AVIAN SPECIES DIVERSITY AND DISTRIBUTION IN AND AROUND NORTH NANDI FOREST, KENYA

By

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DECLARATION

Declaration by Candidate

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without prior permission of the author and/or University of Eldoret.

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Mark Cheruiyot Bett

(NRM/PGW/04/13)

Declaration by Supervisors

This thesis has been submitted with our approval as university supervisors.

Signed …….. Date ……

Dr. Muchane Muchai

Signed …….. Date ……

Catherine Waweru

DEDICATION

This work is dedicated to my parents Mr. and Mrs. Joseph Rono, my siblings and all those who love nature and biodiversity conservation for posterity. God bless you all.

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ABSTRACT

Species-rich tropical forests are becoming increasingly fragmented, degraded, and declining in size threatening the survival of avian species that depend on them. Yet, avian species diversity and distribution in fragmented forests remain relatively unknown. This study was conducted between January 2015 and June 2015 in and around North Nandi Forest. The main aim of the study was to assess avian species diversity and distribution in four habitats; indigenous forest, disturbed forest, plantation forest and farmland. Birds were surveyed using point counts, timed species counts; distance line transects and mist nets. Shannon-Weiner diversity index H' for bird community ranged from 3.060 for plantation forest to 4.053 in disturbed forest. Bird species richness was significantly different in the four habitats surveyed (χ^2=26.747, df=3, P<0.0001). There was also significant difference in bird abundance across the four habitats (ANOVA; F=15.141, df=3, 1121, P<0.0001). Results on distribution of bird feeding guilds revealed a significant difference in abundance across the four habitats for insectivores (F=3.090, df=3, 297, P<0.0001) and granivores (F=10.496, df=3, 297, P<0.0001). The abundance of frugivores, raptors, nectarivores and omnivores showed no significant difference across the four habitats (P>0.05 in all cases). PCA multivariate analysis revealed that two variables; diameter at breast height and ground cover with eigen values >1 were strongly correlated with habitat structure in all the four habitats and explained 73.2% of the total variance. Linear regression analysis revealed a significant difference between bird species richness and tree diameter at breast height (F=99.760, r^2=0.73, df=1, 1268, P<0.0001) and tree height (F=97.134, r^2=0.71, df=1, 1268, P<0.0001). Bird abundance also revealed a significant difference with diameter at breast height (F=77.654, r^2=0.58, df=1, 1268, P<0.0001) and tree height (F=68.163, r^2=0.51, df=1, 1268, P<0.0001). Habitat destruction (70%) was the main detrimental human activity on the avifaunal habitats while subsistence hunting of birds (10%) only directly affected certain bird species. The middle age bracket (20-40 years) visited the forest most frequently (χ^2=19.485, df=4, P=0.001), males were mainly involved in timber extraction and livestock grazing as opposed to females took part in firewood and medicinal herbs collection. Conservation efforts of forest birds should focus on maintaining large forest patches while in farmlands, bird conservation should focus on maintaining extensive environmental-friendly farming systems that promote sustainable agricultural development in North Nandi Forest and its surroundings.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ATHB	Afro-Tropical Highland Biome
CBO	Community Based Organization
CFA	Community Forest Association
DBH	Diameter at Breast Height
DTC	Distance Transect Counts
FAO	Food and Agriculture Organization
GCB	Guineo-Congolian Biome
IBA	Important Bird Area
KFS	Kenya Forest Service
NNF	North Nandi Forest
PC	Point Counts
PCA	Principal Component Analysis
SE	Standard Error
TSC	Timed Species Counts
SPSS	Statistical Package for Social Scientists

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Global bird diversity is at a major risk due to forest destruction and fragmentation (Brooks *et al.*, 1999, Kwok and Corlett, 2000). Species-rich forests in the tropics are becoming increasingly fragmented, threatening the survival of species that depend on them (Bennun *et al.*, 1996; Daily, 2001; Kwok and Corlett, 2000; Owiunji and Plumptre, 1998). These forests are characterized by rich and varied plant and animal diversity, and provide habitat for half or more of the world's known terrestrial plant and animal species (MEA, 2005a; Osborne, 2000; Wilson, 1988); making them the world's most diverse ecosystems. Indeed, approximately 30% of the world's bird species are entirely dependent on tropical forests (either during winter or year round) such that if all tropical forests were lost they would disappear completely (Myers, 1992).

In Africa, the Congo basin contains the largest mass of rain forest where it continues westwards into Gabon and Cameroon (Richards, 1996). In East Africa, the area of continuous forest reaches its eastern limit at Bwamba in western Uganda (about 30°E). In the East of the Western Rift Valley, forests similar to tropical rain forest are absent except for outliers of various sizes, e.g. Budongo Forest and fragments near Lake Victoria in Uganda, a remnant near Kakamega town in western Kenya and some small areas in northwestern Tanzania. The Nandi forest system in Kenya (South and North Nandi) is a unique mid-altitude ecosystem transitional in composition between the

equatorial forests of central Africa (Guineo-Congolian rain forest) and the afro-montane forests of central Kenya and is not regarded as truly rain forest (Gebreselasse, 2012).

The North Nandi Forest Important Bird Area (IBA) is a strip of high canopy Forest Reserve on the edge of the Nandi escarpment, Rift Valley province, Kenya (Musila *et al*., 2010). About 80% of the forest reserve is closed-canopy at the 30 – 35m level, but with the heads of the tallest trees projecting to 40m or more above the ground. Dominant tree species include; *Croton spp*. *Prunus sp*. *Albizia spp*. *Syzygium spp*. *Celtis sp.* and *Drypetes sp.* with an undergrowth of *Acanthus spp.* and *Brilliantaisia spp*. The avifauna is similar to that of the adjacent Kakamega Forest mostly comprising of Guinea-Congo tropical rain forest with 24 out of 43 Kenyan bird species and Afro-tropical Highland biome where 34 out of 67 bird species are found. About 160 species have been recorded in the past (Bennun and Njoroge, 1999; Zimmerman *et al*., 1996). It is one of the important sites in Kenya for globally threatened Turner's Eremomela *Eremomela turneri* and range restricted Chapin's Flycatcher (vulnerable) (Bird Life International, 2000; Musila *et al.,* 2010; Stattersfield *et al.,* 1998).

Birds play a significant ecological role in forest ecosystems such as pollination, especially of trees with sturdy, brightly colored flowers (Sutherland, 2000). Nectarivores visit flowering understory and canopy trees and carry pollen grains from one plant to another therefore aid in cross and self pollination. Frugivorous birds assist in the natural regeneration by dispersing seeds and fertilize the germinating 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 and 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; Newmark, 2006; Renjifo, 2001; Stratford and Stouffer 1999). Many rainforest understory insectivores are specialists in their foraging techniques, use specific habitats and micro-habitats, are non-migratory and have large territories (Stouffer and Bieregaard, 1995b; Terborgh *et al.*, 1990). This demonstrates that habitat modification affects bird distribution and that it is important 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. pasturelands 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 ultimate effect of habitat fragmentation and degradation is the reduction of population size and increased vulnerability to extinction (Simberloff, 1994). This exposes risks to many tropical rainforest species, as they are less distributed and do not adapt well to conditions outside the forest (Turner, 1996).

North Nandi Forest and its surrounding modified habitats is facing an imminent threat from encroachment and human activities; such as uncontrolled logging, charcoal burning and firewood collection, while intense pressure from cattle-grazing is affecting the

structure and regeneration of this forest (Bennun and Njoroge, 1999; Musila, *et al.*, 2004; Ng'weno *et al.*, 2005). These activities are likely to significantly reduce or locally exterminate populations of avian species that are highly sensitive to habitat disturbance. This study therefore sought to compare avian species diversity, that is, species richness and relative abundance in indigenous forest (undisturbed), forest edge (disturbed), exotic tree plantations and small scale farmlands adjacent to the forest reserve. The study also evaluated the distribution of bird feeding guilds in habitat patches and determined current threats facing the avifauna and its habitats. It has also recommended appropriate conservation strategies for the birds and their habitats.

1.2 Statement of the problem

Tropical forests are Earth's most complex ecosystems in terms of structure and species diversity. However, bird species in these forests appear to have a highly patchy spatial distribution and often have restricted ranges and their ecology is poorly known (Sayer *et al.*, 1992). Little information on the avifauna of North Nandi Forest is known based on previous ornithological work, e.g. (Bennun and Njoroge, 1999; Musila *et al.*, 2010; Zimmerman *et al.*, 1996).

With accelerating human population growth around this forest reserve, habitat degradation and fragmentation are changing vegetation structure and thereby threatening the present avian biodiversity (Musila *et al.*, 2010). However, very few studies have looked at modified habitats, such as disturbed forest edges; farmland and plantation forests could sustain bird communities and act as alternative habitats when primary forest has been destroyed. This study aimed to assess the impacts of habitat modification on the diversity and distribution of bird feeding guilds in and around North Nandi Forest. The

study therefore attempted to answer the following questions; what are the impacts of habitat modification on richness and abundance of birds?, what is the distribution of bird feeding guilds in the four habitat patches surveyed?, what is the influence of vegetation structure in different habitat patches on bird species richness and abundance?, and what are the current threats facing avifauna and their forest habitats in North Nandi Forest?

1.3 Justification of the study

The results of this study provide baseline information that is relevant to understanding the richness and composition of North Nandi Forest's avifauna. It also gives an indication of the forest's overall value for the conservation of biological diversity (Bennun *et al*., 1996). Birds fulfill most of the criteria for a good indicator group for monitoring ecological changes (Furness and Greenwood, 1993; Pearson, 1995).

When a forest is modified, birds respond in a detectable way. While some primary forest species persist in modified habitats, those that are specialized in one way or another are likely to be negatively affected (Svein *et al*., 2000; Thiollay, 1992). Therefore, this study established appropriate information that is critical in formulating measures to mitigate current threats facing the various habitats and in turn recommended conservation measures to improve avian diversity in the study area.

1.4 Main objective

The main objective of this study was to compare avian species diversity and their distribution in indigenous forest, disturbed forest, forest plantations and farmlands in and around North Nandi Forest.

1.4.1 Specific objectives:

1. To determine the impacts of habitat modification on diversity of birds in the study area.
2. To evaluate distribution of bird feeding guilds in four habitat patches found in the study area.
3. To determine the impact of vegetation structure in the four habitat patches on bird species richness and abundance.
4. To assess the current threats that the avifauna and their habitats are facing.

1.5 Hypotheses of the study:

$H_{01:}$ Avifaunal diversity is similar in all habitat patches in the study area.

$H_{A1:}$ Avifaunal diversity is different in all habitat patches in the study area.

$H_{02:}$ Bird feeding guilds are uniformly distributed in the four habitat patches in the study area.

$H_{A2:}$ Bird feeding guilds are not uniformly distributed in the four habitat patches in the study area.

$H_{03:}$ Bird species richness and abundance are not affected by vegetation structure in different habitat patches.

$H_{A3:}$ Bird species richness and abundance are affected by vegetation structure in different habitat patches.

1.6 Research questions

1. What are the current threats that avifauna and their forest habitats in North Nandi Forest face?

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Background information

The total African forest coverage is estimated to be 635,412,000 ha which is equivalent to 21 % of total land area of Africa and accounts for 16% of global forest cover (Gebreselasse, 2012). In East Africa, forests similar to tropical forest are absent except for outliers of various sizes loc.cit, (Schifter and Cunningham-van Someren, 1998). Among all African ecosystems, tropical forest is the most species-rich ecosystem housing more than half of Africa's biota (Sayer *et al*., 1992). It has been estimated that over 8000 plant species, some 80% of which are endemic (White, 1983) are found in tropical forests of Africa.

Tropical forests play important roles in regulating local and global climate (Yeshitela, 2008). Tropical forests sequestrate large amounts (half of) terrestrial carbon dioxide (Gorte and Sheikh, 2010; Köhler *et al*., 2003) and maintain atmospheric humidity (Lalfakawma, 2010). Environmentally, they are crucial in reducing soil erosion, maintaining soil moisture and regulating stream flow as well as budgeting heat of the area and provide shelter to a diverse variety of flora and fauna (Lalfakawma, 2010). Millions of people living in or around tropical forests (Naughton-Treves and Weber, 2001) depend on the forests for many forest products and environmental services. Tropical forests are the main source of energy in the form of fuel wood; provide timber and non-timber forest products; are sources of food, particularly in times of drought and famine; and are sources of traditional medicines. Hence, these tropical ecosystems are very important socially, economically and environmentally for the well-being of mankind. It is therefore

very crucial to understand their biodiversity, such as avifauna, and the information generated can form a baseline for reference in assessing the well-being of these ecosystems.

The North Nandi Forest is important in that it is a unique mid-altitude ecosystem transitional in composition between the equatorial forests of central Africa (Guineo-Congolian rain forest, which Kakamega forest is the easternmost relic (Kokwaro, 1988) and the afro-montane forests of central Kenya. These forests form an important water catchment function and their rivers feed LakeVictoria (Kamugisha *et al.,* 1997). A rapidly growing population places pressure upon these forests as the forests become an increasingly important resource for satisfying the daily needs of the local people. Charcoal burning, illegal pit sawing, hunting, livestock grazing, collection of medicinal plants and fuel wood are some of the threats to which the forest is currently exposed (Mitchell, 2004). These factors have contributed to the current appearance of the forests as a mosaic of dense forest, clearings, forest plantations, regenerating forest areas, and natural grasslands (Kamugisha *et al.,* 1997).

2.2 Species diversity

Species are the elementary units of biological association, and any change in species diversity may alter to some extent ecosystem function 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 individuals are distributed among these

species (species evenness, species equitability, or abundance of each species) (Lloyd and Ghelardi 1964; Margalef 1958; 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 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).

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 the natural habitat of the area (Luck *et al.,* 2003).

2.3 Shannon diversity index

The Shannon index (H') has probably been the most widely used index in community ecology. It is based on information theory and is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a

collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even (Meerman, 2004). The Shannon-Weiner diversity index (H') is calculated using the following equation.

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

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

In literature, the Shannon Index is sometimes referred to as the 'Shannon Weaver' Index (Niklaus *et al.*, 2001; Poole, 1974;) and sometimes as the 'Shannon–Wiener' Index (Hixon and Brostoff, 1983; Sax, 2002).

The Shannon index (H') has two properties that have made it a popular measure of species diversity: (1)" *H'* = 0 if and only if there is one species in the sample, and (2) *H'* is maximum only when all *S* species are represented by the same number of individuals, that is, perfectly even distribution of abundances. When all species in a sample are equally abundant, it seems intuitive that an evenness index should be maximum and decrease toward zero as the relative abundances of the species diverge away from evenness (Meerman, 2004).

2.4 Bird Surveys

Species inventories and population monitoring are common tasks of biologists, and a variety of avian survey and monitoring techniques are available (Sutherland *et al.*, 2004).

While each technique has its advantages, the most appropriate technique will depend on the specific objectives of the study, the size of the study area, characteristics of the species and habitat of interest, and the logistic and financial feasibility of implementing the study (Nalwanga *et al.*, 2012).

2.5 Strip transects

Strip transects are one of the most commonly used survey techniques for determining avian species composition and density (Sutherland, 2011). Essentially, strip transects are modified versions of a sample plot in which the observer performs counts while traveling along a fixed transect line instead of searching over an entire plot (Ronconi & Burger, 2009). Transects are randomly located, often within stratified sub-areas of the total study area, to obtain representative samples of the species and numbers of each species present (Sutherland, 2011). If density estimates are desired, the counts are limited to objects within a fixed distance of the transect line (Buckland *et al.*, 2009). In such cases, the sampled plot becomes a rectangular strip extending a specified distance on either side of the transect line (Buckland *et al.*, 2009)

Density estimates from strip transect surveys operate on the assumption that all animals within the plot are detected, thus surveys are best conducted in open habitats where visibility is unobstructed (Sutherland, 2011). Binoculars (image-stabilized models are best) are commonly used during ground- and boat-based strip transect surveys to aid visual detection and species identification, but visual aids are of little use during aerial surveys (Ronconi & Burger, 2009). The ability to make quick and accurate assessments of bird locations in relation to survey boundaries is imperative for reliable density

estimates (Nalwanga *et al.,* 2012). Errors in estimating bird location relative to the transect line can have a considerable effect on density estimates (Miller, 2016).

2.6 Point Counts

Point counts are another of the most commonly used survey techniques for determining avian species composition and abundance (Sutherland, 2011). Point counts are essentially strip transects of zero length in which the observer performs the count in a 360º arc around a fixed survey station (Miller, 2016). Survey stations are randomly located throughout the study area to obtain representative samples of the species and numbers of each species present (Buckland *et al.,* 2005). If density estimates are desired from point counts, the counts are limited to objects within a fixed radius from the survey point. In such cases, the sampled plot becomes a circular plot of specified radius from the survey point (Bibby *et al.,* 1992).

Point count surveys have been developed for a variety of species and habitats which may not be effectively surveyed with other survey techniques (Alldredge, 2007). Point counts are especially useful in difficult terrain where it is not be possible to establish practical transects or perform counts while travelling along the transect line; for example ground-based surveys of wetland birds in shallow marshy habitat with soft substrates, or surveys in steep terraced agricultural fields (Alldredge, 2007). Because point count observers are sedentary, they may be more likely to detect shy species that would otherwise hide and escape detection when mobile and conspicuous strip transect observers approach (Miller, 2016).

Point counts based on vocal cues have been developed for situations where visual cues are limited, such as nocturnal surveys or heavily vegetated habitats (Buckland *et al.,* 2005). For some species, vocal cues may be the only reliable means of detection; for example, most counts of secretive birds in heavily vegetated marshes have relied on vocal cues for determining their presence and abundance (Buckland *et al.,* 2005). However, distances from the point count station are often difficult to determine from vocal cues, making density estimates problematic (Miller, 2016).

2.7 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, attributes, and activities of their component species; for example, their mode of feeding, acquiring nutrients, mobility, and zones of habitat that they occupy or otherwise exploit (Simberloff and Dayan, 1991).

Guilds are useful in comparative study of communities. Since it is usually impossible to study all species living in an ecosystem at once, 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 and Dayan, 1991). Birds can be placed into several trophic structures based on their feeding behaviours: insectivores, frugivores, omnivores, carnivores, nectarivores, piscivores and granivores (Wells, 1999, 2007). The type of habitat is a great determinant on these feeding guilds.

2.8 Threats facing forest habitats and avifauna

2.8.1 Habitat degradation

Habitat degradation and severe ecosystem alterations due to anthropogenic activities are the most important cause for biodiversity losses worldwide (Muchai *et al.,* 2002a). Tropical regions, which harbor the vast majority of this diversity (Gray *et al.,* 2007), are subjected to increasing land-cover changes as a result of accelerating human population growth (Teketay, 1992). Worldwide, tropical forests are being logged and degraded because of an increasing demand for forest resources, or are converted into farmland and plantations (Laube *et al.*, 2008; Otieno and Muchai, 2007).

Because degraded and modified habitats make up a growing proportion of the tropics nowadays, it is important to assess their ability to sustain biodiversity (Gray *et al.,* 2007; Laube *et al.*, 2008). Alterations in species richness and composition can also affect the functional diversity of the community (Gray *et al.,* 2007) and changes in provided ecosystem services can, in turn, have an effect on humans (Clough *et al.*, 2009).

2.8.2 Habitat fragmentation

Habitat fragmentation or subdivision is defined as a process in which a wide area of habitat for example, natural forest is changed into a number of smaller patches of smaller total area, isolated from each other by a matrix of different land uses distinct from the previous land use type (Lens, *et al.*, 2000; Lindenmyer and Fischer, 2006).

In most cases fragmentation is strongly associated with human induced disturbances. Fahrig (2003) distinguished between four different effects of habitat fragmentation on

habitat pattern. These include; (a) reduction in habitat amount, (b) increase in number of habitat patches, (c) decrease in sizes of habitat patches, and (d) increase in isolation of patches. Hence, habitat connectivity is considered to be very important to dispersal success, persistence, and genetic diversity of species in fragmented landscapes (Schooley and Branch, 2011).

2.8.3 Implications of Habitat fragmentation and degradation

Forest fragmentation and degradation have an impact on biodiversity i.e. increasing isolation of habitats, endangering species of plants, mammals and birds (Lens *et al.*, 2000; Muchai and du Plessis, 2005). However the effects of habitat fragmentation on species diversity vary across different habitats and taxa and could be both positive and negative (Fahrig, 2003). Positive effects include the creation of edge habitat and increasing the abundance of edge or gap species while negative effects include increasing the local rate of extinction by reducing population sizes through reducing habitat size and/or making patches of habitat (Fahring, 2003), creating forest edges and altering microclimate at forest edges, changing forest dynamics, and increasing predation at forest edges (Wade *et al*., 2006).

Deforestation and degradation of forests can result in fragmentation and later in the disappearance of that particular forest. Due to such kind of forest degradation and fragmentation a forest that was one block in early 1900s, resulted into three different forests i.e. Kakamega, South Nandi and North Nandi Forest (Schaab *et al.*, 2010). These three fragmented forest blocks arose mainly due to a combination of agricultural

expansion, uncontrolled livestock grazing, unsustainable firewood collection, charcoal making, and inappropriate land and tree tenure regimes (Musila *et al*., 2010).

Birds are one group of organisms responsible for a number of ecosystem services, which include; pollination, pest control, seed dispersal and scavenging. A decline in their diversity would therefore mean a decline in the services they provide (Şekercioğlu *et al.*, 2004). Of course, changes in bird species composition may also affect their ecosystem services, such as seed-eating and dispersal.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study area

3.1.1 Geographical location

The North Nandi Forest is located at longitude 34^{o} 51' 0" E and 35^{o} 10' 0" E and latitude 0^{o} 33' 30" N and 0^{o} 4' 30" N, at 1,700-2,130 m above sea level, in Rift Valley Province, Nandi County. It is a Forest Reserve important for Globally-threatened species, restricted-range species and Guinea-Congo forest biome species. This is a strip of high-canopy forest on the edge of the Nandi escarpment, above and immediately east of Kakamega Forest. North Nandi stretches for more than 30 km from North to South and is 3–5 km wide for most of its length. North Nandi Forest forms part of the eastern most relic of the Guinea Congo Tropical Rain Forest (Baillie *et al.,* 2004).

3.1.2 Gazettement and History of North Nandi Forest

North Nandi Forest was first gazetted in 1936 as a Trust Forest covering 11,850 ha. In 1968, the North Nandi Nature Reserve was established, with a total area of 3,434 ha. Since gazettement, a total of 1,343 ha have been excised, including part of the nature reserve. An additional 410 ha have been converted to Nyayo Tea Zone. Of the present gazetted forest area (10,500 ha), approximately 8,000 ha is indigenous closed-canopy forest, the remainder consisting of cultivation, scrub, grassland, plantations (exotic monoculture trees) and tea (Blackett, 1994). All areas outside the Nature Reserve were originally slated for conversion to plantation forest and are currently being implemented.

The main threats to the forest habitat include; illegal timber extraction, charcoal burning, forest grazing and unsustainable removal of forest products (Musila *et al*., 2010). The main impacts of destruction of the natural forest are reduction of water, habitat destruction and climate change in the long run (Musila *et al*., 2010). The natural forest should therefore be conserved to enhance these products and services.

3.1.3 Climate

The area has a cool and moderate wet climate. It receives an average mean annual rainfall between 1,200 mm to 2,000 mm. The rainfall distribution is bimodal, with a principal wet season between March and June, and a subsidiary wet period in September-October. The distribution of rainfall is affected by topography and the south-westerly winds from the Lake Victoria. The eastern side of the zone receives the lowest rainfall while the southern parts receive higher amounts of rainfall (KFS, 2010).

3.1.4 Hydrology

Drainage is mainly eastwards into the King'wal and Kimondi River systems, which flow through the South Nandi forest and westwards into the Yala River and eventually to Lake Victoria. The average discharge of springs in the forest is approximately 0.5 – 2 litres per second (KFS, 2010).

3.1.5 Soils

The soils are well-drained, friable and moderately fertile, Sandy and clay loams are the main soil types found in the County with a few areas having humic nitosols which are generally suitable for production of various crops (KFS, 2010).

3.1.6 Fauna and Flora

North Nandi Forest is an Important Bird Area (IBA) with 160 species of resident birds. The forest is a habitat for the globally threatened Turner's Eremomela *turneri* and range-restricted Chapin's Flycatcher *lendu.* Species of regional concern includes African Green Ibis *Bostrychia olivacea,* African Crown Eagle *Stephanoaetus coronatus,* Red Chested Owlet *Glaucidium perlatum,* Thick-billed Honey guide *Indicator conirostris* (all vulnerable) and Southern Hyliota *Hyliota australis* (Zimmerman *et al*., 1996).

The thick forest canopy in addition to birds is also rich in mammals; Black and White Colobus Monkey *Colobus guereza,* Blue Monkey *Cercopithecus mitis,* Red-tailed Monkey *C. ascanius,* African Giant Squirrel *Protoxerus stangeri,* Potto *Perodicticus potto,* Lord Derby's Anomalure *Anomalurus derbianus* and African Palm Civet *Nandinia binotata* (Musila *et al*., 2010).

North Nandi Forest floral species based on previous studies focuses on tree species (Gebreselasse, 2012) which form favourable habitats for birds. Indigenous forest was characterized by tall mature closed canopy indigenous tree species such as *Diospyros sp. Celtis sp.* and *Schefflera sp.* among others. Disturbed forest composed of open canopies, understory vegetation creating a matrix of micro habitats. Plantation forest was characterized by pure monoculture exotic trees such as *Eucalyptus spp.* and *Cupresus spp.* mostly creating bare ground. Farmland was composed of small scale tea farms, mixed crop farms and livestock grazing fields (Figure 3.1).

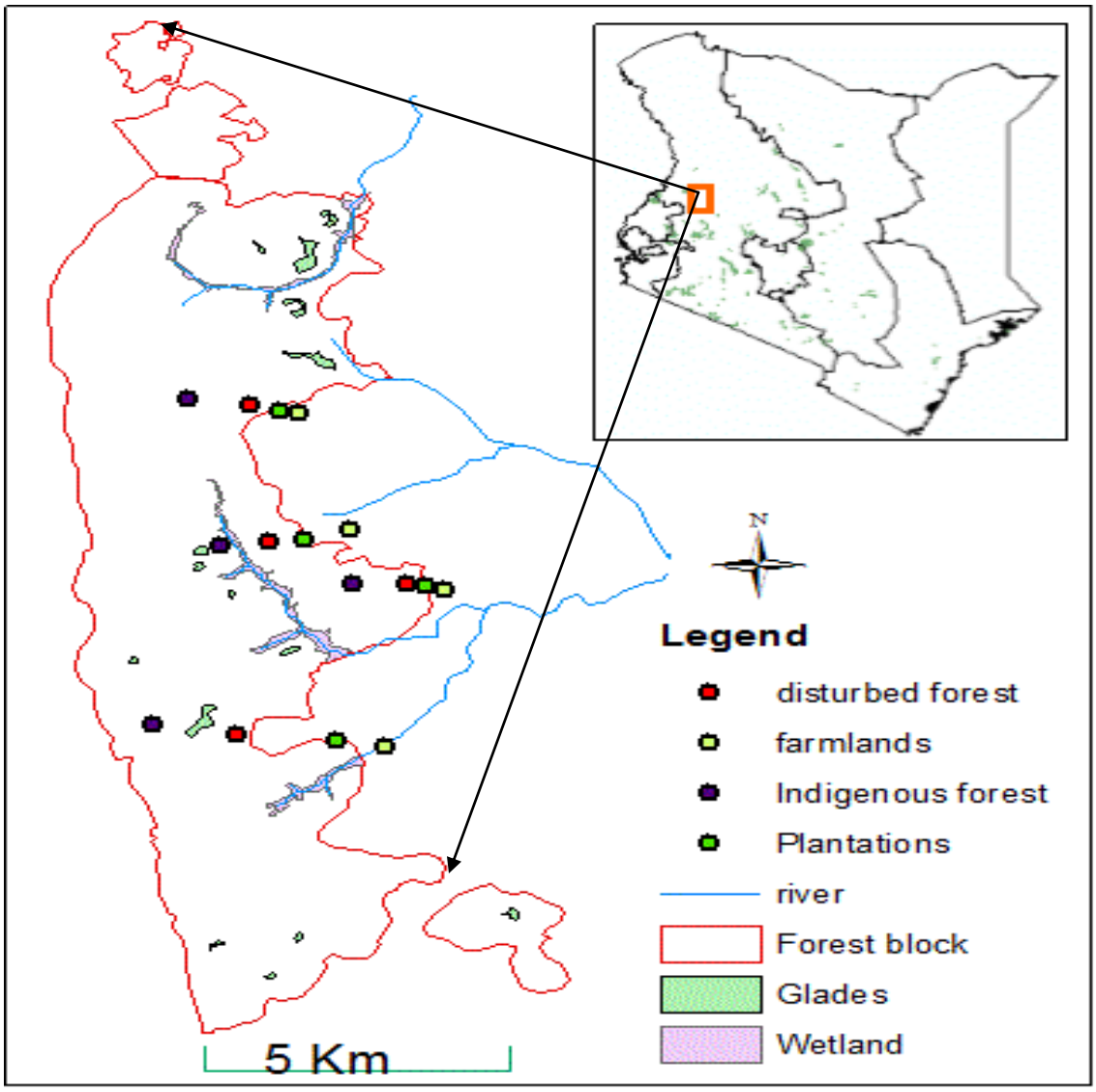

Figure 3.1: Map of North Nandi Forest, Kenya showing the various study habitats; indigenous forest, disturbed forest, plantation forest and farmland. Source: Author (2016)

3.2 Research Design

Fieldwork was conducted over a six-month period between January and July 2015. This study was based on descriptive research design which included naturalistic observations and surveys. Description of opinion on the investigated phenomena was explored and the information generated used to make inferences about the entire population from which the sample was drawn.

This type of design is appropriate to the study since opinions on avian diversity and current threats facing forest habitats were gathered from field surveys, local community members and key respondents.

3.3 Selection of study sites

The North Nandi Forest covers a broad area with tall canopy trees and ever flowing fresh water streams and rivers which form a good habitat for several bird species. This study was conducted on the eastern part of the forest due to its representation of the various habitats and its accessibility and proximity to the community who constantly interact with the forest.

Different habitats namely: indigenous forest, disturbed forest, plantation forest and farmland were identified based on size, structure and composition of vegetation and the general forest condition during a preliminary survey of the study area.

The indigenous forest area is the core habitat and borders the disturbed forest and was the biggest portion of the study area as it formed the main forest habitat. The disturbed forest comprised the outer forest boundary bordering the plantations (exotic tree plantations)

and covered approximately a 500 m strip. The plantation forest bordered the tea buffer zone area and occasionally overlapped. The farmland habitat formed the outermost habitat and bordered the tea buffer zone (an area approximately 1km strip from the tea border was used).

Based on the above criteria, four villages namely, 'Kapchepkok', 'Ngatatia', 'Kapkuto' and 'Kipsamoite' bordering the forest were used to achieve replication of the data collected.

3.4 Data Collection

3.4.1 Bird Surveys

The four main systematic methods used to sample and census birds were distance line transect count (DTC), timed-species counts (TSC), fixed radius point counts (PC) and mist netting.

3.4.1.1 Establishment of transects

Five transects of a minimum of 500 m long were laid randomly in each habitat based on their sizes except in the indigenous forest habitat where routes used by the locals when grazing cattle in the forest, collecting firewood or accessing the western part of the forest were used. Transects were 500 m from each other and 60 m from the edge of each habitat except in the disturbed forest to minimize the edge effect.

3.4.1.2 Point counts

Point count method (Bibby *et al*. 1992) was used for gathering data on abundance and diversity of birds. Four point count stations, each with a maximum of 50 m radius (0.8 ha), were marked on each transect 200 m apart. Point counts were conducted between

7:00 am and 11:00 am when bird activity was high. Counts of birds were made for 10 minutes at each station and all bird species recorded as either seen or heard. Counts were not carried out when it was raining, windy or misty to avoid biases due to unfavorable weather conditions.

3.4.1.3 Timed species-counts

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 (Buckland *et al.*, 2009). At least five 40-minute TSCs were conducted each day in each of the habitat found at the study area. Each TSC was separated by at least 100 m or 10-minute walk to 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 were recorded and scored according to when they were first recorded to give a 'commonness index' (4 if in the first ten minutes, 3 if in the next ten minutes, 2 in the next ten minutes, 1 in the last ten minutes; species not recorded during that specific TSC scored a '0' (Buckland *et al.*, 2009). 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. To establish distribution patterns, the encounter rate was also computed based on the proportion of all TSCs in which a species was recorded.

In addition to Timed Species counts, opportunistic observations were used to enrich the species checklist.

3.4.1.4 Mist netting

Mist nets were used to sample understory and other skulking species. Standard mist-nets (6m and 12m with 4 panels) were laid in two habitats only (i.e. indigenous forest and disturbed forest edge). To avoid stressing the birds as well as increase the catch-ability of more and diverse understory and skulking species, mist nets were shifted to new locations every two days. All birds caught were identified using field guides. All birds captured were ringed with uniquely-numbered aluminium rings and standard biometric measurements taken, before the birds were released (Sutherland, 2011).

3.4.1.5 Distance line transect counts

Birds were observed using a pair of 8*42 binoculars and surveyed using variable width line transects and distance analyses as described by Laake *et al.* (1993). Line transects were used to sample bird species in plantation forest and farmland where mist-nets were not used. The number of birds, perpendicular distance, sighting distance and sighting angle were recorded in data sheets for these two habitats as described by Bibby, *et al.* (1998). This method was used to collect data on relative abundance of birds in plantation forest and farmland only, since it suits extensive, open and uniform habitats.

3.4.2 Bird feeding guilds

Bird species in each of the four habitats (indigenous forest, disturbed forest, plantation forest and farmland) were classified according to their main food type based on observations and literature. Six categories were identified: Insectivore-invertebrate feeder, Granivore-seed-eater, Frugivore-fruit-eater, and Raptors-birds of prey-meat eater, Nectarivore-nectar feeder and Omnivore-Mixed feeders. This approach was consistent with the classification used by Githiru *et al.* (2009).

3.4.3 Forest dependency

To explore forest dependency, bird species were classified either as forest-specialist (FF), forest generalist (F), forest visitors (small-f) or non-forest (non-f) species (Bennun *et al.*, 1996); FF and F are dependent on forests, while small-f and non-f are not. The number of species in each of the four categories for the entire study area was obtained.

3.4.4 Vegetation surveys

In each of the four habitats identified, that is, indigenous forest, disturbed forest, plantation forest and farmland vegetation variables were surveyed in a 10m by 10m quadrat (Musila, 2011). This included: diameter at breast height (dbh) of various intervals ((1) Large≥30cm, (2) Medium≥15-29.9cm, (3) Small≥5-14.9cm and (4) Very Thin≥1.5-4.9cm) only on trees, percentage ground cover, percentage mid-canopy cover, percentage canopy cover, tree height, shrub height and disturbance index. Opportunistically, all signs of human or animal disturbance such as grazing, charcoal burning, fuel wood collection on each quadrat were recorded whenever encountered (Musila, 2011). Disturbance index was categorized as (1) High-Severe disturbance of vegetation cover, (2) Medium-Moderate disturbance of vegetation cover, or (3) Low-Slight disturbance of vegetation cover.

3.4.5 Assessment of threats to avifauna and forest habitats

Questionnaires were used to identify current threats facing birds and forest habitats. Local community members living in the four villages 'Kapchepkok', 'Ngatatia', 'Kapkuto' and 'Kipsamoite' bordering the forest 1km from the plantation forest were sampled. Systematic random sampling technique was used to select respondents, where every 5th household from 507 households was selected. One hundred questionnaires (25

per village) were issued relating to the use of various habitats in the forest and targeted respondents (15 years and above) who actively interacted with these forest habitats (Kothari, 2004). Questionnaire format adopted open and closed-ended questions.

Twenty five (25) questionnaires relating to protection and conservation of the forest were administered purposively selected Kenya Forest Service officers (10 officers) and Community Forest Associations (15 officials) operating in the study area.

3.5 Data analyses

All data were explored and in case of significant departure from normal distribution (Zar, 1996), appropriate transformation methods were applied. A probability of Type I error of 0.95 ($\alpha = 0.05$ or less) was accepted as significant (unless otherwise noted). Data were analyzed using SPSS program (Nie *et al.,* 2011) unless otherwise stated.

3.5.1 Species accumulation curves modeling

This simple test aimed to compare how close the total number of species recorded during the study with the potential total number of species actually in the study area. A species accumulation curve was prepared using the progressive number of new bird species seen every day from Day 1 to Day 16 of the study. An asymptotic model was fitted to the species accumulation curve of observed data, using non linear regression procedures (Gaidet *et al.,* 2005).

3.5.2 Bird species diversity

Data on avian species diversity in various forest habitats was calculated using the **Shannon-Weiner 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-Weiner diversity index (H') was calculated using the following equation.

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

Where: H = the Shannon-Weiner diversity index, P_i = fraction of the entire population made up of species i, S = numbers of species encountered, $\sum$ = 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 (Morris *et al.,* 2014).

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 i 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 a higher diversity (Morris *et al.*, 2014).

Sorenson's similarity index was used to compare similarity of bird species across the four habitats (Soka *et al.,* 2013), using the following equation:

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

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

3.5.3 Bird 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 frequently seen the species, the more abundant it is (Bibby *et al*., 1992). 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 for mean differences in bird abundance across the four habitats at 5% significance level. For species richness chi-square test for goodness of fit was used to show differences in the four habitats. 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 differences between each of the four habitats. Significant levels for statistical tests were set at $P \leq 0.05$. Means are presented ± SE.

3.5.4 Vegetation analysis

Variables describing vegetation structure in relation to bird diversity were determined as described by Díaz (2006). Vegetation variables sampled from the four habitats in the study area were explored and proportion of data, such as vegetation cover, were transformed using arcsine transformation which involves taking the arcsine of the square

root of a number. The result is given in radians, not degrees, and may range from $-\pi/2$ to $\pi/2$ and is commonly used for proportions. Principal component analysis was done to find out variables with similar eigen values and show the nature of their relationship (Bro and Smilde, 2014). Vegetation principal components were rotated by varimax Kaiser normalized procedure to facilitate interpretation (Bro and Smilde, 2014). Stepwise multiple regression models were used to determine which vegetation variables accounted for the greatest amount of variation in bird species abundance and diversity in the four habitats (Seber *et al.*, 2012).

3.5.5 Assessment of threats to avifauna and forest habitats

The responses of local community members, community based organization officials and forest rangers to questions on forest exploitation and avifaunal decline were analyzed using descriptive statistics, where frequencies were used to draw pie-charts and bar-graphs. Comparisons of social demographic characteristics such as sex and age against activities towards forest exploitation was done through cross tabulation using Pearson chi square (χ^2) at 5% significance level.

CHAPTER FOUR

RESULTS

4.1 Bird species diversity

Overall, a total of 151 bird species were recorded in the study area. Of the 151 species, 114 were recorded using only one of the four methods (50 being unique for PC, 35 for TSC, 25 for DTC and 4 for mist netting) underlying the value of having at least two methods in initial surveys. These comprised 143 bird species from point counts, distance transect counts (82 species), timed-species counts (130 species) and mist netting (22 species). An extra 3 species were observed opportunistically, bringing the total to 151 species identified during the study (complete checklist in Appendix 1). From the species accumulation curve, it was apparent that the complete avian community may not have been realized during this study (Figure 4.1). Based on the upper and lower confidence limits of this estimate, the number of species expected in North Nandi Forest was likely to be between 120 and 180 bird species. The species accumulation curves revealed that additional avian surveys in indigenous forest, disturbed forest and farmlands might record some new species since their curves did not level off until the last survey day while plantation forest curve leveled off in day 14 showing that increased searches was unlikely to record new additional species in this habitat.

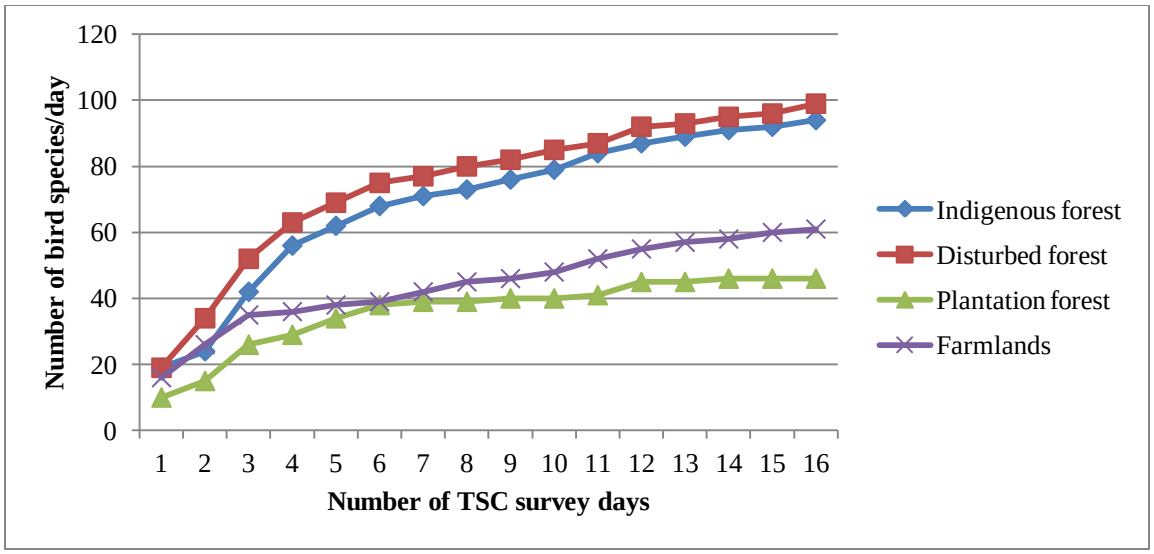

Figure 4.1: Species discovery curves of birds in and around North Nandi Forest. Additional surveys may not record new bird species in plantation forest.

4.2 Relative abundance of bird species

Based on point count method, a total of 3,232 individual birds were observed and recorded in and around North Nandi Forest. A total of 974 birds were recorded in farmland being the highest abundance translating to 0.108 birds ha^{-1}. Disturbed forest with 805 birds (0.089 birds ha^{-1}) and indigenous forest with 766 birds (0.085 birds ha^{-1}) had intermediate abundance. Plantation forest had the least abundance with 687 birds (0.076 birds ha^{-1}). The percentage relative abundance of bird species recorded in the four habitats with relative abundance >2% is shown in Tables 4.1. The full list of percentage relative abundance of all birds in the four habitats is shown in Appendices 2, 3, 4, and 5.

Table 4.1: Relative abundance of bird species recorded in the four habitats using distance point count method in and around North Nandi Forest. Relative abundance greater than 2% in descending order.

Indigenous forest	R.A %	Disturbed forest	R.A %	Plantation forest	R.A %	Farmland	R.A %
Common Bulbul	8.877	Common Bulbul	9.193	Black-and-white Mannikin	21.543	Black-and-white Mannikin	13.86
Grey Apalis	5.222	Speckled Mousebird	4.224	Baglafecht Weaver	9.316	Black-crowned Waxbill	6.674
Black-and-white Casqued Hornbill	4.830	Grey Apalis	3.851	Common Bulbul	7.569	White-eyed Slaty Flycatcher	5.852
Yellow-whiskered Greenbul	4.047	Cinnamon-chested Bee-eater	3.354	White-eyed Slaty Flycatcher	6.114	Speckled Mousebird	5.749
White-headed Wood-hoopoe	3.916	Angola Swallow	3.106	African Dusky Flycatcher	5.095	Baglafecht Weaver	5.236
Black Saw-wing	3.786	Yellow-whiskered Greenbul	2.981	Cinnamon-chested Bee-eater	4.076	Common Bulbul	4.517
Cabanis's Greenbul	3.786	Black-and-white Mannikin	2.857	Ring-necked Dove	3.785	Lesser Striped Swallow	4.517
Cinnamon-chested Bee-eater	3.655	Cabanis's Greenbul	2.857	African Pied Wagtail	3.493	Variable Sunbird	4.312
Angola Swallow	3.525	White-eyed Slaty Flycatcher	2.857	Pale Flycatcher	3.202	Singing Cisticola	3.593
Black-collared Apalis	3.133	Variable Sunbird	2.733	African Paradise Flycatcher	3.057	Common Fiscal	2.977
Montane White-eye	3.003	Vieillot's Black Weaver	2.733	Common Fiscal	2.620	Chubb's Cisticola	2.669
Grey-throated Barbet	2.480	Amethyst Sunbird	2.360	Chubb's Cisticola	2.475	Ring-necked Dove	2.464
Joyful Greenbul	2.480	African Blue Flycatcher	2.112	Olive Thrush	2.475	House Sparrow	2.361

There was a significant difference in bird abundance across the four habitats (ANOVA; F=15.141, df=3, 1121, P<0.0001). Tukey's pair wise comparison tests revealed that farmlands significantly differed from all the other three habitats. Abundance was highest in farmlands (1.781±0.034 birds ha^{-1}), intermediate in disturbed forest (1.541±0.264 birds ha^{-1}) and indigenous forest (1.531±0.269 birds ha^{-1}) and lowest in plantation forest (1.426±0.355 birds ha^{-1}) (Table 4.2, Figure 4.2).

4.2.1 Bird species dominance

Point count results in and around North Nandi Forest revealed that the Common Bulbul *Pycnonotus barbatus* was the most dominant bird in both Indigenous forest (8.88%) and Disturbed forest (9.19%). Other dominant bird species in Indigenous forest were; Grey Apalis *Apalis cinerea* (5.22%), Black-and-white Casqued Hornbill *Bycanistes subcylindricus* (4.83%) and Yellow-whiskered Greenbul *Andropadus latirostris* (4.05%) while the remaining bird species had less than 3%. In Disturbed forest other dominant bird species were; Speckled Mousebird *Colius striatus* (4.22%), Grey Apalis *Apalis cinerea* (3.85%), Cinnamon-chested Bee-eater *Merops oreobates* (3.35%) and Angola Swallow *Hirundo angolensis* (3.11%), the other bird species had less than 2%.

Table 4.2: Mean bird abundance of four habitats in and around North Nandi Forest. Means with the same alphabetical letter are not significantly different (Tukey HSD (Honest Significant Difference) test). n= Number of birds sampled for each habitat type.

Habitat	Mean	Standard error	n
Indigenous forest	1.531b	0.269	269
Disturbed forest	1.541b	0.254	316
Plantation forest	1.426b	0.355	234
Farmlands	1.781a	0.034	279

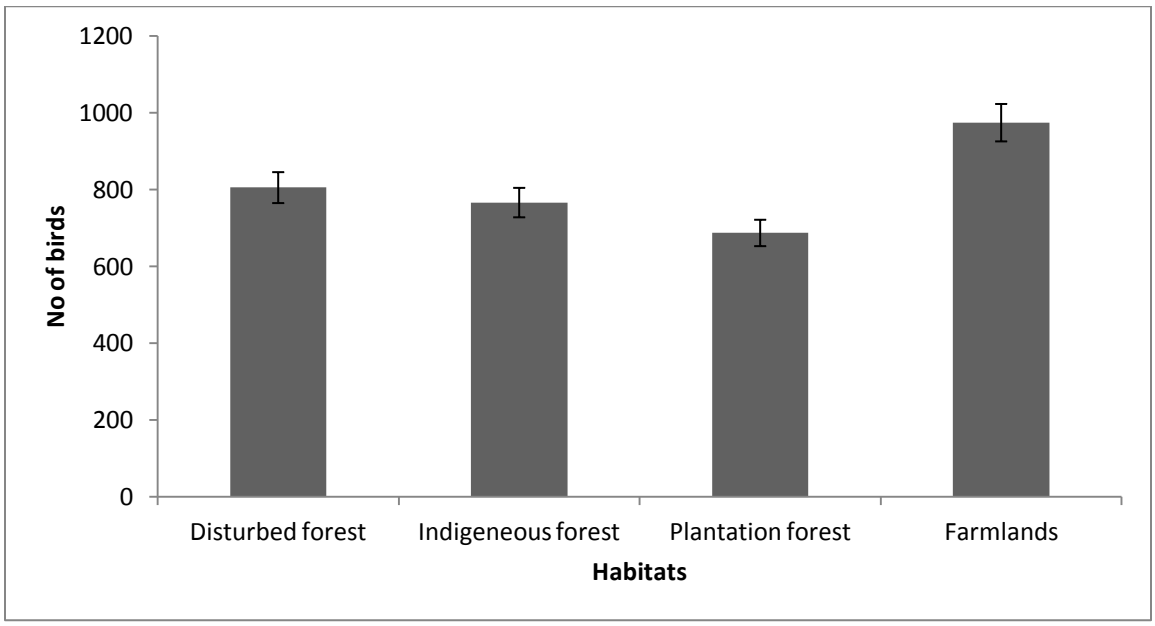

Figure 4.2: Mean bird abundance across four habitats in and around North Nandi Forest. Farmland had significantly higher bird counts than plantation forest; Error bars indicate percentage errors at α = 0.05

Black-and-white Mannikin *Spermestes bicolor* was the most dominant bird in both plantation forest (21.54%) and farmland (13.86%). Other dominant bird species in plantation forest were; Baglafecht Weaver *Ploceus baglafecht* (9.32%), Common Bulbul *Pycnonotus barbatus* (7.57%), White-eyed Slaty Flycatcher *Melaenornis fischeri* (6.11%), African Dusky Flycatcher *Muscicapa adusta* (5.09%), and Cinnamon-chested Bee-eater *Merops oreobates* (4.08%) the remaining bird species had less than 3%. Dominant bird species in farmland were; Black-crowned Waxbill *Estrilda nonnula* (6.67%), White-eyed Slaty Flycatcher *Melaenornis fischeri* (5.85%), Speckled Mousebird *Colius striatus* (5.75%) and Baglafecht Weaver *Ploceus baglafecht* (5.24%) while other bird species had less than 4%.

Using distance line transect method, 47 species of birds were recorded in farmlands while 35 species were recorded in plantation forest. Percentage relative abundance of bird species in plantation forest and farmland >2% is as shown (Table 4.3). Full list of percentage relative abundance of all birds using distance line transects in the two habitats is shown in Appendices 6, and 7.

Table 4.3: Relative abundance of bird species recorded in plantation forest and Farmland using distance line transects method in and around North Nandi Forest. Relative abundance greater than 2 the list below is in descending order.

Plantation forest	R.A %	Farmland	R.A %
Common Bulbul	10.921	Black-and-white Mannikin	11.534
Baglafecht Weaver	8.565	Black-crowned Waxbill	9.759
Black-and-white Mannikin	8.351	Baglafecht Weaver	6.591
Pale Flycatcher	7.709	Speckled Mousebird	6.337
African Dusky Flycatcher	5.353	White-eyed Slaty Flycatcher	6.337
Black Saw-wing	4.925	Common Waxbill	5.196
White-eyed Slaty Flycatcher	4.711	Common Bulbul	4.943
Chubb's Cisticola	4.497	Pale Flycatcher	3.676
Angola Swallow	4.283	House Sparrow	3.042
Cinnamon-chested Bee-eater	4.069	Speke's Weaver	3.042
African Pied Wagtail	3.854	Chubb's Cisticola	2.662
Common Fiscal	3.640	Amethyst Sunbird	2.408
White-browed Robin Chat	2.998	Barn Swallow	2.408
African Paradise Flycatcher	2.784	Singing Cisticola	2.281
Amethyst Sunbird	2.570	African Pied Wagtail	2.155
House Sparrow	2.141	Common Fiscal	2.028

ANOVA results revealed a significance difference between bird abundance in Plantation forest and Farmlands ($F=15.689$, $df=1, 388$, $P<0.0001$). Farmland had a higher abundance (1.805 ± 0.038 birds ha^{-1}) compared to plantation forest (1.590 ± 0.037 birds ha^{-1}).

Black-and-white Mannikin *Spermestes bicolor*, Equatorial Akalat *Sheppardia equatorialis* and Black-collared Apalis *Apalis pulchra* were the most abundant birds caught by mist nets in the two habitats; indigenous forest and disturbed forest habitats (Appendix 8).

4.3 Bird diversity indices

Shannon-Weiner diversity index H' values in the study area ranged from 3.0 to 4.0 showing a relatively diverse bird community. Simpson's diversity index D for the four habitats in and around North Nandi Forest showed a similar trend as H' values with disturbed forest having the highest value (D=0.976) hence the highest species diversity while plantation forest (D=0.923) had the lowest species diversity. D was subtracted from 1 to give the higher values the highest diversity (Table 4.4).

Table 4.4: Diversity indices for four habitats in and around North Nandi Forest. Shannon-Weiner diversity index H' values above 1.7 and less than 7.0 indicate a diverse community hence all habitats in this study fit this criterion. Simpson's diversity index D after subtraction from 1 showed a high diversity for all habitats with values above 0.9 close to 1.

Habitat	H'	D	1-D
Disturbed forest	4.053	0.024	0.976
Indigenous forest	3.896	0.028	0.972
Farmland	3.482	0.046	0.954
Plantation forest	3.060	0.077	0.923

4.3.1 Similarity of bird species between different habitats

Sorenson's similarity index Cs was used to compare similarity of bird species richness across the four habitats. Indigenous forest and disturbed forest had the highest similarity association with 89.34%. The Cs between Plantation forest and Farmlands was 60.37%, while Cs between Indigenous forest and Farmlands was 59.39%. The similarity association in Disturbed forest and Plantation forest was the lowest at 38.54%.

Some bird species were only found in a particular habitat during the survey such as Tiny Cisticola *Cisticola nanus* and Village Weaver *Ploceus cucullatus* in plantation forest. Bird species restricted to indigenous forest, disturbed forest, farmland and plantation habitats have no similarity index hence unique to these habitats only. Bird species shared across all the four habitats were unique as they showed similarity association across these habitats. Birds in indigenous forest are specialized to their habitat, while those found in disturbed forest are generalists and visitor bird species that adapt to a changing matrix of micro habitats. Bird species restricted to farmland habitat are mostly none-forest dependent, bird species found in all habitats have the ability to utilize survival resources in all habitats (Table 4.5).

Table 4.5: Bird species restricted to indigenous forest, disturbed forest and farmlands during the survey in and around North Nandi Forest.

Common Name	Scientific Name	Indigenous forest	Disturbed forest	Farmlands	All habitats
Mountain Buzzard	*Buteo oreophilus*	*			
Dusky Tit	*Parus funereus*	*			
Jameson's Wattle-eye	*Dyaphorophyia jamesoni*	*			
Red-headed Malimbe	*Malimbus rubricollis*	*			
Turner's Eremomela	*Eremomela turneri*	*			
Common Cuckoo	*Cuculus canorus*		*		
Black-backed Puffback	*Dryoscopus cubla*		*		
Black-headed Gonolek	*Laniarius erythrogaster*		*		
Violet-backed Starling	*Cynniricinclus leucogaster*		*		
Blackcap	*Sylvia atricapilla*		*		
African Firefinch	*Lagonosticta rubricata*			*	
Lesser Striped Swallow	*Cecropis abyssinica*			*	
Lesser Masked Weaver	*Ploceus intermedius*			*	
Speckled Mousebird	*Colius striatus*				*
White-eyed Slaty Flycatcher	*Melaenornis fischeri*				*
Common Bulbul	*Pycnonotus barbatus*				*

4.4 Bird species richness

The total number of bird species recorded in the four habitats in and around North Nandi Forest was 151 species. Disturbed forest had the highest species richness with 99 species followed by indigenous forest with 94 species. Farmland had 62 species while plantation forest had the least species richness with 45 species.

Chi-square test for goodness of fit results revealed a significant difference in bird species richness in the four habitats (χ^2=26.747, df=3, P<0.0001). Indigenous forest and disturbed forest had a higher species richness compared to lower species richness in plantation forest and farmland (Figure 4.3).

4.5 Bird species of interest (Biome, threatened, migrant and endemic species)

Twenty six (26) of the 151 bird species recorded were biome-characteristic species, 15 bird species were from the Afro-Tropical Highland Biome while 11 bird species were from Guineo-Congolian Biome (Table 4.6). Other species of interest recorded included, 20 species considered globally threatened, regionally threatened, scarce and endemic by the ornithological bird committee of East African Natural History Society (Table 4.7). A total of 7 migrant species were recorded during the survey, 4 Afro tropical Migrant species and 3 Palearctic Migrant species (Table 4.8).

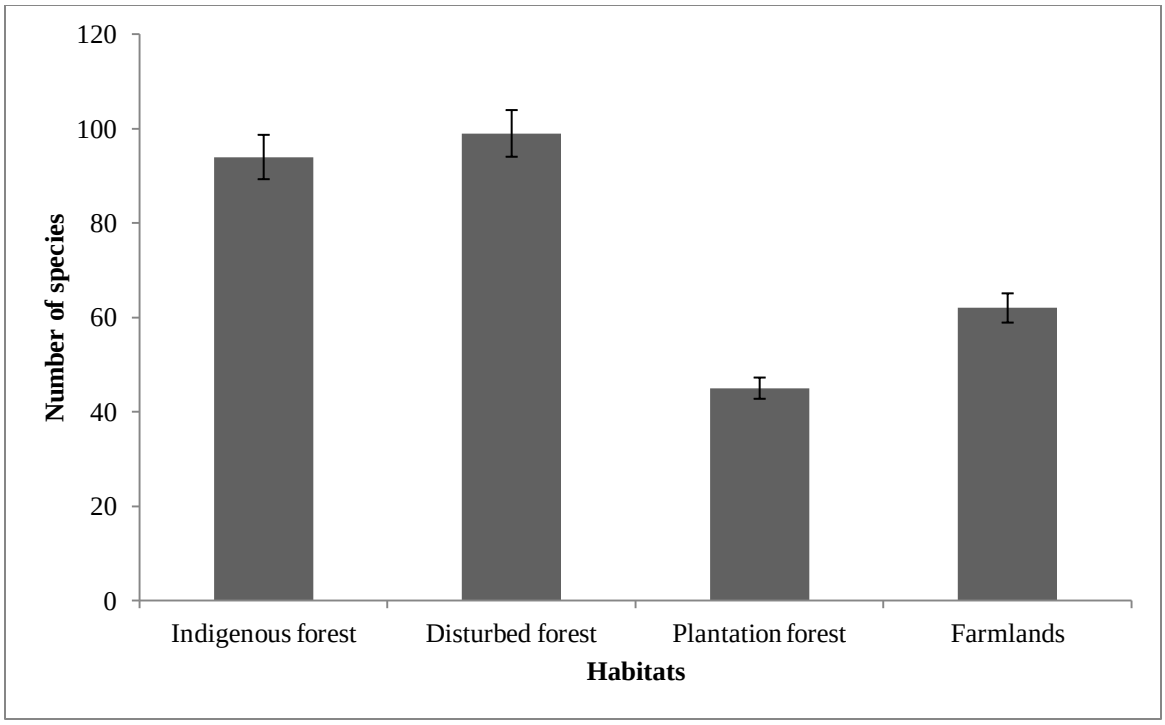

Figure 4.3: Distribution of bird species across four habitats in and around North Nandi Forest. Disturbed forest and indigenous forest had high bird species variability as compared to low bird species variability in farmlands and plantation forest; Error bars indicate percentage errors at α = 0.05.

Table 4.6: Biome restricted bird species recorded in and around North Nandi Forest during the survey. Afro-Tropical Highland biome and Guineo-Congolian biome bird species seen mainly in indigenous forest and disturbed forest.

Common Name	Scientific Name	Biome
African Citril	*Crithagra citrinelloides*	Afro-Tropical Highland Biome
African Hill Babbler	*Pseudoalcippe abyssinica*	Afro-Tropical Highland Biome
Baglafecht Weaver	*Ploceus baglafecht*	Afro-Tropical Highland Biome
Black-collared Apalis	*Apalis pulchra*	Afro-Tropical Highland Biome
Chubb's Cisticola	*Cisticola chubbi*	Afro-Tropical Highland Biome
Cinnamon-chested Bee-eater	*Merops oreobates*	Afro-Tropical Highland Biome
Equatorial Akalat	*Sheppardia aequatorialis*	Afro-Tropical Highland Biome
Fine-banded Woodpecker	*Campethera tullbergi*	Afro-Tropical Highland Biome
Grey Cuckooshrike	*Coracina caesia*	Afro-Tropical Highland Biome
Hartlaub's Turaco	*Tauraco hartlaubi*	Afro-Tropical Highland Biome
Mountain Greenbul	*Andropadus nigriceps*	Afro-Tropical Highland Biome
Mountain Illadopsis	*Illadopsis pyrrhoptera*	Afro-Tropical Highland Biome
Shelley's Greenbul	*Andropadus masukuensis*	Afro-Tropical Highland Biome
White-eyed Slaty Flycatcher	*Melaenornis fischeri*	Afro-Tropical Highland Biome
White-tailed Crested Flycatcher	*Eliminia albonotata*	Afro-Tropical Highland Biome
Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*	Guineo-Congolian Biome
Brown Illadopsis	*Illadopsis fulvescens*	Guineo-Congolian Biome
Buff-throated Apalis	*Apalis rufogularis*	Guineo-Congolian Biome
Plain Greenbul	*Andropadus curvirostris*	Guineo-Congolian Biome
Dusky Tit	*Parus funereus*	Guineo-Congolian Biome
Green-headed Sunbird	*Cyanomitra verticalis*	Guineo-Congolian Biome
Jameson's Wattle-eye	*Dyaphorophyia jamesoni*	Guineo-Congolian Biome
Petit's Cuckooshrike	*Campephaga petiti*	Guineo-Congolian Biome
Kenya Rufous Sparrow	*Passer rufocinctus*	Guineo-Congolian Biome
Turner's Eremomela	*Eremomela turneri*	Guineo-Congolian Biome
Western Oriole	*Oriolus brachyrhynchus*	Guineo-Congolian Biome

Table 4.7: Globally Threatened, Regionally threatened, Endemic and Nationally Scarce bird species recorded during the study in and around North Nandi Forest. Source: Ornithological bird committee of East African Natural History Society (2009).

Common Name	*Scientific Name*	Globally threatened	Regionally threatened	Scarce	Endemic
Grey Crowned Crane	*Balearica regulorum*	*			
Turner's Eremomela	*Eremomela turneri*	*			*
Southern Hyliota	*Hyliota australis*		*		
Lesser Honeyguide	*Indicator minor*		*		
Least Honeyguide	*Indicator exilis*			*	
Mountain Illadopsis	*Illadopsis pyrrhoptera*			*	
White-tailed Crested Flycatcher	*Eliminia albonotata*			*	*
African Citril	*Crithagra citrinelloides*				*
Brown-chested Alethe	*Alethe poliocephala*				*
Bar-throated Apalis	*Apalis thoracica*				*
African Dusky Flycatcher	*Muscicapa adusta*				*
African Grey Flycatcher	*Bradornis microrhynchus*				*
Long-tailed Widowbird	*Euplectes progne*				*
Montane White-eye	*Zosterops poliogastrus*				*
Red-fronted Warbler	*Urorhipis rufifrons*				*
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*				*
Speckled Mousebird	*Colius striatus*				*
Fine-banded Woodpecker	*Campethera tullbergi*				*

Table 4.8: Afro-tropical Migrant (AM) bird species and Palearctic Migrant (PM) bird species recorded during the survey in and around North Nandi Forest. AM bird species move within the continent of Africa, while PM bird species move from Eurasia (Europe) to Africa and vice versa.

Common Name	Scientific Name	Migrant status
Hoopoe	*Upupa epops*	AM,PM
Blackcap	*Sylvia atricapilla*	PM
Barn Swallow	*Hirundo rustica*	PM
Common Cuckoo	*Cuculus canorus*	PM
African Paradise Flycatcher	*Terpsiphone viridis*	AM
Violet-backed Starling	*Cynniricinclus leucogaster*	AM
Woodland Kingfisher	*Halcyon senegalensis*	AM

4.6 Forest Dependency

A total of 52 Forest generalist bird species, 43 Forest visitor bird species, 40 Forest specialist bird species and 16 non-forest bird species were recorded during the study (Appendix 9). Forest generalist bird species had the highest abundance, while forest visitors and forest specialist bird species had intermediate abundance. Non-forest bird species had the least abundance (Figure 4.4).

4.7 Common bird species

Based on Time Species Count Index (on a scale of 1-4, 4 being the commonest index in descending order to 1), the commonest bird species in indigenous forest were the Green Hylia and Western Oriole respectively (Figure 4.5a). The commonest bird species in disturbed forest were the Plain Greenbul and Montane White-eye respectively (Figure 4.5b). The commonest bird species in plantation forest were African Citril and White-browed Robin Chat respectively (Figure 4.5c) while the commonest bird species in the farmland were Black-crowned Waxbill and Common Fiscal, respectively (Figure 4.5d).

4.8 Rare bird species

Based on Time Species Count Index (on a scale of 1-4, 1 being the rarerest index), the rarerest bird species, that is, with the least average index in indigenous forest included; Jameson’s Wattle-eye, and Turner's Eremomela among others (Table 4.9a). The rarerest bird species in disturbed forest include; Yellow-bellied Wattle-eye and White-tailed Crested Flycatcher among others (4.9b). The rarerest bird species in plantation forest included; Montane White-eye and Northern Black Flycatcher among others (Table 4.9c). The rarerest bird species in farmland included; Red-billed Hornbill and Greater Blue-eared Starling among others (4.9d).

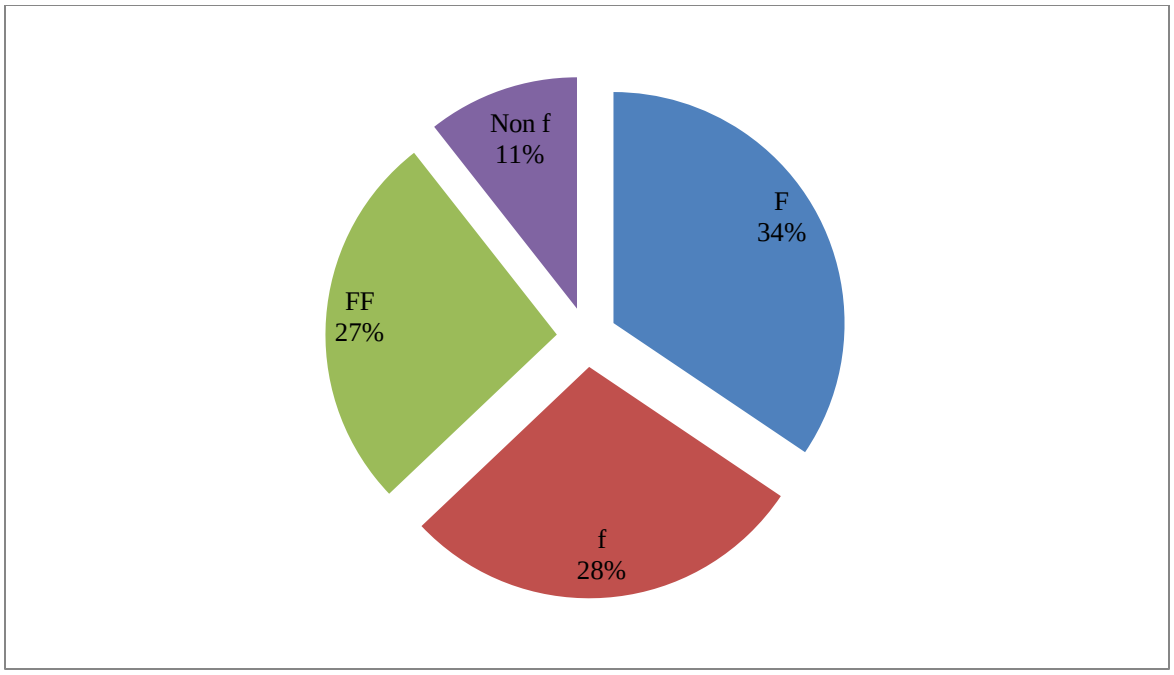

Figure 4.4: Proportions of bird forest dependency categories in and around North Nandi Forest. F-Forest generalist bird species, FF-Forest specialist bird species, f-Forest visitor bird species and Non f-Non-forest bird species. Forest generalist dominated the species assemblage, while few non-forest bird species were recorded during the survey.

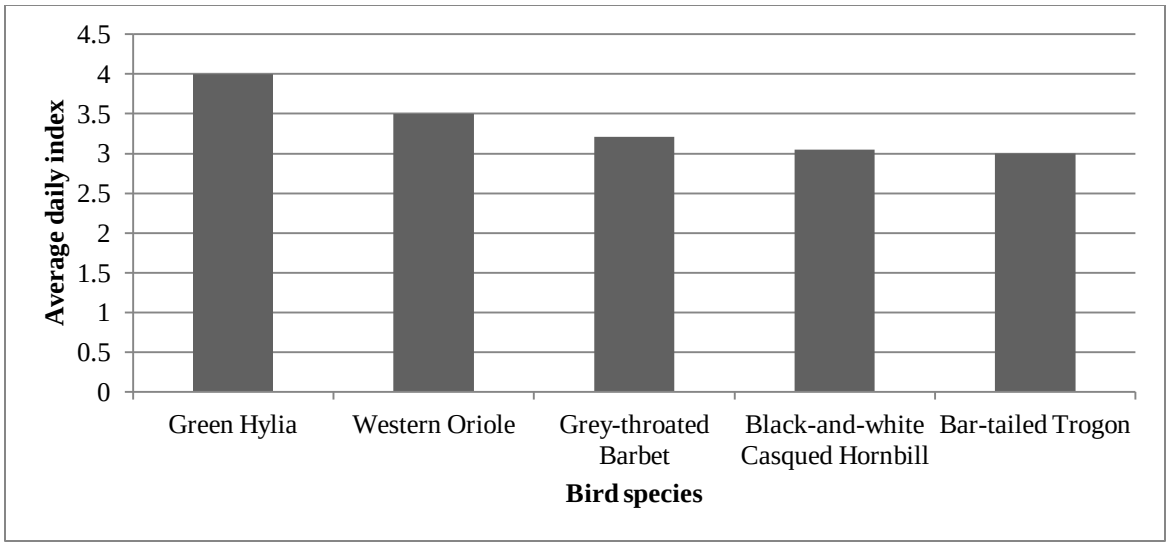

Figure 4.5a: Top-5 Commonest bird species in indigenous forest based on relative abundance using TSC Index (scale 1-4). 4 is the commonest index in descending order.

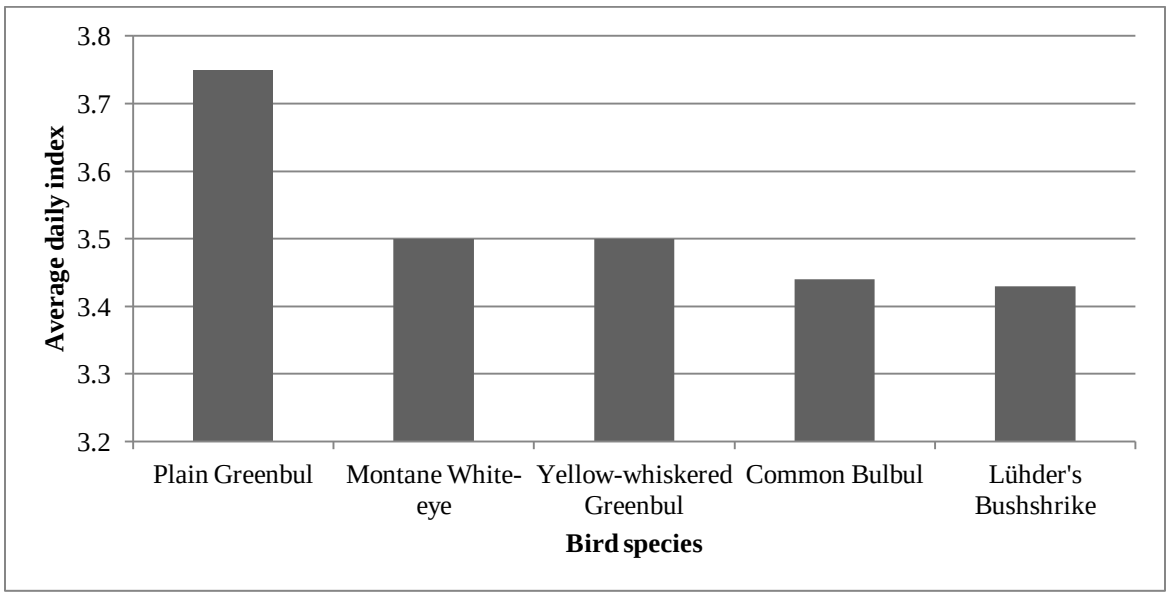

Figure 4.5b: Top-5 Commonest bird species in disturbed forest based on relative abundance using TSC Index (scale 1-4). 4 is the commonest index in descending order.

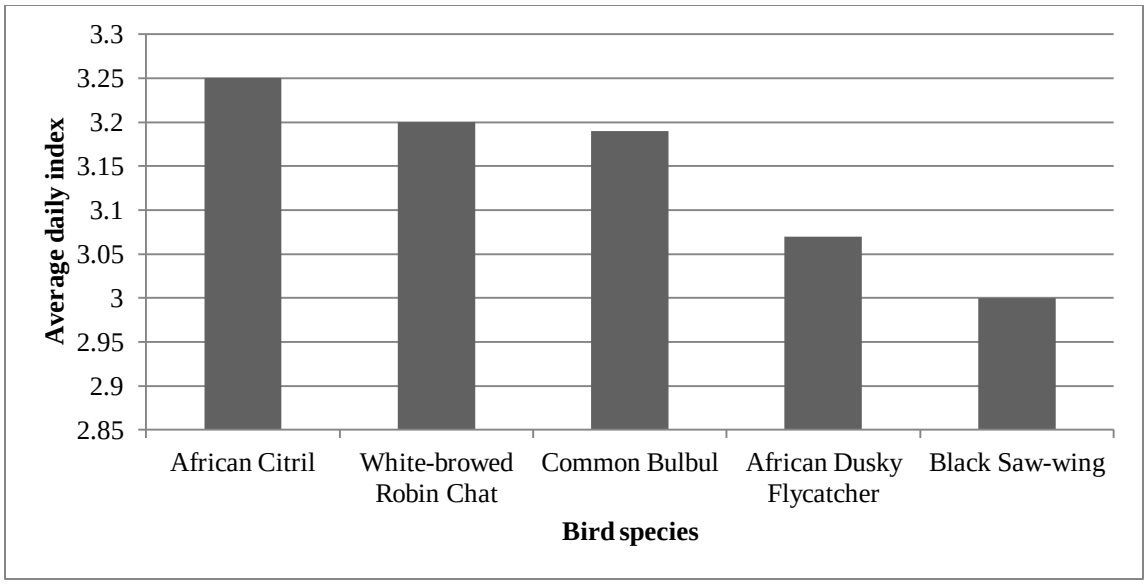

Figure 4.5c: Top-5 Commonest bird species in plantation forest based on relative abundance using TSC Index (scale 1-4). 4 is the commonest index in descending order.

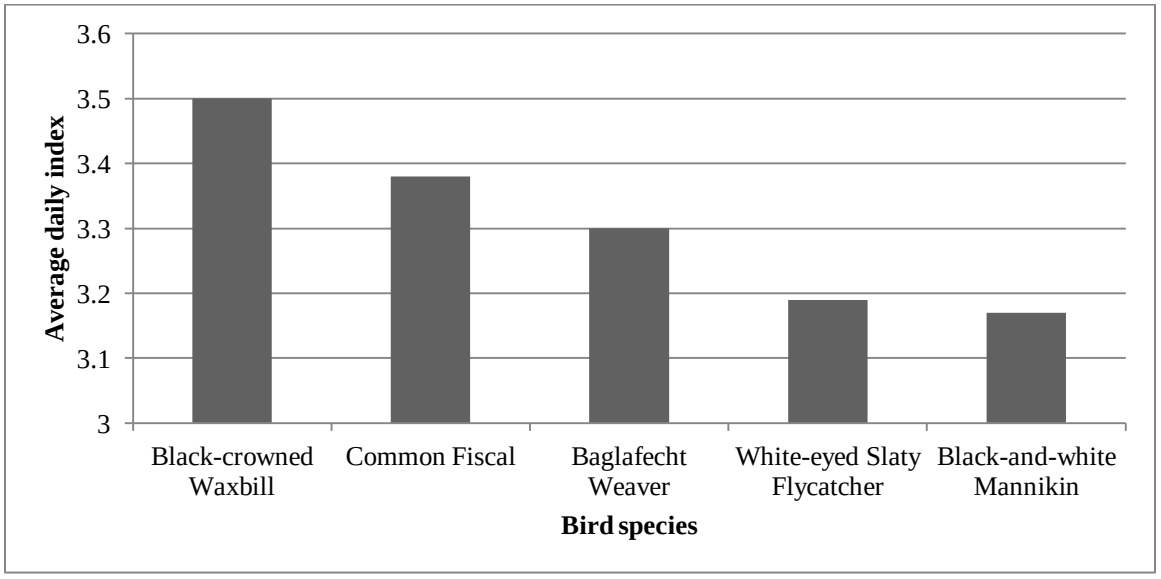

Figure 4.5d: Top-5 Commonest bird species in farmlands based on relative abundance using TSC Index (scale 1-4). 4 is the commonest index in descending order.

Table 4.9a: Five rarerest bird species in indigenous forest based on relative abundance using TSC index (scale 1-4, 1 is the rarerest index). The list below is in ascending order.

Common Name	Scientific Name	Average daily index
Jameson's Wattle-eye	*Dyaphorophyia jamesoni*	1
Turner's Eremomela	*Eremomela turneri*	1
Hoopoe	*Upupa epops*	1
Southern Hyliota	*Hyliota australis*	1
White-starred Robin	*Pogonocichla stellata*	1.5

Table 4.9b: Five rarerest bird species in disturbed forest based on relative abundance using TSC index (scale 1-4, 1 is the rarerest index). All bird species in the list below have an average daily index of 1.

Common Name	Scientific Name	Average daily index
Yellow-bellied Wattle-eye	*Dyaphorophyia concreta*	1
White-tailed Crested Flycatcher	*Eliminia albonotata*	1
African Emerald Cuckoo	*Chrysococcyx cupreus*	1
Brown-backed Woodpecker	*Picoides obsoletus*	1
Mountain Yellow Warbler	*Chloropeta similis*	1

Table 4.9c: Five rarerest bird species in plantation forest based on relative abundance using TSC index (scale 1-4, 1 is the rarerest index). The list below is in ascending order.

Common Name	Scientific Name	Average daily index
Montane White-eye	*Zosterops poliogastrus*	1.5
Northern Black Flycatcher	*Melaenornis edolioides*	1.6
Olive Thrush	*Turdus olivaceus*	1.75
Red-eyed Dove	*Streptopelia semitorquata*	1.82
Tawny-flanked Prinia	*Prinia subflava*	2

Table 4.9d: Five rarerest bird species in farmlands based on relative abundance using TSC index (scale 1-4, 1 is the rarerest index). The list below is in descending order.

Common Name	Scientific Name	Average daily index
Red-billed Hornbill	*Tockus erythrorhynchus*	1
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	1.25
Augur Buzzard	*Buteo augur*	1.33
Northern Black Flycatcher	*Melaenornis edolioides*	1.58
Amethyst Sunbird	*Chalcomitra amethystina*	1.8

4.9 Bird feeding guilds

4.9.1 Distribution of feeding guilds across the habitats

Overall, in all the four habitats, insectivores dominated the species assemblage. In indigenous forest and disturbed forest, frugivores came second unlike in the plantation forest and farmland whereby granivores were the second dominant feeding guild. In all the four habitats omnivores had the least proportion (Figure 4.6).

ANOVA results used to compare mean distribution of various feeding guilds across the four habitats revealed that insectivores ($F=3.090$, $df=3, 297$, $P=0.027$) and granivores ($F=10.496$, $df=3, 297$, $P<0.0001$) had a significant difference across the four habitats. Densities of insectivores were highest in disturbed forest (0.63 ± 0.049 birds ha^{-1}) and indigenous forest (0.63 ± 0.050 birds ha^{-1}), intermediate in farmland (0.42 ± 0.063 birds ha^{-1}) and lowest in plantation forest (0.31 ± 0.075 birds ha^{-1}). Frugivores, raptors, nectarivores and omnivores showed no significant differences across the four habitats ($P>0.05$ in all cases). Multiple comparisons test using Tukey test revealed that granivores had a significant difference between indigenous forest and disturbed forest versus plantation forest and farmlands with the latter two having low proportions.

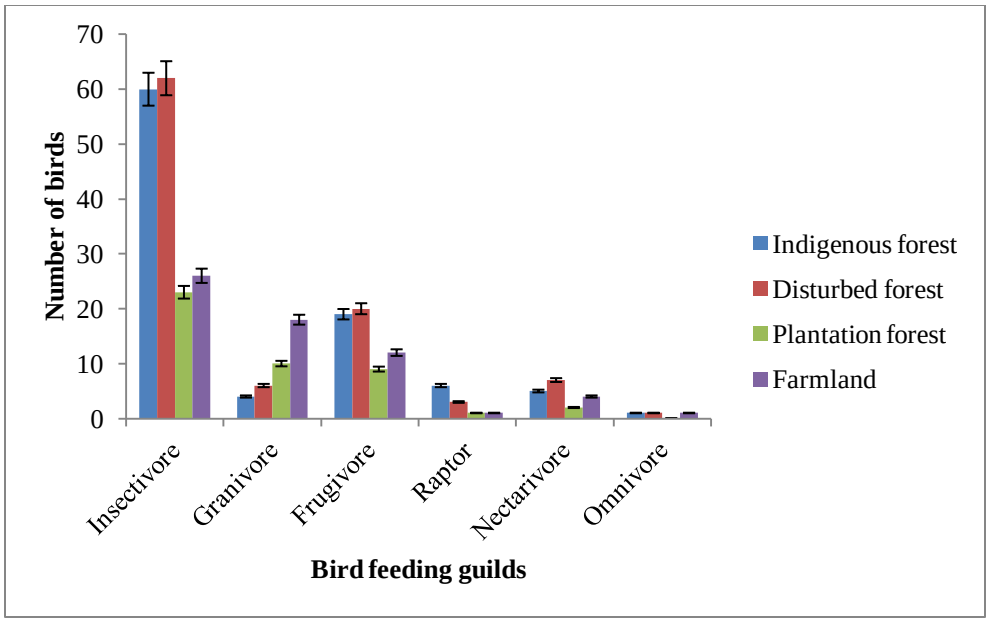

Figure 4.6: Proportions of different feeding guilds in indigenous forest, disturbed forest, plantation forest and farmland. Insectivores had significantly higher proportion in the four habitats. Percentage error bars.

4.10 Vegetation structure

4.10.1 Summary of vegetation characteristics

Disturbed forest had the highest mean percent ground cover 0.750±0.010 (75%) while indigenous forest had the lowest mean percent ground cover 0.439±0.008 (43.9%). Indigenous forest had the highest mean percent mid-canopy cover 0.604±0.007 (60.4%) and canopy cover 0.838±0.004 (83.85%) but farmlands had the least mean percent mid-canopy cover 0.005±0.002 (0.5%) and canopy cover 0.000±0.000 (0.0%). Indigenous forest had the mean tallest trees (21.53±0.797 m) and shrubs (3.52±0.087 m) as opposed to mean shortest trees (0.24±0.069 m) and shrubs (1.45±0.033 m) in farmland. In indigenous forest 1.63±0.058 and disturbed forest 1.79±0.080 vegetation was mainly composed of large sized trunk trees (DBH ≥30 cm). In plantation forest 2.16±0.049

medium sized trunk trees (DBH≥15-29.9cm) dominated while in farmland 2.95±0.013 small sized stems dominated the vegetation (DBH ≥ 5-14.9 cm) (Table 4.10).

Disturbance index of the plot patches sampled for various vegetation characteristics in each habitat using observations revealed that disturbed forest (3.29±0.053) had the highest disturbance index. Indigenous forest (2.92±0.019) and farmland (2.94±0.014) had intermediate disturbance index. Plantation forest (2.00±0.000) had the least disturbance index in terms of trees cut down and young tree seedlings being trampled by livestock grazing (Table 4.10).

4.10.2 Association of vegetation variables and habitat structure

Six vegetation variables in the four habitats were extracted based on the strength of eigen values by principal component analysis method. Two variables; diameter at breast height and ground cover with eigen values >1 were strongly correlated with habitat structure in all the four habitats with an explained variance of 73.2%. Four variables; mid canopy cover, canopy cover, tree height and shrub height with eigen values <1 were not strongly correlated with habitat structure with an explained variance of 26.8 %. DBH and ground cover were the two most significant variables which characterized vegetation structure in the four habitats in North Nandi Forest. (Table 4.11, Figure 4.7).

Table 4.10: Means and standard errors at α = 0.05 of vegetation variables sampled across four habitats in and around North Nandi Forest.

Vegetation characteristics	Indigenous forest (Means±SE)	Disturbed forest (Means±SE)	Plantation forest (Means±SE)	Farmlands (Means±SE)
Diameter at Breast Height (%)	1.63±0.058	1.79±0.080	2.16±0.049	2.95±0.013
Ground cover (%)	0.439±0.008	0.750±0.010	0.475±0.015	0.630±0.009
Mid-canopy cover (%)	0.604±0.007	0.456±0.029	0.340±0.018	0.005±0.002
Canopy cover (%)	0.838±0.004	0.465±0.019	0.604±0.021	0.000±0.000
Tree height (m)	21.53±0.797	17.93±0.982	11.98±0.437	0.24±0.069
Shrub height (m)	3.52±0.087	2.20±0.120	0.33±0.028	1.45±0.033
Disturbance index (High, Medium, Low)	2.92±0.019	3.29±0.053	2.00±0.000	2.94±0.014

Table 4.11: Vegetation variables describing habitat structure in and around North Nandi Forest. Variables arranged in descending percentage explained variance.

Variables	Reproduced correlations	Initial eigen values	Explained variance (%)
Diameter at breast height	0.830**	3.382	56.370
Ground cover	0.657**	1.010	16.833
Mid canopy cover	0.629*	0.803	13.388
Canopy cover	0.770*	0.494	8.239
Tree height (m)	0.891*	0.225	3.757
Shrub height (m)	0.614*	0.85	1.413

All variables were significant at $p<0.05$. Correlation coefficients with double asterisk marks (**) denote highly significant vegetation variables in relation to habitat structure in the four habitats in North Nandi Forest. DBH and ground cover were significant variables in relation to vegetation cover in the four habitats.

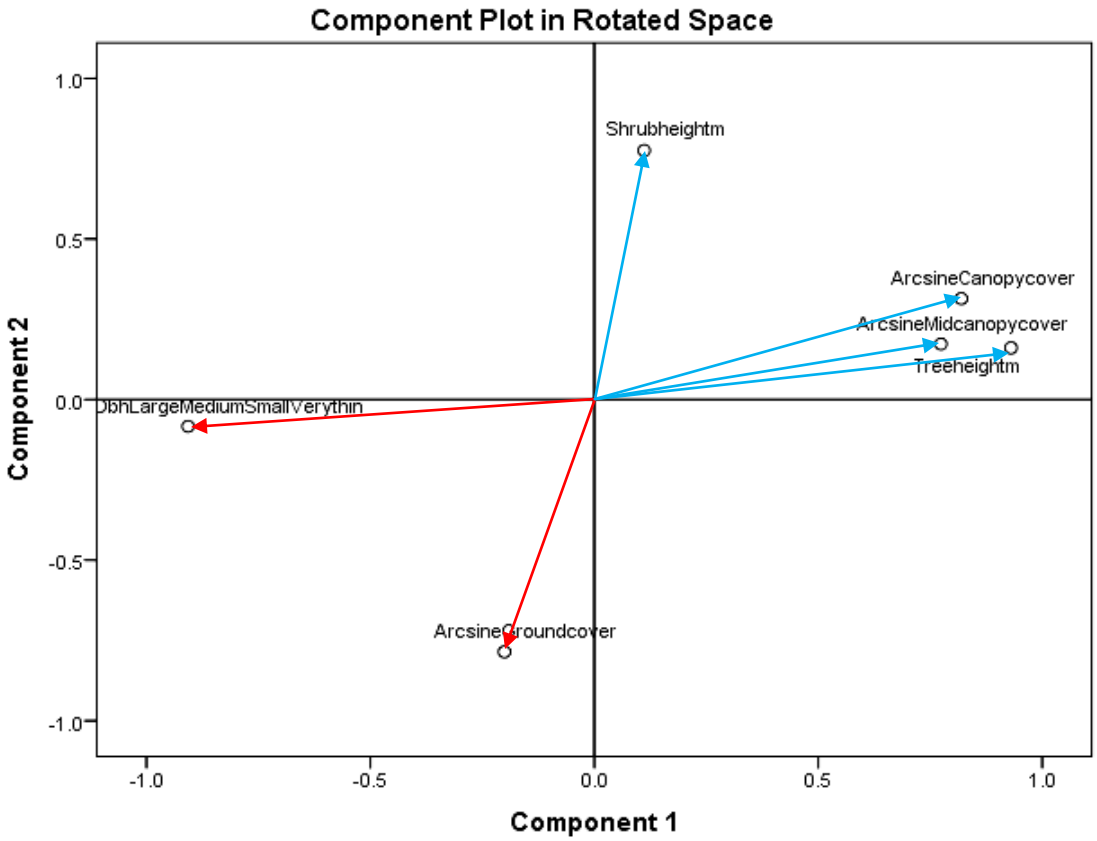

Figure 4.7: Rotated component plot showing closely related vegetation variables. Component 1 shows variables aligned to the x-axis (tree height, mid-canopy cover, canopy cover and DBH). Component 2 shows variables aligned to the y-axis (ground cover and shrub height). Variables with < 1 eigen values and >1 eigen values are placed in the same quadrat space respectively.

4.10.3 Relationship between bird species richness and vegetation variables

When bird species richness was compared with various vegetation variables in and around North Nandi Forest using linear regression, results revealed a strong linear relationship with the following variables; Diameter at breast height ($F=99.760$, $r^2=0.73$, df=1, 1268, $P<0.0001$) and tree height ($F=97.134$, $r^2=0.71$, df=1, 1268, $P<0.0001$). Bird species richness showed a less linear relationship with variables such as; ground cover ($F=64.219$, $r^2=0.48$, df=1, 1268, $P<0.0001$) and shrub height ($F=42.845$, $r^2=0.33$, df=1, 1268, $P<0.0001$), canopy cover ($F=34.723$, $r^2=0.27$, df=1, 1268, $P<0.0001$) and mid-canopy cover ($F=17.330$, $r^2=0.13$, df=1, 1268, $P<0.0001$) (Table 4.12).

4.10.4 Relationship between bird abundance and vegetation variables

Bird abundance across the four habitats in North Nandi Forest when compared with vegetation variables using linear regression revealed a strong linear relationship with the following variables; Diameter at breast height ($F=77.654$, $r^2=0.58$, df=1, 1268, $P<0.0001$), tree height ($F=68.163$, $r^2=0.51$, df=1, 1268, $P<0.0001$) and shrub height ($F=67.215$, $r^2=0.50$, df=1, 1268, $P<0.0001$). Variables which showed less linear relationship included; ground cover ($F=55.499$, $r^2=0.42$, df=1, 1268, $P<0.0001$), canopy cover ($F=20.851$, $r^2=0.16$, df=1, 1268, $P<0.0001$) and mid-canopy cover ($F=15.667$, $r^2=0.12$, df=1, 1268, $P<0.0001$) (Table 4.12).

Table 4.12: Regression model explaining the relationship of vegetation variables with bird species richness and abundance.

Variables	Bird species richness Regression coefficient (r^2)	Bird abundance Regression coefficient (r^2)
Diameter at breast height	0.73**	0.58**
Tree height (m)	0.71**	0.51**
Ground cover	0.47*	0.42*
Shrub height (m)	0.33*	0.50**
Canopy cover	0.27*	0.16*
Mid canopy cover	0.13*	0.12*

All variables were significant at $p<0.05$. Regression coefficients with double asterisk marks (**) denote variables with strong linear relationships.

4.11 Assessment of threats to avifauna and forest habitats

4.11.1 Responses of community members to forest exploitation and avifaunal decline

Community members around North Nandi Forest spread in four villages ('Kapkuto', 'Ngatatia', 'Kipsamoite' and 'Kapchepkok') were targeted for responses to variables affecting forest habitats and birds. A total of (54%) of the respondents were females, (46%) were males. Based on age structure, the middle age bracket (20-39 years-49%) formed majority of the respondents, respondents above 40 years were (34%) while the youngest age bracket (15-19 years) were (17%). Majority of local community members (64%) around North Nandi Forest were members of Community Based Organizations (C.B.O) whose main agenda was to support habitat conservation through forest restoration. The main activity of these organizations included; establishing nurseries of both exotic and indigenous trees and planting them at the forest edge (51%). Raising awareness and education of community members on the need to plant trees (13%) was another activity done (Figure 4.8a).

Local community members responding to questions on declining bird species in and around North Nandi Forest reported that in the recent past, the Crested Guineafowl (43%) had seriously declined and was becoming a rare occurrence species restricted to the indigenous forest only. Other species that had declined include; Grey Crowned Crane (32%), Greater Blue-eared Starling (15%), Hamerkop (6%), and Black-and-white Casqued Hornbill (4%). The two birds of interest in this study, the Globally endangered Turner's Eremomela *turneri* and vulnerable range - restricted Chapin's flycatcher *lendu* were unknown to the local community members who reported neither having seen it nor knowing their local names (Figure 4.8b).

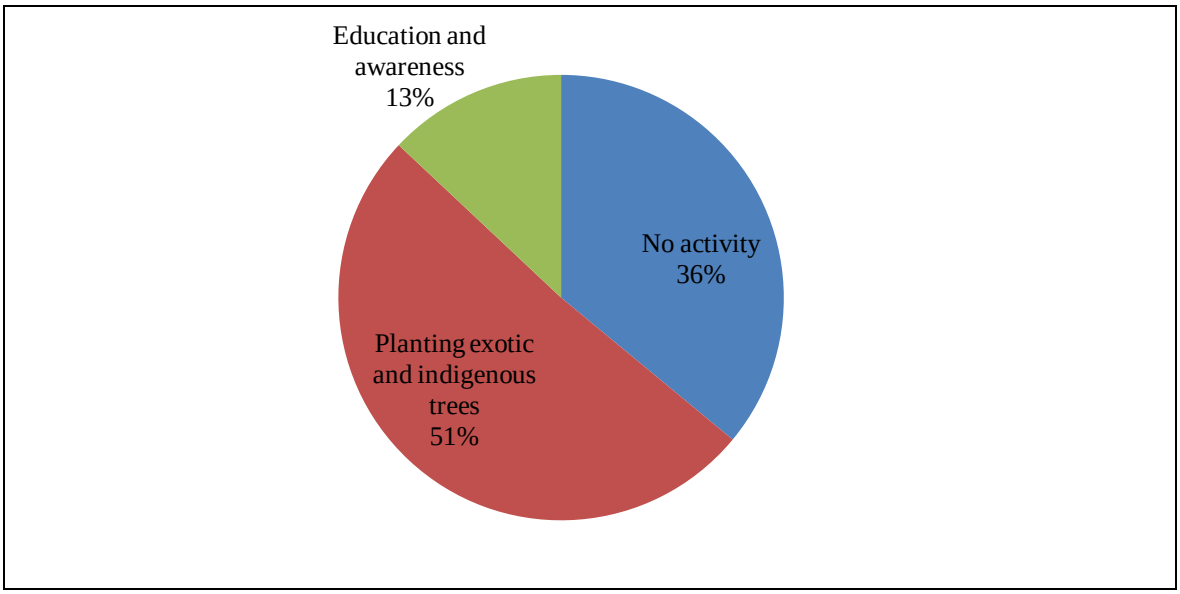

Figure 4.8a: Proportion of activities by Community Based Organizations around North Nandi Forest. Tree planting was the main activity for restoration of the forest habitats.

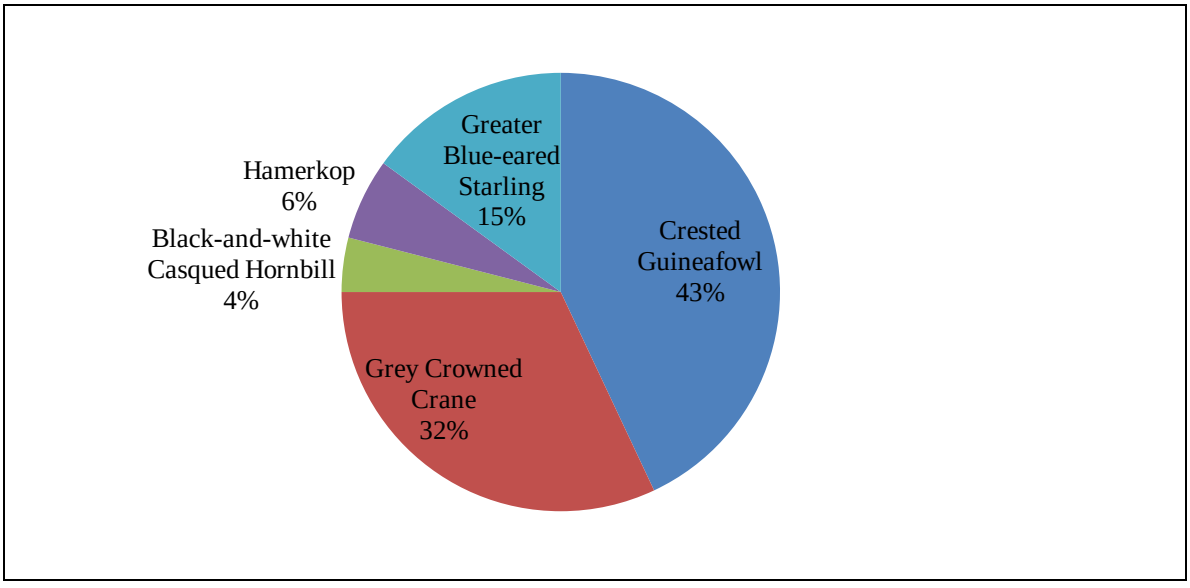

Figure 4.8b: Proportion of declining bird species in and around North Nandi Forest. Crested Guineafowl and Grey Crowned Crane were the most threatened bird species.

Birds that had not been seen around the study area for the last 5-10 years were considered locally extinct. Majority of respondents (59%) reported the Southern Ground hornbill, 27% reported the Northern Anteater Chat and 14% reported the Common Quail as birds that were locally extinct (Figure 4.9a). This data was based on the probability of spotting the birds, that is, their commonness index. Bird species that had become increasingly common in the study area in the last 5-10 years included; Speckled Mouse bird reported by 42% of respondents, followed by Lesser Striped Swallow reported by 20%, Yellow-mantled Widowbird reported by 19%, House Sparrow reported by 12%, Yellow Bishop reported by 5% and Angola Swallow reported by 2% respectively (Figure 4.9b).

Habitat destruction (Clearing of wetlands and bushes for farming) at 70% was given as the main reason for bird disappearance in and around North Nandi Forest. The other reasons suggested for bird disappearance were changes in climatic conditions (20%) and hunting of birds for subsistence use (10%) (Figure 4.10).

Respondents reported that the most appropriate mitigation measures to restore indigenous forest habitat were to carry out re-afforestation on open patches emerging after illegal felling of trees (57%) and intensification of security patrols to allow regeneration and regrowth of tree saplings (43%). In disturbed forest, majority of respondents reported (72%) that re-afforestation was a significant measure while 28% of respondents reported education and awareness raising among local community members on the need to conserve forest edge and water catchment area.

In the plantation forest, afforestation was the only measure proposed by respondents as a way to protect disturbed and indigenous forest from further encroachment. In farmland,

agroforestry was identified by a majority of respondents (75%), as the most significant measure, 25% of respondents reported establishment of bird hides/bird farming as another alternative measure especially for pet birds such as Speckled Pigeons.

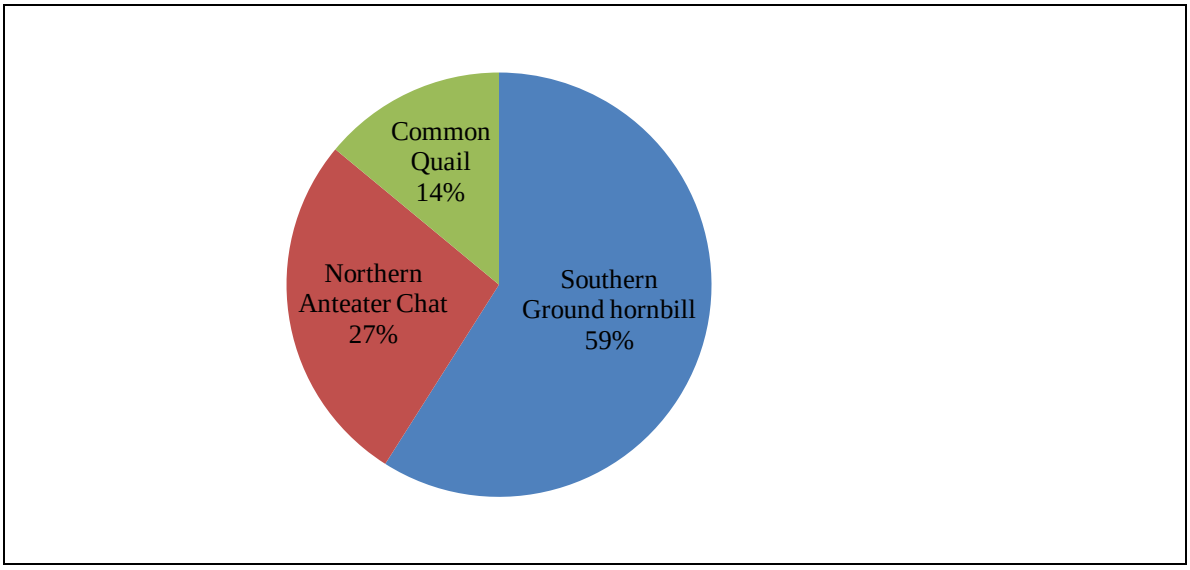

Figure 4.9a: Proportion of birds believed to be locally extinct by the community members around North Nandi Forest. These birds have not been seen within the locality for over half a decade.

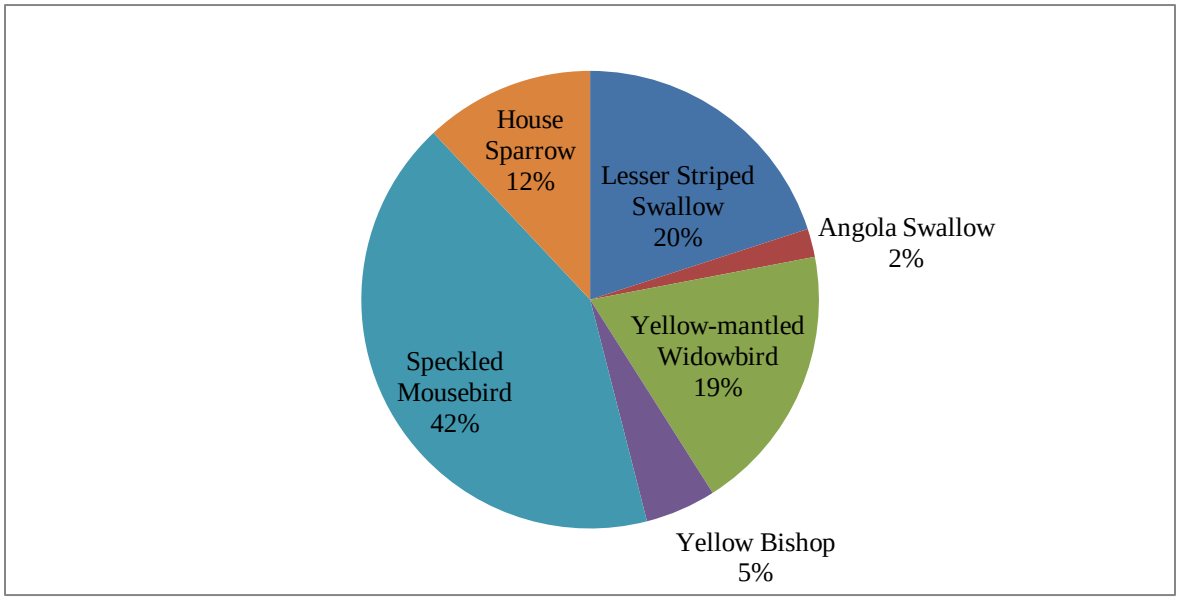

Figure 4.9b: Proportion of common bird species around North Nandi Forest. These bird species have increased in number making them more common.

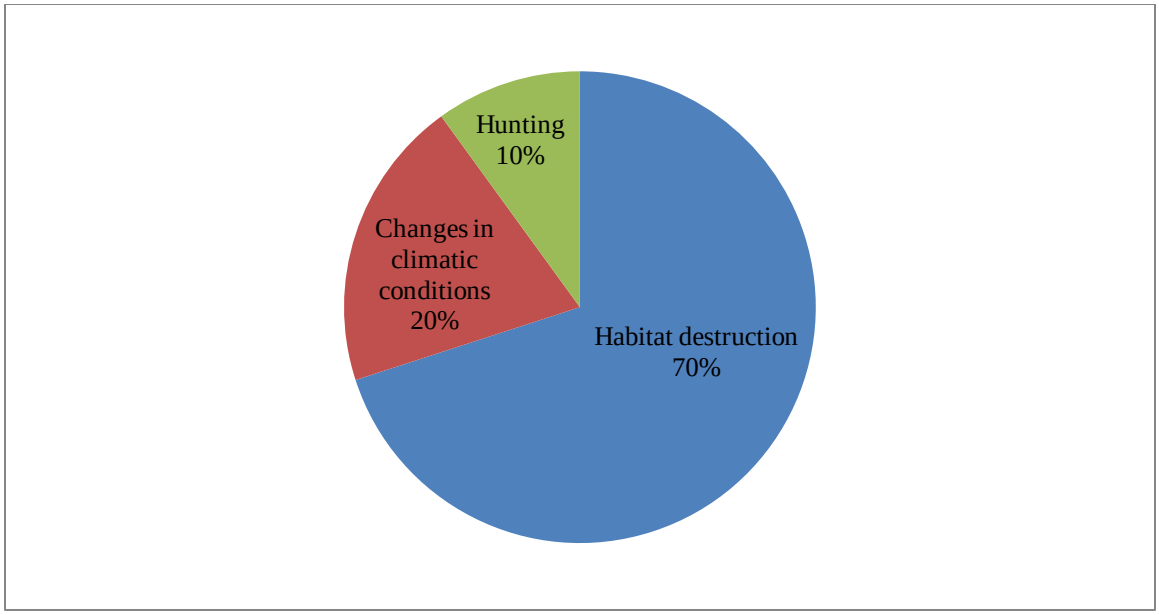

Figure 4.10: Proportion of reasons for bird disappearance in and around North Nandi Forest. Habitat destruction is the most significant factor in bird disappearance.

4.11.2 Relationship between local community age structure and forest activities

The respondents were divided into three age structures (15-19 years, 20-39 years and above 40 years). Age structure was compared with frequency of forest visitation (Daily, Weekly and Monthly). Using Pearson chi-square, results revealed a significant difference between the three age categories and the frequency of forest visitation (χ^2=19.485, df=4, P<0.0001). The middle age bracket (20-39 years) visited the forest most frequently, that is, daily and weekly while the oldest age bracket (Above 40 years) visited mostly on monthly basis (Figure 4.11). The comparison between age structure and the most visited habitat using Pearson chi-square revealed no significant difference between the two. Indigenous forest was the most visited habitat by all the three age categories while

plantation forest was the least visited with the youngest age bracket (15-19 years) not visiting it all (Table 4.13).

Pearson chi-square revealed no significant difference between age structure and human activities in indigenous forest. Almost all age categories participated in similar activities. However, collection of medicinal herbs was significantly done by middle age bracket (20-39 years) and old age bracket (Above 40 years) as opposed to the young (15-19 years) (Table 4.13). Comparison between age structure and human activities in disturbed forest using Pearson chi-square revealed no significant difference. Livestock grazing and firewood collection were the dominant activities across the three age categories (Table 4.13). Comparison between age structure and human activities in Plantation forest using Pearson chi-square revealed no significant difference. Livestock grazing and firewood collection were the most done activities with timber extraction the least activity in all the age categories (Table 4.13).

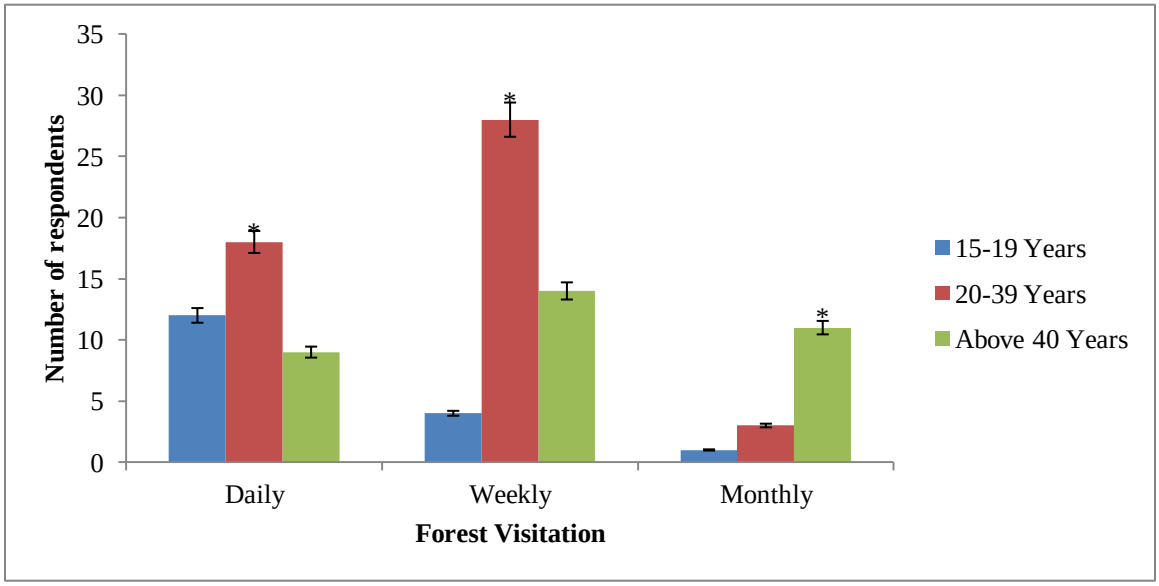

Figure 4.11: Forest visitation by community members around North Nandi Forest. Bars with asterisk marks (*) indicate significant difference at p<0.05. Percentage error bars.

Table 4.13: Association of age structure against forest habitats visited and human activities in these habitats. Pearson chi-square revealed no significant difference in all the variables at $p<0.05$. n=sample size

Age categories	n	Forest habitats (Means±SE)	Activities in indigenous forest (Means±SE)	Activities in disturbed forest (Means±SE)	Activities in plantation forest (Means±SE)
(15-19 years)	17	1.59±0.228	2.53±0.174	2.29±0.114	2.41±0.150
(20-39 years)	49	1.80±0.134	3.06±0.128	2.37±0.075	2.29±0.087
(Above 40 years)	34	1.76±0.158	3.12±0.173	2.35±0.119	2.44±0.105

4.11.3 Relationship between sex roles and activities of local community members in forest habitats

The two sex categories (Male and Female) among community members were used to draw comparisons with forest visitation frequency. Pearson chi-square test results revealed no significant differences suggesting both sex categories visited the forest habitats equally, with monthly visitation being the lowest (Table 4.14). Pearson chi-square test revealed no significant difference between sex and habitats visited. Indigenous forest followed by disturbed forest was the most visited habitat by both gender categories while plantation forest was visited less frequently (Table 4.14).

Pearson chi-square test revealed a significant difference between sex and activities in indigenous forest (χ^2=35.309, df=4, P<0.0001). Males only participated in timber extraction and significantly participated in livestock grazing as opposed to females. Females had the highest participation in firewood collection and collection of herbs (Figure 4.12a).

Pearson chi-square test revealed a significant difference between sex and activities in disturbed forest (χ^2=18.286, df=3, P<0.0001). Males participated more in livestock grazing than females and solely in timber extraction while females participated more in the collection of firewood and medicinal herbs than males (Figure 4.12b). Pearson chi-square test revealed a significant difference between sex and human activities in plantation forest (χ^2=12.627, df=3, P=0.0006). Males solely participated in timber extraction and participated more in livestock grazing as opposed to females who had a higher participation in firewood collection (Figure 4.12c).

Table 4.14: Association of sex categories against forest visitation and habitats visited irrespective of age categories. Pearson chi-square revealed no significant difference in all the variables at p<0.05. n=sample size

Gender	n	Forest visitation (Daily/weekly/monthly) (Means±SE)	Habitats visited (Means±SE)
Male	46	1.65±0.104	1.57±0.131
Female	54	1.85±0.093	1.91±0.128

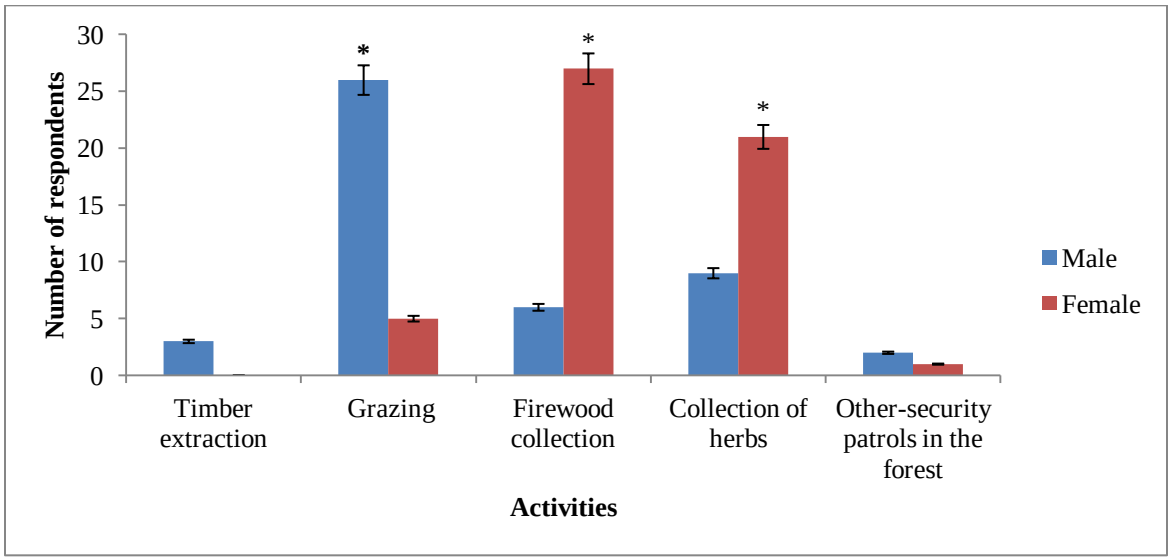

Figure 4.12a: Activities done by community members based on sex roles in indigenous forest around North Nandi Forest. Bars with asterisk marks (*) are significant at p<0.05. Percentage error bars.

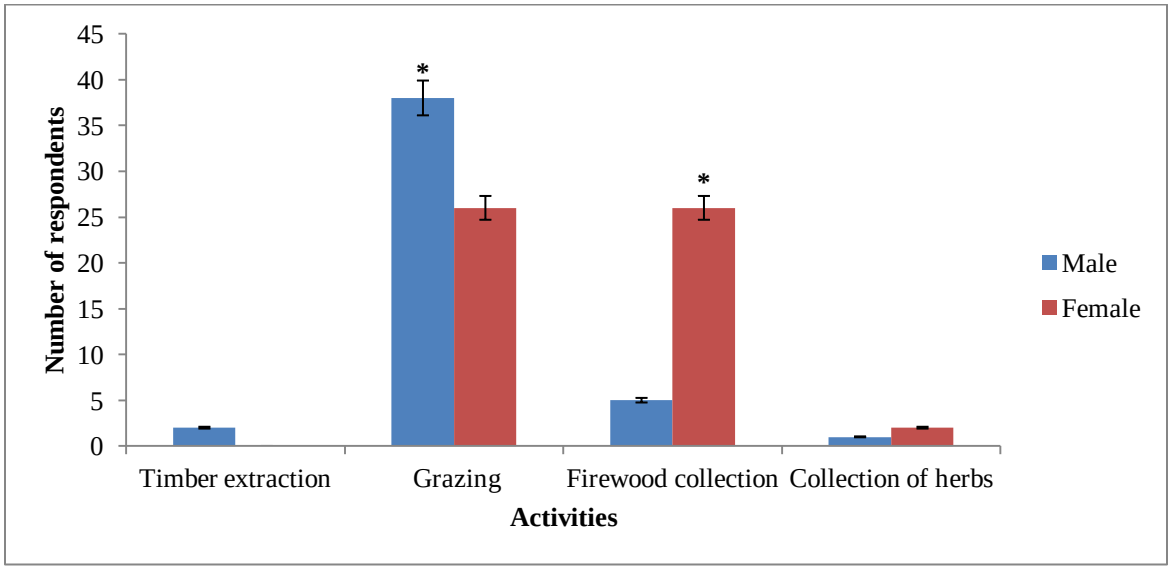

Figure 4.12b: Activities done by community members based on sex roles in disturbed forest around North Nandi Forest. Bars with asterisk marks (*) are significant at p<0.05. Percentage error bars.

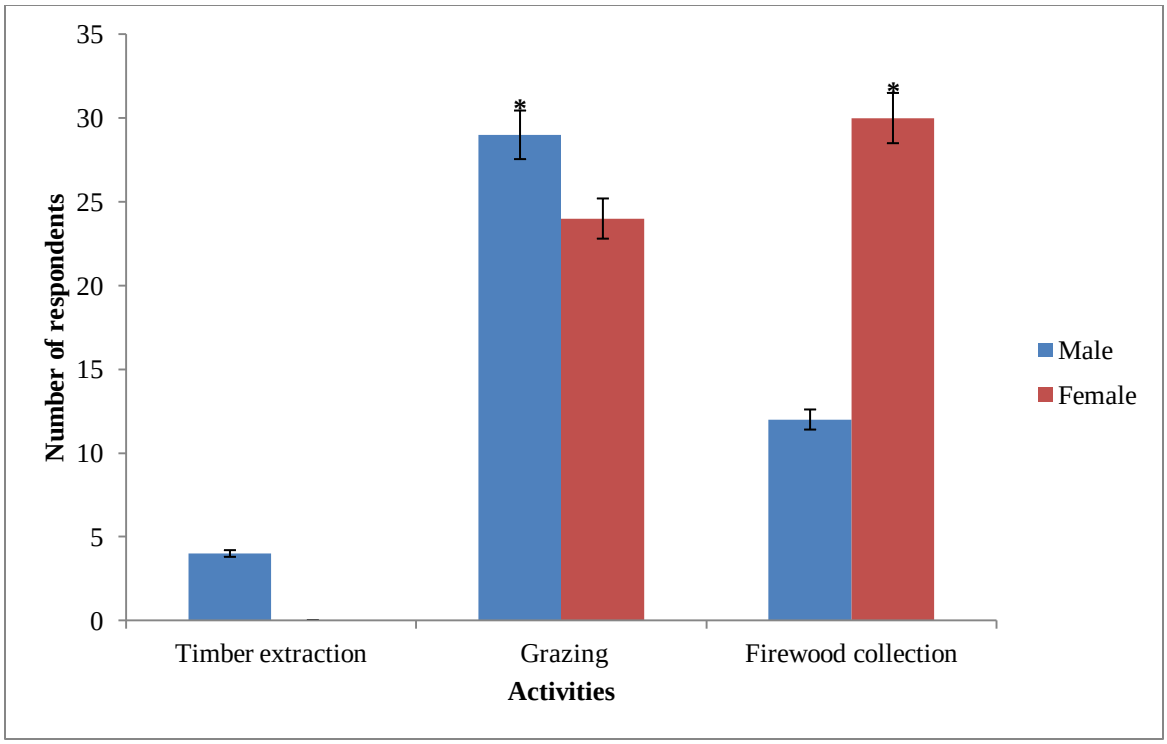

Figure 4.12c: Activities done by community members based on sex roles in Plantation forest around North Nandi Forest. Bars with asterisk marks (*) are significant at $p<0.05$. Percentage error bars.

4.12 Responses of Kenya forest rangers and community based organization officials to forest exploitation and avifaunal decline

Kenya Forest Service rangers operating three posts in North Nandi Forest and Community based organization officials from five of these organizations were tasked with the responsibility of answering questions on forest exploitation and conservation of avifauna dependent on forested habitat.

Based on their responses to frequency of patrols, results revealed that majority (60%) of these officials and rangers conducted patrols in the forest on daily basis, followed by weekly patrols (32%) and monthly patrols (8%). Patrols were mainly conducted in indigenous forest (76%), followed by disturbed forest (16%) and lastly, plantation forest (8%) respectively.

The main human activity with the greatest negative impact on forested habitats was timber extraction (60%) followed by firewood collection (24%) and charcoal burning at (16%). Indigenous forest (76%) was the most adversely affected, followed by disturbed forest (20%) and finally plantation forest (4%).

The main activity geared towards forest conservation by community based organizations and forest rangers was planting of tree seedlings in plantation forest and disturbed forest (52%) followed by arresting forest offenders for prosecution (16%), nursery preparation (12%), conservation of water catchment areas (12%) and selling of tree seedlings to farmers for agro forestry (8%) respectively.

The only activity by the respondents geared towards bird conservation was provision of security and scouting for local and international researchers. According to the

respondents, the main challenges affecting forest and bird conservation in and around Nandi North Forest were habitat destruction (64%), followed by lack of management initiatives by relevant conservation authorities (24%) and finally subsistence hunting of birds (12%) especially game birds such as Crested Guinea fowl.

Respondents (52%) reported that the most appropriate measures to mitigate challenges affecting bird and forest conservation in indigenous forest were intensification of security patrols, re-introduction of bird species that have become locally extinct (28%) and education and awareness raising (20%) of the locals on the need to plant both exotic and indigenous trees were the other measures reported. Measures to mitigate challenges in disturbed forest were; reforestation efforts and intensification of patrols while afforestation was the main measure in plantation forest. In farmland habitat, the main measure to mitigate challenges affecting bird and forest conservation were agro-forestry (56%) followed by introduction of bird hides and pet farming (24%), followed by raising awareness on the need to plant trees (16%) and protection of wetlands in farms (16%) respectively.

CHAPTER FIVE

DISCUSSIONS

5.1 Bird species diversity and composition

Generally, the study area had a relatively diverse bird community. Both Shannon diversity index H' and Simpson's diversity index D indicated that disturbed forest had the highest bird species diversity while plantation forest had the lowest diversity. Bird species diversity measurements for indigenous forest, and farmland were intermediate. The higher species diversity in disturbed forest may be due to the existence of diverse vegetation types and micro habitats created by human activities which favored varieties of bird species. Indigenous forest and farmland, that is, indigenous trees and mixed crop farming respectively had specialized vegetation structure hence supported only a group of specialized birds (Soka *et al.,* 2013). Forest specialist birds in indigenous forest and granivorous birds in farmland represent an intermediate diversity because other groups of birds were not represented. Low species diversity in plantation forest was due to one vegetation type; monoculture of exotic trees that supported low bird species diversity due to low variety in food resources and nesting sites (Law *et al.,* 2014). Bird diversity in the study was significantly influenced by vegetation structure in the various habitats as also reported by Soka *et al.* (2013) in Tanzanian terrestrial and farmland habitats.

In this study, a total of 151 bird species were recorded over the 120 days survey period in and around North Nandi Forest. This checklist is unlikely to be complete and more species may yet be recorded with more intensive surveys. According to the databases held at the Ornithology section of the National Museums of Kenya, the number of species expected for this area (using Quarter Degree Square by Lewis and Pomeroy (1989) is

about 160 species. In the recent past, Musila *et al.* (2010) recorded 108 bird species. This fairly high species richness may be attributed to the diversity of habitats within the forest as well as its location at the intersection of two bio-diverse biomes, the Afrotropical Highlands Biome and Guinea- Congo Forest biome. The forest compares favorably with other frequently visited bird-watching hotspots in the region, such as Kakamega Forest with 160 species and 122 species for Mount Elgon (Schifter and Cunningham-van Someren, 1998) as well as Gongoni Forest Reserve, South Coast, Kenya with 140 bird species (Ogoma *et al.*, 2010). However, it is slightly lower than Arabuko-Sokoke Forest with about 230 species (Fanshawe, 1995).

The higher values in bird species richness observed in disturbed forest and 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. The plantation forest and farmland had uniformly aged plants and physiognomy hence a far less structural complexity with lower bird species richness than in the diverse indigenous and disturbed forests (Munyekenye *et al.*, 2008).

The farmland habitat had the highest bird abundance due to flocking birds that aggregate and feed in patches of grasslands and subsistence crops. Families Estrilidae (Black-and-white Mannikin *Spermestes bicolor* and Black-crowned Waxbill *Estrilda nonnula*) and Ploceidae (Baglafecht Weaver *Ploceus baglafecht* and Yellow-mantled Widowbird *Euplectes macroura*) had the highest number of individuals in this habitat. The high

number of birds in this terrestrial habitat may be attributed to greater resources such as food and nesting sites hence ability to support more birds (Walwert *et al.,* 2004).

5.2 Bird species of interest

The total number of 15 Afro-Tropical Highland Biome (ATHB) bird species and 11 Guineo-Congolian Biome (GCB) species recorded in and around North Nandi Forest during this study was slightly lower than those recorded in the past. Musila *et al*. (2010) recorded 21/34 (ATHB) bird species and 21/24 (GCB) bird species. The low number of biome-restricted species in this study may be attributed to the fact that different habitats were surveyed equally without stronger emphasis on indigenous forest and disturbed forest, which had significantly higher numbers of these species.

The range-restricted Chapin's flycatcher *lendu* (globally threatened) was not recorded in this study but North Nandi Forest is an important site for this bird in Kenya (Bennun and Njoroge, 1999). This species is a rare resident of Kakamega Forest Important Bird Area (Zimmerman *et al*., 1996) and with the current healthy habitat conditions present in the surveyed section of indigenous forest, the flycatcher may still be there (Musila *et al.*, 2006). Globally threatened Turner's Eremomela *turneri* was recorded in two different survey days in both indigenous forest and disturbed forest at the onset of the wet season in the month of May. A total of 17 individuals in groups of 4 and 5 birds were seen perching and feeding on flowering *Croton megalocarpus* trees. This species was recorded in a recent survey (Musila *et al*., 2010) but has also been previously recorded in South Nandi Forest and Kakamega Forest (Bennun and Njoroge, 1999). From this study, based on observations, the main dominant canopy tree in the forest was a healthy population of

megalocarpus, an indication that the flycatcher may increase in population in the near future if it is indeed significantly dependent on this tree.

Another globally threatened species, the Grey Crowned Crane *regulorum* was recorded in the farmland habitat which stretched to adjacent wetlands. This species was only recorded through opportunistic surveys as the birds locally migrated from farmlands to wetlands in the forest for roosting and breeding. For protection, these birds mainly nest in the forest wetlands and only come out to forage in adjacent farmlands. Other regionally threatened bird species recorded in this study were; Southern Hyliota *australis* and Lesser Honeyguide *minor*. The Nationally scarce species recorded included; Least Honeyguide *exilis,* Mountain Illadopsis *pyrrhoptera* and White-tailed Crested Flycatcher *albonotata*. Additional bird species may be recorded in the study area in long term surveys that combine different bird survey methods in different seasons, both day and night (Bibby *et al*., 1998).

5.3 Forest dependent bird categories

A total of 40 forest specialists, 52 forest generalists, 43 forest visitors and 16 non-forest bird species were recorded in and around North Nandi Forest. Forest specialists are true forest birds which are characteristic of the interior less-disturbed forest; rarely occurring in non-forest habitat (Bennun and Howell, 2002) suggesting therefore that North Nandi Forest still has relatively good habitat conditions with low human disturbance.

5.4 Bird feeding guilds and distribution

Overall, insectivores had a significant higher proportion across the four habitats with frugivores, granivores, omnivores, nectarivores and raptors showing a similar trend in

and around North Nandi Forest. Similar results from past studies by Munyekenye *et al.*, (2008) in Kakamega Forest and Engelen (2012) in Ethiopia showed similarity in the proportions of the guilds observed in different habitats suggesting that these habitats may additionaly support bird species from different guilds.

When the guilds were compared separately in various habitats, frugivorous birds had higher proportions in indigenous forest and disturbed forest, which 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 Hartlaub's Turaco *Tauraco hartlaubi*, Bar-tailed Trogon *Apaloderma vittatum*, Double-toothed Barbet *Lybius bidentatus* and Ross's Turaco *Musophaga rossae* to forage. Granivores had higher proportions in Plantation forest and Farmlands. The high species numbers of granivores in Farmlands is likely to be related to the dominance by wild and cultivated grasses, as well as annual herbs (Waltert *et al*., 2005).

Nectarivores had almost similar proportions in all habitats, they were found in flowering cultivated crops and gardens in farmlands. Many forest-related nectarivores were difficult to detect in the forest canopy due to their small size and low vocalizations (Waltert *et al*., 2005) and this may have been the reason for low observations in Indigenous forest and Disturbed forest. Raptors and Omnivores had least proportions across in all habitats and this may be due to changes in bird distribution because of breeding requirements and food availability making classifications less precise (Engelen, 2012) especially for omnivorous birds. Similar results were recorded by Njoroge *et al*. (2008) in Ishaqbini Community Conservancy in Ijara District, Kenya.

Results of 57 studies from Asia and the Neotropics on tropical birds specifically by Gray *et al.* (2007) revealed that birds from different feeding guilds responded differently to forest disturbance. Whereas granivorous species increased 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 pronounced 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). Furthermore, results showed that birds in agricultural plantation habitats were more often generalists.

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 pronounced for species of the understory and large insectivores in general. Birds of the understory are thought to be so sensitive to disturbance because of their inability to disperse in a non-forest matrix (Newmark, 1991; Şekercioğlu *et al.*, 2002).

Other studies on birds of East African montane forests in Kenya (Borghesio, 2008; Laube *et al.*,2008; Mulwa *et al.*,2012), Uganda (Naidoo, 2004; Şekercioğlu, 2002;) 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; Mulwa *et al.,* 2012; Şekercioğlu *et al.,* 2002) and sometimes also frugivores (Borghesio, 2008; Kirika *et al.,* 2008).

5.5 Effects of modified habitat patches on avian diversity

Open patches created by deforestation in disturbed forest allowed sunlight to penetrate through to the ground allowing growth of dense *Brillantaisia sp* herbs covering the ground and as this vegetation flowers, nectarivores begin to colonise this layer. The canopy layer of indigenous forest was mainly covered by *megalocarpus* above 40m in height with *Celtis africana* at 35m and above alternating with it, *Schefflera abyssinica* at 32m was also an important canopy tree, this layer is important for the survival of canopy-dependant birds and is the main habitat for the globally endangered Turner's Eremomela *turneri* and vulnerable range - restricted Chapin's flycatcher *lendu* in this forest (Musila *et al.,* 2006).

The mid-canopy cover in both indigenous and disturbed forests was covered by trees between a height of 20m to 30m such as; *Polyscias fulva, Macaranga kilimandscharica, Diospyros abyssinica, Cassipourea malasoma, Tabernaemontana stapfiana* among several others as observed by Gebreselasse, (2012) in this forest reserve. The undergrowth layer composed of intertwined shrub vegetation mainly of *Acanthus sp* and *Solanum mauritianum* and is an important habitat for the shy and skulking bird species such as; Brown-chested Alethe, Dusky Tit and Mountain Illadopsis among others (Musila *et al.,* 2010). There was no mid-canopy or canopy layer in farmland due to clearance of tall vegetation for plantation of cash and subsistence crops such as tea and maize respectively. Granivores such as Kenya Rufous Sparrow and Yellow-mantled Widowbird

dominated the farmland. In the tea farms, a specialist omnivore the Blue-headed Coucal was often seen, this bird forages in dense tea plantations and wetlands (Githiru *et al.,* 2009).

Bird species richness and abundance was strongly correlated with diameter at breast height and tree height in terms of habitat structure in the four habitats. Indigenous forest and disturbed forest with tall mature trees had the highest bird diversity due to availability of food and nesting resources highlighting the fact that maintenance of the current habitat structure is important for future survival of birds. A study by Musila, (2011) on bird species richness in three fragmented coastal forests in Kenya revealed similar results, fragments with tall mature trees having large diameter at breast height had high bird richness.

Secondary forests such as disturbed and plantation forests in this study are still largely unknown in terms of biodiversity use for short or long term purposes (Barlow *et al.,* 2007). Despite the fact that in this study plantation forest had the lowest bird diversity (species richness and abundance) it also acted as a sink habitat having bird species from both indigenous forest, disturbed forest and farmlands such as Cinnamon-chested Bee-eater, African Blue Flycatcher and African Dusky Flycatcher. A study by Styring *et al.* (2011) in Malaysian Borneo in a plantation of *Acacia mangium* similarly found that small sized species of insectivorous, nectarivorous and frugivorous birds common in native forest were also common in older plantations though large and rare species were rarely observed.

Another similar study by Barlow *et al.* (2007) on bird diversity in primary, secondary and *Eucalyptus sp* plantations in North-East Brazilian Amazon found out that species richness was significantly higher in primary forest which is correlated to food availability and decreased from older to younger secondary forest and then plantations. Although secondary and plantation forests do not provide a suitable habitat for all species occurring in primary forest, they may provide dispersal routes over short distances and are important for creating corridors between primary forests. Additionally degraded forests that have been selectively logged and allowed to regenerate provide greater value than planted forests and conservation efforts should be made to prioritize these habitats (Barlow *et al.,* 2007). Regeneration of disturbed forest in North Nandi Forest is important in order to retain its current IBA status since it is significantly becoming larger than the indigenous forest.

5.6 Detrimental impacts of human activities on birds and their habitats

Habitat destruction and subsistence hunting of birds were the main human activities that directly impacted on avian diversity in and around North Nandi Forest. Clearing of wetlands for farming by local community members bordering the forest negatively affected birds dependent on wetlands for nesting and foraging such as the Hadada Ibis, Sacred Ibis, Olive Ibis, Hamerkop and Grey Crowned Crane. The wetland inside the forest which extends outside to the community is about 300 ha (Musila *et al*., 2010). In January 2015, part of this wetland was razed down by fire, destroying bird species and their habitat.

Subsistence hunting was observed in the fourth site of indigenous forest i.e. ‘Kipsamoite’, where community members had laid several traps on a trail used by

Crested Guinea fowl. This activity may significantly reduce the number of this bird species if unchecked because they are currently restricted to the habitat due to severe hunting in farmland, this scenario was reported by Perveen and Khan, (2010) on Crane species in Northern Pakistan. Human activities with the greatest impact on the forested habitat were timber extraction or illegal logging, firewood collection and charcoal burning. These activities change the vegetation structure of these habitats affecting bird diversity (Musila, 2011). The most adversely affected habitat by these activities was indigenous forest, followed by disturbed forest and lastly plantation forest.

Based on age structure, the middle age bracket (20-40 years) visited the forest habitats most frequently on a daily basis and this maybe due to the high population in this age bracket as opposed to the younger and older age bracket. Unemployment in this middle age group is a significant factor that drives them to exploit cheaply accessible forest resources such as firewood, logging of timber for fencing and construction and grazing of domestic animals in all the three habitats (indigenous forest, disturbed forest and plantation forest). Livestock grazing in the indigenous forest has led to further opening up of undergrowth vegetation and thickets significantly affecting understory and skulking bird species. Uncontrolled livestock grazing in the forest continues as earlier observed by Musila *et al*., (2010) thus is interfering with the rate of forest regeneration. This is happening through trampling of young germinating tree seedlings as well as feeding and damaging of young saplings by grazing animals.

Based on sex both males and females visited the forest habitats at the same frequency but differed in terms of activities done in these habitats. Timber extraction for fencing poles and construction was solely done by males and they targeted both indigenous forest and

disturbed forest. *Syzygium guineense*, a fruiting canopy tree was mainly targeted for fencing poles and it has been seriously logged to a point that it is now only found in the indigenous forest, this tree is important to frugivorous canopy birds such as the Turacos and Black-and-white Casqued Hornbill. Collection of firewood and medicinal herbs was mainly done by females. Firewood collection was regulated through issuance of permits by KFS and cutting of fallen trees on the ground was permitted by the Kenya Forest Rangers. No restrictions were placed on collection of medicinal herbs. Debarking of herbal trees was rampant leading to these trees dying and being removed for firewood. Continuous removal of dead wood by the surrounding community might affect the density and distribution of cavity-nesting bird species (e.g. wood peckers) due to the decline in quantity of dead wood (Veiga *et al.*, 2013a and 2013b) and food (Waiyaki, 1995). Illegal forest exploitation should be curbed in order to ensure future survival of avifaunal diversity in North Nandi Forest.

5.7 Appropriate conservation strategies of birds and their habitats

Based on this study, the main conservation strategies to mitigate detrimental human activities on forest habitats and birds in and around North Nandi Forest were to intensify security patrols in indigenous forest in order to allow for regeneration of trees and provide a more suitable habitat for birds. This is currently being done by Kenya Forest Service rangers and Community Forest Association scouts. Majority of forest reserves in Kenya are jointly managed by government parastatals and the local community creating harmonious conservation efforts (Musila, 2011) as is the case in this study. In disturbed forest, re-afforestation of open patches using indigenous tree seedlings was identified as a key conservation strategy; that would create more bird nesting sites and feeding sites.

Afforestation in plantation forest is important in creating sink and dispersal habitats for forest birds. Agro-forestry in farmland creates extended habitats for birds especially non-forest birds. A study by Fahrig *et al.* (2008) in Kakamega forest, Kenya demonstrates the fact that plantations with a mixture of indigenous tree species can have high conservation value for avifauna.

Community-based organizations geared towards forest conservation engaged in the planting of both exotic and indigenous tree seedlings and educating farmers on the need to practice agro-forestry to eliminate overdependence on forest resources thus protecting birds and their habitats (Otto *et al.,* 2013). The Kenya Forest Service rangers provide protection of the forest against illegal logging and with the help of community forest scouts arrest offenders for prosecution (KFS, 2010). Their efforts have significantly reduced forest exploitation especially charcoal burning in the forest. Kenya Forest Service rangers and community scouts conduct daily patrols in disturbed and indigenous forest, provide security and act as guides for local and international researchers in the forest hence indirectly participate in biodiversity conservation.

The Nyayo Tea zone a Kenyan parastatal involved in planting tea and exotic tree plantations (*Eucalyptu*s sp and *Cupresus lusatanica*) in the forest edge in order to curb further human encroachment into the forest have now established tea or tree strips along the eastern border of the forest reserve (KFS, 2010). Their efforts have not only ensured that the disturbed and indigenous forests have not been encroached by humans but also provide employment to the middle age group (20-40 years) members of the community in tea estates hence reducing pressure on forest resources.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. High bird diversity in indigenous forest and disturbed forest was attributed to the presence of large, tall mature trees providing adequate food and nesting resources. However, plantation forest enhanced bird diversity and abundance in sites where natural forest succession was slow or where the indigenous forest was threatened, by acting as sink habitats as its canopy cover developed.
2. Insectivorous birds dominated in all habitats due to availabity of insects. In disturbed forest, open patches created by deforestation allowed undergrowth vegetation thus encouraging more skulking bird species and nectarivorous birds. Granivorous birds thrived well in farmland since they depended on subsistence crops and grazing fields.
3. Vegetation structure composed of large DBH trees formed dense tall canopies in indigenous forest and disturbed forest which harboured high bird diversity. Farmland habitat was characterized by few agro-forest trees and rapid changing cash and food crop cover which was not suitable in enhancing bird diversity.
4. From this study detrimental human activities still played a big negative role in the disappearance and local extinction of bird species. The indigenous forest was fast changing to disturbed forest further worsening the status of globally threatened bird species. However, some conservation strategies currently in place such as reforestation of the forest edge by Community Forest Association and Kenya Forest Service may in the near future slowly reverse this trend.

6.2 Recommendations

North Nandi Forest Reserve is an Important Bird Area in Kenya with a rich avifaunal diversity. However, with the continued human pressure on forest resources, the reserve is facing enormous conservation challenges which require urgent attention in order to secure the future of existing biodiversity. With the inception of devolved system of governance the following interventions are therefore proposed:

1. Maintaining a mix of habitats and mapping of these habitat patches for monitoring vegetation cover will aid bird diversity and conservation. The Nandi County government through its ministry of tourism, marketing and coo-operative development should establish bird watching sites in the reserve, which will in turn support bird conservation and diversity as they seek to achieve the eco-tourism goal as enshrined in the County Integrated Development Plan.

2. There is need to increase the number of Kenya Forest Rangers and Community Forest Association scouts by the relevant authorities in order to intensify security patrols and allow regeneration without further exploitation of forest resources in indigenous forest. Reforestation of open patches in disturbed forest should focus on indigenous fruiting trees which will in turn allow more frugivore birds and nectarivore birds to colonise it and improve bird diversity in the long run.

3. In the farmland habitat, farmers should be encouraged to practice more agro-forestry 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 reducing pressure on the forest resources. The County government should also fasttrack conservation of wetlands already set aside for biodiversity conservation as they are important breeding sites for most wetland birds such as the globally endangered Grey crowned crane.

4. As a way forward there is need for further research in North Nandi Forest. More detailed ecological studies especially on the range restricted Chapin's Flycatcher (vulnerable) which was not seen or heard in this survey should be done. Using better detactability methods, their population status should be established and comparisons with the same species in Kakamega forest drawn. Mapping of habitat patches in North Nandi Forest should be done to clearly show the indigenous forest, disturbed forest and plantation forest boundaries as well as wetlands in the forest reserve. This will aid in management practices such as planting indigenous trees to create habitat corridors between fragments.

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APPENDICES

Appendix 1: Species checklist of North Nandi Forest and its surrounding area during the survey period January 2015-July 2015.

Family Name	Common Name	Scientific Name
Accipitridae	African Harrier Hawk	*Polyboroides typus*
Accipitridae	Augur Buzzard	*Buteo augur*
Accipitridae	Great Sparrowhawk	*Accipiter melanoleucus*
Accipitridae	Little Sparrowhawk	*Accipiter minullus*
Accipitridae	Tawny Eagle	*Aquila rapax*
Accipitridae	Mountain Buzzard	*Buteo oreophilus*
Alcedinidae	Woodland Kingfisher	*Halcyon senegalensis*
Bucerotidae	Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*
Bucerotidae	Crowned Hornbill	*Tockus alboterminatus*
Bucerotidae	Red-billed Hornbill	*Tockus erythrorhynchus*
Campephagidae	Grey Cuckooshrike	*Coracina caesia*
Campephagidae	Petit's Cuckooshrike	*Campephaga petiti*
Capitonidae	Double-toothed Barbet	*Lybius bidentatus*
Capitonidae	Grey-throated Barbet	*Gymnobucco bonapartei*
Capitonidae	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*
Cisticolidae	Black-collared Apalis	*Apalis pulchra*
Cisticolidae	Chubb's Cisticola	*Cisticola chubbi*
Cisticolidae	Grey-backed Camaroptera	*Camaroptera brachyura*
Cisticolidae	Grey-capped Warbler	*Eminia lepida*
Cisticolidae	Singing Cisticola	*Cisticola cantans*
Cisticolidae	Tawny-flanked Prinia	*Prinia subflava*
Cisticolidae	Tiny Cisticola	*Cisticola nanus*
Cisticolidae	White-chinned Prinia	*Schistolais leucopogon*
Cisticolidae	Bar-throated Apalis	*Apalis thoracica*
Cisticolidae	Black-throated Apalis	*Apalis jacksoni*
Cisticolidae	Buff-throated Apalis	*Apalis rufogularis*
Cisticolidae	Grey Apalis	*Apalis cinerea*
Cisticolidae	Olive-green Camaroptera	*Camaroptera chloronota*
Cisticolidae	Red-fronted Warbler	*Urorhipis rufifrons*
Coliidae	Speckled Mousebird	*Colius striatus*
Columbidae	African Mourning Dove	*Streptopelia decipiens*
Columbidae	Dusky Turtle Dove	*Streptopelia lugens*
Columbidae	Red-eyed Dove	*Streptopelia semitorquata*
Columbidae	Ring-necked Dove	*Streptopelia capicola*
Columbidae	Speckled Pigeon	*Columba guinea*

Columbidae	Tambourine Dove	*Turtur tympanistria*
Cuculidae	African Emerald Cuckoo	*Chrysococcyx cupreus*
Cuculidae	Common Cuckoo	*Cuculus canorus*
Cuculidae	Blue-headed Coucal	*Centropus monachus*
Dicruridae	Common Drongo	*Dicrurus adsimilis*
Estrildidae	Black-and-white Mannikin	*Spermestes bicolor*
Estrildidae	Black-crowned Waxbill	*Estrilda nonnula*
Estrildidae	Common Waxbill	*Estrilda astrild*
Estrildidae	African Firefinch	*Lagonosticta rubricata*
Estrildidae	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*
Fringillidae	African Citril	*Crithagra citrinelloides*
Fringillidae	Brimstone Canary	*Crithagra sulphurata*
Gruidae	*Grey Crowned Crane	*Balearica regulorum*
Hirundinidae	Angola Swallow	*Hirundo angolensis*
Hirundinidae	Black Saw-wing	*Psalidoprocne pristoptera*
Hirundinidae	Barn Swallow	*Hirundo rustica*
Hirundinidae	Lesser Striped Swallow	*Cecropis abyssinica*
Indicatoridae	Least Honeyguide	*Indicator exilis*
Indicatoridae	Lesser Honeyguide	*Indicator minor*
Laniidae	Grey-backed Fiscal	*Lanius excubitoroides*
Laniidae	Long-tailed Fiscal	*Lanius cabanisi*
Laniidae	Common Fiscal	*Lanius collaris*
Malaconotidae	Black-backed Puffback	*Dryoscopus cubla*
Malaconotidae	Black-headed Gonolek	*Laniarius erythrogaster*
Malaconotidae	Doherty's Bushshrike	*Chlorophoneus dohertyi*
Malaconotidae	Lühder's Bushshrike	*Laniarius luehderi*
Malaconotidae	Slate-coloured Boubou	*Laniarius funebris*
Malaconotidae	Tropical Boubou	*Laniarius aethopicus*
Meropidae	Cinnamon-chested Bee-eater	*Merops oreobates*
Monarchidae	African Paradise Flycatcher	*Terpsiphone viridis*
Monarchidae	African Blue Flycatcher	*Elminia longicauda*
Monarchidae	White-tailed Crested Flycatcher	*Eliminia albonotata*
Motacillidae	Grassland Pipit	*Anthus cinnamomeus*
Motacillidae	Yellow-throated Longclaw	*Macronyx croceus*
Motacillidae	African Pied Wagtail	*Motacilla aguimp*
Muscicapidae	African Dusky Flycatcher	*Muscicapa adusta*
Muscicapidae	African Grey Flycatcher	*Bradornis microrhynchus*
Muscicapidae	Northern Black Flycatcher	*Melaenornis edolioides*
Muscicapidae	Pale Flycatcher	*Bradornis pallidus*
Muscicapidae	Snowy-headed Robin Chat	*Cossypha niveicapilla*
Muscicapidae	White-browed Robin Chat	*Cossypha heuglini*

Muscicapidae	White-eyed Slaty Flycatcher	*Melaenornis fischeri*
Muscicapidae	White-starred Robin	*Pogonocichla stellata*
Muscicapidae	Equatorial Akalat	*Sheppardia aequatorialis*
Muscicapidae	Common Stonechat	*Saxicola torquatus*
Musophagidae	Ross's Turaco	*Musophaga rossae*
Musophagidae	Hartlaub's Turaco	*Tauraco hartlaubi*
Nectariniidae	Amethyst Sunbird	*Chalcomitra amethystina*
Nectariniidae	Collared Sunbird	*Hedydipna collaris*
Nectariniidae	Green-headed Sunbird	*Cyanomitra verticalis*
Nectariniidae	Green-throated Sunbird	*Chalcomitra rubescens*
Nectariniidae	Olive-bellied Sunbird	*Cinnyris chloropygius*
Nectariniidae	Variable Sunbird	*Cinnyris venustus*
Nectariniidae	Olive Sunbird	*Cyanomitra olivacea*
Nectariniidae	Scarlet-chested Sunbird	*Chalcomitra senegalensis*
Numididae	*Crested Guineafowl	*Guttera pucherani*
Oriolidae	Western Oriole	*Oriolus brachyrhynchus*
Paridae	White-bellied Tit	*Parus albiventris*
Paridae	Dusky Tit	*Parus funereus*
Passeridae	House Sparrow	*Passer domesticus*
Passeridae	Kenya Rufous Sparrow	*Passer rufocinctus*
Phoeniculidae	Common Scimitarbill	*Rhinopomastus cyanomelas*
Phoeniculidae	White-headed Wood-hoopoe	*Pheoniculus bollei*
Picidae	Brown-backed Woodpecker	*Picoides obsoletus*
Picidae	Buff-spotted Woodpecker	*Campethera nivosa*
Picidae	African Grey Woodpecker	*Dendropicos goertae*
Picidae	Fine-banded Woodpecker	*Campethera tullbergi*
Platysteiridae	Black-headed Batis	*Batis minor*
Platysteiridae	Black-throated Wattle-eye	*Platysteira peltata*
Platysteiridae	Jameson's Wattle-eye	*Dyaphorophyia jamesoni*
Platysteiridae	Yellow-bellied Wattle-eye	*Dyaphorophyia concreta*
Ploceidae	Baglafecht Weaver	*Ploceus baglafecht*
Ploceidae	Village Weaver	*Ploceus cucullatus*
Ploceidae	Long-tailed Widowbird	*Euplectes progne*
Ploceidae	Spectacled Weaver	*Ploceus ocularis*
Ploceidae	Vieillot's Black Weaver	*Ploceus nigerrimus*
Ploceidae	Black-billed Weaver	*Ploceus melanogaster*
Ploceidae	Red-headed Malimbe	*Malimbus rubricollis*
Ploceidae	Lesser Masked Weaver	*Ploceus intermedius*
Ploceidae	Speke's Weaver	*Ploceus spekei*
Ploceidae	Yellow Bishop	*Euplectes capensis*
Ploceidae	Yellow-mantled Widowbird	*Euplectes macroura*

Psittacidae	Meyer's Parrot	*Poicephalus meyeri*
Pycnonotidae	Common Bulbul	*Pycnonotus barbatus*
Pycnonotidae	Joyful Greenbul	*Chlorocichla laetissima*
Pycnonotidae	Little Greenbul	*Andropadus virens*
Pycnonotidae	Yellow-whiskered Greenbul	*Andropadus latirostris*
Pycnonotidae	Cabanis's Greenbul	*Phyllastrephus cabanisi*
Pycnonotidae	Plain Greenbul	*Andropadus curvirostris*
Pycnonotidae	Mountain Greenbul	*Andropadus nigriceps*
Pycnonotidae	Shelley's Greenbul	*Andropadus masukuensis*
Scopidae	*Hamerkop	*Scopus umbretta*
Sturnidae	Greater Blue-eared Starling	*Lamprotornis chalybaeus*
Sturnidae	Violet-backed Starling	*Cynniricinclus leucogaster*
Sylviidae	Blackcap	*Sylvia atricapilla*
Sylviidae	Cinnamon Bracken Warbler	*Bradypterus cinnamomeus*
Sylviidae	Green Hylia	*Hylia prasina*
Sylviidae	Mountain Yellow Warbler	*Chloropeta similis*
Sylviidae	Southern Hyliota	*Hyliota australis*
Sylviidae	Yellow-bellied Eremomela	*Eremomela icteropygialis*
Sylviidae	Black-faced Rufous Warbler	*Bathmocercus rufus*
Sylviidae	Turner's Eremomela	*Eremomela turneri*
Threskiornithidae	Hadada Ibis	*Bostrychia hagedash*
Timaliidae	African Hill Babbler	*Pseudoalcippe abyssinica*
Timaliidae	Brown Illadopsis	*Illadopsis fulvescens*
Timaliidae	Grey-chested Babbler	*Kakamega poliothorax*
Timaliidae	Mountain Illadopsis	*Illadopsis pyrrhoptera*
Timaliidae	Pale-breasted Illadopsis	*Illadopsis rufipennis*
Timaliidae	Scaly-breasted Illadopsis	*Illadopsis albipectus*
Trogonidae	Bar-tailed Trogon	*Apaloderma vittatum*
Turdidae	Olive Thrush	*Turdus olivaceus*
Turdidae	Brown-chested Alethe	*Alethe poliocephala*
Upupidae	Hoopoe	*Upupa epops*
Viduidae	Pin-tailed Whydah	*Vidua macroura*
Zosteropidae	Montane White-eye	*Zosterops poliogastrus*

Appendix 2: Relative abundance of bird species recorded in indigenous forest in North Nandi Forest. EA# denotes East African number and K'09# Kenyan number as per the ornithological bird committee of East African Natural History Society checklist of the birds of Kenya.

EA#	K'09#	Common Name	Scientific Name	**Relative abundance%**
729	726	Common Bulbul	*Pycnonotus barbatus*	8.877
945	718	Grey Apalis	*Apalis cinerea*	5.222
550	490	Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*	4.830
702	734	Yellow-whiskered Greenbul	*Andropadus latirostris*	4.047
525	476	White-headed Wood-hoopoe	*Pheoniculus bollei*	3.916
672	634	Black Saw-wing	*Psalidoprocne pristoptera*	3.786
713	746	Cabanis's Greenbul	*Phyllastrephus cabanisi*	3.786
514	465	Cinnamon-chested Bee-eater	*Merops oreobates*	3.655
662	641	Angola Swallow	*Hirundo angolensis*	3.525
950	710	Black-collared Apalis	*Apalis pulchra*	3.133
982	818	Montane White-eye	*Zosterops poliogastrus*	3.003
553	494	Grey-throated Barbet	*Gymnobucco bonapartei*	2.480
725	738	Joyful Greenbul	*Chlorocichla laetissima*	2.480
831	906	African Dusky Flycatcher	*Muscicapa adusta*	1.958
988	626	Dusky Tit	*Parus funereus*	1.958
761	858	Equatorial Akalat	*Sheppardia aequatorialis*	1.958
1007	615	African Paradise Flycatcher	*Terpsiphone viridis*	1.828
357	348	Tambourine Dove	*Turtur tympanistria*	1.828
543	482	Crowned Hornbill	*Tockus alboterminatus*	1.567
391	368	Ross's Turaco	*Musophaga rossae*	1.567
774	869	Snowy-headed Robin Chat	*Cossypha niveicapilla*	1.436
1152	944	Variable Sunbird	*Cinnyris venustus*	1.436
751	805	Mountain Illadopsis	*Illadopsis pyrrhoptera*	1.175
704	727	Shelley's Greenbul	*Andropadus masukuensis*	1.175
975	790	Turner's Eremomela	*Eremomela turneri*	1.175
1333	1080	African Citril	*Crithagra citrinelloides*	1.044
142	175	Augur Buzzard	*Buteo augur*	1.044
1020	554	Black-throated Wattle-eye	*Platysteira peltata*	1.044
698	733	Plain Greenbul	*Andropadus curvirostris*	1.044
117	158	African Harrier Hawk	*Polyboroides typus*	0.914
1149	923	Amethyst Sunbird	*Chalcomitra amethystina*	0.914
752	803	Pale-breasted Illadopsis	*Illadopsis rufipennis*	0.914
1304	1021	Black-crowned Waxbill	*Estrilda nonnula*	0.783
947	714	Black-headed Apalis	*Apalis melanocephala*	0.783
134	169	Great Sparrowhawk	*Accipiter melanoleucus*	0.783

879	779	Green Hylia	*Hylia prasina*	0.783
62	75	Hadada Ibis	*Bostrychia hagedash*	0.783
1064	578	Tropical Boubou	*Laniarius aethopicus*	0.783
530	480	Common Scimitarbill	*Rhinopomastus cyanomelas*	0.653
1080	582	Grey Cuckooshrike	*Coracina caesia*	0.653
842	896	Northern Black Flycatcher	*Melaenornis edolioides*	0.653
1246	992	Red-headed Malimbe	*Malimbus rubricollis*	0.653
480	439	Speckled Mousebird	*Colius striatus*	0.653
844	899	African Grey Flycatcher	*Bradornis microrhynchus*	0.522
886	756	Black-faced Rufous Warbler	*Bathmocercus rufus*	0.522
1017	551	Black-headed Batis	*Batis minor*	0.522
899	677	Chubb's Cisticola	*Cisticola chubbi*	0.522
1146	919	Green-headed Sunbird	*Cyanomitra verticalis*	0.522
816	854	Olive Thrush	*Turdus olivaceus*	0.522
753	802	Scaly-breasted Illadopsis	*Illadopsis albipectus*	0.522
1089	606	Western Oriole	*Oriolus brachyrhynchus*	0.522
616	538	African Grey Woodpecker	*Dendropicos goertae*	0.392
737	807	African Hill Babbler	*Pseudoalcippe abyssinica*	0.392
948	712	Black-throated Apalis	*Apalis jacksoni*	0.392
1055	564	Doherty's Bushshrike	*Chlorophoneus dohertyi*	0.392
578	512	Double-toothed Barbet	*Lybius bidentatus*	0.392
1063	576	Lühder's Bushshrike	*Laniarius luehderi*	0.392
927	706	White-chinned Prinia	*Schistolais leucopogon*	0.392
1002	618	White-tailed Crested Flycatcher	*Eliminia albonotata*	0.392
563	500	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	0.392
426	388	Blue-headed Coucal	*Centropus monachus*	0.261
942	716	Buff-throated Apalis	*Apalis rufogularis*	0.261
940	715	Chestnut-throated Apalis	*Apalis porphyrolaema*	0.261
933	722	Grey-backed Camaroptera	*Camaroptera brachyura*	0.261
749	806	Grey-chested Babbler	*Kakamega poliothorax*	0.261
398	366	Hartlaub's Turaco	*Tauraco hartlaubi*	0.261
524	474	Hoopoe	*Upupa epops*	0.261
1143	920	Olive Sunbird	*Cyanomitra olivacea*	0.261
585	522	Scaly-throated Honeyguide	*Indicator variegatus*	0.261
1000	616	African Blue Flycatcher	*Elminia longicauda*	0.131
371	342	African Mourning Dove	*Streptopelia decipiens*	0.131
485	443	Bar-tailed Trogon	*Apaloderma vittatum*	0.131
607	532	Buff-spotted Woodpecker	*Campethera nivosa*	0.131
130	165	Little Sparrowhawk	*Accipiter minullus*	0.131
892	774	Mountain Yellow Warbler	*Chloropeta similis*	0.131
133	168	Rufous-breasted Sparrowhawk	*Accipiter rufiventris*	0.131

Appendix 3: Relative abundance of bird species recorded in disturbed forest in North Nandi Forest. EA# denotes East African number and K'09# Kenyan number as per the ornithological bird committee of East African Natural History Society checklist of the birds of Kenya.

EA#	K'09#	Common Name	Scientific Name	Relative Abundance%
729	726	Common Bulbul	*Pycnonotus barbatus*	9.193
480	439	Speckled Mousebird	*Colius striatus*	4.224
945	718	Grey Apalis	*Apalis cinerea*	3.851
514	465	Cinnamon-chested Bee-eater	*Merops oreobates*	3.354
662	641	Angola Swallow	*Hirundo angolensis*	3.106
702	734	Yellow-whiskered Greenbul	*Andropadus latirostris*	2.981
1319	1045	Black-and-white Mannikin	*Spermestes bicolor*	2.857
713	746	Cabanis's Greenbul	*Phyllastrephus cabanisi*	2.857
840	895	White-eyed Slaty Flycatcher	*Melaenornis fischeri*	2.857
1152	944	Variable Sunbird	*Cinnyris venustus*	2.733
1233	982	Vieillot's Black Weaver	*Ploceus nigerrimus*	2.733
1149	923	Amethyst Sunbird	*Chalcomitra amethystina*	2.360
1000	616	African Blue Flycatcher	*Elminia longicauda*	2.112
672	634	Black Saw-wing	*Psalidoprocne pristoptera*	2.112
550	490	Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*	2.112
553	494	Grey-throated Barbet	*Gymnobucco bonapartei*	1.615
701	730	Little Greenbul	*Andropadus virens*	1.615
1063	576	Lühder's Bushshrike	*Laniarius luehderi*	1.615
842	896	Northern Black Flycatcher	*Melaenornis edolioides*	1.615
543	482	Crowned Hornbill	*Tockus alboterminatus*	1.491
698	733	Plain Greenbul	*Andropadus curvirostris*	1.491
899	677	Chubb's Cisticola	*Cisticola chubbi*	1.366
357	348	Tambourine Dove	*Turtur tympanistria*	1.366
525	476	White-headed Wood-hoopoe	*Pheoniculus bollei*	1.366
831	906	African Dusky Flycatcher	*Muscicapa adusta*	1.242
616	538	African Grey Woodpecker	*Dendropicos goertae*	1.242
1007	615	African Paradise Flycatcher	*Terpsiphone viridis*	1.242
761	858	Equatorial Akalat	*Sheppardia aequatorialis*	1.118
950	710	Black-collared Apalis	*Apalis pulchra*	1.118
816	854	Olive Thrush	*Turdus olivaceus*	1.118
391	368	Ross's Turaco	*Musophaga rossae*	1.118
1205	964	Baglafecht Weaver	*Ploceus baglafecht*	0.994
1019	553	Brown-throated Wattle-eye	*Platysteira cyanea*	0.994
982	818	Montane White-eye	*Zosterops poliogastrus*	0.994
1070	575	Slate-coloured Boubou	*Laniarius funebris*	0.994

1304	1021	Black-crowned Waxbill	*Estrilda nonnula*	0.870
945	721	Grey-capped Warbler	*Eminia lepida*	0.870
62	75	Hadada Ibis	*Bostrychia hagedash*	0.870
725	738	Joyful Greenbul	*Chlorocichla laetissima*	0.870
1156	931	Olive-bellied Sunbird	*Cinnyris chloropygius*	0.870
373	344	Ring-necked Dove	*Streptopelia capicola*	0.870
933	722	Grey-backed Camaroptera	*Camaroptera brachyura*	0.745
751	805	Mountain Illadopsis	*Illadopsis pyrrhoptera*	0.745
1143	920	Olive Sunbird	*Cyanomitra olivacea*	0.745
845	898	Pale Flycatcher	*Bradornis pallidus*	0.745
1017	551	Black-headed Batis	*Batis minor*	0.621
1065	580	Black-headed Gonolek	*Laniarius erythrogaster*	0.621
1082	610	Common Drongo	*Dicrurus adsimilis*	0.621
924	702	Tawny-flanked Prinia	*Prinia subflava*	0.621
1023	546	Yellow-bellied Wattle-eye	*Dyaphorophyia concreta*	0.621
1333	1080	African Citril	*Crithagra citrinelloides*	0.497
778	856	Brown-chested Alethe	*Alethe poliocephala*	0.497
884	755	Cinnamon Bracken Warbler	*Bradypterus cinnamomeus*	0.497
794	878	Common Stonechat	*Saxicola torquatus*	0.497
879	779	Green Hylia	*Hylia prasina*	0.497
587	521	Lesser Honeyguide	*Indicator minor*	0.497
893	674	Singing Cisticola	*Cisticola cantans*	0.497
1089	606	Western Oriole	*Oriolus brachyrhynchus*	0.497
772	867	White-browed Robin Chat	*Cossypha heuglini*	0.497
485	443	Bar-tailed Trogon	*Apaloderma vittatum*	0.373
1148	922	Green-throated Sunbird	*Chalcomitra rubescens*	0.373
752	803	Pale-breasted Illadopsis	*Illadopsis rufipennis*	0.373
1002	618	White-tailed Crested Flycatcher	*Eliminia albonotata*	0.373
970	786	Yellow-bellied Eremomela	*Eremomela icteropygialis*	0.373
563	500	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	0.373
417	384	African Emerald Cuckoo	*Chrysococcyx cupreus*	0.248
371	342	African Mourning Dove	*Streptopelia decipiens*	0.248
142	175	Augur Buzzard	*Buteo augur*	0.248
675	1059	Grey Wagtail	*Motacilla cinerea*	0.248
1039	596	Grey-backed Fiscal	*Lanius excubitoroides*	0.248
749	806	Grey-chested Babbler	*Kakamega poliothorax*	0.248
451	412	Nubian Nightjar	*Caprimulgus nubicus*	0.248
934	723	Olive-green Camaroptera	*Camaroptera chloronota*	0.248
147	178	Tawny Eagle	*Aquila rapax*	0.248
117	158	African Harrier Hawk	*Polyboroides typus*	0.124
426	388	Blue-headed Coucal	*Centropus monachus*	0.124

Appendix 4: Relative abundance of bird species recorded in plantation forest around North Nandi Forest.EA# denotes East African number and K'09# Kenyan number as per the ornithological bird committee of East African Natural History Society checklist of the birds of Kenya.

EA#	K'09#	Common Name	Scientific Name	Relative abundance%
1319	1045	Black-and-white Mannikin	*Spermestes bicolor*	21.543
1205	964	Baglafecht Weaver	*Ploceus baglafecht*	9.316
729	726	Common Bulbul	*Pycnonotus barbatus*	7.569
840	895	White-eyed Slaty Flycatcher	*Melaenornis fischeri*	6.114
831	906	African Dusky Flycatcher	*Muscicapa adusta*	5.095
514	465	Cinnamon-chested Bee-eater	*Merops oreobates*	4.076
373	344	Ring-necked Dove	*Streptopelia capicola*	3.785
673	1062	African Pied Wagtail	*Motacilla aguimp*	3.493
845	898	Pale Flycatcher	*Bradornis pallidus*	3.202
1007	615	African Paradise Flycatcher	*Terpsiphone viridis*	3.057
1043	600	Common Fiscal	*Lanius collaris*	2.620
899	677	Chubb's Cisticola	*Cisticola chubbi*	2.475
816	854	Olive Thrush	*Turdus olivaceus*	2.475
772	867	White-browed Robin Chat	*Cossypha heuglini*	2.183
1149	923	Amethyst Sunbird	*Chalcomitra amethystina*	2.038
357	348	Tambourine Dove	*Turtur tympanistria*	2.038
893	674	Singing Cisticola	*Cisticola cantans*	1.892
844	899	African Grey Flycatcher	*Bradornis microrhynchus*	1.310
381	358	Meyer's Parrot	*Poicephalus meyeri*	1.310
371	342	African Mourning Dove	*Streptopelia decipiens*	1.164
370	343	Red-eyed Dove	*Streptopelia semitorquata*	1.164
662	641	Angola Swallow	*Hirundo angolensis*	1.019
672	634	Black Saw-wing	*Psalidoprocne pristoptera*	1.019
681	1068	Grassland Pipit	*Anthus cinnamomeus*	1.019
982	818	Montane White-eye	*Zosterops poliogastrus*	1.019
1258	1004	Yellow Bishop	*Euplectes capensis*	1.019
1184	953	House Sparrow	*Passer domesticus*	0.873
1185	955	Kenya Rufous Sparrow	*Passer rufocinctus*	0.873
1260	1006	Yellow-mantled Widowbird	*Euplectes macroura*	0.873
1000	616	African Blue Flycatcher	*Elminia longicauda*	0.728
892	774	Mountain Yellow Warbler	*Chloropeta similis*	0.582
1328	1049	Pin-tailed Whydah	*Vidua macroura*	0.582
924	702	Tawny-flanked Prinia	*Prinia subflava*	0.582
1333	1080	African Citril	*Crithagra citrinelloides*	0.437
1267	1048	Parasitic Weaver	*Anomalospiza imberbis*	0.437

Appendix 5: Relative abundance of bird species recorded in farmland around North Nandi Forest.EA# denotes East African number and K'09# Kenyan number as per the ornithological bird committee of East African Natural History Society checklist of the birds of Kenya.

EA#	K'09#	Common Name	Scientific Name	Relative abundance%
1319	1045	Black-and-white Mannikin	*Spermestes bicolor*	13.860
1304	1021	Black-crowned Waxbill	*Estrilda nonnula*	6.674
840	895	White-eyed Slaty Flycatcher	*Melaenornis fischeri*	5.852
480	439	Speckled Mousebird	*Colius striatus*	5.749
1205	964	Baglafecht Weaver	*Ploceus baglafecht*	5.236
729	726	Common Bulbul	*Pycnonotus barbatus*	4.517
667	647	Lesser Striped Swallow	*Cecropis abyssinica*	4.517
1152	944	Variable Sunbird	*Cinnyris venustus*	4.312
893	674	Singing Cisticola	*Cisticola cantans*	3.593
1043	600	Common Fiscal	*Lanius collaris*	2.977
899	677	Chubb's Cisticola	*Cisticola chubbi*	2.669
373	344	Ring-necked Dove	*Streptopelia capicola*	2.464
1184	953	House Sparrow	*Passer domesticus*	2.361
1185	955	Kenya Rufous Sparrow	*Passer rufocinctus*	2.361
772	867	White-browed Robin Chat	*Cossypha heuglini*	2.259
673	1062	African Pied Wagtail	*Motacilla aguimp*	2.053
62	75	Hadada Ibis	*Bostrychia hagedash*	1.848
662	641	Angola Swallow	*Hirundo angolensis*	1.540
660	640	Barn Swallow	*Hirundo rustica*	1.437
1303	1020	Common Waxbill	*Estrilda astrild*	1.437
1111	822	Greater Blue-eared Starling	*Lamprotornis chalybaeus*	1.335
845	898	Pale Flycatcher	*Bradornis pallidus*	1.335
1260	1006	Yellow-mantled Widowbird	*Euplectes macroura*	1.232
794	878	Common Stonechat	*Saxicola torquatus*	1.129
1230	980	Speke's Weaver	*Ploceus spekei*	1.129
381	358	Meyer's Parrot	*Poicephalus meyeri*	1.027
1039	596	Grey-backed Fiscal	*Lanius excubitoroides*	0.821
1328	1049	Pin-tailed Whydah	*Vidua macroura*	0.821
1309	1027	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	0.821
391	368	Ross's Turaco	*Musophaga rossae*	0.821
426	388	Blue-headed Coucal	*Centropus monachus*	0.719
1337	1089	Brimstone Canary	*Crithagra sulphurata*	0.719
370	343	Red-eyed Dove	*Streptopelia semitorquata*	0.719
842	896	Northern Black Flycatcher	*Melaenornis edolioides*	0.616
1294	1037	African Firefinch	*Lagonosticta rubricata*	0.616
1149	923	Amethyst Sunbird	*Chalcomitra amethystina*	0.616
1228	978	Lesser Masked Weaver	*Ploceus intermedius*	0.616
371	342	African Mourning Dove	*Streptopelia decipiens*	0.513
142	175	Augur Buzzard	*Buteo augur*	0.513
672	634	Black Saw-wing	*Psalidoprocne pristoptera*	0.513
903	693	Tiny Cisticola	*Cisticola nanus*	0.513
694	1065	Yellow-throated Longclaw	*Macronyx croceus*	0.513
1211	969	Black-billed Weaver	*Ploceus melanogaster*	0.411
578	512	Double-toothed Barbet	*Lybius bidentatus*	0.411
1210	967	Spectacled Weaver	*Ploceus ocularis*	0.411
514	465	Cinnamon-chested Bee-eater	*Merops oreobates*	0.411

Appendix 6: Bird relative abundance recorded in plantation forest using distance line transect method in and around North Nandi Forest. The list below is in descending order.

Species Name	***Scientific Name***	**Relative abundance%**
Common Bulbul	*Pycnonotus barbatus*	10.921
Baglafecht Weaver	*Ploceus baglafecht*	8.565
Black-and-white Mannikin	*Spermestes bicolor*	8.351
Pale Flycatcher	*Bradornis pallidus*	7.709
African Dusky Flycatcher	*Muscicapa adusta*	5.353
Black Saw-wing	*Psalidoprocne pristoptera*	4.925
White-eyed Slaty Flycatcher	*Melaenornis fischeri*	4.711
Chubb's Cisticola	*Cisticola chubbi*	4.497
Angola Swallow	*Hirundo angolensis*	4.283
Cinnamon-chested Bee-eater	*Merops oreobates*	4.069
African Pied Wagtail	*Motacilla aguimp*	3.854
Common Fiscal	*Lanius collaris*	3.640
White-browed Robin Chat	*Cossypha heuglini*	2.998
African Paradise Flycatcher	*Terpsiphone viridis*	2.784
Amethyst Sunbird	*Chalcomitra amethystina*	2.570
House Sparrow	*Passer domesticus*	2.141
Olive Thrush	*Turdus olivaceus*	1.927
Ring-necked Dove	*Streptopelia capicola*	1.927
African Blue Flycatcher	*Elminia longicauda*	1.713
Kenya Rufous Sparrow	*Passer rufocinctus*	1.713
Yellow Bishop	*Euplectes capensis*	1.285
Meyer's Parrot	*Poicephalus meyeri*	1.071
Pin-tailed Whydah	*Vidua macroura*	1.071
Speckled Mousebird	*Colius striatus*	1.071
Tambourine Dove	*Turtur tympanistria*	1.071
Tawny-flanked Prinia	*Prinia subflava*	1.071
Grassland Pipit	*Anthus cinnamomeus*	0.857
Tiny Cisticola	*Cisticola nanus*	0.857
Montane White-eye	*Zosterops poliogastrus*	0.642
Yellow-mantled Widowbird	*Euplectes macroura*	0.642
African Citril	*Crithagra citrinelloides*	0.428
African Mourning Dove	*Streptopelia decipiens*	0.428
Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*	0.428
Yellow-bellied Eremomela	*Eremomela icteropygialis*	0.214
Yellow-bellied Wattle-eye	*Dyaphorophyia concreta*	0.214

Appendix 7: Bird relative abundance recorded in farmlands using line transect method in and around North Nandi Forest. The list below is in descending order.

Species Name	***Scientific Name***	**Relative abundance%**
Black-and-white Mannikin	*Spermestes bicolor*	11.534
Black-crowned Waxbill	*Estrilda nonnula*	9.759
Baglafecht Weaver	*Ploceus baglafecht*	6.591
Speckled Mousebird	*Colius striatus*	6.337
White-eyed Slaty Flycatcher	*Melaenornis fischeri*	6.337
Common Waxbill	*Estrilda astrild*	5.196
Common Bulbul	*Pycnonotus barbatus*	4.943
Pale Flycatcher	*Bradornis pallidus*	3.676
House Sparrow	*Passer domesticus*	3.042
Speke's Weaver	*Ploceus spekei*	3.042
Chubb's Cisticola	*Cisticola chubbi*	2.662
Amethyst Sunbird	*Chalcomitra amethystina*	2.408
Barn Swallow	*Hirundo rustica*	2.408
Singing Cisticola	*Cisticola cantans*	2.281
African Pied Wagtail	*Motacilla aguimp*	2.155
Common Fiscal	*Lanius collaris*	2.028
Yellow-mantled Widowbird	*Euplectes macroura*	2.028
African Firefinch	*Lagonosticta rubricata*	1.901
White-browed Robin Chat	*Cossypha heuglini*	1.774
Lesser Masked Weaver	*Ploceus intermedius*	1.267
Red-eyed Dove	*Streptopelia semitorquata*	1.267
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	1.267
Spectacled Weaver	*Ploceus ocularis*	1.267
Common Stonechat	*Saxicola torquatus*	1.014
Lesser Striped Swallow	*Cecropis abyssinica*	1.014
Ring-necked Dove	*Streptopelia capicola*	1.014
Kenya Rufous Sparrow	*Passer rufocinctus*	1.014
Angola Swallow	*Hirundo angolensis*	0.887
Meyer's Parrot	*Poicephalus meyeri*	0.887
African Mourning Dove	*Streptopelia decipiens*	0.760
Black-billed Weaver	*Ploceus melanogaster*	0.760
Cinnamon-chested Bee-eater	*Merops oreobates*	0.760
Variable Sunbird	*Cinnyris venustus*	0.760
Yellow Bishop	*Euplectes capensis*	0.760
Blue-headed Coucal	*Centropus monachus*	0.634
Northern Black Flycatcher	*Melaenornis edolioides*	0.634
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	0.507
Yellow-throated Longclaw	*Macronyx croceus*	0.507
Augur Buzzard	*Buteo augur*	0.380
Double-toothed Barbet	*Lybius bidentatus*	0.380
Hadada Ibis	*Bostrychia hagedash*	0.380
Pin-tailed Whydah	*Vidua macroura*	0.380
Tambourine Dove	*Turtur tympanistria*	0.380
African Paradise Flycatcher	*Terpsiphone viridis*	0.253
Dusky Turtle Dove	*Streptopelia lugens*	0.253
Tawny Eagle	*Aquila rapax*	0.253
White-bellied Tit	*Parus albiventris*	0.253

Appendix 8: Birds captured during mist netting sessions in and around North Nandi Forest.

Common Name	***Scientific Name***	**Disturbed Forest**	**Indigenous Forest**	**Grand Total**
Black-and-white Mannikin	*Spermestes bicolor*	7	0	7
Equatorial Akalat	*Sheppardia aequatorialis*	3	4	7
Black-collared Apalis	*Apalis pulchra*	2	5	7
Singing Cisticola	*Cisticola cantans*	1	4	5
Cabanis's Greenbul	*Phyllastrephus cabanisi*	4	0	4
Grey-capped Warbler	*Eminia lepida*	3	1	4
Chubb's Cisticola	*Cisticola chubbi*	0	4	4
Common Bulbul	*Pycnonotus barbatus*	3	0	3
Speckled Mousebird	*Colius striatus*	2	1	3
Blackcap	*Sylvia atricapilla*	2	0	2
Olive Sunbird	*Cyanomitra olivacea*	2	0	2
Black-throated Apalis	*Apalis jacksoni*	0	2	2
African Blue Flycatcher	*Elminia longicauda*	0	2	2
African Paradise Flycatcher	*Terpsiphone viridis*	1	0	1
Black-crowned Waxbill	*Estrilda nonnula*	1	0	1
Brimstone Canary	*Crithagra sulphurata*	1	0	1
Brown-chested Alethe	*Alethe poliocephala*	1	0	1
Black-throated Wattle-eye	*Platysteira peltata*	1	0	1
Grey-backed Camaroptera	*Camaroptera brachyura*	1	0	1
Snowy-headed Robin Chat	*Cossypha niveicapilla*	1	0	1
Yellow-whiskered Greenbul	*Andropadus latirostris*	1	0	1
Eastern Double-collared Sunbird	*Cinnyris mediocris*	0	1	1

Appendix 9: List of Forest dependency categories in and around North Nandi Forest

Common Name	Scientific Name	Forest Dependency Categories
African Citril	*Crithagra citrinelloides*	F
African Emerald Cuckoo	*Chrysococcyx cupreus*	F
African Harrier Hawk	*Polyboroides typus*	*f*
African Mourning Dove	*Streptopelia decipiens*	*f*
African Paradise Flycatcher	*Terpsiphone viridis*	F
Amethyst Sunbird	*Chalcomitra amethystina*	*f*
Angola Swallow	*Hirundo angolensis*	*f*
Augur Buzzard	*Buteo augur*	*f*
Blackcap	*Sylvia atricapilla*	F
Baglafecht Weaver	*Ploceus baglafecht*	F
Black-and-white Casqued Hornbill	*Bycanistes subcylindricus*	F
Black-and-white Mannikin	*Spermestes bicolor*	*f*
Black Saw-wing	*Psalidoprocne pristoptera*	*f*
Black-backed Puffback	*Dryoscopus cubla*	F
Black-collared Apalis	*Apalis pulchra*	F
Black-crowned Waxbill	*Estrilda nonnula*	*f*
Black-headed Batis	*Batis minor*	F
Black-headed Gonolek	*Laniarius erythrogaster*	F
Village Weaver	*Ploceus cucullatus*	*f*
Black-throated Wattle-eye	*Platysteira peltata*	F
African Blue Flycatcher	*Elminia longicauda*	*f*
Brimstone Canary	*Crithagra sulphurata*	*f*
Meyer's Parrot	*Poicephalus meyeri*	F
Brown-backed Woodpecker	*Picoides obsoletus*	F
Buff-spotted Woodpecker	*Campethera nivosa*	F
Chubb's Cisticola	*Cisticola chubbi*	F
Cinnamon Bracken Warbler	*Bradypterus cinnamomeus*	F
Cinnamon-chested Bee-eater	*Merops oreobates*	F
Collared Sunbird	*Hedydipna collaris*	F
Common Bulbul	*Pycnonotus barbatus*	*f*
Common Cuckoo	*Cuculus canorus*	F
Common Drongo	*Dicrurus adsimilis*	*f*
Common Waxbill	*Estrilda astrild*	*f*
*Crested Guineafowl	*Guttera pucherani*	F
Crowned Hornbill	*Tockus alboterminatus*	*f*
Doherty's Bushshrike	*Chlorophoneus dohertyi*	F
Double-toothed Barbet	*Lybius bidentatus*	*f*

African Dusky Flycatcher	*Muscicapa adusta*	F
Dusky Turtle Dove	*Streptopelia lugens*	*f*
Grassland Pipit	*Anthus cinnamomeus*	*f*
Great Sparrowhawk	*Accipiter melanoleucus*	F
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	*f*
Green Hylia	*Hylia prasina*	F
Green-headed Sunbird	*Cyanomitra verticalis*	F
Green-throated Sunbird	*Chalcomitra rubescens*	F
African Grey Flycatcher	*Bradornis microrhynchus*	F
African Grey Woodpecker	*Dendropicos goertae*	*f*
Grey-backed Camaroptera	*Camaroptera brachyura*	*f*
Grey-backed Fiscal	*Lanius excubitoroides*	*f*
Grey-capped Warbler	*Eminia lepida*	*f*
*Grey Crowned Crane	*Balearica regulorum*	F
Grey-throated Barbet	*Gymnobucco bonapartei*	F
*Hamerkop	*Scopus umbretta*	F
Joyful Greenbul	*Chlorocichla laetissima*	F
Little Greenbul	*Andropadus virens*	F
Little Sparrowhawk	*Accipiter minullus*	*f*
Long-tailed Fiscal	*Lanius cabanisi*	F
Long-tailed Widowbird	*Euplectes progne*	*f*
Lühder's Bushshrike	*Laniarius luehderi*	F
Montane White-eye	*Zosterops poliogastrus*	F
Mountain Yellow Warbler	*Chloropeta similis*	F
Northern Black Flycatcher	*Melaenornis edolioides*	*f*
Olive Thrush	*Turdus olivaceus*	F
Olive-bellied Sunbird	*Cinnyris chloropygius*	F
Pale Flycatcher	*Bradornis pallidus*	F
Pin-tailed Whydah	*Vidua macroura*	*f*
Red-billed Hornbill	*Tockus erythrorhynchus*	*f*
Red-eyed Dove	*Streptopelia semitorquata*	*f*
Ring-necked Dove	*Streptopelia capicola*	*f*
Ross's Turaco	*Musophaga rossae*	F
Singing Cisticola	*Cisticola cantans*	*f*
Slate-coloured Boubou	*Laniarius funebris*	F
Snowy-headed Robin Chat	*Cossypha niveicapilla*	F
Southern Hyliota	*Hyliota australis*	F
Speckled Mousebird	*Colius striatus*	*f*
Speckled Pigeon	*Columba guinea*	*f*
Spectacled Weaver	*Ploceus ocularis*	*f*
Tambourine Dove	*Turtur tympanistria*	F

Tawny Eagle	*Aquila rapax*	*f*
Tawny-flanked Prinia	*Prinia subflava*	*f*
Tiny Cisticola	*Cisticola nanus*	*f*
Tropical Boubou	*Laniarius aethopicus*	*f*
Variable Sunbird	*Cinnyris venustus*	*f*
Vieillot's Black Weaver	*Ploceus nigerrimus*	*f*
Violet-backed Starling	*Cynniricinclus leucogaster*	*f*
Western Oriole	*Oriolus brachyrhynchus*	F
White-bellied Tit	*Parus albiventris*	*f*
White-browed Robin Chat	*Cossypha heuglini*	*f*
White-chinned Prinia	*Schistolais leucopogon*	F
White-eyed Slaty Flycatcher	*Melaenornis fischeri*	F
White-starred Robin	*Pogonocichla stellata*	F
Yellow-bellied Eremomela	*Eremomela icteropygialis*	F
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	F
Yellow-throated Longclaw	*Macronyx croceus*	F
Yellow-whiskered Greenbul	*Andropadus latirostris*	F
African Hill Babbler	*Pseudoalcippe abyssinica*	FF
Hoopoe	*Upupa epops*	FF
Common Scimitarbill	*Rhinopomastus cyanomelas*	FF
Bar-tailed Trogon	*Apaloderma vittatum*	FF
Bar-throated Apalis	*Apalis thoracica*	FF
Black-throated Apalis	*Apalis jacksoni*	FF
Black-billed Weaver	*Ploceus melanogaster*	FF
Black-faced Rufous Warbler	*Bathmocercus rufus*	FF
Brown Illadopsis	*Illadopsis fulvescens*	FF
Brown-chested Alethe	*Alethe poliocephala*	FF
Buff-throated Apalis	*Apalis rufogularis*	FF
Cabanis's Greenbul	*Phyllastrephus cabanisi*	FF
Plain Greenbul	*Andropadus curvirostris*	FF
Dusky Tit	*Parus funereus*	FF
Equatorial Akalat	*Sheppardia aequatorialis*	FF
Fine-banded Woodpecker	*Campethera tullbergi*	FF
Grey Apalis	*Apalis cinerea*	FF
Grey Cuckooshrike	*Coracina caesia*	FF
Grey-chested Babbler	*Kakamega poliothorax*	FF
Hartlaub's Turaco	*Tauraco hartlaubi*	FF
Jameson's Wattle-eye	*Dyaphorophyia jamesoni*	FF
Least Honeyguide	*Indicator exilis*	FF
Mountain Buzzard	*Buteo oreophilus*	FF
Mountain Greenbul	*Andropadus nigriceps*	FF

Mountain Illadopsis	*Illadopsis pyrrhoptera*	FF
Olive Sunbird	*Cyanomitra olivacea*	FF
Olive-green Camaroptera	*Camaroptera chloronota*	FF
Pale-breasted Illadopsis	*Illadopsis rufipennis*	FF
Petit's Cuckooshrike	*Campephaga petiti*	FF
Red-fronted Warbler	*Urorhipis rufifrons*	FF
Red-headed Malimbe	*Malimbus rubricollis*	FF
Scaly-breasted Illadopsis	*Illadopsis albipectus*	FF
Scarlet-chested Sunbird	*Chalcomitra senegalensis*	FF
Shelley's Greenbul	*Andropadus masukuensis*	FF
Lesser Honeyguide	*Indicator minor*	FF
Turner's Eremomela	*Eremomela turneri*	FF
White-headed Wood-hoopoe	*Pheoniculus bollei*	FF
White-tailed Crested Flycatcher	*Eliminia albonotata*	FF
Yellow-bellied Wattle-eye	*Dyaphorophyia concreta*	FF
African Firefinch	*Lagonosticta rubricata*	Non f
African Pied Wagtail	*Motacilla aguimp*	Non f
Barn Swallow	*Hirundo rustica*	Non f
Blue-headed Coucal	*Centropus monachus*	Non f
Common Fiscal	*Lanius collaris*	Non f
Common Stonechat	*Saxicola torquatus*	Non f
Hadada Ibis	*Bostrychia hagedash*	Non f
House Sparrow	*Passer domesticus*	Non f
Lesser Masked Weaver	*Ploceus intermedius*	Non f
Lesser Striped Swallow	*Cecropis abyssinica*	Non f
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	Non f
Kenya Rufous Sparrow	*Passer rufocinctus*	Non f
Speke's Weaver	*Ploceus spekei*	Non f
Woodland Kingfisher	*Halcyon senegalensis*	Non f
Yellow Bishop	*Euplectes capensis*	Non f
Yellow-mantled Widowbird	*Euplectes macroura*	Non f
Legend		
*Opportunistic surveys		
FF-Forest specialist		
F-Forest generalist		
f-Forest visitors		
Non f-None forest		

Appendix 10: QUESTIONNAIRE FOR COMMUNITY MEMBERS

A: PERSONAL DETAILS

Date of visit .....Sub-Location.....……Village.....

1. Age: (01) 15- 20 years (02) 20-40 years (03) Above 40 years

2. Sex: (01) Male (02) Female

B. HABITAT USE

3. How often do you visit the forest?

(01) Daily (02) Weekly (03) Monthly

4. Which forest habitat do you visit most frequently?

(01) Indigenous forest (02) Plantations (Exotic trees) (03) Forest edge?

……

5. What activities do you undertake in the indigenous forest?

01) Timber extraction

02) Grazing

03) Firewood collection

04) Collection of herbs

05) Other, please specify……

6. What activities do you undertake at the forest edge?

01) Timber extraction

02) Grazing

03) Firewood collection

04) Collection of herbs

05) Other, please specify……

7. What activities do you undertake in the tree plantations?

01) Timber extraction

02) Grazing

03) Firewood collection

04) Collection of herbs

05) Other, please specify……

C. HABITAT RESTORATION

8. Do you belong to any community based organization (CBO) that is concerned with the conservation of forest habitats?

01) Yes 02) No

If yes, state the name of your CBO……..

9. What conservation activities do you carry out?

……
……

D. AVIFAUNA CONSERVATION

10. In your opinion, which bird species do you think has seriously declined in number? Please list them:

……

11. Which common species of birds do you not see anymore? Please list them:

.....

12. Which bird species is/are now very common than before? Please list them:

.....

13. In your opinion, what reasons can you suggest may have caused the disappearance of these bird species?

.....
.....

14. In which habitat do you usually see many different bird species?

(01) Indigenous forest (02) Plantations (Exotic trees) (03) Forest edge (04) Farmlands.

15. In which habitat do you usually see many bird numbers be they of one species aggregate?

(01) Indigenous forest (02) Plantations (Exotic trees) (03) Forest edge (04) Farmlands.

16. In your opinion, what do you think are the main challenges affecting bird conservation efforts currently?

.....
.....

17. What do you think can be done to solve the challenges facing conservation of birds?

Indigenous forest	Plantations (Exotic trees)	Forest edge	Farmlands

Appendix 11: QUESTIONNAIRE FOR KFS OFFICIALS AND CFA OFFICIALS

A: PERSONAL DETAILS

Date……..

Title of Respondent……

Officer rank……

B: HABITAT USE

1. How often do you carry out security patrols in the forest habitats?

(01) Daily (02) Weekly (03) Monthly

2. Which forest habitat do you mostly focus on during your patrols?

(01) Indigenous forest (02) Plantations (Exotic trees) (03) Forest edge.

……

3. In your own opinion, which human activity has the greatest negative impact on forest habitats?

01) Timber extraction

02) Grazing

03) Firewood collection

04) Collection of herbs

05) Other, please
specify……

4. Which forest habitat is most adversely affected by these human activities?

(01) Indigenous forest (02) Plantations Exotic trees) (03) Forest edge.

C. HABITAT RESTORATION/CONSERVATION

5. What initiatives/activities has your organization undertaken to conserve the forest habitats?

……
……
……

6. In your opinion, which forest habitat seems to be responding more positively to your efforts in terms of regeneration?

(01) Indigenous forest (02) Plantations (Exotic trees) (03) Forest edge.

7. Are some of your activities geared towards bird diversity conservation?

01) Yes 02) No

If yes, state what
activity…….

8. In your opinion, what is the best way to conserve these forest habitats?

Indigenous forest	Plantations (Exotic trees)	Forest edge	Farmlands

9. What do you think are the main challenges affecting bird and forest habitat conservation efforts currently?

……
……
……
……
……
……

10. What measures would you recommend to mitigate these challenges?

Indigenous forest	Plantations (Exotic trees)	Forest edge	Farmlands

Appendix 12: Bird species composition, richness and diversity across the four habitats in and around North Nandi Forest.

Parameters	**Indigenous Forest**	**Disturbed Forest**	**Plantation Forest**	**Farmland**
Number of individuals	766	805	687	974
Species richness	94	99	45	62
Shannon's diversity index	3.896	4.053	3.060	3.482
Simpson's diversity index	0.972	0.976	0.923	0.954
No of species common in all habitats	18	18	18	18
No of species exclusive to each habitat	24	19	2	12
No of threatened species in each habitat	7	4	1	1

Appendix 13. Photo galleries of birds caught in disturbed forest and indigenous forest during the survey.

Plate 1.Equatorial Akalat- Disturbed forest. Source: Author (2016)

Plate 2. Grey-backed Camaroptera- Disturbed forest. Source: Author (2016)

Plate 3.Cabanis's Greenbul- Indigenous forest. Source: Author (2016)

Plate 4.Brown-chested Alethe- Indigenous forest. Source: Author (2016)