicola rubetra*	1
White throated bee eater	*Merops albicollis*	1
Streaky seed eater	*Crithagra striolata*	1
Red collared widow bird	*Euplectes ardens*	1
Emerald spotted wood dove	*Turtur chalcospilos*	1
Namaqua doves	*Oena capensis*	1
Singing cisticola	*Cisticola cantans*	1
White browed robin chat	*Cossypha heuglini*	1
White browed coucal	*Centropus superciliosus*	1
White wagtail	*Motacilla alba*	1
Compact weaver	*Ploceus superciliosus*	1
Blue spotted wood dove	*Turtur afer*	1
Grey headed sparrow	*Passer griseus*	1
Grey wagtail	*Motacilla cinerea*	1
Little swift	*Apus affinis*	1
Long tailed cisticola	*Cisticola angusticauda*	1
Northern wheat eater	*Oenanthe*	1
Pintailed whydah	*Vidua macroura*	1
Rattling cisticola	*Cisticola chiniana*	1
Rosy breasted long claw	*Macronyx ameliae*	1
Tambourine dove	*Turtur tympanistria*	1

White browed coucal	*Centropus superciliosus*	1
Pied wheatear	*Oenanthe pleschanka*	1
Pied crow	*Corvus albus*	1
Purple grenadier	*Granatina ianthinogaster*	1

Appendix 7; Bird species abundance in the sugarcane farms using line transect method.List in descending order.

Name of bird	Scientific name	Density (bird/ha)PC
Common bulbul	*Pycnonotus barbatus*	3
Common stone chat	*Saxicola torquatus*	3
Eurasian bee eater	*Merops apiaster*	3
Common waxbill	*Estrilda astrild*	3
Common fiscal	*Lanius collaris*	2
Baglafecht weaver	*Ploceus baglafecht*	2
African citril	*Crithagra citrinelloides*	2
Barn swallow	*Hirundo rustica*	2
Bronze sunbird	*Nectarinia kilimensis*	2
Emerald spotted wood dove	*Turtur chalcospilos*	1
Fantailed widow bird	*Euplectes axillaris*	1
Jackson golden backed weaver	*Ploceus jacksoni*	1
Red collared widow bird	*Euplectes ardens*	1
Blue headed Coucal	*Centropus monachus*	1
Northern ant eater chat	*Myrmecocichla aethiops*	1
Harlequin quail	*Coturnix delegorguei*	1
Augur buzzard	*Buteo augur*	1
Red billed fire finch	*Lagonosticta senegala*	1

White browed robin chat	*Cossypha heuglini*	1
Yellow wagtail	*Motacilla alba*	1
Streaky seed eater	*Crithagra striolata*	1
Amethyst sunbird	*Chalcomitra amethystina*	1
Ring necked dove	*Streptopelia capicola*	1
Winding cisticola	*Cisticola galactotes*	1
Black kite	*Milvus migrans*	1
Blue spotted wood dove	*Turtur afer*	1
Scarce swift	*Schoutenapus myoptilus*	1
Speckled mouse bird	*Colius striatus*	1
Speke's weaver	*Ploceus spekei*	1
Black crowned tchagra	*Tchagra senegala*	1
Bronze manikins	*spermestes cucullatus*	1
Compact weaver	*Ploceus superciliosus*	1
Pied crow	*Corvus albus*	1
Red eyed dove	*Streptopelia semitorquata*	1
Tawny flanked Prinia	*Prinia subflava*	1
White throated bee eater	*Merops albicollis*	1
Purple grenadier	*Granatina ianthinogaster*	1

Appendix 8; Bird species abundance in the indigeneous forest using point count method.List in descending order.

Name of bird	Scientific name	Density (birds/ha)
common bulbul	*Pycnonotus barbatus*	45
Grey throated barbet	*Gymnobucco bonabartei*	32
Speckled mouse bird	*Colius striatus*	30
Double toothed barbet	*Lybius bidentatus*	28
Barn swallow	*Hirundo rustica*	27
Bronze sun bird	*Nectarinia kilimensis*	27
African citril	*Crithagra citrinelloides*	16
Spectacled weaver bird	*Ploceus ocularis*	16
African blue fly catcher	*Elminia longicauda*	14
African goshawk	*Accipiter tachiro*	12
Cape robin chat	*Cossypha caffra*	12
Grey capped social weaver	*Pseudonegrida arnaudi*	11
Holubs golden weaver	*Ploceus xanthops*	11
Montane white eye	*Zosterops poliogastrus*	11
Purple grenadier	*Granatina ianthinogaster*	11
African dusk fly catcher	*Muscicapa adusta*	6
Brown parrot	*Poicephalus cryptoxanthus*	6
Variable sunbird	*Cinnyris venustus*	6
Red capped robin chat	*Cossypha natalensis*	6
Grey crowned crane	*Balearica regulorum*	5

Joyful green bul	*Chlorocichla laetissima*	5
Mountain wagtail	*Motacilla clara*	5
Red eyed dove	*Streptopelia semitorquata*	5
Village weaver	*Ploceus cucullatus*	5
Woodland kingfisher	*Halycyon senegalensis*	5
Whin chat	*Saxicola rubetra*	5
Yellow wagtail	*Motacilla flava*	5
African pied wagtail	*Motacilla aguimp*	4
African pygmy kingfisher	*Ceyx pictus*	4
Cinnamon chested bee eater	*Merops oreobates*	4
Common wattle eye	*Platysteira cyanea*	4
Copper sunbird	*Cinnyris cupreus*	4
Ross's Turaco	*Musophaga rossae*	4
Southern black fly catcher	*Melaenornis pammellaina*	4
Tropical boubou	*Laniarius aethiopicus*	4
African thrush	*Turdus pelios*	4
Common Drongo	*Dicrurus adsimilis*	4
Compact weaver	*Ploceus superciliosus*	4
Eastern grey plantain eater	*Crinifer zonurus*	4
Grey backed camaroptera	*Camaroptera brevicaudata*	4
Helmeted guinea fowl	*Numida meleagris*	4
Long crested eagle	*Lophaetus occipitalis*	4

Purple banded sunbird	*Cinnyris bifasciatus*	4
Ring necked dove	*Streptopelia capicola*	4
Sooty chat	*Myrmecocichla nigra*	4
Southern ground hornbill	*Burcovus abyssinicus*	4
Spot flanked barbet	*Tricholaema lacrymosa*	4
Streaky seed eater	*Crithagra striolata*	4
African green pigeon	*Treron calvus*	4
Augur buzzard	*Buteo augur*	4
Baglafecht weaver	*Ploceus baglafecht*	4
Cape wagtail	*Motacilla capensis*	4
Collared sun bird	*Hedydipna collaris*	4
Common fiscal	*Lanius collaris*	4
Common stone chat	*Saxicola torquatus*	4
Common wax bill	*Estrilda astrild*	4
Red eyed dove	*Streptopelia semitorquata*	4
Red fronted tinker bird	*Tricholaema diademata*	4
Tambourine dove	*Turtur tympanistria*	4
Yellow fronted canary	*Serinus mozambicus*	4
Black and white casqued hornbill	*Bycanistes subcylindricus*	4
Tawny flanked prinia	*Prinia subflava*	4
White throated bee eater	*Merops albicollis*	3

Black billed barbet	*Lubius guifsobarito*	3
Black cap	*Sylivia atricapilla*	3
Black crowned tchagra	*Tchagra senegala*	3
Eastern pale chanting goshawk	*Melierax poliopterus*	3
Emerald spotted wood dove	*Turtur chalcospilos*	3
Grey headed sparrow	*Passer griseus*	3
Northern ant eater chat	*Myrmecocichla aethiops*	3
Red billed fire finch	*Lagonosticta senegala*	3
Spotted fly catcher	*Muscicapa striata*	3
White eyed slaty fly catcher	*Melaenornis fischeri*	3
Black cuckoo shrike	*Campephaga flava*	3
Black headed batis	*Batis minor*	3
Black headed heron	*Ardea melanocephala*	3
Black headed oriole	*Oriolus larvatus*	3
Black headed village weaver	*Ploceus cucullatus*	3
Eurasian bee eater	*Merops apiaster*	3
Fantailed widow bird	*Euplectes axillaris*	3
Golden breasted bunting	*Emberiza flaviventris*	3
Greater blue eared sterling	*Lamprotornis chalybaeus*	3
Great sparrow hawk	*Accipiter melanoleucus*	3

Grey throated barbet	*Gymnobucco bonabartei*	3
Grey wag tail	*Motacilla cinerea*	3
Klaas cuckoo	*Chrisococcx klaas*	3
Northern double collared sun bird	*Cinnyris reichenowi*	3
Olive bellied sunbird	*Cyanomitra chrolopygius*	3
Red billed ox pecker	*Buphagus erhythrorynchus*	3
White browed coucal	*Centropus superciliosus*	3
Yellow Rumped tinker bird	*Pogonialus bilineatus*	3
African paradise fly catcher	*Terpsiphone viridis*	3
Black kite	*Milvus migrans*	3
Black lord babbler	*Turdoides shapei*	3
Black throated wattle eye	*Platysteira peltata*	3
Blue headed coucal	*Centropus monachus*	3
Blue spotted wood dove	*Turtur afer*	3
Bronze manikins	*spermestes cucullatus*	3
Cattle egret	*Bulbulcus ibis*	3
Green headed sun bird	*Cyanomitra verticalis*	3
Hadada ibis	*Bostrichia hagedash*	3
Harlequin quail	*Coturnix delegorguei*	3
Little greenbul	*Andropadus virens*	3

Little swift	*Apus affinis*	3
Pied crow	*Corvus albus*	3
Pin tailed whydah	*Vidua macroura*	3
Yellow white eye	*Zosterops senegalensis*	2
Red shouldered cuckoo shrike	*Campephaga flava*	2
Scarce swift	*Schoutenapus myoptilus*	2
Yellow throated leave love	*Chlorocichla flavicollis*	2
Yellow whiskered greenbul	*Andropardus latirostris*	2
Red headed malimbe	*Malimbus rubricollis*	2
Red headed weaver	*Anapalectes melanotis*	1

Appendix 9; Relative abundance of bird species recorded in sugarcane farms. List in descending order.

Species name	Scientific name	Relative abundance%
Eurasian bee eater	*Merops apiaster*	10.71
Common stone chat	*Saxicola torquatus*	8.92
Fantailed widow bird	*Euplectes axillaris*	8.92
Common fiscal	*Lanius collaris*	8.03
Common wax bill	*Estrilda astrild*	8.03
Red collared widow bird	*Euplectes ardens*	7.14
Barn swallow	*Hirundo rustica*	6.25
Baglafecht weaver	*Ploceus baglafecht*	5.35
Common bulbul	*Pycnonotus barbatus*	4.46
African citril	*Crithagra citrinelloides*	3.57
Bronze sunbird	*Nectarinia kilimensis*	3.57
Tawny flanked prinia	*Prinia subflava*	3.57
Blue headed coucal	*Centropus monachus*	2.67
Emerald spotted wood dove	*Turtur chalcospilos*	2.67
Red billed fire finch	*Lagonosticta senegala*	2.67
Yellow wag tail	*Motacilla flava*	2.67
Harlequin quail	*Coturnix delegorguei*	1.78
Northern ant eater chat	*Myrmecocichla aethiops*	1.78
Whin chat	*Saxicola rubetra*	1.78

Yellow fronted canary	*Serinus mozambicus*	1.78
Compact weaver	*Serinus mozambicus*	0.89
Grey wagtail	*Motacilla cinerea*	0.89
Hildebrandt's francolin	*Francolinus hilderbrandti*	0.89
Red eyed dove	*Streptopelia semitorquata*	0.89

Appendix 10; Relative abundance of bird species recorded in the tea farms.List in descending order.

Species name	scientific name	Relative abundance in %
Eurasian bee eater	*Merops apiaster*	10
Fan tailed widow bird	*Euplectes axillaris*	10
Common bulbul	*Pycnonotus barbatus*	8.33
Blue headed coucal	*Centropus monachus*	6.67
Winding cisticola	*Cisticola galactotes*	6.67
Barn swallow	*Hirundo rustica*	5
Common waxbill	*Estrilda astrild*	5
Red billed fire finch	*Lagonosticta senegala*	5
Baglafecht weaver	*Ploceus baglafecht*	3.33
Cape robin chat	*Cossypha caffra*	3.33
Grey wagtail	*Motacilla cinerea*	3.33
Harlequin quail	*Coturnix delegorguei*	3.33
Red collared widow bird	*Euplectes ardens*	3.33
Sooty chat	*Myrmecocichla nigra*	3.33
Yellow wagtail	*Motacilla flava*	3.33
Bronze sunbird	*Nectarinia kilimensis*	1.67
Common fiscal	*Lanius collaris*	1.67
common stone chat	*Saxicola torquatus*	1.67
Compact weaver	*Ploceus superciliosus*	1.67
Little swift	*Apus affinis*	1.67

Northern ant eater chat	*Myrmecocichla aethiops*	1.67
Northern wheat ear	*Oenanthe oenanthe*	1.67
Pintailed whydah	*Vidua macroura*	1.67
Ring necked dove	*Streptopelia capicola*	1.67
scarce swift	*Schoutenapus myoptilus*	1.67
Streaky seed eater	*Crithagra striolata*	1.67
Yellow fronted canary	*Serinus mozambicus*	1.67

Appendix 11; Relative abundance of bird species recorded in indigenous forest. List in descending order.

Species name	scientific name	Relative abundance in %
Common bulbul	*Pycnonotus barbatus*	13.40
Grey throated barbet	*Gymnobucco bonabartei*	7.22
Speckled mouse bird	*Colius striatus*	6.18
Double toothed barbet	*Lybius bidentatus*	5.15
Barn swallow	*Hirundo rustica*	4.12
Bronze sunbird	*Nectarinia kilimensis*	4.12
African citril	*Crithagra citrinelloides*	4.12
Spectacled weaver bird	*Ploceus ocularis*	4.12
African blue fly catcher	*Elminia longicauda*	4.12
African goshawk	*Accipiter tachiro*	4.12
Cape robin chat	*Cossypha caffra*	3.09
Grey capped social weaver	*Pseudonegrida arnaudi*	3.09
Holub's golden weaver	*Ploceus xanthops*	3.09
Montane white eye	*Zosterops poliogastrus*	3.09
Purple grenadier	*Granatina ianthinogaster*	2.06
African dusk fly catcher	*Muscicapa adusta*	2.06
Brown parrot	*Poicephalus cryptoxanthus*	2.06
Variable sunbird	*Cinnyris venustus*	2.06

Red capped robin chat	*Cossypha natalensis*	2.06
Grey crowned crane	*Balearica regulorum*	2.06
Joyful greenbul	*Chlorocichla laetissima*	2.06
Mountain wagtail	*Motacilla clara*	2.06
Red eyed dove	*Streptopelia semitorquata*	2.06
Village weaver	*Ploceus cucullatus*	2.06
Woodland kingfisher	*Halycyon senegalensis*	2.06
Whin chat	*Saxicola rubetra*	1.03
Yellow wagtail	*Motacilla flava*	1.03
African pied wagtail	*Motacilla aguimp*	1.03
African pygmy kingfisher	*Ceyx pictus*	1.03
Cinnamon chested bee eater	*Merops oreobates*	1.03
Common wattle eye	*Platysteira cyanea*	1.03
Copper sunbird	*Cinnyris cupreus*	1.03
Ross's Turaco	*Musophaga rossae*	1.03
Southern black fly catcher	*Melaenornis pammellaina*	6.76
Tropical boubou	*Laniarius aethiopicus*	4.86
African thrush	*Turdus pelios*	4.53
Common Drongo	*Dicrurus adsimilis*	4.17
Compact weaver	*Ploceus superciliosus*	4.02

Eastern grey plantain eater	*Crinifer zonurus*	4.02
Grey backed camaroptera	*Camaroptera brevicaudata*	2.41
Helmeted guinea fowl	*Numida meleagris*	2.41
Long crested eagle	*Lophaetus occipitalis*	2.05
Purple banded sunbird	*Cinnyris bifasciatus*	1.75
Ring necked dove	*Streptopelia capicola*	1.75
Sooty chat	*Myrmecocichla nigra*	1.68
Southern ground hornbill	*Burcovus abyssinicus*	1.68
Spot flanked barbet	*Tricholaema lacrymosa*	1.68
Streaky seed eater	*Crithagra striolata*	1.68
African green pigeon	*Treron calvus*	0.88
Augur buzzard	*Buteo augur*	0.88
Baglafecht weaver	*Ploceus baglafecht*	0.88
Cape wagtail	*Motacilla capensis*	0.84
Collared sun bird	*Hedydipna collaris*	0.8
Common fiscal	*Lanius collaris*	0.8
Common stone chat	*Saxicola torquatus*	0.8
Common wax bill	*Estrilda astrild*	0.8
Red eyed dove	*Streptopelia semitorquata*	0.73
Red fronted tinker bird	*Tricholaema diademata*	0.73
Tambourine dove	*Turtur tympanistria*	0.69
Yellow fronted canary	*Serinus mozambicus*	0.69

Black and white casqued hornbill	*Bycanistes subcylindricus*	0.65
Tawny flanked prinia	*Prinia subflava*	0.65
White throated bee eater	*Merops albicollis*	0.65
Black billed barbet	*Lubius guifsobarito*	0.65
Black cap	*Sylivia atricapilla*	0.65
Black crowned tchagra	*Tchagra senegala*	0.65
Eastern pale chanting goshawk	*Melierax poliopterus*	0.47
Emerald spotted wood dove	*Turtur chalcospilos*	0.47
Grey headed sparrow	*Passer griseus*	0.47
Northern ant eater chat	*Myrmecocichla aethiops*	0.47
Red billed fire finch	*Lagonosticta senegala*	0.47
Spotted flycatcher	*Muscicapa striata*	0.47
White eyed slaty fly catcher	*Melaenornis fischeri*	0.47
Black cuckoo shrike	*Campephaga flava*	0.43
Black headed batis	*Batis minor*	0.43
Black headed heron	*Ardea melanocephala*	0.43
Black headed oriole	*Oriolus larvatus*	0.43
Black headed village weaver	*Ploceus cucullatus*	0.43

Eurasian bee eater	*Merops apiaster*	0.43
Fantailed widow bird	*Euplectes axillaris*	0.43
Golden breasted bunting	*Emberiza flaviventris*	0.43
Greater blue eared sterling	*Lamprotornis chalybaeus*	0.43
Great sparrow hawk	*Accipiter melanoleucus*	0.43
Grey throated barbet	*Gymnobucco bonabartei*	0.43
Grey wagtail	*Motacilla cinerea*	0.43
Klaas cuckoo	*Chrisococcx klaas*	0.43
Northern double collared sun bird	*Cinnyris reichenowi*	0.43
Olive bellied sunbird	*Cyanomitra chrolopygius*	0.43
Red billed ox pecker	*Buphagus erhythrorynchus*	0.43
White browed coucal	*Centropus superciliosus*	0.43
Yellow Rumped tinker bird	*Pogonialus bilineatus*	0.43
African paradise fly catcher	*Terpsiphone viridis*	0.4
Black kite	*Milvus migrans*	0.4
Black lord babbler	*Turdoides shapei*	0.4
Black throated wattle eye	*Platysteira peltata*	0.4
Blue headed coucal	*Centropus monachus*	0.4
Blue spotted wood dove	*Turtur afer*	0.4

Bronze manikins	*spermestes cucullatus*	0.4
Cattle egret	*Bulbulcus ibis*	0.4
Green headed sun bird	*Cyanomitra verticalis*	0.4
Hadada ibis	*Bostrichia hagedash*	0.4
Harlequin quail	*Coturnix delegorguei*	0.4
Little greenbul	*Andropadus virens*	0.4
Little swift	*Apus affinis*	0.4
Pied crow	*Corvus albus*	0.4
Pin tailed whydah	*Vidua macroura*	0.4
AfricanYellow white eye	*Zosterops senegalensis*	0.36
Red shouldered cuckoo shrike	*Campephaga flava*	0.29
Scarce swift	*Schoutenapus myoptilus*	0.29
Yellow throated leave love	*Chlorocichla flavicollis*	0.29
Yellow whiskered Greenbul	*Andropardus latirostris*	0.29
Red headed malimbe	*Malimbus rubricollis*	0.21
Red headed weaver	*Anapalectes melanotis*	0.14

Appendix 12: Afrotropical (AM) and Palaearctic (PM) Migrants

Common name	scientific name	Migrant status
Black kite	*Milvus migrans*	AM,PM
Long crested eagle	*Lophaetus occipitalis*	AM
African harrier hawk	*Polyboroides typus*	AM
Black billed barbet	*Lubius guifsobarito*	AM,PM
African pied wagtail	*Motacilla aguimp*	AM
African pygmy kingfisher	*Ceyx pictus*	AM
Black cuckoo shrike	*Campephaga flava*	AM
Cattle egret	*Bulbulcus ibis*	AM
Bronze sunbird	*Nectarinia kilimensis*	PM
Eurasian bee eater	*Merops apiaster*	PM
Little swift	*Apus affinis*	AM
White throated bee eater	*Merops albicollis*	AM
White wagtail	*Motacilla alba*	PM
Yellow wagtail	*Motacilla flava*	PM
African paradise fly catcher	*Terpsiphone viridis*	AM
Northern wheat ear	*Oenanthe oenanthe*	PM
Pied wheatear	*Oenanthe pleschanka*	PM
Red capped robin chat	*Cossypha natalensis*	AM
Spotted fly catcher	*Muscicapa striata*	PM
Collared sunbird	*Hedydipna collaris*	AM
Barn swallow	*Hirundo rustica*	PM
Baglafecht weaver	*Ploceus baglafecht*	AM
Black cap	*Sylivia atricapilla*	PM

Black lored babbler	*Turdoides shapei*	PM
Whin chat	*Saxicola rubetra*	PM