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EFFECTS OF SACRED GROVE SIZE AND ISOLATION DISTANCE ON AVIFAUNAL ASSEMBLAGES IN FOREST-SAVANNAH TRANSITION ZONE OF GHANA

BY

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Thesis submitted to the Department of Conservation Biology and Entomology of the School of Biological Science, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy degree in Wildlife Management

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DECLARATION

I hereby declare that this thesis is the results of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature ……………………………….. Date ………………….....

Name ………………………………………………………………………..

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature ………………………………... Date ……………………

Name: Justus Deikumah, PhD

Co-supervisor's Signature ………………………………... Date ………………...

Name: Prof. K. A. Monney

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ABSTRACT

Sacred groves which are remnants of old-growth forests protected by indigenous people with the view that their gods reside in them and protect them from all forms of calamities, may be important areas for forest-dependent birds in Ghana. However, the information of how bird communities utilize them is inadequate. Bird survey was conducted in the sacred groves located in the forest-savanna transition zone of Ghana. The goal was to determine the effects of sacred grove size and isolation (distance from the nearest large fragment) on the density and diversity of tropical forest-dependent bird species. Thirty sacred groves were selected and point transect method of bird sampling was adopted for the survey. The findings revealed that sacred groves of larger sizes supported a large number of different species of birds. The study, however, also revealed that, most bird community composition was basically determined by the structure of the vegetation. Similarly, it has also been shown that, sacred groves protect habitats which are suitable for the conservation of birds. In view of this, it is recommended that effective conservation measures should be put in place, taking into consideration the concerns of the local people, so as to conserve this relict of old growth forests.

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KEY WORDS

Sacred groves

Transition

Survey

Isolation

Density

Diversity

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DEDICATION

To my sister, Vida and husband, Emmanuel

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CHAPTER ONE

INTRODUCTION

Background to the study

Tropical rainforests have been described as non-seasonal, water-loving formations that are interspersed with trees, but are also rich in lianas and epiphytes (Hill & Hill, 2001). The undergrowth consists largely of tree seedlings, saplings and young woody climbers and have few herbaceous ground flora (Hill & Hill, 2001). Forests are well-known for their high species numbers. For instance, a hectare of primary forest may contain over 100 tree species (Valencia, Balslev, & Miño, 1994). It has been estimated that, tropical forest ecosystems habour at least two thirds of the earth's terrestrial biodiversity (Gardner *et al*., 2009). It also offers important local, regional and global benefits by means of provision of economic goods and ecosystem services (Gardner *et al*., 2009).

Fairly due to high plant diversity, tropical forests may habour diverse animal species including several insects, amphibians, reptiles, mammals and birds. They also serve other important functions in the environment, some of these include; provision of oxygen, carbon sequestration and the absorption of greenhouse gases. Rather unfortunately, tropical forests have been rendered the epicenter of current and future extinctions (Bradshaw *et al*., 2009). This is due to the influence of persistently high rate of deforestation and forest degradation, overharvesting, invasive species and global environmental change. The rate of deforestation is unprecedented in the evolutionary history of tropical-rainforests and thus may

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exert negative effects on the ecosystem (Sodhi *et al*., 2004). Deforestation results in fragmentation of the rainforest or any forest that is regenerating in the face of regional development and colonization.

In tropical forests, deforestation often involves the conversion of landscapes with continuous forest to ones with remnant forest patches set in a matrix of non-forest vegetation. The changes in tropical environment have consequences on biodiversity at both the landscape and the forest-fragment level.

About 12% of birds are likely to go extinct in the next 100 years (Şekercioğlu *et al*., 2004). This extinction rate is usually attributed to human activities such as deforestation and hunting. Deforestation of tropical lands can have both local and global effects. Globally, deforestation leads to the loss of habitat for millions of species. It deprives the forests of portion of their canopy which blocks the sun's rays during the day and holds in the heat at night. This disruption leads to more extreme temperature swings that can be harmful to plants and animals. Trees play an important role in absorbing the greenhouse gases that fuel global warming – fewer trees means larger amount of gases entering the atmosphere – and increased speed and severity of global warming. Locally, climate may perhaps turn out to be more life-threatening, soil possibly will undergo physical and chemical deterioration and hydrological balances may be disturbed.

Habitat fragmentation

Fragmentation of habitats due to natural processes or human disturbance has been documented for many landscapes around the globe (Andren, 1994; Fahrig, 2003; Maldonado-Coelho & Marini, 2000; Manu *et al*. 2005 ; Wiens, 1995). It has been

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pointed out that large islands may contain more species than small because there is a lower limit to the size of island acceptable for many species (Bell et al., 2005). This general ecological effect seems also to apply to habitat fragmentation. Habitat fragmentation entails loss of habitat and an increase in isolation (Dami *et al*., 2013). It can trigger outcomes such as edge effects, decreased colonization, increased mortality and habitat degradation (Andren, 1994). This may lead to an increase in extinction rate, loss of biological diversity and the alteration in the patterns of species distribution across fragments (Saunders *et al.*, 1991). For instance, bird species richness was found to be dependent on fragment size in the Mediterranean area (Herrando & Brotons, 2002).

The main cause of declines in bird diversity resulting from forest fragmentation are edge effects and reduction in available habitats (Ford *et al*., 2001). The non-forest habitats generated by forest fragmentation may perhaps increase in carrying capacity of generalist species, open field competitors or nest parasites that may interrelate with forest interior birds (Manu, 2002). The continual loss of original habitats may result in sudden decrease in size of the remaining habitat and increased isolation of fragments. Subsequently, edges would become more abrupt. An effect of edge is that population and community dynamics within a patch may be dominated by external factors such as predation, parasitism or physical disturbances (Wiens, 1995). These variations might be complemented by less indirect effects. It has been pointed out that the resource base of insectivorous birds may change if fragmentation affects the distribution and abundance of insects (Roland, 1993). Habitat structure available to birds could change as a

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result of decline in large predators following the rise in herbivores that feed on the vegetation (Angelstam, 1992).

The structure of the landscape is, therefore, often important for the composition of the community and the type of surrounding habitats that may strongly influence the communities in forest fragments. Part of the effects of fragmentation is due to its influence on resources, so birds that forage differently are likely to respond differently. How birds use an area is also likely to affect their response to fragmentation (Stouffer & Bierregaard, 1995). On the basis of their response to habitat fragmentation, some birds have been categorized as forest interior species because of their response to habitat fragmentation as a result of their sensitivity to forest fragmentation. Other bird species are referred to as forest generalist species and forest visitors, because they are favoured by forest fragmentation (Lynch & Whigham, 1984). The fraction of edge might be somewhat larger in small fragments.

Within wildlife communities, there occasionally seems to be a subgroup of species that attain their greatest intrinsic rate of increase in habitat interiors that are distant from ecological edges, wherever major landscape elements adjoin (Temple & Cary, 1988). These habitat interior species presumably evolved in natural ecosystems that featured large continuous tracts of habitats that normally contained relatively few edges. For these species, anthropogenic processes of habitat fragmentation result in quantitative loss of the total area of the habitat available, as well as qualitative alteration of the remaining habitat.

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The number of bird species in woods is governed by internal factors such as: habitat variables and size as well as external factors like edge effects and isolation (Opdam *et al*., 1984). Interpatch distance, patch density and the density of the corridor network influence the probability of occurrence. The role of spatial heterogeneity in regulating community diversity has been given attention by ecologists (MacArthur & MacArthur, 1961).

Habitat fragmentation usually leads to reduction in area, and size of the population resulting in the loss of some species from fragments and an increased sensitivity of the remaining populations to chance (Wiens, 1995). Because of fragment isolation, recolonization following local extinctions may then be slowed. Species diversity is reduced and community composition is altered because some species such as large predators or sedentary specialists are sensitive to these effects. Increasing threat to biodiversity loss demands new conservation approaches. This may facilitate fair share of the wider values of conservation to the local communities and positive local attitudes towards conservation goals (Anthwal *et al*., 2006).

A fragmented landscape may probably exhibit some amount of edge relative to the interior (Wiens, 1995). Edge effects refer to the changes in population or community structures that occur at the boundary of two habitats. Edge effects negatively affect species that require forest interior habitats. It reduces the quality of habitat within fragments for species. It also affects species that have evolved in contiguous habitats and now the habitat has been fragmented. Edge effects also apply to succession, when vegetation spreads rather than being

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lost to competitors. Different species are suited either to the edges or to interior regions of the habitat, resulting in a varied distribution.

When habitats bordering fragmented landscapes are modified, it generates unfavorable conditions along the fragment edges, which could then affect such habitat-related characteristics as succession and habitat structure.

Within tropical rain forests, lots of environmental characteristics are changed close to forest edges that border agricultural clearings, in particular in the first 100 meters of the edge (Laurance, 1996; 2000). In response to these changes, vegetation structure, floristic composition and wildlife communities also may perhaps be distorted in forest close to edges.

The fragmentation of forested landscape in the forest-savanna transition belt has contributed to the decline in the forest quality (Hurd & Civco, 2010). This fragmentation is the result of anthropogenic activities, mainly through the clearing of forests for agricultural and industrial purposes. Recently, urban expansion has contributed to the decline of forest lands (Rudel et al., 2005). Fragmentation in these areas has led to changes in the microclimate, increase in invasive species, parasites and predators. Consequently, the ecosystems' ability to protect the flow of water and forest quality has been modified by fragmentation (Hurd & Civco, 2010).

Despite these changes caused by habitat fragmentation, sacred groves have been the ideal centers for biodiversity conservation (Tripathy *et al.*, 2010) in the forest-savanna transition zone. Various plants and animals that are threatened in the forest-savanna transition zone are well conserved in sacred groves located in this zone. Sacred groves provide shelter for many faunal species (Ray & Ramachandra, 2010). Birds that were common everywhere are now observed only in sacred groves (Benson, 2014). Sacred groves serve as habitats for native species of plants and animals that have no other habitat left, or are over hunted or harvested. Sacred groves not only protect species of biodiversity value, they also protect species that are important to agriculture (Benson, 2014). Recently, there has been many challenges that are causing threats to the sustainability of sacred groves in the maintenance of biodiversity. Some of these challenges include; logging, bushfires, slash and burn, weakening of traditional institutions. These have negatively affected the existence of sacred groves in the forest-savanna transition zone, and have consequently led to the decline in species that depend on them for their survival.

Problem Statement

Sacred groves are natural areas that have been preserved by the local people from overexploitation for religious and social purposes (Benson, 2014). They provide ecosystem services such as pollination, dispersal and serve as provider of herbal medicine for the community. Sacred groves serve as sanctuaries for native flora and fauna species (Khan *et al.*, 2008) They provide habitat for species important to agriculture which include pollinators and birds that eat crop pests (Blicharska *et al*., 2013).

By tradition, wildlife was considered as an important resource that provided several benefits to indigenous communities. Therefore, they were mainly protected by customs and taboos. Nonetheless, lately, many indigenous communities have embraced western education and religious values (Chandrakanth *et al*., 2004), and so have begun to question things for which no explanations nor scientific bases existed. This is particularly the case in many sub-Saharan African countries where traditional beliefs dominated their societies with enormous adherence to cultural beliefs. With the advent of Christianity, and other non-native beliefs, cultural infiltration has resulted in the collapse of some traditions and taboos that protected natural resources and cultural heritage sites such as forests and ancestral burial grounds. As people now believe that what used to be a taboo is now a mere imposition of tradition, they now use resources without consideration to traditions that instil fear and discipline. Secondly, but not in isolation, the prodigious increase in human population has led to the demand for more resources (Khan *et al*., 2008) than the environment could provide. Also communities have expanded alongside with increasing human population into sacred areas. This has made sacred groves lose their importance accorded them in recent times. Many activities now threaten their existence and that of their constituent biota. They have been gradually degraded through agricultural practices, deforestation and encroachment of previously inaccessible areas. It has been estimated that over 90 percent of the high forest in Ghana have been logged since the late 1940s (Tamakloe, 2000) and during that period, sacred groves were intact and served as potential refuges for many endemic species (Anthwal *et al*., 2006). These forests harbour about 70% of all bird species recorded in Ghana (Tamakloe, 2000). Thus, the loss of sacred groves would result in the loss of species that depend on it. Understanding how changes in response to taboos and customs in recent times are useful in preserving sacred groves is crucial for conservation decisions towards conservation of biodiversity.

Despite, the importance of sacred groves and the alarming rate at which they are being destroyed including the biodiversity they support, no studies have investigated the influence of sacred grove size and isolation distance from nearest largest patch globally. Moreover, most fragmentation studies were conducted mostly in high forest zones (Barbosa & Marquet, 2002; Lynch & Whigham, 1984; Manu, 2002 ; Manu, 2003; Soulé *et al*., 1992). No studies that tested the species-area hypothesis of the island biogeography theory has related avifauna assemblage structure to sacred groove size and isolation distance particularly in the forest-savanna transition zones.

Purpose of the Study

The main aim of this study was to ascertain the value of sacred groves and their capacity to conserve species. Understanding how sacred grove size and isolation distance influence bird assemblage structure may help to effectively evaluate the current ecological role of sacred groves and formulate strategies for their protection and conservation in the era of declining bird species.

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Main Objectives

i) To estimate species richness, diversity, density and abundance of forest-dependent birds in sacred groves of varying sizes and isolation distance from nearest largest forest reserve.

ii) To estimate diversity and density of different functional guilds of birds in sacred groves of varying sizes and isolation distance from nearest largest forest reserve.

iii) To quantify vegetation characteristics and anthropogenic activities within sacred groves and relate them to variations observed in species assemblages.

Research Questions

i) Do sacred groves of varying sizes and isolation distance from the nearest largest forest fragments affect bird species assemblages?

ii) Do sacred groves of varying sizes and isolation distance from the nearest largest forest fragments influence assemblage of different functional guilds of birds?

iii) Do site-scale vegetation characteristics in sacred groves of varying sizes influence bird species assemblages?

iv) Do anthropogenic activities influence bird species assemblages in sacred groves?

Significance of the Study

This study highlights the key role sacred groves play in conservation of bird species in tropical forest-savannah transition ecological systems. There exist a mutual relationship between birds and sacred groves. Sacred groves provide resources such as food, nesting sites and cover for birds, and the birds in return provide important ecosystem services such as; pollination, dispersal of seeds and fruits which help in forest regeneration. Birds can be used as a monitoring tool to

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check the status of sacred groves. This can be done by determining the presence of a particular species of birds in a grove. For instance, the presence of a forest visitor species in a sacred grove is an indication of forest disturbance (Bennun *et al.*, 1996). The study also highlights that traditional ecological knowledge offers a means to improving research and environmental impact assessments.

Delimitation

This study was conducted in sacred groves located in the forest-savanna transition zone of the country. These areas are becoming wooded lands at a faster rate. These changes may be result of climatic factors such as increasing temperatures and decreasing precipitation, which may often lead to frequent bushfires and drought events. However, the main drivers according to this study are non-climatic, and included deforestation, logging, and extraction of charcoal, expansion of agricultural lands mining activities. The variables considered were, the size of the sacred groves, the distance to nearest large fragments (isolation distance), vegetation characteristics, disturbance regimes (explanatory) and bird assemblage information including; functional groups (habitat preference, foraging behaviour, feeding guilds). However, parameters such as matrix effects, edge effects were not taken into consideration.

Limitations

The goal of a complete bird survey is to count all the birds present in a specific area in order to obtain an unbiased estimation of assemblage data. However, in this study, counts were limited to birds within a specific radius from the survey point, thus, species sighted between points were not recorded. This may lead to

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bias in the estimation of total species found in an area. It was also difficult to estimate distance between point counts station and vocal cues making distance estimation problematic. This method is not suitable when counting easily disturbed birds, they mostly flee from the observer. With this method, it is likely that an observer may count an individual species more than once. This may possibly affect the total number of species found in an area.

Definition of Terms

During the study, many terms were used. Some of these include;

Species density – number of species per unit area

Species diversity – number of different species represented in a given community

Transition zone – a zone which lies between the forest ecotone and savanna ecotone

Sacred grove – pristine forest protected by indigenous communities with the view that their gods reside in them and protect them from calamities

Organization of the Study

The thesis has been divided into five chapters with each chapter having specific sub-topics that are well discussed.

Chapter one – provides general introduction to the research which include; background to the study, statement of problem, purpose of study, research questions, specific objectives and justification.

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Chapter two – discusses into details review of related literature, considering the theoretical framework such as; species-area hypothesis and the theory of island biogeography in line with the study. Also the concept of sacred groves was dealt with in this chapter.

Chapter three - this chapter describes the details of the study area, study design, materials and methods employed for data collection.

Chapter four – this highlights the results of the data in line with the objectives of the study. It examined the effects of isolation on distance on bird species density and diversity. It also determined how vegetation covariates influenced bird assemblage information in the forest-savanna transition zone of Ghana. Likewise, the chapter discusses the major findings of the study in line with the objectives and in relation to relevant literature that were reviewed.

Chapter five presents the summary, conclusion and recommendation of the study. It summarizes major findings of the study and draws conclusions based on the results. Some recommendations were therefore made to that effect.

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CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter highlights the relation of the study to reviewed literature, considering theoretical frameworks in relation with the study and also the gap it fills. It commences by considering the theoretical framework of the study.

Theoretical Framework

One of the oldest and well-known patterns within biogeography that explains patchy spatial distribution of individuals in species is the species-area relationship (Wineland, 2015). Species-area relationship has been explored for a wide array of taxa which may range from diatom to fish through to insects, birds, vascular plants and mammals (Connor & McCoy, 2001). It has also been examined in different habitats such as islands, lakes, rivers, woodlands, grasslands. This theory describes the relationship between the area of a habitat and the number of species found within that area. Larger areas harbour higher number of species in a taxonomic group, and empirically, the relative number seem to follow systematic mathematical relationship (Wineland, 2015). Two major theories have been suggested to explain the important positive relationship that exists between numbers of species and area. This is the theory of island biogeography (MacArthur & Wilson, 2015) and the habitat-diversity hypothesis. The former proposed that the number of species increases with greater area, and mostly becomes asymptotic for the largest areas. This is because larger islands reduce extinction for larger populations (Wineland, 2015).

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On the other hand, the habitat-diversity hypothesis debates that with increase in amount of sampled area, different species and habitats are encountered, and this may result in increased species number with area. It is therefore necessary to study how the species-area hypothesis applies to the traditional way of biodiversity conservation.

Anthropogenic Habitat Disturbances

In both the tropics and the temperate regions, forest wildlife is negatively affected by anthropogenic forest disturbance (Posa & Sodhi, 2006). Human-induced disturbance are widely variable in intensity, extent and periodicity and are mostly facilitated by several economic events such as timber, and non-timber resource extraction, forest fragmentation, other forms of forest destruction and conversion of forest to other forms of land use (Peres *et al*., 2004). Some examples of human activities that can severely affect wildlife may consist of hunting, selective logging at varying degrees of intensity, slash-and-burn agriculture, plantation forestry, selective removal of understory to produce crops that thrive in shades, and outright deforestation for large-scale livestock operations (Peres *et al*., 2004).

The faunal groups in human-induced habitats can be significantly defaced in disturbed habitats. This is likened to those in strictly undisturbed forest lands that harbour a full complement of plant and animal species which are restricted to the remaining pristine forests. Anthropogenic disturbance disrupt complex biotic interactions that maintain ecosystem integrity, bringing about a cascade of ecological impacts. For instance, it has been pointed out that habitat disturbance can cause declines in pollination (Kremen, 2005), and as well leads to the

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modification in visitation rate of animal fruit-consumers to rainforest trees (Luck & Daily, 2003).

Hunting is conceivably the most pervasive form of human disturbance in tropical forests (Peres et al., 2004). In most parts of West Africa and the neo-tropics, hunting is persistent relatively due to the increasing human population that move from urban centers and dwell in frontiers of forests. The taste for bushmeat by forest dwellers has increased due to the paucity of alternative sources of protein and modified hunting techniques. Large-bodied species such as large game birds and mammals are mostly affected by hunting because these species are known to provide highly desirable meat packages and are hunted for commercial and subsistence purposes (Peres, 2001). Unfortunately, these species tend to have low fecundity rate and thus pull through slowly from persisting pressure.

Logging Activities

Logging is considerably one of the major anthropogenic activities in tropical forests. It is believed that logging affects over 15000 km^2 of forest in Amazon alone annually (Peres *et al*., 2004). When logging occurs, the forest canopy opens up, and primary production is then shifted to the forest understorey layer. Species such as birds and butterflies that mostly dwell in the canopy layer tend to forage at the understorey layer. This change in foraging behavior helps to replace species that specialized in foraging in closed forest interior of pristine forests. The process also creates opportunity for large terrestrial browsers such as elephants, okapis and forest duikers. It can adversely affect forest specialists and favor forest generalists which are able to switch between resources. Logging brings about

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efficient off-take of important fruiting species, and this to a greater extent affect frugivores. It results in homogenous forest which is doubtful to maintain the range of biodiversity found in primary forest. Logging may also destroy many intricate interactions among species, which may have a long term effect. Moreover, logging cannot be looked at in isolation from other forms of forest disturbance. In logged forests, logging camps, logging roads and skidding trails are created. These tend to increase demand for bushmeat and easy access to formerly undisturbed forests.

Sacred Groves

Every aspect of religion and cultural practices is deeply rooted with the forest that helps in nature conservation (Amoako-Atta, 1998). It also acts as the subject of a great deal of myth, legend and lore. As at now there exists some communities whose livelihood are entirely reliant on forest resources and their traditional practices preserve a huge number of wild plant species for various reasons e.g. food, fiber, shelter or medicine. Regrettably, many developmental activities and modifications in people's attitude in terms of beliefs in religious practices convey thoughtless actions towards forest. These result in destruction of forest at an alarming rate and decreasing biodiversity. But, there are some forest patches which are left untouched because of social fencing by the local people. This nature of forest brings the idea of "sacred grove". Sacred groves are one of the first cases for traditional conservation. Sacred groves form a linkage between present society and the past in terms of biodiversity, culture, religion and ethnic traditions (Khan *et al.*, 2008). They are forest patches conserved by the local people – it is linked with their socio-cultural and religious practices (Basu, 2000). The concept of sacred groves can be associated with communities that have conserved several virgin forest by setting them apart for the ancestral spirit or deities.

These groves harbour rich biodiversity and play an important role in biodiversity conservation. Sacred groves are distributed over a wide ecosystem and help in conservation of rare and endemic species (Chandrakanth *et al*., 2004). It helps in improving the fertility of the soil through efficient nutrient cycling, conserving soil moisture through humus build up in the soil and partly through a deeply placed root system which has root biomass uniformly distributed throughout the soil profile. The value of sacred grove is immense as they are good sources of a variety of non-wood products, fatty oils, species like pepper, cinnamon, nutmeg and medicinal plants etc. (Anthwal *et al*., 2006).

Sacred groves are multi-faceted social institutions and signify the dynamic social forces linked with access and control over resources. They possess a great heritage of diverse gene pool of many forest species having socio-cultural and religious attachments and possessing medicinal values (Khan *et al*., 2008). Sacred groves are ecologically and genetically important. They are abodes of rare, endemic and endangered species of flora and fauna (Anthwal *et al*., 2006).

In Ghana, there are 240 forest reserves that are known to have close links with sacred groves and/or socio-cultural ties with local communities (Nganso *et al*., 2012). The number of sacred groves in Ghana ranges from 2000 to 3200, in which

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almost 80% of them are located in the Southern part of the country (Gordon, 1992).

Many of them have been set aside as special abodes that are sternly protected by customary laws and/or beliefs, obliged by taboos. People visit this place occasionally only for important ceremonies and religious performances (Sarfo-Mensah & Oduro, 2007). Many local communities have made conventions in order to prevent people from violating their taboos. For example, in the South-Western part of the country, a village named Nanhini habour two sacred groves which are Namafua and Kobri sacred groves. In Namafua sacred grove, people are not allowed to farm, hunt and collect snails from it (Corbin, 2008). However, they are allowed to tap the oil palms trees for wine and also collect medicinal herbs from it. Also lands surrounding the grove with streams in them are not to be visited during the sacred days of deities associated with the grove (Corbin, 2008). Many sacred groves harbour untouched vegetation and are particularly rich in trees and other organisms such as, epiphytes, amphibians, reptiles, birds, insects etc. Sacred groves contain the only representative of near-natural vegetation in many parts of Ghana. In addition, quite a few rare and threatened species are found only in sacred groves, which are, maybe, the last refuge for these vulnerable species (Khan *et al*., 2008). Sacred groves serve as home of reservoir of many plants used in preparing traditional medicines. Though isolated groves do not harbour any major mammalian wildlife with exception of primates and small mammals like bats, civet cats etc. they provide home for species such as birds, butterfly, and insects

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CHAPTER THREE

MATERIALS AND METHODS

Introduction

This chapter describes the details of the study area, study design and the materials and methods used for data collection and methods for data analyses. Others include; experimental design and disturbance regimes.

Study Area

The study was conducted in the forest-savannah transition zone of Ghana, located between 6º15' - 7º 28' N and 0º20' - 2º35' W (Figure 1). The forest-savanna transition zone covers an area of about 10630 km^2 (Beier *et al.*, 2002). It ranges from the northern part of Ashanti Region through the Brong Ahafo Region and the southern part of the Northern Region. In this zone, a forest slowly starts to fade into savannah region. Some of the major towns in this zone are, Sunyani, Techiman, Berekum, Dormaa, Nsuatre, and Nkoranza. Some of the sacred groves located in these areas are: Duasidan sacred grove (near Dormaa Ahenkro), Tano Boase sacred grove (near Techiman), Botene sacred grove (located in Nsuatre), Boaben – Fiema Monkey Sanctuary (near Nkoranza) and Mfensi sacred grove (near Berekum). These area produce larger portion of food crops such as grains, cereals and tubers in Ghana. Lately, cash crops such as cashew and cocoa have been widespread in this area. The climatic conditions in the transitional zone have made the cultivation of food crops more favourable as compared to the northern part of the country. It has an annual rainfall of 1430 mm.

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The forest-savanna transition zone is characterized by the co-existence of two distinct ecosystems: forest and savanna. Majority of the tree species found here are forest species but a substantial number are either savanna species or species that are typical of both forest and savanna. The zone an uneven tree canopy with emergent trees of more than 60m in height. Some of the tree species found in this area are mostly *Triplochiton scleroxylon, Ceiba pentandra, Ficus exasperata, Milicia excels, and Tieghemella beckelii*. It consists of understory layers which is composed of grasses like elephant grasses and other woody creepers.

3.3 Map of Study Area

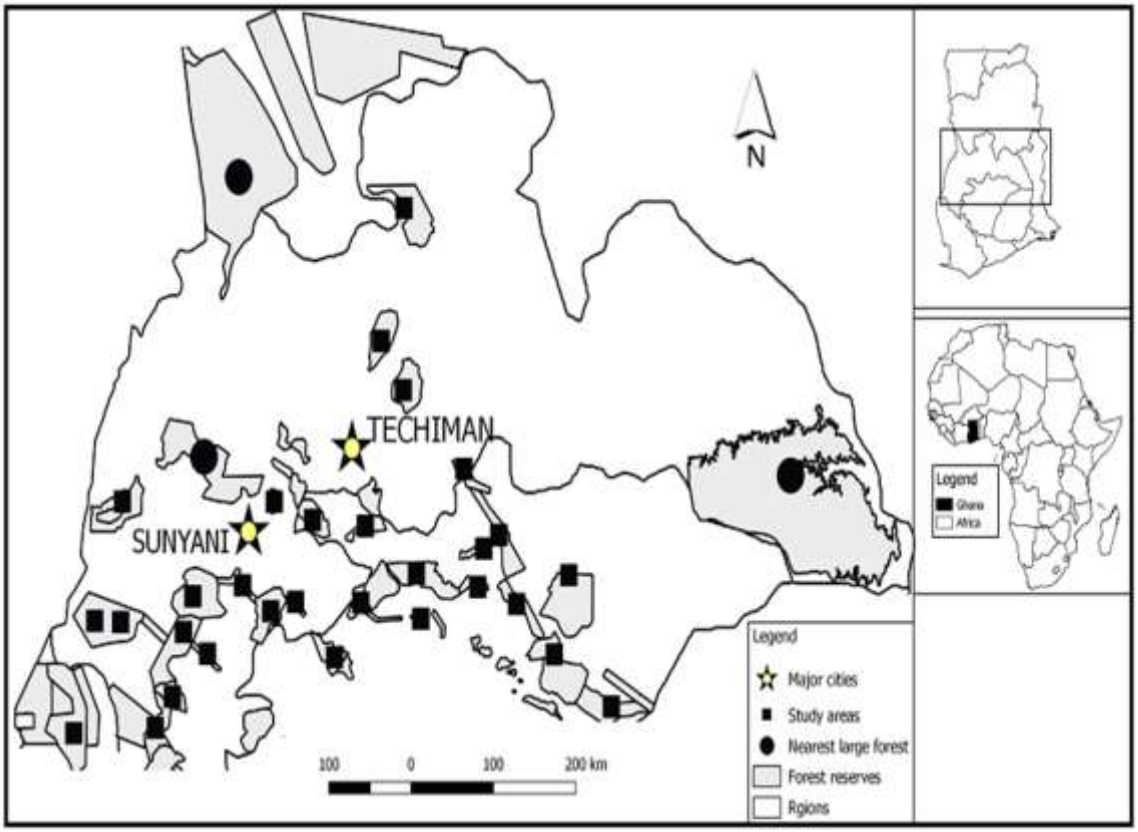

Figure 1: Map of forest-savanna transition zone showing the study locations. Insert is Africa map showing the location of Ghana.

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Study Design

Thirty sacred groves were selected in the forest-savanna transition zone in Ghana. The sacred groves selected were distributed across the study areas, spanning different distances from the forest zone. Birds were surveyed twice in the dry season and in the wet season. The survey was undertaken in the early hours of the day (06:00 GMT – 10:00 GMT) before sunrise, and hours before sunset (14:30 GMT – 17:30 GMT). An effort was made to avoid multiple counting of individuals. In order not to be bias in the comparison of species encountered in small and large groves, sacred groves were categorized into three; large (> 10 ha), medium (4.1 ha – 10 ha) and small (2.5 ha – 4 ha). Study patches were located in the forest-savanna transition zone with a minimum spacing of 2 km between sites. A total of 120 point count stations were established in the study patches. The points were regularly distributed in each study patch.

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Table 1: Lists of sacred groves that were sampled for birds

Sacred groves	Size category	Area (ha)
Abontema	medium	4.8
Amanfo	small	5.1
Ankoben	small	3.48
Anyin	small	3.8
Asumagya	large	52
Banmu	medium	6.5
Boaben-Fiema	large	20
Bobiri Forest	large	500
Bonwire	medium	8
Botene	medium	4.5
Buoyam	large	36.5
Domase	small	2.8
Domfete	small	2.3
Duasidan	large	20.3
Jachie	large	11
Jamde	small	3.5
Mfensi	medium	8
Kobiri	medium	5.4
Koraa	small	3.2
Koti	small	3.4
Kuntenase	small	2.6

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Table 1 Continued

Nchiraa	medium	4.82
Nsapor	small	2.5
Nyinakofi	medium	7.5
Mpow	large	12.4
Oforikrom	medium	4.2
Owabi	large	13
Penkoase	small	5.1
Pepaase	medium	5.8
Tano	large	15.6

Bird survey

Bird surveys were conducted between January-April (dry season) and May – August (wet season) in 2016. Point transect method of sampling was adopted for these surveys (Buckland *et al.*, 2001) to provide impartial density estimates even when low numbers of species are recorded. Point transect is suitable for closed habitats with high canopies such as the areas selected. In each selected sacred grove, four (4) point count stations were established with a fixed radius of 50m, each separated by a minimum distance of 150 m. The observer walked on predetermined transects and stopped at a fixed point, listening, looking for and recording birds within a fixed period of ten minutes. A pair of 8 x 42 binoculars was used to detect and identify birds encountered. Bird species identified by sight

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were confirmed by using a field guide of birds of Ghana (Borrow & Demey, 2013)

On reaching a point count station, five minutes was allowed for the birds to resume their normal activities. The same observer carried out all bird surveys under comparable weather conditions (i.e. avoiding rainy, windy or misty days) at the same time of the day (06 hrs – 10:30 hrs and 14:30 hrs – 17:30 hrs).

Vegetation Survey

Vegetation survey was conducted to characterize the structure and composition of the vegetation of each site. At each count station, three 20 x 20 m quadrat was selected and all tree species categorized into large, medium and small were counted in the quadrat, and the average was estimated. Within the same quadrat, fruiting trees and flowering trees were also counted and recorded. Canopy cover was visually estimated within a 2 x 2 m quadrat placed in the 20 x 20 m quadrat. This was estimated by looking at the wrong side of the binoculars within three 2 x 2 m quadrat (Bibby, 2000).

The size of each sacred grove and the distance from the center of each to the nearest continuous forest reserve was estimated from quantum GIS software (Version 2.14.3). Coordinates were taken at the center of each site using a Garmin 12 GPS. With the GIS software QGIS the coordinates were overlaid on a Landsat image and land use map (Helmer *et al*., 2000). Also a fixed radius of 50m was taken with the help of the Garmin 12 GPS. With additional information from the GIS software the area of each site was determined by drawing polygons around the GPS coordinates. With the same software, the distance from each study patch

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to the nearest large fragments was determined. Sacred groves were grouped into sizes according to their area; small sacred grove (area 0.5 – 3.9 hectares), medium sacred grove (area 4.0 – 7. 9 hectares) and large sacred groves (area ≥ 8 hectares).

Disturbance Regime

The level of disturbance in each grove was estimated. These include, hunting activities, chain saw operations, and intensity of fuel wood collection. Hunting index was estimated by observing the presence of waste cartridges, traps and hunters' trails. Hunting activities were categorized into: minimum (i. e. if the encounter rate of hunting activities ranges from 1-5), moderate (encounter rate ranges from 6-10) and high (encounter rate > 10). Likewise, number of observations of chainsaw operations were classified into minimum (1-3), moderate (4-6) and high (≥ 7) based on intensity of activity. Fuelwood collection was also determined. These activities were categorized into minimum (1-5), moderate (6-10) and high (≥ 10).

Ecological Attributes

The ecological attributes of birds detected were classified based on existing literature. Bird species sampled were grouped into food preference and foraging behaviour categories in order to determine whether sacred grove size and isolation distance influence foraging behaviour differently (Holbech, 2009). A total of eight major foraging behaviours were identified, these were ground gleaners, branch gleaners, leaf gleaners, bird sallyers, insect sallyers, fruit hovers, insect hovers, and branch peck. Furthermore, each species was also classified into the three forest-habitat preference categories, as defined in Holbech (2009) i.e. forest specialists (FF), forest generalists (F) and forest visitors (f) (Bennun *et al*., 1996)

Similarly, different feeding guilds were also assessed; these were frugivores, insectivores, granivores, nectarivores and carnivores (Appendix J). Bird species were also classified into residents or migrants based on whether they occur throughout the year or they use these habitats as breeding sites.

Data Analyses

The response variables were tested for normality using Shapiro-Wilk test. The response variables used in the final modelling are overall species density, species diversity, species richness, abundance and species evenness. All statistical analyses were performed in R (R Development Core Team, 2013). Species accumulation curve was constructed to help estimate total species diversity or species pools from counted numbers of samples or isolates as result of habitat loss and fragmentation. It also helps to record the cumulative number of species found in a particular study area as a function of the cumulative effort expended in searching for them. For instance, the species effort curve has been used elsewhere to extrapolate species richness (Llorente, 1993). Mean plots have been presented to determine if the mean varies between different groups of the data or to find out if there are any shift in the location of species. Similarly, scatter plots were presented in this work to show how much one variable is affected by another. These plots also suggest various kinds of parametric correlation between variables with a certain confidence interval.

Bird species density estimate was performed in DISTANCE 6.2 software. The diversity, richness and abundance of bird species were estimated using the Vegan Package in R statistical software (Oksanen *et al*., 2015). Bird species evenness was estimated by dividing species diversity with natural logarithm of species richness [H/In(S)], where S=species richness, H=species diversity, and In=natural logarithm (Mulder *et al*., 2004)

A general linear model was performed to test for the influence of all combinations of explanatory variables on each of the response variables. Model averaging of all possible combinations of the explanatory variables was performed for each response variable. This provides means for ranking the importance of all explanatory variables known to have influenced the model in some way (Burnham & Anderson, 2003). Models were compared and ranked according to Akaike's information criteria (AIC's) and Akaike's weights (Burnham & Anderson, 2003).

The model with low AIC and high Akaike's weight indicated the best model. All explanatory variables were standardized to have a mean of zero and standard deviation of 1. A test for collinearity was conducted among the local-scale explanatory variables using Pearson's correlation coefficient. Pairs of explanatory variables with high correlation can be considered as proxies of one another (Zuur *et al*., 2010). For pairs of explanatory variables that had coefficients of correlation > 0.5, the explanatory variable with least influence on any response variable was removed from the final analyses (Appendix I).

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In this study, the explanatory variables that had relevant ecological importance on bird species density were; patch size, season, tree density, fruiting and flowering trees. With species diversity, patch size, tree density, fruiting trees and flowering trees being the best predictors. These four explanatory variables also had an important positive influence on the functional groups of species.

Mostly, four highest ranking explanatory variables were obtained from summed Akaike's weights which best predict species density and diversity. Vegetation variables explained more variation in both independent variables than disturbance index. The explanatory variables were entered into the model in a stepwise manner based on the ecological importance to the study.

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CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter highlights the results of the data in line with the objectives of the study. It examines the effects of sacred grove size and isolation distance on bird species density and diversity. It also examines the effects of sacred grove size and isolation on bird's feeding guilds. Similarly, the chapter discusses the major findings of the study in line with the objectives and in relation to relevant literature that were reviewed.

A total of 2908 individual birds of 110 species, 69 genera, 35 families and 21 orders were recorded from all the sites. Of all the 30 patches, the highest percentage of individuals sighting was in Duasidan sacred grove, comprising of 7.3% (Mean = 0.07, ±1.25 SD) of the total number of individuals, followed by Jachie sacred grove 5.5% (0.048, ±1.569) and Boabeng Fiema sacred grove 4.7% (0.047, ± 1.58). Penkoase sacred groves recorded the least number of species 2.3% (0.012, ± 0.571). The highest number of species recorded in terms of habitat prefrence was forest visitor birds (46) e.g. *Tockus fasciatus, Turtur afer, Streptopelia semitorquata*. Thirty eight (38) forest generalists were recorded e.g. *Hylia prasina, Thescelocichla leocopleura, Poicephalus senegalensis.* The least number of occurence of habitat preference birds was forest specialist species, only twenty six (26) species were recorded, e.g. *Ceuthmochares aureus, Gymnoboccu calvus, Tricholaema hirsuta*. In terms of feeding guilds, 22 species of frugivores

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(e.g *Pogoniulus chrysoconus, Crinifer piscator*), 39 species of insectivores (e.g. *Chrysococcyx klass, Merops albicollis*), 22 species of granivores (e.g. *Platysteira cyanea, Ploceus cucullatus*) 10 species of carnivores (e.g. *Falco biamicus, Accipiter badia*), 10 species of nectarivores (e.g. *Cinnyris vanustus, Cynomitra verticalis*) and 7 species of omnivores (e.g *Corvus albus, Pycnonotus barbatus*) were recorded. With foraging behaviour in birds, 20 species of fruit gleaners (e.g *Lybius dubius*), 28 species of leaf gleaners (e.g. *Cameroptera brachyura*), 7 species of ground gleaners (e.g. *Passer griseus*), 38 species of insect sallyers (e.g. *Cuculus clamosus*), 10 species of bird hovers (e.g. *Milvus migrans*), 2 species of branch peck (e.g. *malimbus rubricollis*), 3 species of bird sallyers (e.g. *Accipiter badia*), 1 species of fruit hovers (*Phyllastrephus albigularis*) were recorded (Appendix E).

Data exploration

Species accumulation curve showed that sightings increased sharply from the first sampling, but with increase in cumulative points, the rate of addition of new species decreased. At the cumulative point of 600, species effort curve reached an asymptote, which indicates that most of the species in the areas had been adequately surveyed and recorded (Fig. 2)

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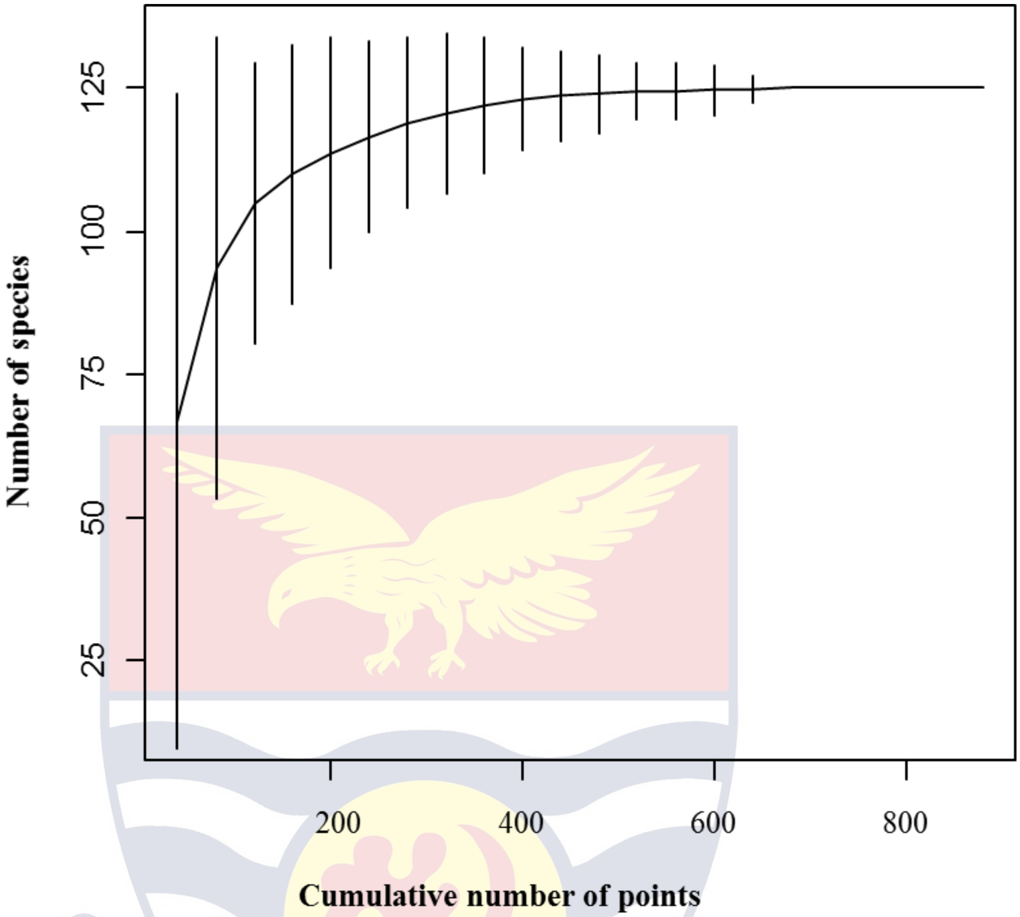

Figure 2: Species accumulation curve showing cumulative number of species observed at the sampling sites (Error bars: 95% confidence interval)

A General Linear Model showed that there was a positive significant relationship between bird species density and patch size ($F_{1,\ 58}$: 43.95, R^2 =0.44, p value = < 0.05). The adjusted R^2 value means that 44% of variations had been explained by the independent variables. There was a significant positive relationship between tree density and bird species density ($F_{1,\ 58}$: 31, R^2 =0.35, p value = < 0.05). The adjusted R^2 value of 31 showed that, 31% variability was explained by the independent variables. This means that increase in density of trees results in increase in bird species density (Fig. 4) irrespective of patch size. There was also a significant difference between the numbers of species recorded in both seasons. This indicates that during the dry season, fewer bird species were encountered as compared with the wet season which experienced higher bird sighting in the sacred groves (Fig. 5).

Increase in number of fruiting trees resulted in an increase in bird species density. This showed that there was a significant positive relationship between the density of birds and the number of fruiting trees ($F_{1, 58}$: 12.76, R^2 =0.8, p value < 0.05). R^2 value of 0.8 indicates that 8% of variation was explained by the predictors e.g. tree density (Fig.6). Tree density had a significant positive relationship with the diversity of birds. ($F_{1, 58}$:33.2, R^2 =0.37, p value < 0.05). Adjusted R^2 value of 0.37 meant that 37% of variations had been explained by the independent variables. As the density of trees increase, the diversity of bird species increase (Fig.7). There was a significant positive relationship between patch size and bird diversity ($F_{1, 58}$: 18.93, R^2 =0.23, p value < 0.05).The adjusted R^2 value showed that 23% of variability was explained by the independent variables. As the size of the patch increased, the diversity of bird species increased (Fig.8). A general linear model showed that there was a significant positive relationship between the density of trees and the density of forest specialists ($F_{1, 58}$: 31.92, R^2 = 0.35 p value < 0.05). An adjusted R^2 of 0.35 meant that 35% of variation has been explained by the explanatory variables. This indicates that as the density of trees increase, the density of forest specialists also increased (Fig. 9).

A significant negative relationship existed between tree density and the density of forest generalists. It means that as the density of trees increases, the density of forest generalists decreases ($F_{1, 58}$: 22.9, $R^2 = 0.28$, p value < 0.05). The adjusted R^2 of 0.28 meant that 28% of variation had been explained by the independent variables. (Fig.10). There was a significant negative relationship between tree density and the density of forest visitors ($F_{1, 58}$: 91.47, $R^2 = 0.61$, p value < 0.05). The adjusted R^2 value of 0.61 showed that a relatively large amount (61%) of variation had been explained. It means that as the density of trees increased, the density of forest visitors decreased (Fig. 11). A general linear model indicated that there was a significant positive relationship between the density of trees and the diversity of forest specialists ($F_{1, 58}$: 42.16, $R^2 = 0.42$ p value < 0.05). A 42% variation was explained by the independent variables. This indicated that as the density of trees increased, the diversity of forest specialist also increased (Fig. 12). There was a significant positive relationship between the fruiting trees and the diversity of forest specialists. This means that as the number of fruiting trees increased, the diversity of forest specialists also increased ($F_{1, 58}$: 6.23, $R^2 = 0.1$, p value < 0.05).

The small adjusted R^2 value of 0.10 showed that very small amount (10%) of variation was explained by the independent variables (Fig. 13). A significant negative relationship was shown between the density of trees and the diversity of forest generalists ($F_{1, 58}$: 12.91, $R^2 = 0.17$, p value < 0.05). An adjusted R^2 value of 0.17 is an indication that 17% of variability had been explained by the predictors. This also means that as the density of trees increase, the diversity of forest generalists decrease (Fig.14). Figure 15 shows that a significant negative relationship existed between tree density and the diversity of forest visitors ($F_{1, 58}$:

42.37, $R^2 = 0.42$, p value < 0.05). An adjusted R^2 of 0.42 meant that 42% of variation was explained by the independent variables. It indicates that as the density of trees increases, the diversity of forest visitors decreases.

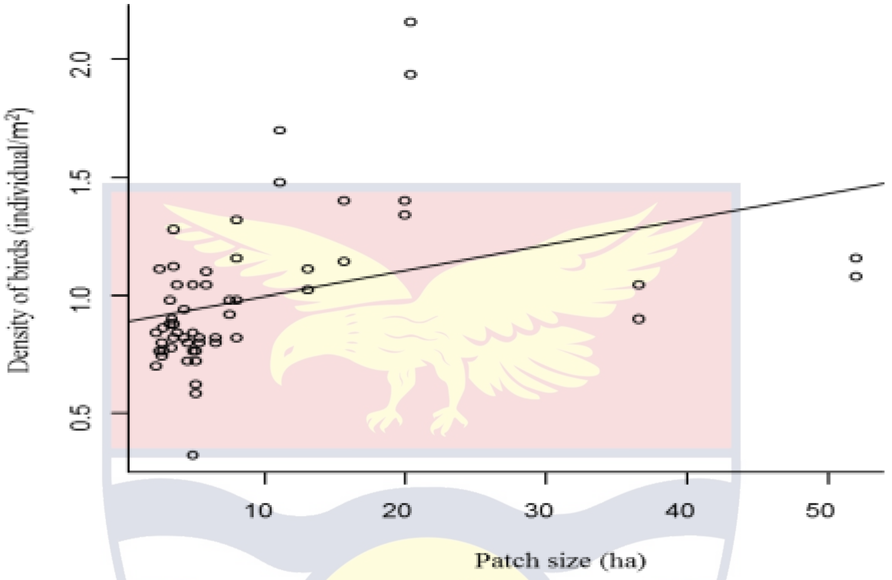

Figure 3: The relationship between patch size and density of birds

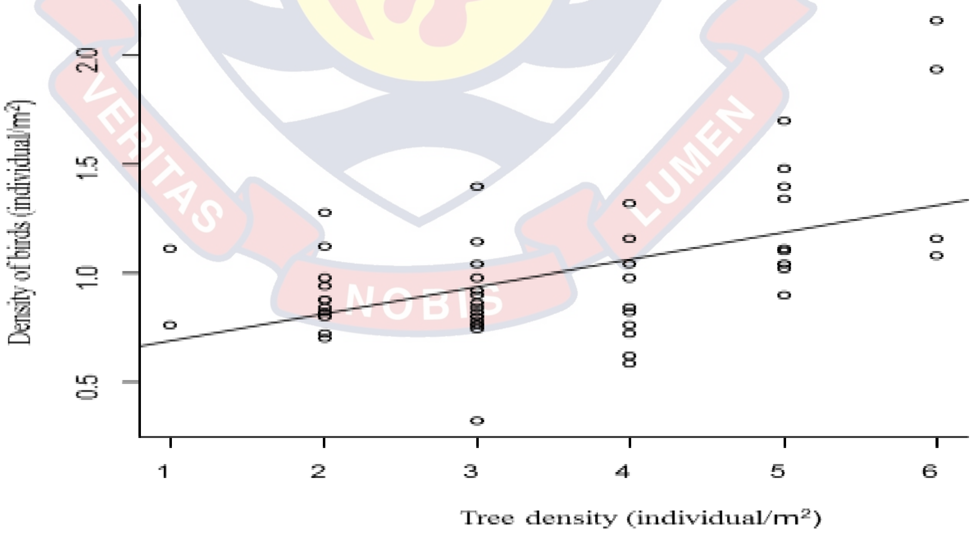

Figure 4: **The relationship between bird species density and the density of trees**

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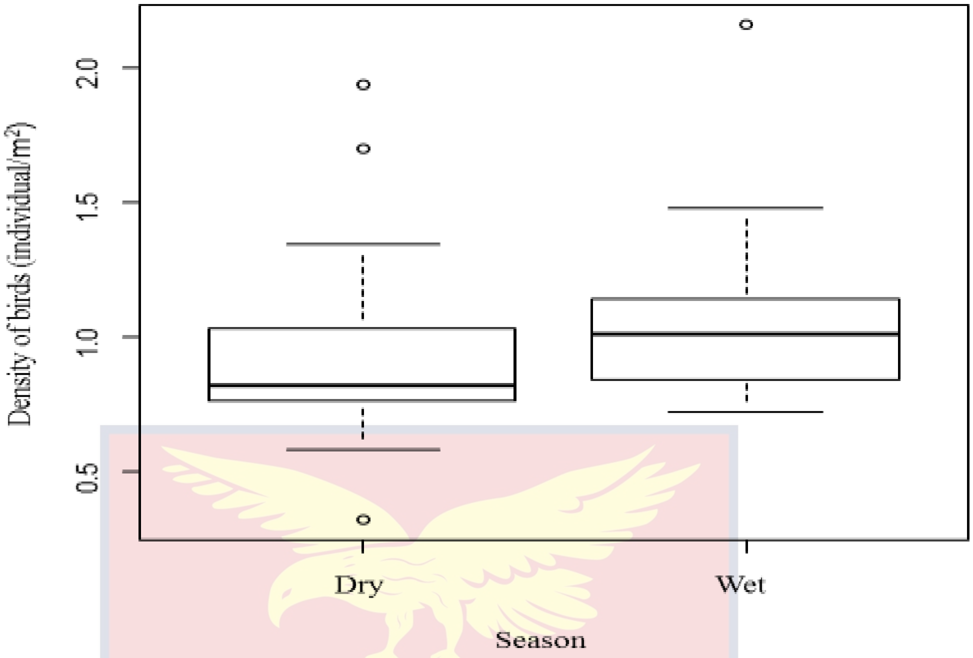

Figure 5: **The relationship between bird species density and seasonal variation**

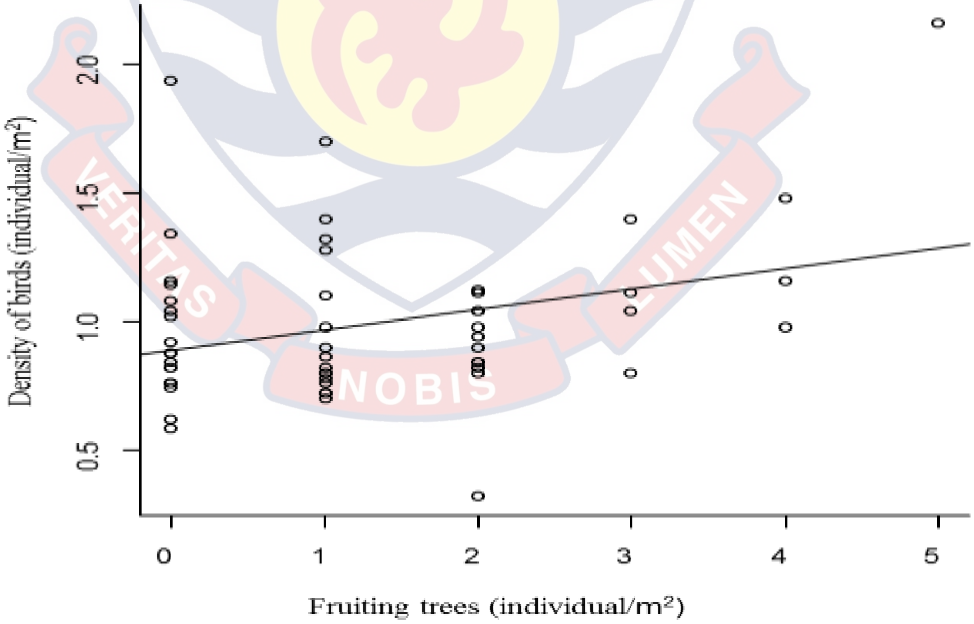

Figure 6: **The relationship between bird species density and the number of fruiting trees**

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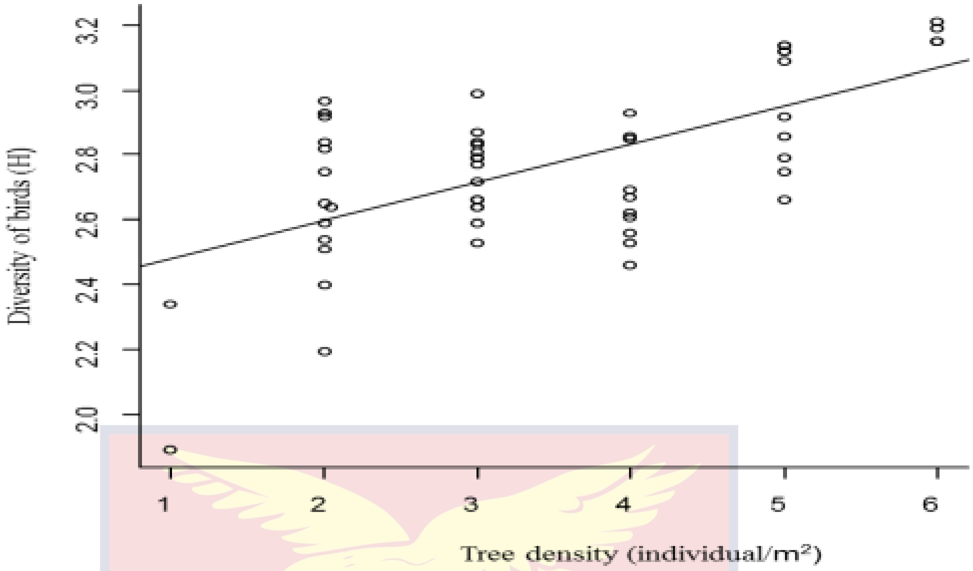

Figure 7: The relationship between bird species diversity and the density of trees

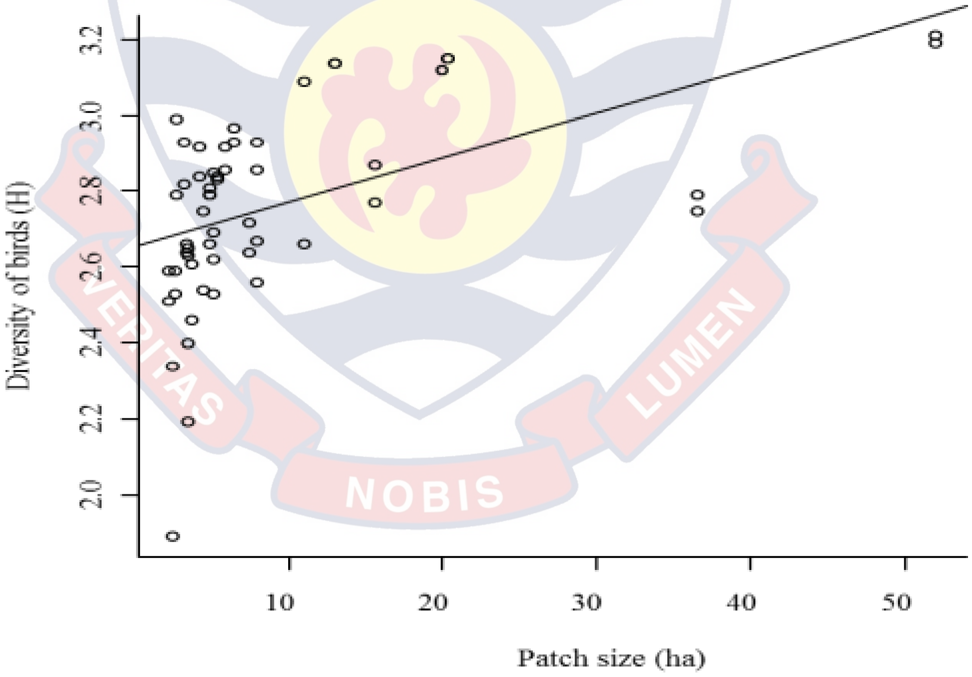

Figure 8: **The relationship between bird species diversity and patch size**

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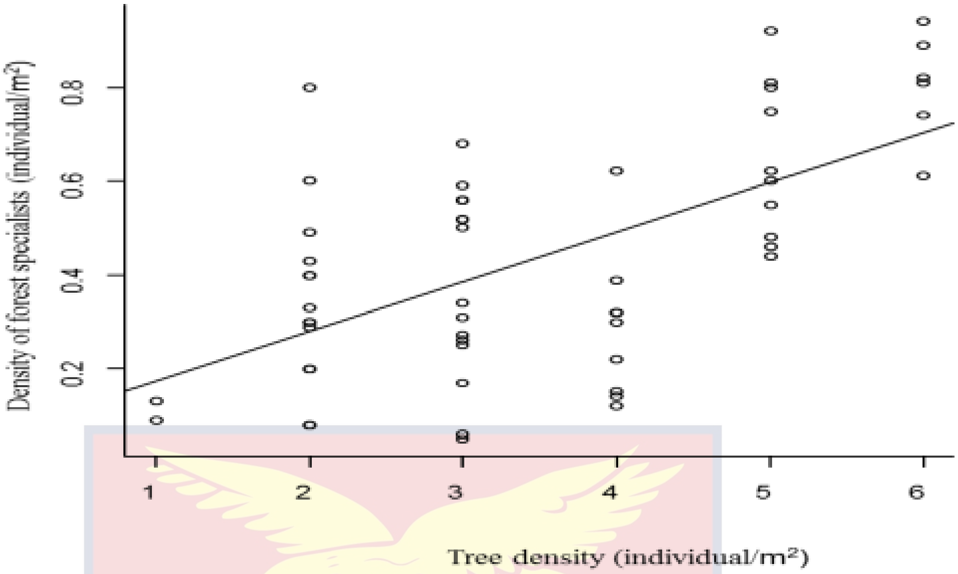

Figure 9: The relationship between tree density and the density of forest specialists

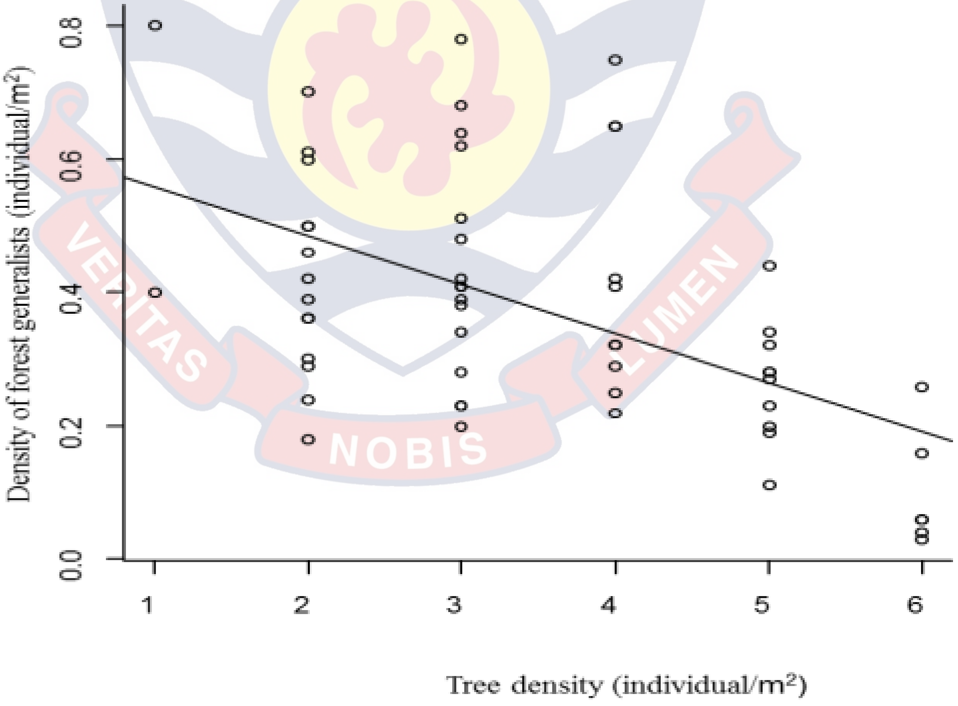

Figure 10: **The relationship between tree density and the density of forest generalists**

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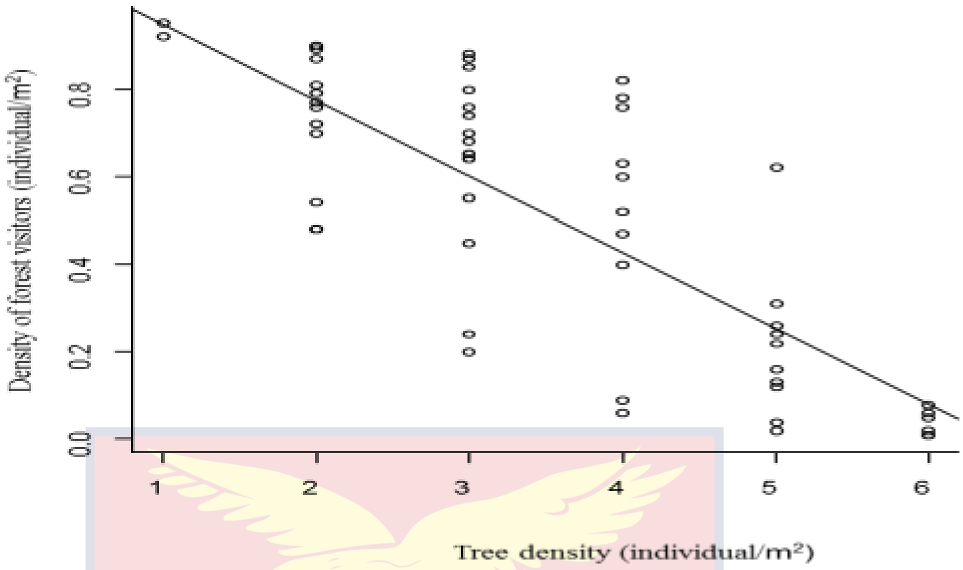

Figure 11: **The relationship between tree density and the density of forest visitors**

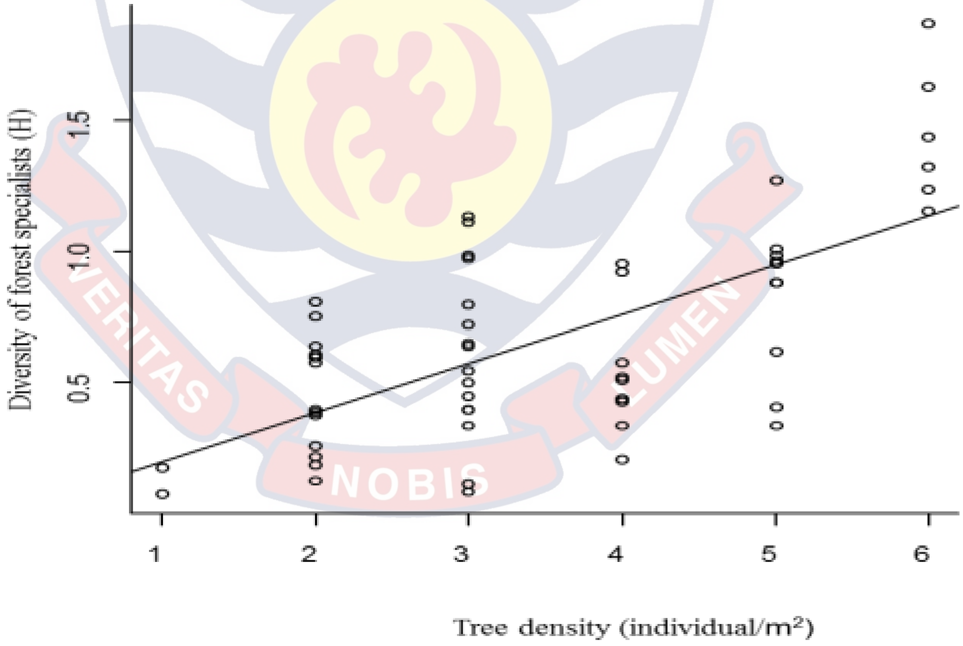

Figure 12: **The relationship between tree density and the diversity of forest specialists**

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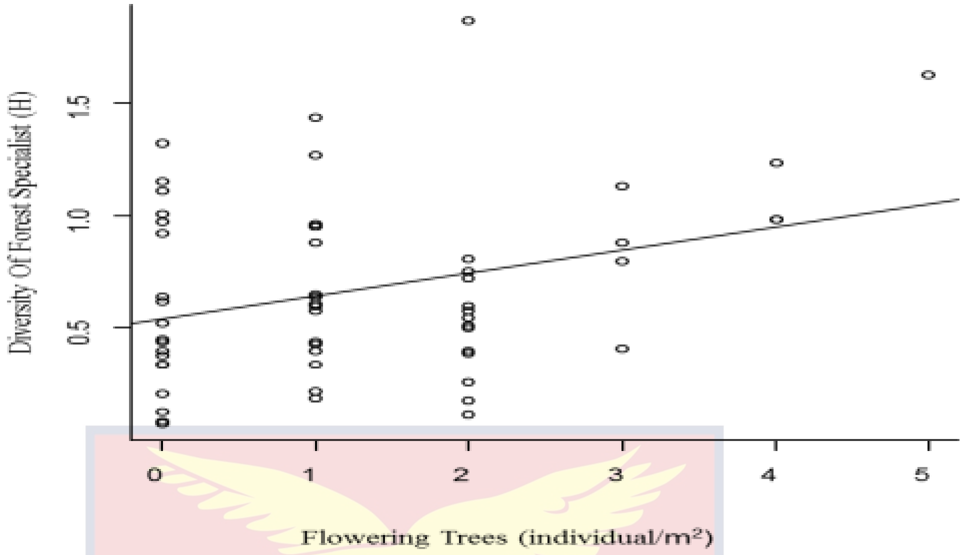

Figure 13: ***The relationship between the diversity of forest specialists and flowering trees***

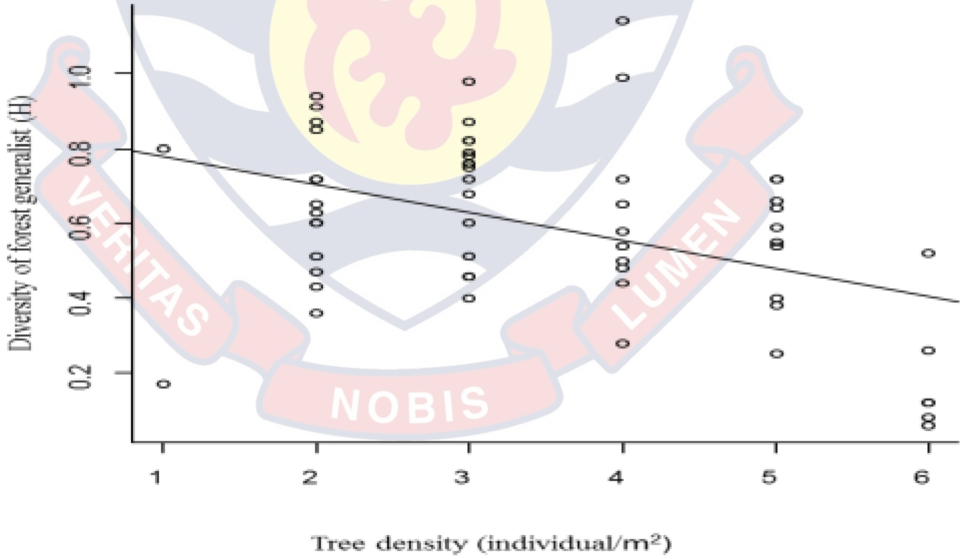

Figure 14: **The relationship between tree density and the diversity of forest generalists**

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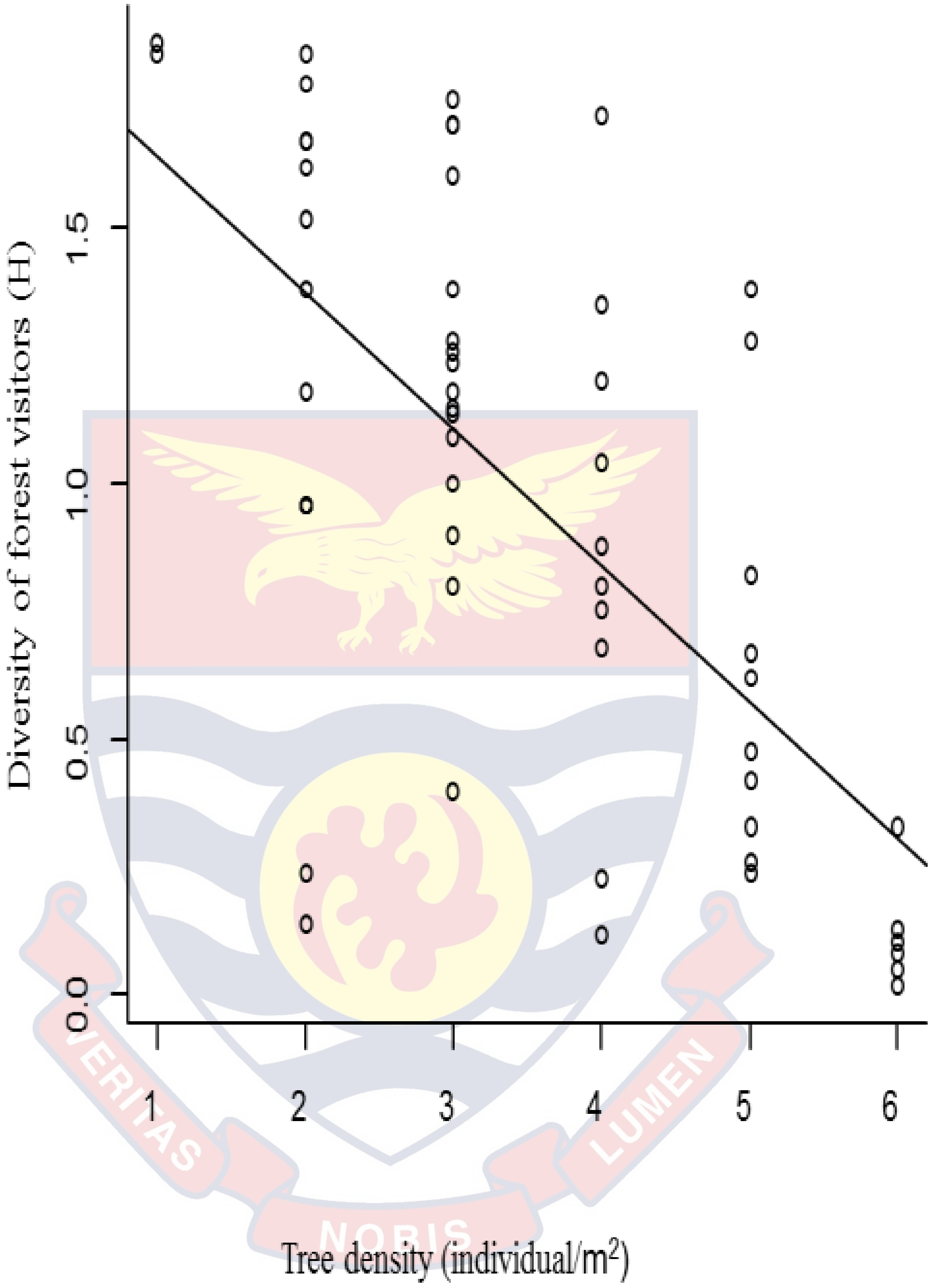

Figure 15: **The relationship between tree density and the diversity of forest visitors**

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The mean density of birds was higher in larger patches (1.5), but low in medium and small patches. Mean density of medium patches was slightly higher than that of smaller patches (0.9 and 0.85 respectively). Also larger patches were shown to have higher diversity of birds (3.05), followed by medium patches (2.8). Small patches had the least diversity of birds (2.5). Bird abundance was very high in larger patches (65), medium patches had the mean abundance of 44, and bird abundance was low in small patches (41). Evenness in bird species was higher in medium patches (0.925), this was followed by larger patches which had an evenness of (0.92), and the evenness in smaller patches was low (0.90). With, bird species richness, larger patches had the highest richness (27.8), medium patches had richness of (21.5), but the least richness was shown in small patches (Fig 16).

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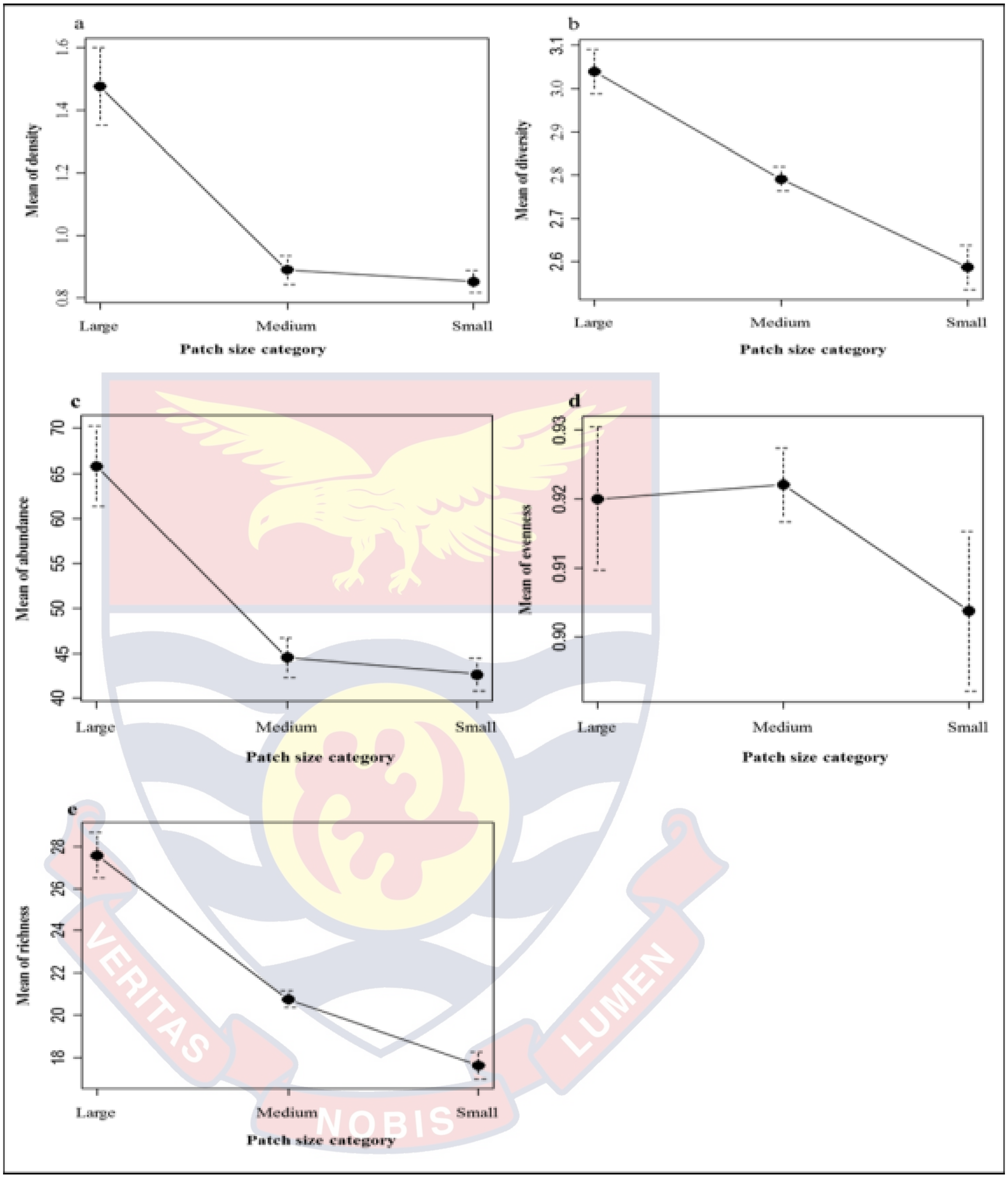

VERITAS NOBIS LUMEN

***Figure 16*: Variation in sacred grove size categories in relation to [a) density (b) diversity (c) abundance (d) evenness (e) richness of birds]**

Mean of density of species recorded in the dry season was lower (0.96 meters) than the species recorded in the wet season (1.10 meters). In the dry season,

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diversity of birds was lower (2.72 meters) but that of the wet season was quite high (2.82 meters). Relatively, species abundance in the wet season was high (53 meters) but the abundance of species in the dry season was low (46 meters). With bird species richness, high number (22 meters) was recorded in the wet season whereas dry season had low number of species richness (20.2 meters). However, the mean of evenness of species was high (0.92 meters) in the dry season and was relatively low (0.91 meters) in the wet season (Fig.17).

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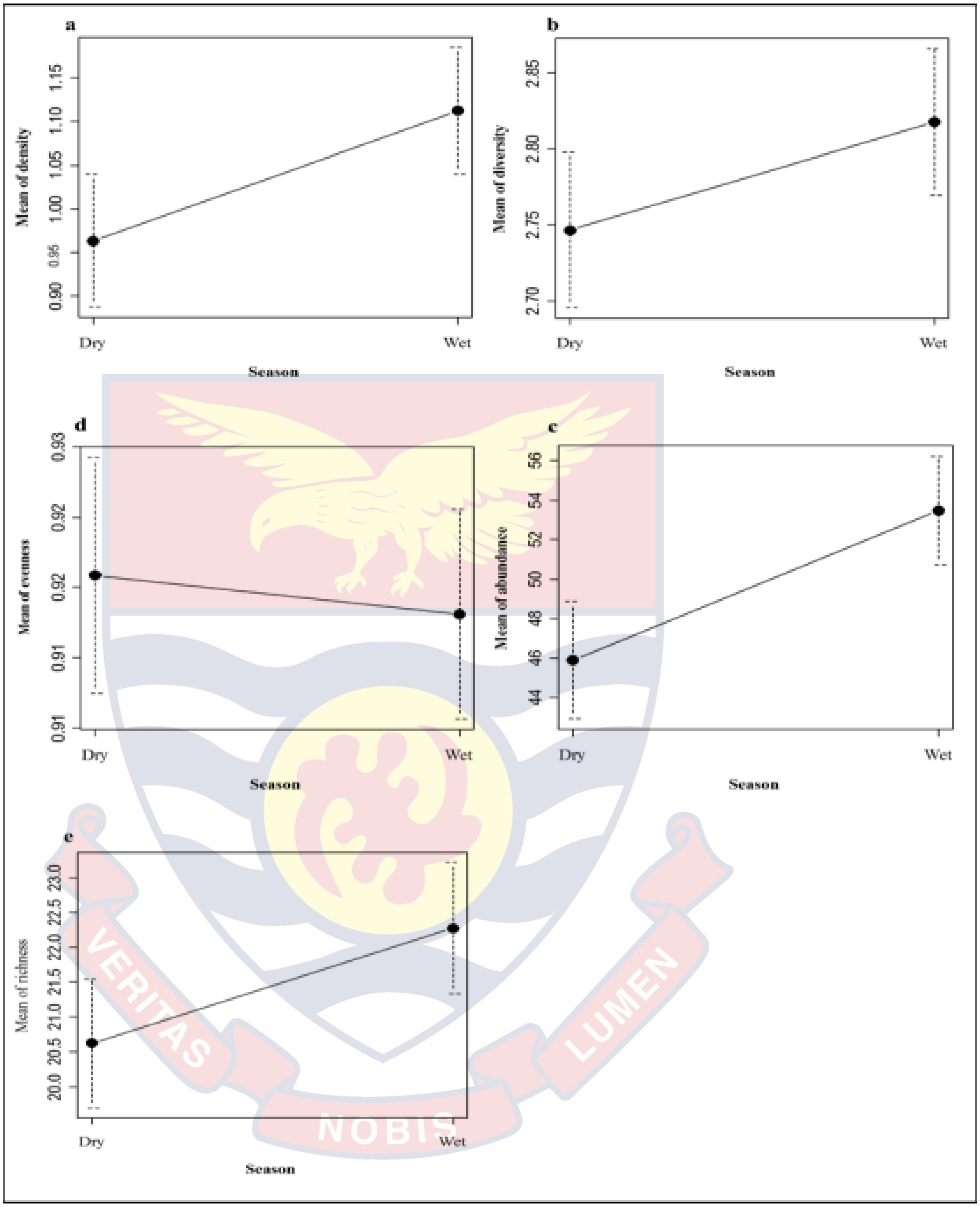

Figure 17: **Comparison of species assemblage information in relation to [a) density (b) diversity (c) abundance (d) evenness (e) richness of birds (Error bar 95% CI)] between seasons.**

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The mean density of forest specialist species in the wet season was higher (0.50) as compared to the mean density of forest specialist species which is low (0.35). For forest generalist species, the mean density was high (0.45) in the wet season but it was low (0.30) in the dry season. The mean density of forest visitors was low in the dry season (0.48) whereas in the wet season, it was quite high (0.54). The diversity of forest specialist was low (0.60) during the dry season, but it increased during the wet season (0.73). For forest generalist species, the diversity was high in the wet season (0.65), but in the dry season, the diversity reduced (0.55). Moreover, with forest visitors, the diversity was low (0.90) during the dry season, but in the wet season, it increased slightly (1.03) (Fig. 18).

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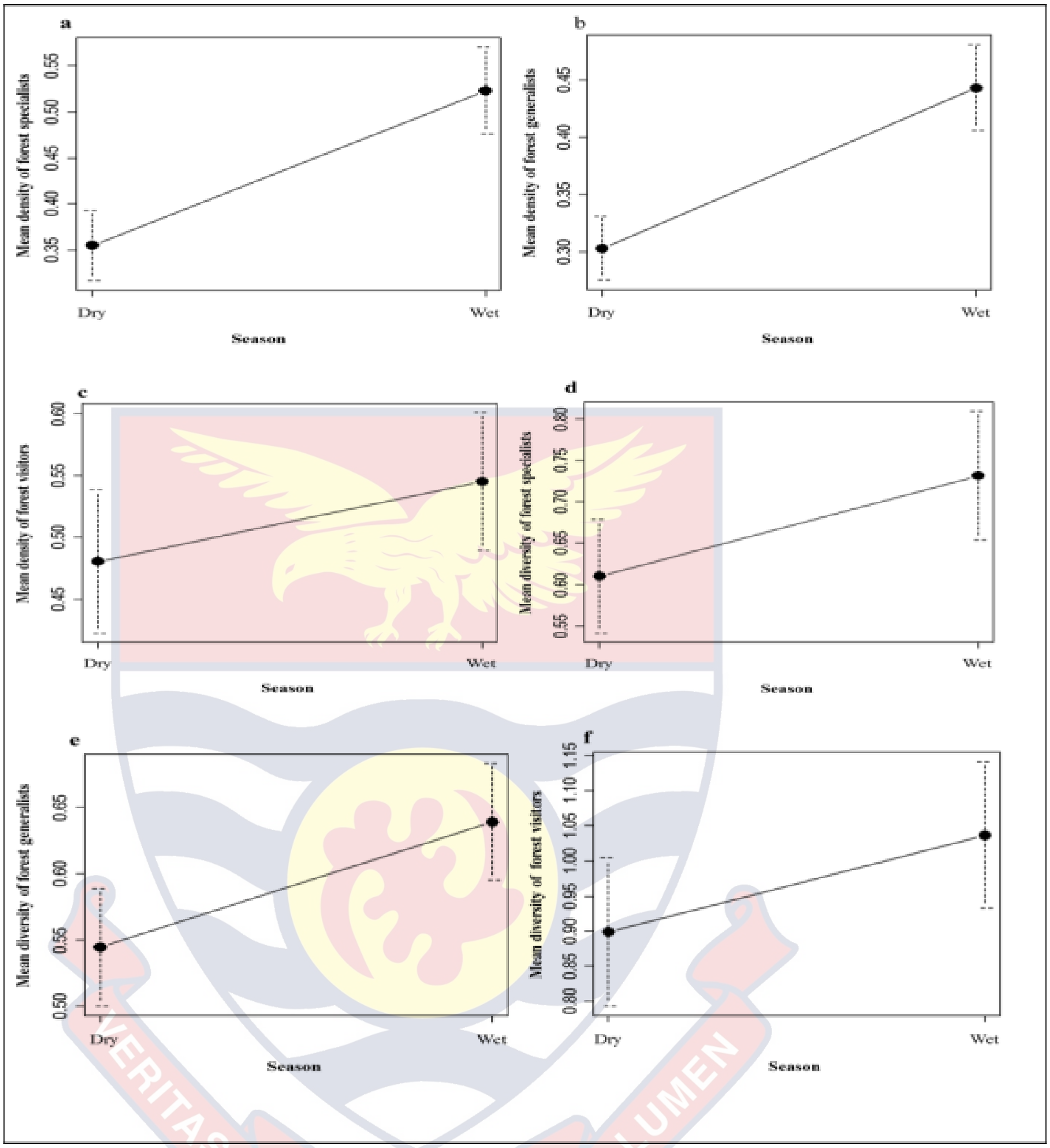
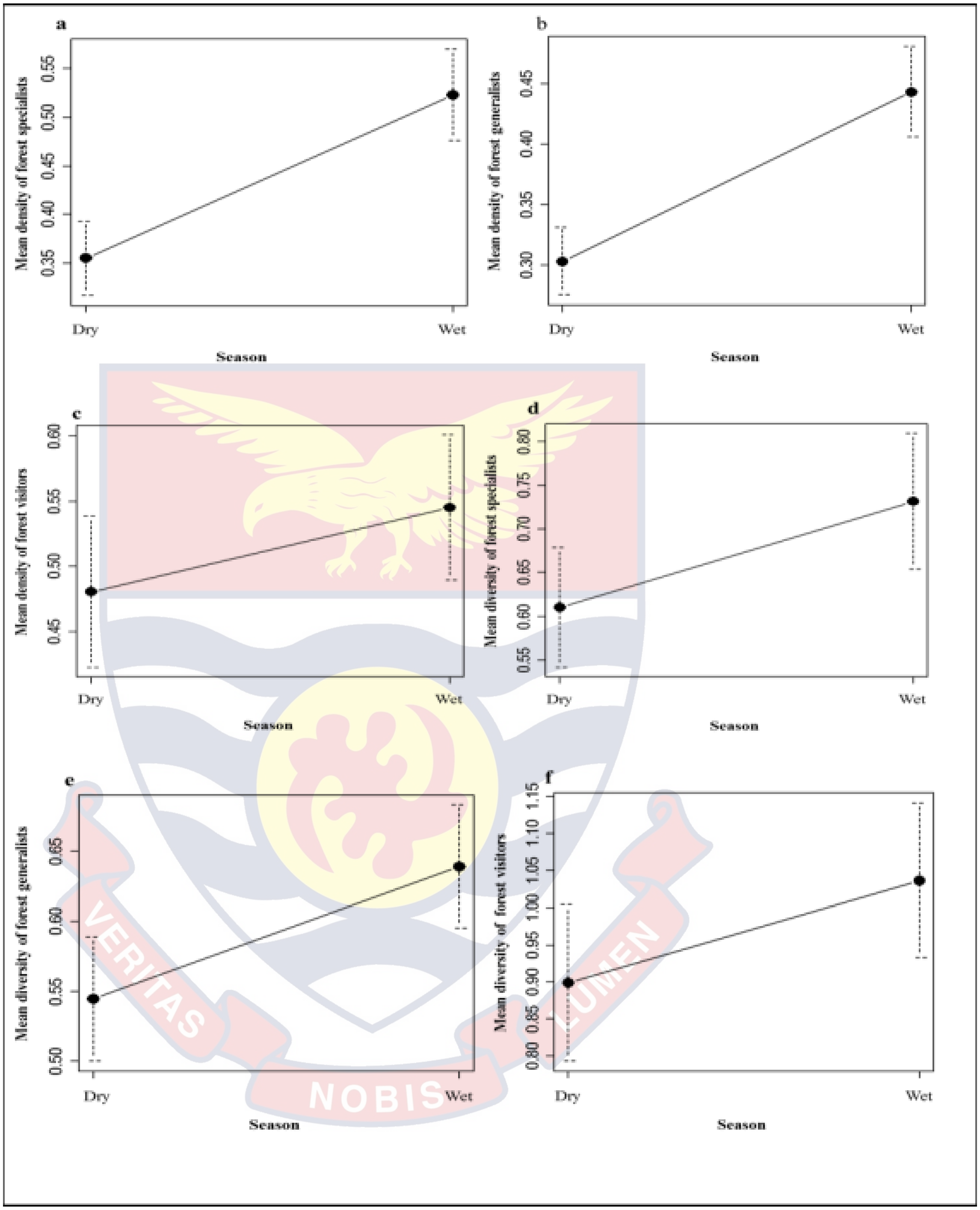

a
Mean density of forest specialists
0.35
0.40
0.45
0.50
0.55
Dry
Wet
Season
b
Mean density of forest generalists
0.30
0.35
0.40
0.45
Dry
Wet
Season
c
Mean density of forest visitors
0.45
0.50
0.55
0.60
Dry
Wet
Season
d
Mean diversity of forest specialists
0.55
0.60
0.65
0.70
0.75
0.80
Dry
Wet
Season
e
Mean diversity of forest generalists
0.50
0.55
0.60
0.65
Dry
Wet
Season
f
Mean diversity of forest visitors
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
Dry
Wet
Season



VERITAS LUMEN NOBIS

Figure 18: Comparison of species assemblages in relation to [a) density of forest specialists b) density of forest generalists c) density of forest visitors d) diversity of forest specialists e) diversity of forest generalist f) diversity of forest visitors between seasons]

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The density of forest specialists was higher in large patches (0.7), but it was relatively low in medium and small patches (0.39, and 0.3) respectively. With forest generalists, bird density was very low in large forests (0.22), however, bird density was higher in medium patches (0.44) and in smaller patches (0.42). This means that more forest generalists’ birds were detected in medium patches than in smaller patches. Smaller patches harbour more birds of forest visitors (0.75), medium patches harbour relatively low number of forest generalists’ species (0.5) and larger patches harbor very small number of forest generalists’ species (0.15).

In Figure 19d, larger patches harbour more diversity of forest specialists (1.10), medium patches also harbour small diversity of forest specialist (0.4), and small patches host very small diversity of forest specialists (0.2). The diversity of forest generalist was low in small patches (0.42). Diversity of forest generalists was higher in medium patches (0.7), it was high in medium patches (0.6) but it was very low in large patches. The diversity of forest visitors was higher in small patches (1.3), high in medium patches (0.9), but was low in large patches (0.5) (Fig. 19).

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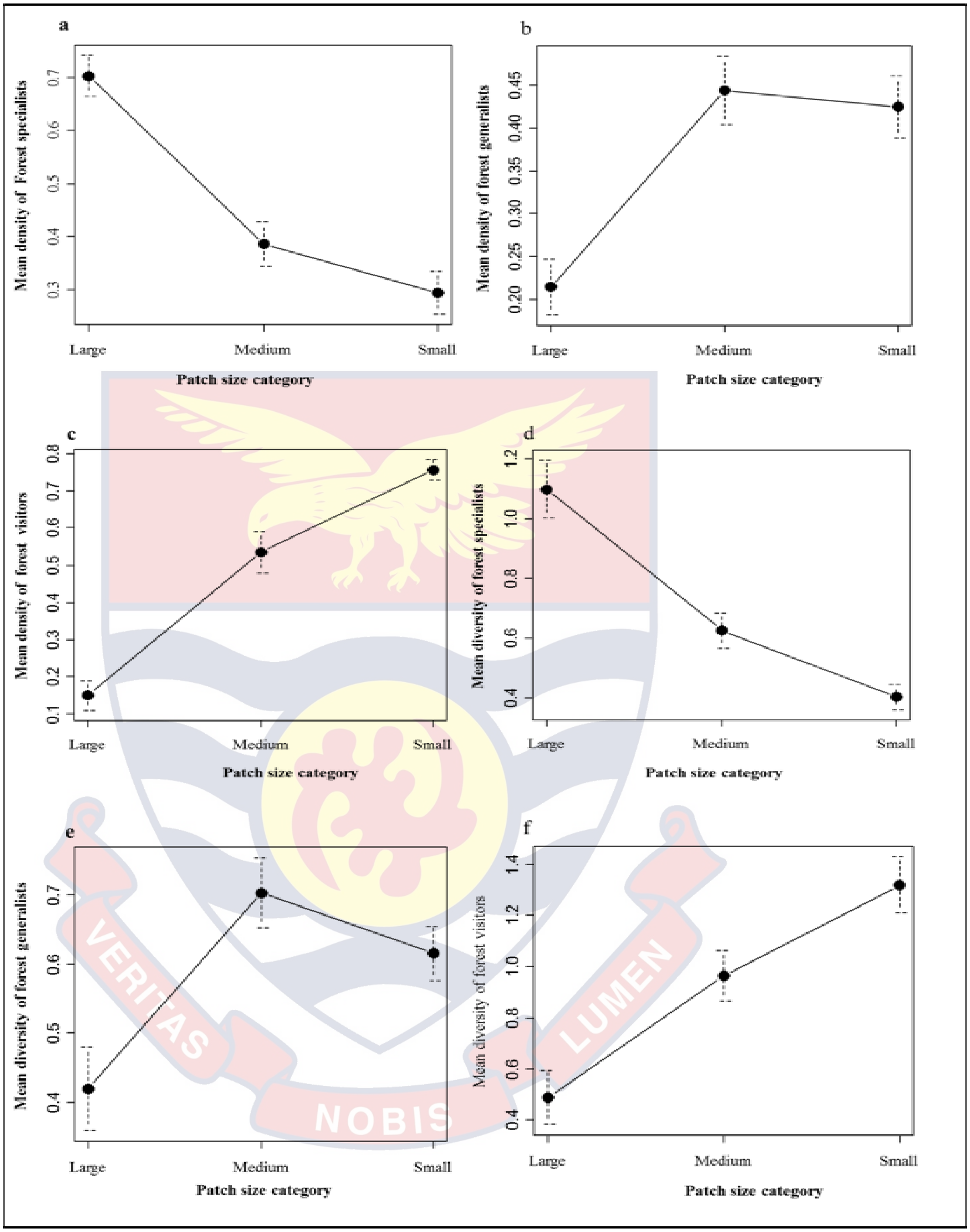

VERITAS LUMEN NOBIS

***Figure 19*: Comparison of species assemblage information with sacred groove size in relation to [a) density of forest specialists b) density of forest generalist c) density of forest visitors d) diversity of forest specialist e) diversity of forest generalist f) diversity of forest visitor]**

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The mean of frugivores was higher in larger patches (1.0), but it was relatively low in medium and small patches (0.75 and 0.65) respectively. Mean of granivores was higher in larger patches (1.15), and was low in both medium and small patches (0.62 and 0.45) respectively. Also larger patches harbour more insectivores (0.87), medium and small patches harbour relatively low density of insectivores (0.65 and 0.45). Nectarivores density was higher in large patches (0.90), small patches host considerably low density (0.6), but medium patches harbour the least density of nectarivores (0.55). With carnivores, larger patches has the highest density (0.22), followed by smaller patches (0.05), and the least density of carnivores was found in medium patches (0.03) (Fig. 20).

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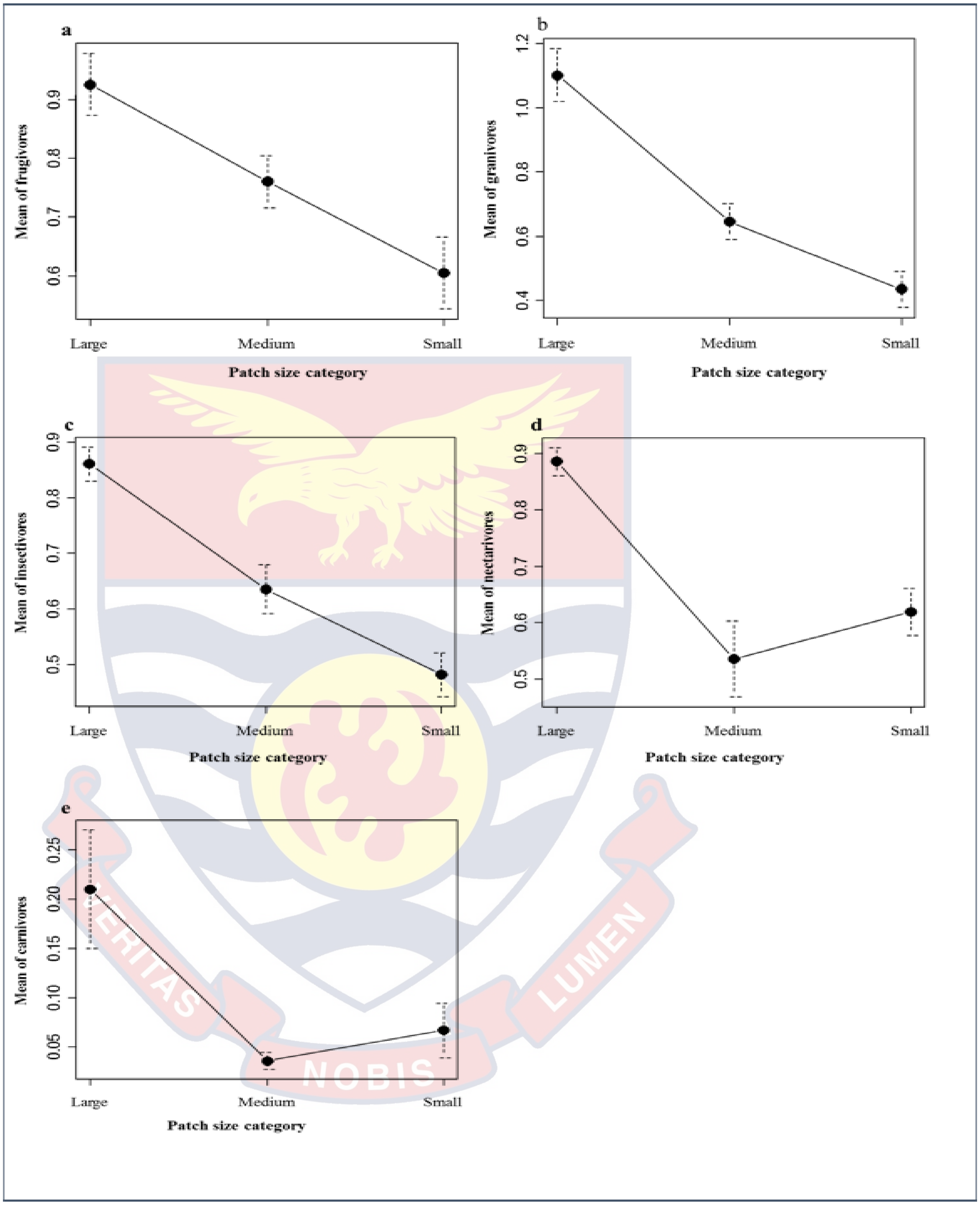

Figure 20**: The species assemblage information on size categories [a) frugivores b) granivores c) insectivores d) nectarivores e) carnivores]**

The density of frugivorous birds was high in the wet season (0.80), whereas in the dry season it was relatively low (0.70). For granivorous birds, the density was high in wet season (0.75) as compared with the low density in the dry season (0.62). Insectivorous birds' density was high in the wet season (0.70) but was low in the dry season (0.58). Nectarivores' species density was low in the dry season (0.63) whilst the density of species was high in the wet season (0.70). The density of carnivores was high in the wet season (0.12) but was low in the dry season (0.06) (Fig. 21).

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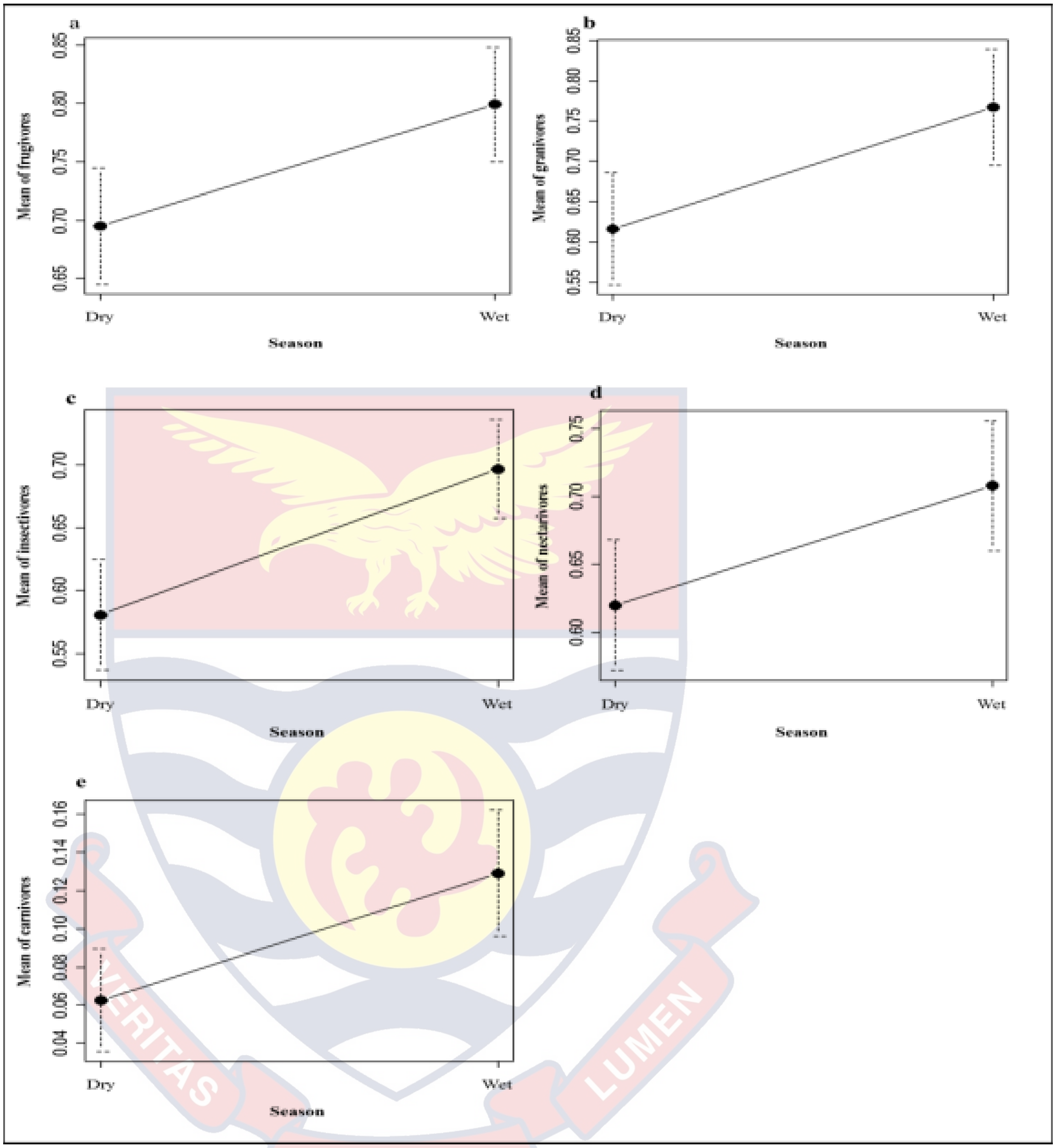

***Figure 21*: Seasonal variation in bird feeding guilds in relation to [a) frugivores b) granivores c) insectivores d) nectarivores e) carnivores]**

Mean density of ground bird gleaners was higher in large patches (29), and it was relatively low in medium and smaller patches (26 and 24) respectively. With leave gleaners, the highest mean density was found in large patches (27.5), the mean density of medium patches was 22, and small patches had mean density of 18 which was the lowest. Large patches had high density of branch gleaners (6.8), the density of branch gleaners was low in small and medium patches but that of small patches (3.0) was higher than medium patches (2.5). The density of bird sallyers was high in large patches (28), however, in medium (22) and small patches (18), the density was quite low.

Insect sallyers were found to be higher in larger patches (6.0), but it was relatively low in medium and smaller patches (3 and 2.6). In insect hoverers, medium patches had the highest density, but the density of insect hoverers in large and small patches was same (6.0). Larger patches had higher density of fruit hoverers (7.5). Small and medium patches had low density of fruit hoverers (3 and 2.7). The density of branch peck was very high in large patches, but it was low in medium and small patches (14 and 10) (Fig. 22).

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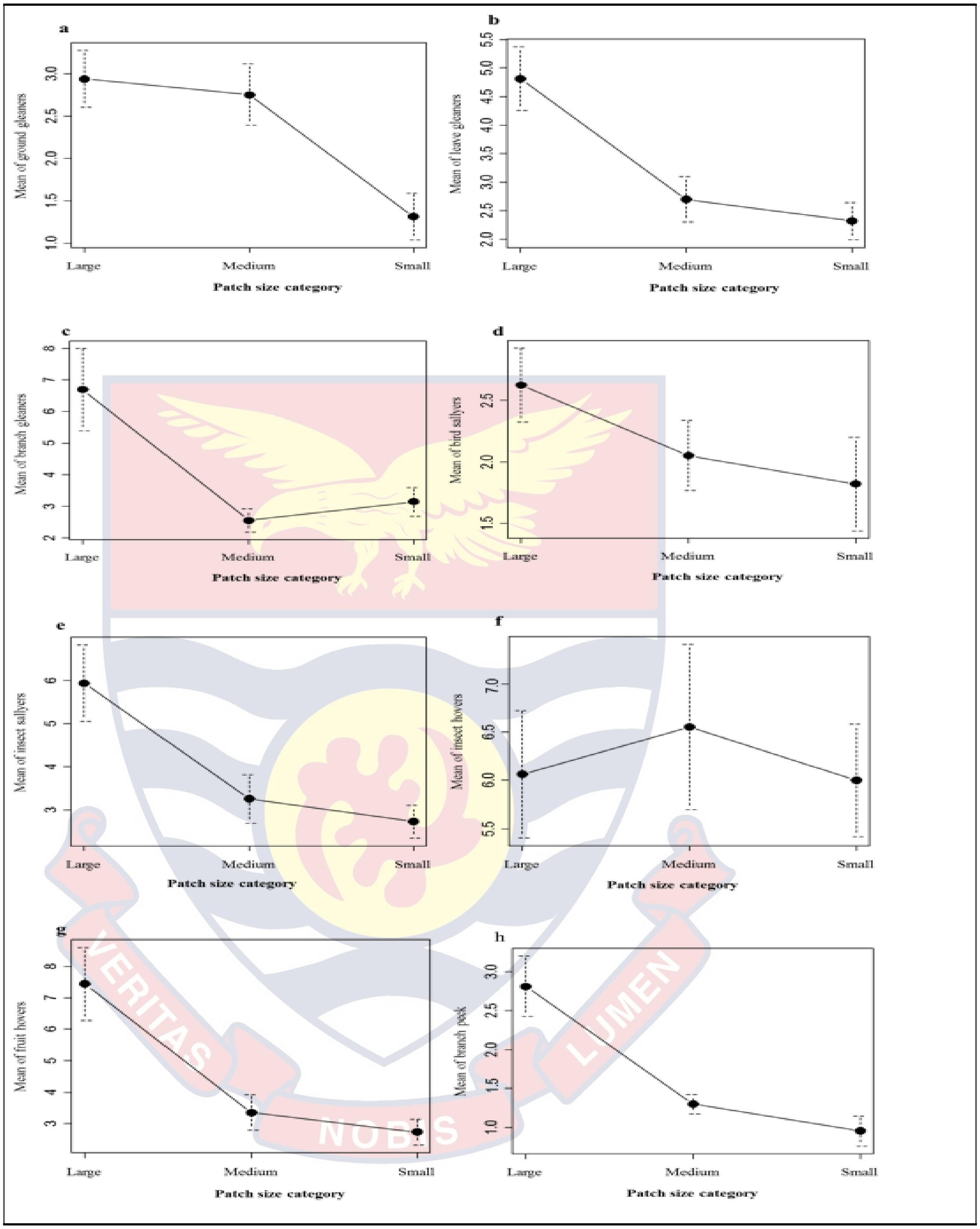

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Figure 22: **Variation in bird assemblages between size categories with [a) density of leave gleaners b) density of fruit gleaners c) density of branch gleaners d) density of bird sallyers e) density of insect sallyers f) density of insect hovers g) density of fruit hovers h) density of branch peck]**

Model Averaging

Eight predictors were used in the final modeling. These were: size, isolation distance, season, fruiting trees, flowering trees and canopy cover, human traps and chain saw activities. The results of the model – average indicated that among all the predictors, tree density was the most important influential predictor of bird attributes in all the sampled areas. This has been shown in the summed Akaike's weight (∑ωi) (Table 1). The remaining predictors do have important influence; however, some have relatively low influence whiles others have very small influence.

With density of bird species, patch size and tree density are the most influential predictors (∑ωi = 1.0 and 1.0), the next was flowering trees which has relatively small influential value (∑ωi = 0.61). Season and fruiting trees however have very small influence on bird species density (∑ωi = 0.31 and 0.33) respectively. Also with birds' diversity, tree density was shown to be the most important predictor with a summed Akaike's weight of (∑ωi =1.0). This was followed by fruiting trees and patch size which had extremely very small influence on bird species diversity (∑ωi = 0.19 and 0.17) in that respect. On bird species richness, tree density obviously is the most important predictor (∑ωi =1.0). Fruiting trees, flowering trees and patch size have relatively small influence on bird species richness ∑ωi = 0.60, 0.52 and 0.39 respectively. Bird species evenness was best predicted by tree density (∑ωi =1.0). Human traps has an important influence on bird species evenness (∑ωi =0.83). This was followed by flowering trees which has low influence on evenness (∑ωi =0.41**)**. With species abundance, the most important predictor was tree density (∑ωi =1.0). Fruiting trees and season influenced bird abundance but it was low (∑ωi = 0.32 and 0.27).

Table 2: Model average results of all the best predictors with bird assemblage measures

Response	Explanatory	Coefficients	Std.Error	UCI	LCI	P value	∑ωi
Density	Flowering trees	0.076	0.045	0.092	-0.085	0.097	0.61
	Patch size	**0.002**	**0.000**	**0.001**	**-0.001**	< **0.01**	**1**
	Tree density	**0.103**	**0.028**	**0.059**	**-0.053**	**< 0.01**	**1**
	Season	0.109	0.106	0.219	-0.196	0.311	0.31
	Fruiting trees	0.047	0.037	0.074	-0.070	0.207	0.33
Diversity	Flowering trees	0.045	0.027	0.054	-0.051	0.101	0.44
	Tree density	**0.120**	**0.021**	**0.043**	**-0.038**	**< 0.01**	**1**
	Fruiting trees	0.032	0.022	0.043	-0.042	0.149	0.19
	Patch size	0.000	0.000	0.001	-0.001	0.249	0.17
Richness	Fruiting trees	0.852	0.445	1.252	-0.493	0.061	0.6
	Tree density	**2.200**	**0.380**	**1.580**	**0.091**	**< 0.01**	**1**
	Flowering trees	0.999	0.571	1.689	-0.549	0.086	0.52
	Patch size	0.008	0.006	0.011	-0.011	0.180	0.39
Evenness	Trap	**-0.012**	**0.005**	**0.010**	**-0.011**	**0.032**	**0.83**
	Tree density	**0.010**	**0.004**	**0.007**	**-0.007**	**0.014**	**1**
	Fruiting trees	-0.004	0.004	0.008	-0.008	0.400	0.26
Abundance	Flowering trees	4.145	1.741	10.629	3.804	0.020	0.41

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Tree density	**5.375**	**1.300**	**9.536**	**4.440**	**< 0.01**	**1**
Fruiting trees	3.197	1.406	7.251	1.739	0.026	0.32
Season	7.552	3.437	32.693	19.220	0.032	0.27

Std.Error=standard error, UCI=upper confidence interval, LCI=lower confidence interval, $\sum\omega_i$=summed Akaike's weight

With the density of forest specialists, tree density, fruiting trees and flowering trees are the most important influential variables as indicated by the summed Akaike's weight (Table 2). Likewise, tree density, fruiting and flowering trees are the best predictors of forest generalists' density. Density of forest visitors was best predicted by season and tree density.

Also patch size, fruiting trees, tree density and flowering trees were shown to significantly influence the diversity of forest specialists. Isolation distance, size and tree density were the best predictors of forest generalist species. Moreover, the diversity of forest visitors were best predicted by human traps, tree density and flowering trees (Table 2).

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Table 3: Model-average results of functional groups with their important predictors

Response	Predictors	Coefficients	Std.Error	UCI	LCI	P value	∑ωi
FFdensity	Flowering trees	3.681	2.080	11.733	3.580	0.083	0.65
	Tree density	**5.192**	**1.284**	**9.183**	**4.150**	**< 0.01**	**1**
	Fruiting trees	2.651	1.763	8.129	1.218	0.140	0.56
Fdensity	Flowering trees	3.685	2.081	11.747	3.590	0.083	0.6
	Tree density	**5.238**	**1.294**	**9.314**	**4.242**	**< 0.01**	**1**
	Fruiting trees	2.651	1.763	8.129	1.218	0.140	0.51
Fdensity	Flowering trees	**-0.102**	**0.048**	**0.090**	**-0.099**	**0.038**	**0.77**
	Season	**0.218**	**0.099**	**0.216**	**-0.173**	**0.031**	**0.82**
	Tree density	**-0.159**	**0.021**	**0.037**	**-0.044**	**< 0.01**	**1**
FFdiversity	Fruiting trees	**0.070**	**0.033**	**0.067**	**-0.062**	**0.037**	**0.73**
	Size	**0.001**	**0.000**	**0.001**	**-0.001**	**0.002**	**1**
	Tree density	**0.140**	**0.029**	**0.061**	**-0.052**	**< 0.01**	**1**
	Flowering trees	0.057	0.049	0.100	-0.094	0.253	0.41
Fdiversity	Flowering trees	**0.054**	**0.027**	**0.054**	**-0.051**	**0.047**	**0.72**

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	Isodistance	**0.003**	**0.001**	**0.003**	**-0.003**	**0.046**	**0.72**
	Size	**-0.001**	**0.000**	**0.001**	**-0.001**	**0.014**	**1**
	Tree density	**-0.062**	**0.022**	**0.042**	**-0.044**	**0.006**	**1**
Fdiversity	Trap	**0.119**	**0.057**	**0.119**	**-0.105**	**0.042**	**0.71**
	Tree density	**-0.260**	**0.041**	**0.069**	**-0.091**	**< 0.01**	**1**
	Flowering trees	0.006	0.057	0.112	-0.111	0.919	0.23

FFdensity= density of forest specialists, Fdensity=density of forest generalists, fdensity=density of forest visitors, Fdiversity=diversity of forest specialists, Fdiversity=diversity of forest generalists, fdiversity=diversity of forest visitors.

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Feeding Guilds

Frugivores density was best predicted by canopy cover and tree density (Table 3). Although, isolation distance and fruiting trees influence frugivores density; their impact was relatively smaller. With the density of granivores, tree density is the most important predictor, followed by fruiting trees and patch size. Insectivores' density was greatly influenced by fruiting trees and tree density, and this was followed by patch size and isolation in that order. On the density of nectarivores, tree density was the best predictor, followed by fruiting trees and size. Carnivores' density was influenced greatly by tree density, also isolation distance and patch size influence the density of carnivores but the impact is low.

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Table 4: The results of the feeding guilds in birds with their best predictors

Response	Predictors	Coefficients	Std.Error	UCI	LCI	P value	$\sum\omega_i$
Frugivore	Canopy cover	**0.010**	**0.003**	**0.007**	**-0.007**	**0.004**	**1**
	Fruiting trees	**0.058**	**0.026**	**0.052**	**-0.049**	**0.029**	**0.79**
	Isodistance	-0.003	0.002	0.003	-0.003	0.095	0.58
	Tree density	**0.077**	**0.027**	**0.055**	**-0.051**	**0.006**	**1**
Granivore	Fruiting trees	**0.078**	**0.028**	**0.057**	**-0.053**	**0.007**	**0.94**
	Tree density	**0.179**	**0.027**	**0.059**	**-0.049**	< **0.01**	**1**
	Size	0.001	0.000	0.001	-0.001	0.163	0.47
Insectivore	Fruiting trees	**0.039**	**0.018**	**0.037**	**-0.035**	**0.041**	**1**
	Size	0.000	0.000	0.001	-0.001	0.128	0.52
	Tree density	**0.096**	**0.018**	**0.038**	**-0.034**	< **0.01**	**1**
	Isodistance	-0.002	0.001	0.002	-0.002	0.212	0.41
Nectarivore	Fruiting trees	0.036	0.023	0.047	-0.045	0.132	0.52
	Tree density	**0.095**	**0.022**	**0.045**	**-0.041**	< **0.01**	**1**
	Size	0.000	0.000	0.001	-0.001	0.341	0.34

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Carnivore	Isodistance	0.002	0.001	0.002	-0.002	0.119	0.54
	Season	0.067	0.040	0.081	-0.075	0.102	0.57
	Tree density	**0.042**	**0.015**	**0.029**	**-0.028**	**0.005**	1

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With the density of ground gleaners, tree density was the most influential predictor (∑ωi = 0.83), the next was canopy cover which has relatively small influential value (∑ωi = 0.63), the least predictor was intensity of fuelwood collection (∑ωi = 0.60). Also with the density of leave gleaners, tree density and patch size were the most important predictors with summed Akaike's weight of (∑ωi =1.0 and 1.0). The next was isolation distance with a summed Akaike's weight of (0.85). Fruiting and flowering trees had relatively low predictive value ∑ωi = 0.56 and 0.68 respectively. On the density of branch gleaners, tree density and fruiting trees had the highest predictive value (∑ωi =1.0 and 1.0). Patch size and intensity of fuelwood collection had low predictive value (∑ωi = 0.64 and 0.55). Fruiting trees and trap occurrence were the important predictors of the density of bird sallyers (∑ωi = 1.0 and 1.0). Tree density, patch size, canopy cover and flowering trees were the most important predictors of the density of insect sallyers (all had ∑ωi= 1.0). With the density of insect hoverers, the important predictors were; flowering (∑ωi = 0.22), canopy cover (∑ωi = 0.21), isolation distance (∑ωi = 0.27) and tree density (∑ωi = 0.16). Patch size and canopy cover were the most important predictors of fruit hovers (∑ωi = 1.0 and 1.0), the next important predictor was tree density and isolation distance (∑ωi = 0.5 and 0.23). Tree density and patch size were the most influential predictors of the density of branch peck (∑ωi = 1.0 and 1.0), the least predictor of the density of branch peck was the number of fruiting trees (0.27) (Table 4).

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Table 5: A model-average results of feeding behaviours in birds and their best predictors

Response	Explanatory	Coefficients	Std. Error	UCI	LCI	P value	∑ωᵢ
Ground gleaners	Fuel wood collection	0.357	0.183	0.423	-0.293	0.056	0.6
	tree density	**0.358**	**0.171**	**0.396**	**-0.274**	**0.040**	**0.83**
	canopy cover	-0.039	0.023	0.044	-0.046	0.093	0.63
Leave gleaners	canopy cover	**0.059**	**0.021**	**0.043**	**-0.040**	**0.007**	**1**
	fruiting trees	0.433	0.213	0.510	-0.325	0.046	0.56
	isolation distance	**-0.021**	**0.011**	**0.021**	**-0.021**	**0.054**	**0.85**
	Size	**0.005**	**0.002**	**0.005**	**-0.005**	**0.046**	**1**
	tree density	**0.855**	**0.186**	**0.523**	**-0.205**	**0.000**	**1**
	flowering trees	0.554	0.263	0.661	-0.370	0.038	0.68
Branch gleaners	fwd collection	-0.562	0.341	0.477	-0.861	0.108	0.55
	fruiting trees	**0.913**	**0.317**	**0.910**	**-0.331**	**0.005**	**1**
	Size	-0.009	0.005	0.009	-0.009	0.069	0.64
	tree density	**1.284**	**0.318**	**1.032**	**-0.215**	**0.000**	**1**

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Table 5 Continued

Bird sallyers	fruiting trees	**0.646**	**0.135**	**0.352**	**-0.177**	**0.000**	**1**
	Trap	**0.384**	**0.177**	**0.415**	**-0.279**	**0.034**	**1**
Insect sallyers	flowering trees	**-1.263**	**0.295**	**0.205**	**-0.950**	**0.000**	**1**
	Size	**0.009**	**0.004**	**0.007**	**-0.007**	**0.011**	**1**
	tree density	**0.967**	**0.242**	**0.709**	**-0.240**	**0.000**	**1**
	Cancov	**0.020**	**0.030**	**0.059**	**-0.058**	**0.516**	**1**
Insect hovers	flowering trees	**1.016**	**0.383**	**1.138**	**-0.361**	**0.009**	**1**
	Cancov	-0.033	0.034	0.066	-0.068	0.336	0.22
	tree density	0.274	0.287	0.641	-0.483	0.349	0.21
	isodistance	-0.012	0.021	0.041	-0.041	0.569	0.16
Fruit hovers	Size	0.008	0.005	0.010	-0.010	0.125	0.27
	tree density	**1.350**	**0.347**	**1.148**	**-0.212**	**0.000**	1
	isodistance	-0.042	0.023	0.043	-0.045	0.070	0.5
	Cancov	0.061	0.042	0.085	-0.080	0.155	0.23
Branch peck	Size	**0.005**	**0.001**	**0.003**	**-0.003**	**0.001**	**1**

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Table 5 Continued

tree density	**0.448**	**0.098**	**0.237**	**-0.149**	**0.000**	**1**
fruiting trees	-0.138	0.099	0.181	-0.209	0.176	0.27

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Sacred groves of varying sizes (number of small SG’s =11, number of medium SG’s =10 and number of large SG’s = 9) and their associated vegetation covariates significantly influenced tropical bird species assemblages in the study. The mean species richness and abundance of functional guilds such as: frugivores, insectivores, nectarivores, were higher in large sacred groves but lower in both small and medium size sacred groves. It was predicted that the density and diversity of forest birds’ species may differ in sacred groves of varying sizes and isolation distance from the nearest largest forest fragment. This is in line with the species area hypothesis which posits that larger areas tend to contain larger number of species. The results clearly indicated that large sacred groves support high number of forest birds than small and medium size sacred groves. It was also hypothesized that functional guilds of birds may be influenced significantly by sacred groves of varying sizes and isolation from nearest largest forest fragments. As expected, the results showed that sacred groves of varying sizes significantly influenced the functional guilds of birds.

Density of species

The results showed a significant positive patch size response with higher species density (including tree density and flowering trees) at these areas, supporting the first hypothesis. Larger patches harbour more bird species than smaller patches. For instance, Bobiri forest reserve and the Boaben-Fiema monkey’s sanctuary are larger patches and, thus, contain more birds than patches like Amanfo and Nchiraa which are smaller patches. Although previous studies have obtained contrasting results for the effects of patch size and isolation on species density

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(Mönkkönen, Rajasärkkä, & Lampila, 2014). In contrast, these results clearly support the idea that patch size predict bird species density (Mönkkönen et al., 2014; Munguia-Rosas *et al*., 2014). Patch size was one of the most important predictors of bird density and composition in the transition zone of Ghana (Figure 3). Species-area relationship pointed out that large forest fragments hold the greatest number of bird species, characteristic of ecological processes and also sampling effect (Hill & Curran, 2003). There was an extremely low r^2 value derived for the linear regression model. This may be caused by the low density and detectability of birds, and also other factors that may be influencing bird density which were not measured. Some of these factors include; habitat matrix, edge effect and microclimate of the area.

Both island biogeography and metapopulation ecological processes predict positive patch size and negative isolation effect on density (Mönkkönen et al., 2014). In addition, they provide similar predictions with reference to total density. Density ought to decline with decreasing patch size and increasing isolation distance (predominantly subsequent to a certain threshold) as species richness decreases but many may be compensated by higher species- specific densities. Consequently, patch size and isolation distance impacts on total density depend on the level of equilibrium between colonization and extinction (Mönkkönen *et al*., 2014) . Even though small forest patches do not contribute much to the conservation of forest birds, such patches do contain many species of native plants, insects, mammals, and birds (Beier *et al*., 2002). The avian habitat generalists that occur in small patches include pollinators, such as songbirds

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(Nectariniidae), and insectivores shrikes (Laniidae), which most likely offer important ecosystem services in the forest patches.

Number of Trees in Relation to the Density of Birds

High number of trees harboured a greater number of birds' species in the study areas. This result supports the hypothesis that, number of bird species increase with number of trees. However, the result is in contrast with a study which posited that, increase in the number of trees results in decrease in bird number, the changes may be as results of monotony of trees (Bach, 2008). It is possible that the reason for the increase in number of birds and bird species with an increase in number of trees is because of the fact that, different tree species provide different types of nesting and foraging opportunities for birds. Also particular bird species may perhaps roost and forage in specific tree species and, thus, live where these tree species are most abundant. For instance, it has been found elsewhere that some bird species such as Black-throated Green Warblers group at areas where there is a higher density of conifers, and have a higher tendency of avoiding areas where conifers are absent (Bach, 2008). Also, it is possible when there are more trees, there is more heterogeneity in tree species; for that reason birds will spend less energy foraging because the tree species they prefer is available. It was also found that bird species richness increased with the presence of more large trees. This is consistent with a study conducted elsewhere which pointed out that a 12% coverage of an area by trees with a trunk diameter of 50 cm or more increased the number of bird species by an average of two (Ferenc *et al*., 2014). In other words, the presence of larger trees can enhance biodiversity of birds in forest lands. This

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result may be because large and older trees provide holes for species such as woodpeckers, hornbills, hoopoes, owls, to nest in; they may also harbor more insects for foraging.

Effect of Patch Size on Bird Species Diversity

Although most studies of fragmentation demonstrate that patch size has a significant positive correlation with species diversity per patch, this is an artifact of larger sampling effort in large patches (May & Stumpf, 2000). Also studies have revealed that patch size can also have a strong influence on avian diversity (Davis & Brittingham, 2004). It is estimated that one hectare of forest in a small forest harbours clearly smaller number of species of forest birds than one hectare of forest in a large patch (Beier *et al*., 2002). Habitats that are of poor quality and are highly isolated would have smaller bird diversity. In habitats that are low in bird species diversity, they show very steep decline.

Feeding Guilds

Birds usually respond to forest structure at different levels, from the individual to the community (Renner *et* a*l*., 2012). Locally, some species of birds may disappear when part of a tree or the whole tree is removed. This is done so as to compensate by moving to a different place since there is reduction in food availability, and this may affect the breeding success of birds (Renner *et al*., 2012). Changes in forest structure and food availability could result in increase or decrease in many bird population (Wells *et al*., 2011), resulting in different responses to changes in forest structure. Bird species are known to have species-specific preferences for particular forest structures in natural conditions, which

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are associated with foraging schemes as well as other traits that determine bird abundance (Antczak, 2010; Fischer *et al*., 2010; Renner *et al*., 2012). Optimal foraging theory states that, a foraging organism will maximize its fitness by maximizing its net energy intake per unit time, and will usually choose the available food type that produces the most calories for the effort it takes to locate, catch, or consume it.

The distribution of bird feeding guilds is mostly influenced by changes in the structure of the vegetation (Pearman, 2002). Larger patches are well equipped with food sources suitable for different kinds of bird feeding guilds. Insectivorous bird species decreased as the size of the patch decreased. This outcome is congruent with those of other studies that have found a positive relationship between the abundance of insectivores and relatively undisturbed habitat (Chettri *et al*., 2005; Iongh & van Weerd, 2006). A habitat with higher density of trees as well as greater basal areas, is suitable for insects (Chettri *et al*., 2005). It has been opined that moist conditions and dense foliage mostly favor insects (Azman *et al*., 2011). Therefore, larger patches with higher density of trees and greater basal areas would be a suitable habitat for insectivorous birds than medium and small patches, because of food abundance. The abundance of insectivore in large patches indicates that there was adequate number of insects available in this habitat. Greatest number of insectivore species was in the family Pycnonotidae. These species mostly adapt to the seasonal availability of insects. Additionally, insectivorous birds were detected in the interior regions of large patches. It has been pointed out that insectivores were sensitive to changes in habitat (LourenÇo

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& Sergio, 2006). Mostly, insectivorous birds appear to be limited to areas where disturbance is low (Tvardíková, 2010). Insectivores usually have high habitat specificity (Mansor & Sah, 2012). They also tend to be confined to the forest interior than other avian feeding guilds, particularly in the tropical forest which is relatively undisturbed. Insectivorous birds are more specialized than all the other bird guilds (Mansor & Sah, 2012). In addition, they have high tendency of becoming sensitive to prey abundance and behaviour because, invertebrates actively avoid them.

Frugivorous birds feed on a variety of fruits usually obtainable within the larger patches. It has been posited that frugivorous birds' choice of fruit is mostly influenced by seed size and number of fruit, color, nutrient content and fruiting arrangements (Azman *et al*., 2011). Certainly, in small patches which have the simplest vegetation structure, very few species of frugivores occurred unlike in large and medium patches where relatively large number of frugivores occurred. These responses can be linked to the fact that, with the increase in the complexity of vegetation structure, the diversity and resources such as food and shelter increase (Avila-Cabadilla *et al*., 2012). The loss of trees as a results of chainsaw activities, charcoal extraction and agriculture can adversely affect frugivores abundance in the tropics (Avila-Cabadilla *et al*., 2012). These activities will affect the birds' ability to locate suitable roosting sites, because they mostly roost in hollow trees found in mature forest (Evelyn & Stiles, 2003).

In addition, the presence of carnivorous species in the large patches was largely influenced by the availability of their food sources. This outcome is consistent

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with the results of a study conducted in Portugal which revealed that as the number of prey increased, the carnivorous bird's population also increased (LourenÇo & Sergio, 2006). Prey species such as lizards, mouse etc. were available in medium and smaller patches, this made carnivorous bird more abundant in medium and smaller patches.

Nectarivores abundance was higher in large patches. The response of nectarivores to larger patches may be as a result of resource availability in these patches, such as food and nesting materials. However, it has been opined elsewhere that nectarivores population are not so dependent on large dry forest (Cole & Wilson, 2006).They are naturally adapted to inhabiting areas where vegetation has simple structure, such as desert, arid grasslands and lowland dry forest (Avila-Cabadilla *et al*., 2012). These species are known to exploit the trophic resources available in those suitable patches.

The findings of this study revealed that, granivorous bird population increased in larger patches and decreased in smaller and medium patches. The reason for granivorous preference for large patches may be that, there was more production of seeds that are edible to them in the large patches. Meanwhile it has been found elsewhere that, granivorous bird population increased when forest patches were converted to monoculture (Azman *et al*., 2011). This means that granivorous birds preferentially live in smaller and relatively disturbed habitats.

Carnivorous bird population was higher in large patches, this may have been primarily influenced by the availability of their food sources. This result is

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congruent with the results of a study conducted in Portugal which revealed that the number of carnivorous species increased as the number of prey also increased (LourenÇo & Sergio, 2006). Prey species such as; small birds, tree squirrels may have been more abundant in the large patches.

Habitat Preference

Forest specialists are bird species that are mostly found in the forest interior of undisturbed forests. Sometimes, they may persist in secondary forests and forest patches if their ecological needs are not met. Forest specialists were abundant in large patches of the study areas. This findings are consistent with a study by (Estavillo *et al*., 2013) who found out that forest specialist species declined sharply in forests of smaller sizes. Their preference for forests may be as a result of food availability and the need for security cover. These species are usually reluctant to move to areas where there is fewer understory. The reason may be that these areas do not have suitable habitats for foraging and security cover.

Forest generalist species were more abundant in medium and smaller habitats, preferably, areas with fewer understories. These species selected these habitats because they provide easy access and different array of foraging opportunities. In addition, forest generalist species are generalist in foraging preference.

Birds that are often recorded in forests but they are not dependent upon it are forest visitors. They are mostly found in non-forest habitats where they are likely to breed. Their survival is almost certain in those habitats even if all of the forest is degraded. Their presence in a forest, may probably be an indication of forest disturbance. These species tend to be higher in smaller patches than in medium and large patches.

Species Effort Curve

The longer one stays in a habitat, the more birds one detects (Bibby, 2000). As the time spent collecting data increases, the number of new species added to the list asymptotically approaches some ceiling (Bibby, 2000). This was confirmed by equating the number of species obtained by several visits to sites of variables sizes, and, thus, different point stations. This study confirms the obvious: the more time you spend in an area, the more new birds you will see (Bibby, 2000). As shown by the species effort curve, the quality of sacred groves of small and medium size did not differ much. The large size sacred groves, on the other hand, have good quality habitats and the species accumulation curve stands clear of the lower size categories. Studies elsewhere showed species accumulation curve of heterogeneous habitat with some open herbaceous areas leveling off at a higher level than the more-or-less homogenous habitats (Manu, 2002). The changes in the number of bird species per grove size resulted from factors such as, fragment size, site quality, and isolation distance and, probably, the time of the year the points were surveyed. The species effort curve indicated that most species were recorded in the sampled areas. This is useful tool in predicting the number of birds in these areas and, probably, elsewhere with a good degree of accuracy.

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Season

More species were recorded in the wet season of the year compared with the dry season. The wet season period coincides with the peak period of the breeding season for most birds in these areas. Birds' species number in a habitat can be influenced by a number of factors on a local scale (vegetation structure, abundance of food, interspecific competition). Some factors are regional (weather effects) and other factors are geographic (Ryan *et al*., 2016).The factors that influence the seasonal changes in detection of birds have been named as frequency of song, stage of the breeding cycle, nesting synchrony, length of breeding season, influx in community composition, habitat and weather (Niemuth *et al*., 2012).

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CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents the summary, conclusion and recommendation of the study. It summarizes major findings of the study and draws conclusions based on the results. It also provides recommendations that need to be considered in further research and finally provided some conservation and management implications of the study.

Summary

The fragmentation of continuous habitats results from natural events and human disturbance. This change has influenced the distribution and behavioral characteristics of species that reside in forests. Point count methods was used to examine bird species density and diversity in sacred groves found in the transition zone of Ghana in the dry and wet seasons of the year. The main goal of this research was to investigate the effects of patch size and distance from the nearest large fragments on the density and diversity of tropical forest-dependent bird species. There was a significant difference of bird density and diversity between the two seasons. The findings also indicated that there were significant differences in bird diversity among forest patch categories. Similarly, functional groups significantly influenced birds' species density and diversity with patch size category over the season. Even though several small and medium size patches

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contained relatively fewer bird species, the sacred groves have the tendency to conserve important bird species in the ecosystem.

Conclusions

These results indicated that sacred groves of larger sizes support high number of tropical bird species assemblages. In addition, vegetation covariates and anthropogenic indexes exhibited a significant influence on tropical bird species assemblages. This finding has several implications for conservation. Tropical bird species assemblages was reduced in small and medium size sacred grooves, most importantly, forest specialists. This therefore means that, large sacred groves are required to maintain the full diversity of species assemblages.

These results showed that sacred groves of varying sizes has a significant influence on bird species richness and abundance. This suggests that where sacred groves are located in the landscape is essential for the persistence of population and integrity of bird species assemblages.

Though small and medium size groves support small number of bird species, they have the tendency to effectively maintain high species richness. This study indicated a considerable number of frugivores, granivores, insectivores, nectarivores and carnivores were found in the sacred groves. These species play an important role in the forest ecosystem. Some of these include: pollination, dispersal of seeds and fruits and the regeneration of the forest (Şekercioğlu *et al*., 2004). The loss of these species may influence the quality of forest habitats negatively. Thus, it is imperative to conserve biodiversity so as to benefit from small and medium size groves.

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In addition, the study indicated that human-induced activities have done a considerable ecological damage to the health of sacred groves which may affect the entire ecological system. This study has also provided a baseline for species-area related studies of birds in sacred groves located in the forest-savanna transition zone of Ghana. An opposing issue that holds back the conservation of sacred grove is that the village people living nearby the sacred groves are poor and so they depend on the grove to meet up their essential domestic necessities, such as fuel wood, vegetables, medicinal plants etc. It has been suggested that the rural poor depend on biological resources for meeting 90% of their day-to-day needs (Totey & Verma, 1996). Therefore, if an appropriate alternative is not provided to these people for sustaining their economic condition, any measures laid down for the conservation of sacred groves will not be successful.

Recommendations

To conserve sacred groves which represents the remaining vegetation of old-growth forests, it is vital to uphold traditions and beliefs guiding their protection. Recently, these forest patches are facing serious anthropogenic pressure (Khan *et al*., 2008). The loss of sacred groves may also result in the disappearance of rich culture associated with the groves (Kushalapa *et al*., 2001). Current economic and social issues are the main challenges faced by management in the conservation of sacred groves through traditional local systems, resulting in the traditional systems being rendered less operational (Khan *et al*., 2008). Thus, effective conservation measures need to be put in place, taken into consideration the concerns of the local people.

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Vocalisation was very useful for recording birds in this study. The backbone to surveying forest birds in West Africa and elsewhere is the identification of bird species from their calls and songs. Although this tool is difficult to master, there is no alternative when carrying out census of forest birds. Therefore, a detailed knowledge of the calls and songs of the birds is recommended for ornithologist wishing to census birds in West Africa.

Conservation and Management Implications

Maintaining traditions and beliefs so as to protect and conserve the irreplaceable forest patches is important, and it represents the remaining vegetation of concerned areas. The degradation of sacred groves will result in the loss of the remaining flora and fauna. Assessing the effect of patch size and isolation on bird species density and diversity, and comparing their influence with those of other vegetation variables is essential for managing forest fragments for conservation. When species are prioritized, it may help manage deforestation rates beneficially for diversity maintenance by indicting how land and what shape and pattern it should assume to maintain key bird species. Protecting maximum species richness may enable the preservation of important portion of the forest ecosystem: rare and endemic species. These species will be protected more efficiently by the preservation of maximum species richness in larger forest reserves. However, small patches can provide source areas for restoration of more widespread forest in areas that have been greatly degraded. A landscape-level conservation approach is required, which make the most of area to perimeter relationships across number of reserves, protects reserve edges using buffer zones and

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maximizes matrix severity. Also, ecological processes that operate over large distances must not be ignored. They are the processes that situate forest fragment within the landscape.

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APPENDIX

Appendix A: Table of effect size with their corresponding confidence intervals.

Response	Explanatory	Coefficients	UCI	LCI
Density	Flowering trees	0.076	0.092	-0.085
	Size	0.002	0.001	-0.001
	Tree density	0.103	0.059	-0.053
	season	0.109	0.219	-0.196
	Fruiting trees	0.047	0.074	-0.07
Diversity	Flowering trees	0.045	0.054	-0.051
	Tree density	0.12	0.043	-0.038
	Fruiting trees	0.032	0.043	-0.042
	Size	0	0.001	-0.001
Richness	Fruiting trees	0.852	1.252	-0.493
	Tree density	2.2	1.58	0.091
	Flowering trees	0.999	1.689	-0.549
	Size	0.008	0.011	-0.011
Evenness	Trap	-0.012	0.01	-0.011
	Tree density	0.01	0.007	-0.007
	Fruiting trees	-0.004	0.008	-0.008
Abundance	Flowering trees	4.145	10.629	3.804
	Tree density	5.375	9.536	4.44

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Fruiting trees	3.197	7.251	1.739
Season	7.552	32.692	19.22

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Appendix B: Correlation among various measures of density and diversity with functional groups

	Size	*isodist*	*Abd*	*diversity*	*density*	*richness*	*evenness*	*FFd*	*Fd*	*Fd*	*FFdv*	*Fdiv*	*fdv*
size	1.00												
isodist	-0.06	1.00											
abd	0.12	0.02	1.00										
diversity	0.38	-0.03	0.37	1.00									
density	0.66	-0.02	0.82	0.47	1.00								
richness	0.40	-0.03	0.67	0.87	0.72	1.00							
evenness	0.18	0.03	-0.25	0.66	-0.10	0.21	1.00						
FFd	0.38	0.08	0.59	0.70	0.65	0.75	0.25	1.00					
Fd	-0.38	0.00	-0.19	-0.30	-0.34	-0.28	-0.24	-0.25	1.00				
fd	-0.36	-0.06	-0.60	-0.59	-0.64	-0.65	-0.23	-0.67	0.59	1.00			
FFdv	0.53	0.09	0.65	0.58	0.78	0.68	0.15	0.74	-0.43	-0.73	1.00		
Fdiv	-0.45	0.23	-0.28	-0.22	-0.45	-0.31	0.02	-0.17	0.68	0.43	-0.30	1.00	
fdv	-0.36	-0.04	-0.43	-0.46	-0.51	-0.44	-0.28	-0.53	0.52	0.80	-0.65	0.41	1

****isodist=isolation distance, abd=abundance, FFd=density of forest specialists, Fd=density of forest generalists, fd=density of forest visitors, FFdv=diversity of forest specialists, fdiv=diversity of forest generalists, fdv=diversity of forest visitors.

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Appendix B: Correlation among various measures of density and diversity with anthropogenic disturbance

	size	*isodist*	*abd*	*Diversity*	*density*	*richness*	*evenness*	*tdensity*	*cancov*	*Frt*	*flt*	*fwood*	*trap*	*chnsw*
size	1.00													
isodist	-0.06	1.00												
abd	0.12	0.02	1.00											
diversity	0.38	-0.03	0.37	1.00										
density	0.66	-0.02	0.82	0.47	1.00									
richness	0.40	-0.03	0.67	0.87	0.72	1.00								
evenness	0.18	0.03	-0.25	0.66	-0.10	0.21	1.00							
tdensity	0.41	0.06	0.52	0.66	0.60	0.67	0.33	1.00						
cancov	-0.28	0.15	-0.31	-0.25	-0.39	-0.28	-0.17	-0.49	1.00					
frt	0.06	0.04	0.32	0.23	0.26	0.31	-0.03	0.13	-0.08	1.00				
flt	0.13	0.03	0.38	0.33	0.37	0.38	0.05	0.25	-0.03	0.68	1.00			
fwood	-0.04	-0.21	-0.06	-0.09	-0.06	-0.01	-0.13	-0.09	-0.35	0.12	0.04	1.00		
trap	-0.26	-0.20	0.05	-0.15	-0.10	-0.04	-0.30	-0.10	0.18	-0.14	0.00	0.28	1.00	
chnsw	-0.01	-0.06	-0.16	-0.15	-0.12	-0.20	0.04	-0.10	-0.52	-0.06	-0.15	0.46	0.07	1

****isodist=isolation distance, abd=abundance, tdensity=tree density, cancov=canopy cover, frt=fruiting trees, flt=flowering trees, fwood=fuelwood collection, chnsw=chain saw activities .

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************** MEANING OF ABBREVIATIONS

****

STN – scientific names, FAN – family name, HPF – habitat preference, FGD – feeding guilds, FBH – feeding behaviour, HRG – habitat range, TST – threat status, FG – forest generalist, FV – forest visitor, FS – forest specialist, FRU – frugivores, GRA – granivores, OMN – omnivores, INS – insectivores, NEC – nectarivores, CAR – carnivores, FGL – fruit gleaners, LGL – leaf gleaners, GGL – ground gleaners, ISA – insect sallyers, BHV – bird hovers, BGL – branch gleaners, BPK – branch peck, FGH – fruit hovers, BSA - Bird sallyers, WTB – water hovers, SCA – scavenger, RS – resident birds, MG – migrants, LC – least concern.

Appendix E: List and classification of bird species recorded in the study area

STN	HPF	FDG	FBH	HRG	TST	FAN
Tockus fasciatus	FG	FRU	FGL	RS	LC	Bucerotidae
Pycnonotus barbatus	FV	GRA	LGL	RS	LC	Pycnonotidae
Corvus albus	FV	OMN	GGL	RS	LC	Corvidae
Lamprotornis splendidus	FV	FRU	FGL	RS	LC	Sturnidae
Streptopelia semitorquata	FG	FRU	FGL	RS	LC	Columbidae
Tockus nasutus	FV	FRU	FGL	RS	LC	Bucerotidae
Chlorocichla simpli	FG	INS	ISA	RS	LC	Pycnonotidae
Terpsiphone rufiventa	FG	INS	ISA	RS	LC	Sylvidae
Treron calvus	FG	FRU	FGL	RS	LC	Columbidae

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Cinnyris chloropygius	FS	NEC	LGL	RS	LC	Nectariniidae
Andropadus virens	FG	INS	ISA	RS	LC	Pycnonotidae
Chalcomitra senegalensis	FV	NEC	LGL	RS	LC	Nectariniidae
Cameroptera superciliaris	FS	GRA	LGL	RS	LC	Sylvidae
Kaupifalco monogramicus	FG	CAR	BHV	RS	LC	Accipitridae
Sylvietta virens	FV	GRA	LGL	RS	LC	Sylvidae
Spermophaga haematina	FS	GRA	GGL	RS	LC	Estrildidae
Chrysococcyx klass	FG	INS	ISA	RS	LC	Cuculidae
Ploceus cucullatus	FV	GRA	LGL/GGL	RS	LC	Ploceidae
Ceuthmochares aereus	FG	FRU	FGL	RS	LC	Sturnidae
Cameroptera brachyura	FV	GRA	LGL	RS	LC	Sylvidae
Dyaphorophyia blissetti	FS	GRA	LGL	RS	LC	Platysteridae
Dyaphorophyia castania	FS	GRA	LGL	RS	LC	Platysteridae
Hylia prasina	FS	INS	LGL	RS	LC	Sylvidae

STN	HPF	FDG	FBH	HRG	TST	FAN
Merops albicollis	FV	INS	ISA	MG	LC	Meropidae
Tchagra australis	FG	INS	ISA	RS	LC	Laniidae
Ploceus nigricollis	FV	GRA	LGL	RS	LC	Ploceidae
Cinnyris superbus	FS	NEC	LGL	RS	LC	Nectariniidae
Falco ardosiaceus	FV	CAR	BHV	RS	LC	Falconidae
Nicator chloris	FS	INS	ISA	RS	LC	Pycnonotidae
Alcedo cristata	FV	INS	ISA	RS	LC	Alcedinidae

Cisticola cantans	FV	GRA	LGL	RS	LC	Sylvidae
Ploceus nigerrimus	FV	GRA	LGL	RS	LC	Ploceidae
Tchagra senegalensis	FV	INS	ISA	RS	LC	Laniidae
Thescelocichla leucopleura	FG	INS	ISA	RS	LC	Pycnonotidae
Macrosphenus kempi	FS	INS	ISA	RS	LC	Sylvidae
Oriolus brachyrhyncus	FG	INS	ISA	RS	LC	Oriolidae
Centropus senegalensis	FV	OMN	BGL	RS	LC	Cuculidae
Lybius vieilloti	FV	FRU	FGL	RS	LC	Capitonidae
Bubulcus ibis	FV	CAR		RS	LC	Ardeidae
Cinnyris cupreus	FG	NEC	LGL	RS	LC	Nectariniidae
Dicrurus modestus	FG	INS	ISA	RS	LC	Dicruridae
Mesophaga violacea	FG	FRU	FGL	RS	LC	Musophagidae
Cinnyris vanustus	FV	NEC	LGL	RS	LC	Nectariniidae
Coracias cynogaster	FG	INS	ISA	RS	LC	Coraciidae
Turaco persa	FG	FRU	FGL	RS	LC	Musophagidae
Francolinus ahantensis	FG	GRA	GGL	RS	LC	Phasianidae
Malimbus rubricollis	FS	GRA	BPK	RS	LC	Ploceidae
Prionops caniceps	FS	INS	ISA	RS	LC	Prionopidae
Platysteira cyanea	FV	INS	ISA	RS	LC	Platysteridae
Bias musicus	FG	INS	ISA	RS	LC	Muscicapidae
Paser griseus	FV	GRA	GGL	RS	LC	Paseridae
Prinia subflava	FV	GRA	LGL	RS	LC	Sylvidae

Appendix J cont'd

STN	HPF	FDG	FBH	HRG	TST	FAN
Bleda canicapilla	FS	INS	ISA	RS	LC	Pycnonotidae
Lybius dubius	FV	FRU	BGL	RS	LC	Capitonidae
Oxylophus jacobinus	FG	INS	ISA	RS	LC	Cuculidae
Anthretes retrirostris	FG	NEC	LGL	RS	LC	Nectariniidae
Butorides striata	FG	FRU	FGL	RS	LC	Ardeidae
Dendropicos goertae	FV	INS	BPK	RS	LC	Picidae
Cossypha neveicapilla	FS	INS	ISA	RS	LC	Turdidae
Halcyon senegalensis	FG	INS	ISA	RS	LC	Alcedinidae
Turdus pelios	FV	FRU	LGL	RS	LC	Turdidae
Pogoniulus chrysoconus	FS	FRU	FGL	RS	LC	Capitonidae
Accipiter badius	FG	CAR	BHV	RS	LC	Accipitridae
Criniger calurus	FS	INS	ISA	RS	LC	Pycnonotidae
Chrysococcyx capreus	FG	INS	ISA	RS	LC	Cuculidae
Milvus migrans	FG	CAR	BHV	RS	LC	Accipitridae
Cynomitra verticalis	FG	NEC	LGL	RS	LC	Nectariniidae

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Euplectes franciscanus	FV	GRA	LGL	RS	LC	Ploceidae
Dryoscopus gambensis	FG	INS	ISA	RS	LC	Malaconotidae
Oxylophus levaillanti	FG	INS	FGL	RS	LC	Cuculidae
Spermestes cucullatus	FV	GRA	GGL	RS	LC	Estrildidae
Halcyon malimbica	FG	INS	ISA	RS	LC	Alcedinidae
Eurystomus glaucurus	FV	INS	ISA	RS	LC	Coraciidae
Amaurornis flavirostra	WTB	CAR		RS	LC	Rallidae
Turtur tympanistra	FS	FRU	FGL	RS	LC	Columbidae
Nigrita canicapillus	FS	INS	ISA	RS	LC	Estrildidae
Crinifer piscator	FV	FRU	FGL	RS	LC	Musophagidae
Melocichla mentalis	FV	INS	ISA	RS	LC	Sylvidae
Centropus monachus	FS	FRU	FGL	RS	LC	Cuculidae
Falco tinunculus	FV	CAR	BHV	RS	LC	Falconidae
Cynomitra olivacea	FV	NEC	LGL	RS	LC	Nectariniidae
Accipiter tachiro	FG	CAR	BHV	RS	LC	Accipitridae

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Appendix J cont'd

STN	HPF	FDG	FBH	HRG	TST	FAN
Necrosyrtes monachus	FV	CAR		RS	LC	Accipitridae
Buteo augularis	FG	CAR	BHV	RS	LC	Accipitridae
Cisticola erythrops	FV	GRA	LGL	RS	LC	Sylvidae
Falco biamicus	FV	CAR	BHV	MG	LC	Falconidae
Apaloderma narina	FS	INS	ISA	RS	LC	Trogonidae
Apalis nigriceps	FS	INS	ISA	RS	LC	Sylvidae
Tricholaema hirsuta	FS	FRU	FGL	RS	LC	Capitonidae
Bycanistis fistulator	FG	FRU	FGL	RS	LC	Bucerotidae
Strix woodfordii	FS	CAR	BHV	RS	LC	Strigidae
Cinnyris coccinigastrus	FG	INS	ISA	RS	LC	Nectariniidae
Anthreptes seimundi	FG	NEC	LGL	RS	LC	Nectariniidae
Hedydipna collaris	FS	NEC	LGL	RS	LC	Nectariniidae
Poicephalus senegalensis	FV	FRU	FGL	RS	LC	Psittacidae
Spermestes bicolor	FV	GRA	LGL	RS	LC	Ploceidae
Chrysococcyx cuprius	FG	INS	ISA	MG	LC	Cuculidae
Oriolus nigripennis	FS	INS	ISA	RS	LC	Oriolidae
Gymnobucco calvus	FS	FRU	FGL	RS	LC	Capitonidae
Illapdosis cleaveri	FS	INS	ISA	RS	LC	Timaliidae
Pogoniulus bilineatus	FV	FRU	BGL	RS	LC	Capitonidae
Polyboroides typus	FG	CAR	BHV	RS	LC	Accipitridae
Macrosphenus concolor	FG	GRA	LGL	RS	LC	Sylvidae

Turtur afer	FG	FRU	FGL	RS	LC	Columbidae
Cuculus clamosus	FS	INS	ISA	MG	LC	Cuculidae
Halcyon badia	FS	INS	ISA	RS	LC	Alcedinidae
Cisticola lateralis	FV	GRA	LGL	RS	LC	Sylvidae
Andropadus gracilis	FS	INS	ISA	RS	LC	Pycnonotidae
Phyllastrephus albigularis	FG	INS	FRH	RS	LC	Pycnonotidae
Chlorophoneus multicolor	FS	INS	ISA	RS	LC	Malaconotidae
Andropadus latirostris	FG	GRA	GGL	RS	LC	Pycnonotidae

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