

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

KNUST

THE EFFECTS OF DIFFERENCES IN AGRO-ECOSYSTEMS ON THE DIVERSITY  
AND DISTRIBUTION OF AVIFAUNA IN SELECTED AREAS IN THE EASTERN  
REGION OF GHANA

BY

SILAS GODWIN SOGAH

(BSC. HONS. AGRICULTURE)

May, 2012

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ENVIRONMENTAL SCIENCE.

May, 2012

## DECLARATION

I hereby declare that this thesis is the result of my own original work towards the award of M.Sc. and as far as I know, it contains no materials previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Signature..... Date.....

NAME: SILAS GODWIN SOGAH

(STUDENT)

Signature..... Date.....

NAME: STEPHEN AKYEAMPONG

(SUPERVISOR)

Signature: ..... Date.....

NAME: DR. PHILLIP K. BAIDOO

(HEAD OF DEPARTMENT)

## ABSTRACT

The study was conducted in the Eastern Region of Ghana in two agro-ecosystem sites: the oil palm plantation of the Ghana Oil Palm Development Company (GOPDC) Limited at Kwae near Kade and cocoa farms of the Cocoa Research Seed Production Unit of Ghana Cocoa Board (COCOBOD) at Pankese near Nkawkaw and a natural forest area, Esukawkaw Forest Reserve (EFR) near Kadewaso. The objectives were to identify bird species occurrence, bird density, diversity and the influences of the change in habitat types on birds. Line transect technique was used for sampling. A total of 1001 individual birds belonging to 78 families and 216 bird species were identified. The species compositions of birds from the habitat types were significantly different. The diversity of birds in the oil palm plantation differed from that of the Cocoa farms at  $P > 0.05$  ( $t = -4.0149$ ,  $P = 6.963E - 5$ ) as well the forest area since  $P < 0.05$  ( $t = 15.3150$ ,  $P = 0.00000$ ). Diversity of birds found in the Cocoa farms also differed from that of the forest at  $P < 0.05$  ( $t = -14.063$ ,  $P = 1.0836E - 38$ ). The Esukawkaw Forest Reserve had the highest species diversity and evenness of 4.48 and 0.95 respectively while Pankese Cocoa farms had diversity value of 3.54 and evenness of 0.89. Kwae oil palm plantation had diversity and evenness of 3.18 and 0.83 respectively. The relative abundance score of species among the habitat was variable in all the habitat types. It was realized that there was a positive relationship between the number of birds and the habitat types, i.e. as the habitat type approaches the nature of forest, the bird numbers also increase. Therefore, expansion of farmlands and logging could be the main threats to the survival of birds in the three habitat types.

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## DEDICATION

This work is wholeheartedly dedicated to:

1. The Lord Jesus Christ in whom are hidden all the treasures of wisdom and knowledge (Col. 2:3).
2. My dearest wife, Mrs Victoria Amoak-Sogah and son; Derrick Etornam Sogah.
3. My late mother, Madam Torngor Kpese for her love and financial support towards my education.

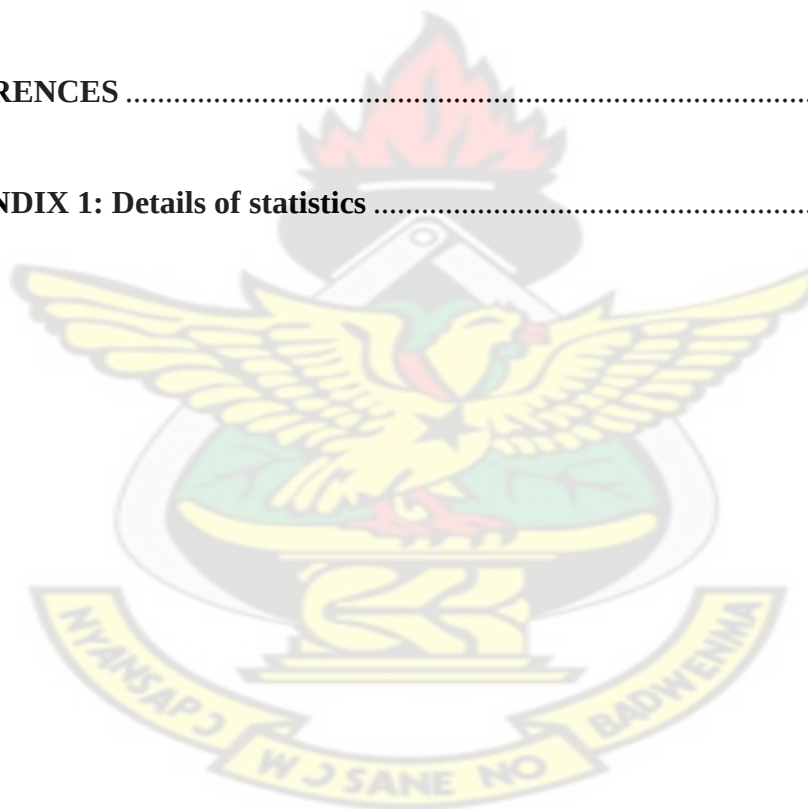


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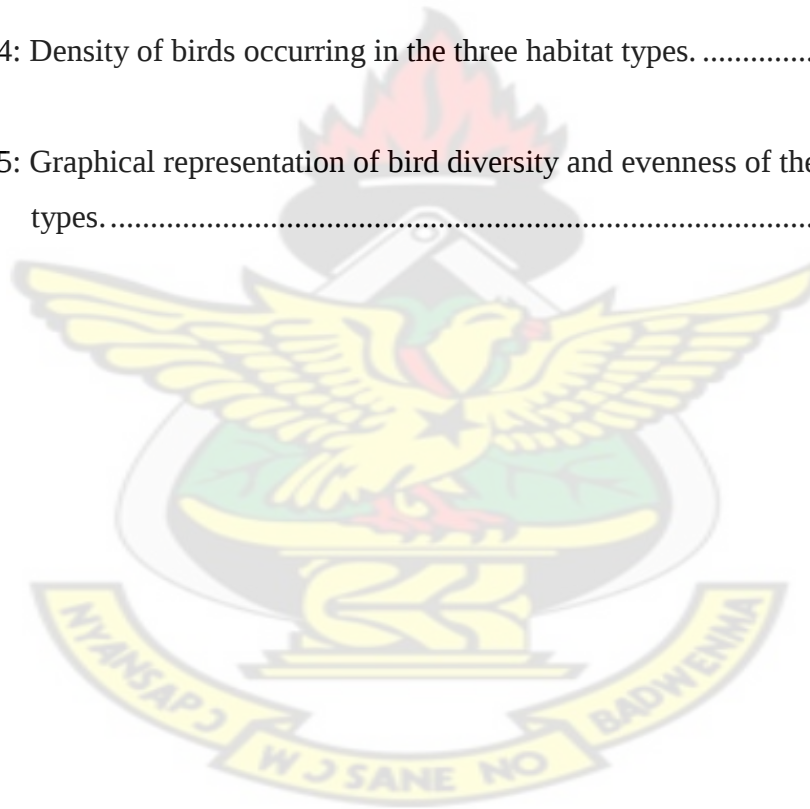
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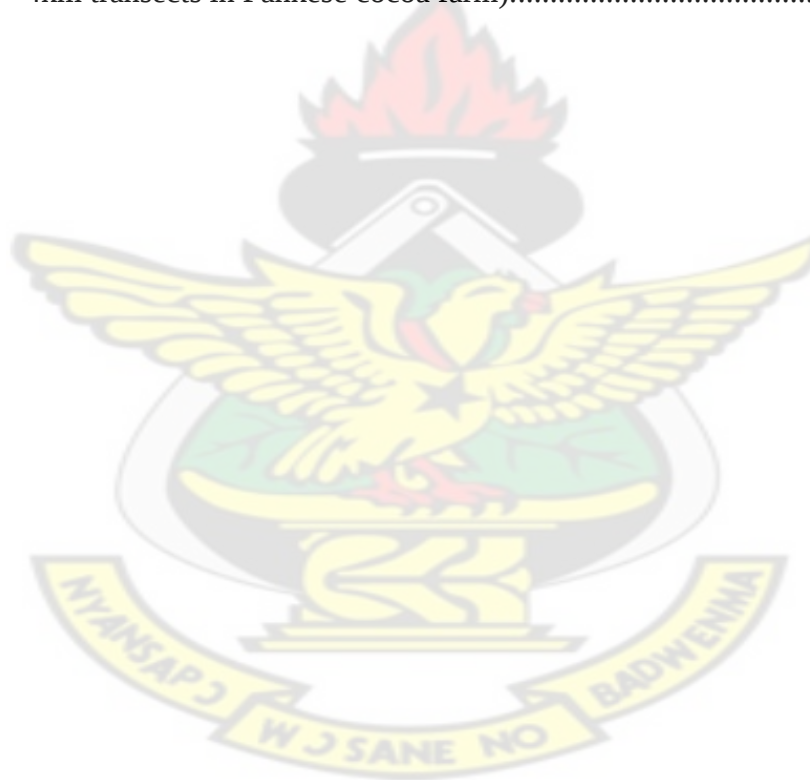
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## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background**

Habitat modification and destruction are rampant and caused by a number of factors including deforestation, bushfires and minning operations. Most of the original forests in Ghana have been destroyed and the bulk of the remaining intact forests are in protected areas with less than one percent outside (Hawthorne & Mussah, 1993). The main causes of deforestation and forest degradation in Ghana are clearance for agricultural ventures, bushfires, timber operations and cutting for fuelwood. Deforestation resulting from increased demand for agricultural land for subsistence farming is directly linked with rapid human population growth (IIED, 1992). The effect is total loss of habitats and niches for many wild animal species and a decrease in species diversity. Species particularly affected by loss of forest habitat include primates.

Ghana's forest and savanna lands still support a diverse array of plant and animal species, although much of the resource is severely depleted. Data on status of individual plant species are not readily available, but it is estimated that over 70% of the original 8.22 million hectares of closed forest in Ghana has been destroyed (IIED, 1992) and only about 10.9% to 11.8% (representing 15,800 to 17,200 square kilometres of forest cover) remains as intact forests. Deforestation rate in the country is estimated at 22,000 square kilometres per annum (Hawthorne and Mussah, 1993). At this rate, without adequate intervention there will be no intact forest left in the country within the next

100 years. The country's productive systems as well as the livelihood and very survival of Ghanaians are threatened by the severe environmental degradation associated with deforestation (e.g. soil erosion, local climate changes, instability of hydrological regimes and loss of biological diversity). Currently there are eight threatened bird species and 14 near-threatened species in Ghana i.e. species at risk and requiring monitoring (Collar and Stuart, 1985; Collar and Andrew, 1988). Four of the threatened species are restricted range species endemic to the Upper Guinea forest block, while two are Palearctic migrants, the Damara tern *Sterna balaerum* and the Roseate tern *Sterna dougallii*. The Damara tern is recorded only rarely on the Ghana coast while the Roseate occurs in appreciable numbers.

In addition to the threatened species, a number of Ghanaian taxa are considered to be of conservation concern (i.e. species requiring special conservation efforts) by virtue of being endemic, flagship species, indicator or keystone species, landraces or by virtue of having social and/or economic value. Keystone/indicator species among the Ghanaian fauna include the African elephant, *Loxodonta africana*, parrots and hornbills (because of their role in forest regeneration) and birds of prey (position in the ecological food chain). Species of economic significance include parrots which are important in the live wild animal export trade and hornbills, francolins, partridges and ducks.

The Earth's ecosystems and its peoples are bound together in a grand and complex symbiosis. We depend on ecosystems to sustain us, but the continued health of ecosystems depends, in turn, on our use and care. Ecosystems are the productive

engines of the planet, providing us with everything from the water we drink to the food we eat and the fiber we use for clothing, paper or lumber. Yet, nearly every measure we use to assess the health of ecosystems indicates that we are drawing on them more than ever and degrading them in some cases at an accelerating pace.

Our knowledge of ecosystems has increased dramatically in recent decades, but it has not kept pace with our ability to alter them. Economic development and human wellbeing will depend in large part on our ability to manage ecosystems more sustainably. One of the major factors that contribute significantly to ecosystem destruction is agriculture.

An agro-ecosystem is a biological and natural resource system managed by humans for the primary purpose of producing food as well as other socially valuable non-food goods and environmental services (Stanley *et al.*, 2000). Conversion of forest and grassland for agriculture has significant impacts on all goods and services. The predominantly positive effects on food outputs have usually been matched by correspondingly negative effects on the provision of water, biodiversity, and carbon storage services and on the quality of the soil resource.

Agricultural land, which supports far less biodiversity than natural forest, has expanded primarily at the expense of forests. About 30% of the potential area of temperate, subtropical and tropical forests has been converted to agriculture. Many of the areas established to protect biodiversity fall in or around agricultural lands, increasing the

difficulties of effective protection. Biodiversity loss is often considerable within high-input agro ecosystems but low-input and extensive systems can also bring about significant biodiversity loss through increased conversion of natural habitats.

Although tree cover is fairly low in agricultural lands of many parts of the world, a majority of rain fed agricultural land in Latin America, Sub-Saharan Africa, and South and South-east Asia has significant and increasing tree cover, which enhances habitat for wild biodiversity. A number of agricultural systems and management strategies such as fallowing, agro-forestry, shade coffee and integrated pest management can encourage diversity as well as productivity.

Dramatic reduction and fragmentation of forest cover in several parts of the world have prompted many to ask what the impacts of such changes are on animal abundance, species richness and community dynamics (Faaborg *et al.*, 1995; McGarigal and McComb, 1995). Random destruction of natural habitats by cutting nesting trees and foraging plants for commercial use of woods and lands are the main factors responsible for narrowing avian foraging habitat and their nesting sites. Thus many species of birds may be forced to inhabit urban areas. Habitat modification is likely to affect the bird assemblages occurring in the newly evolved habitats. Apart from economic gains of the habitat conversion, little or no consideration is given to ecological consequences of forest habitat conversion. It is against this backdrop that this research has been proposed.

## **1.2 Aims and objectives**

The main aim of this research was to gather information on the effects of land use types on the diversity and distribution of avifauna. The selected land use types are the Oil palm plantation, Cocoa farms and a natural forest.

### **The specific objectives were to:**

1. identify bird species occurring in the three habitat types: the Oil palm plantation, Cocoa farms and the natural forest reserve;
2. determine bird density in the three habitat types;
3. determine bird diversity in the three habitat types;
4. determine the effects of differences in the habitat types on bird populations;
5. compare birds' species composition that occur in the three habitat types.

## **1.3 Hypotheses**

1. That species abundance of birds occurring in the three habitat types of Oil palm plantation (Kwae), Cocoa farms (Pankese) and forest area (Esukawkaw forest reserve) were the same.
2. That the diversity of birds within any two habitat types was the same.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Ecological significance of bird populations

People, worldwide, are rapidly degrading ecosystems, especially in the tropics, leading to a massive reduction in biodiversity (Laurance and Bierregaard, 1997; Vitousek *et al.*, 1997; Pimm and Raven, 2000; Dirzo and Raven, 2003). This is best documented in the extinctions and population declines of hundreds of bird species (Bennett and Owens, 1997; Anon., 2006, 2004a; Sekercioglu *et al.*, 2004). The accelerating extinctions of species (Anon., 2006) comprise the tip of the iceberg of global wildlife declines (Hughes *et al.*, 1997; Jackson *et al.*, 2001; Ceballos and Ehrlich, 2002; Gaston *et al.*, 2003) that threaten to disrupt vital ecosystem processes and services (Redford, 1992).

Ecologically, declines and extinctions of distinct populations are as important as the losses of species (Chapin *et al.*, 1998). Reductions in the numbers of individuals in important functional groups are likely to extensively diminish ecosystem processes and services such as decomposition, pest control, pollination, and seed dispersal (Redford, 1992; Myers, 1996; Daily, 1997). Besides the outright loss of ecological factors, changes in the proportions of species in various functional groups may result in the disassembly of ecological communities (Gonzalez and Chaneton, 2002). Currently, 21.5% of bird species are considered “extinction-prone”, a category that includes species that are extinct (1.4%), threatened (12.1%) or near threatened (8.0%) with extinction (Anon., 2006).

Birds are integral to many ecosystem processes, even soil formation (Heine and Speir, 1989), and many species provide key ecosystem services, such as pollination and seed dispersal. Ongoing reductions in bird abundance (Gaston *et al.*, 2003) and species richness (Anon., 2004b) are likely to have far-reaching ecological consequences (Sekercioglu *et al.*, 2004), with diverse societal impacts ranging from the spread of disease and loss of agricultural pest control to plant extinctions and trophic cascades. Rapid losses of bird species may cause substantial reductions in certain ecosystem processes before we have time to study and understand the underlying mechanisms.

Fortunately, birds are the best known class of organisms (Anon., 2004b), and their conservation status has been assessed multiple times (Anon., 2006). Various studies on frugivorous, nectarivorous, and insectivorous birds have established their significance in the dynamics of diverse natural and human-dominated ecosystems (Stiles, 1978, 1985; Proctor *et al.*, 1996; Westcott and Graham, 2000; Mols and Visser, 2002; Croll *et al.*, 2005). Although field studies on birds' ecological effects have been mostly non-experimental and focused on a small subset of species (Feinsinger *et al.*, 1982; Robertson *et al.*, 1999; Rathcke, 2000; Bleher and Bohning-Gaese, 2001; Loiselle and Blake, 2002), research on birds' ecological functions and services is growing and becoming more experimental (Abramsky *et al.*, 2002; Mols and Visser 2002; Croll *et al.*, 2005). Precise understanding of the ecological consequences of bird population losses will be impossible to achieve, yet there is a pressing need to assess avian ecosystem services and estimate the potential ecological effects of differential extinctions in various functional groups.

## 2.2 Diversity and ecosystem function

The role of biodiversity in ecosystem function is a current and active field of inquiry (Chapin *et al.*, 2000; Loreau and Hector, 2001; Tilman *et al.*, 2001; Hooper *et al.*, 2005; France & Duffy, 2006). Since it is usually difficult to isolate and quantify the significance of any one factor, there is ongoing disagreement over the relative contributions of biomass (Schwartz *et al.*, 2000), diversity (Chapin *et al.*, 1997), dominance (Smith *et al.*, 2004), functional richness (Naeem & Wright, 2003), and keystone species (Power *et al.*, 1996). Although it makes intuitive sense that the species that dominate in number and/or biomass are more likely to be important for ecosystem function (Raffaelli 2004; Smith *et al.*, 2004), in some cases even rare species can have a role, for example, in increasing invasion resistance (Lyons and Schwartz, 2001). In tropical communities there are many rare and specialized bird species (Terborgh, 1974); the removal of which may increase invisibility to generalist taxa and have unpredictable impacts that may further damage already impoverished communities.

In contrast to dominant species, by definition a keystone species is one that has an ecosystem impact that is disproportionately large in relation to its abundance (Power *et al.*, 1996; Hooper *et al.*, 2005). Many large frugivores (Stocker and Irvine, 1983) and top predators (Terborgh *et al.*, 2001) can be considered keystones. There is a growing literature on keystone species (Davic, 2003), but identifying keystone species in advance has been difficult (Power *et al.*, 1996). Species that are not thought as “typical” keystones can turn out to be so, even in more ways than one (Daily *et al.*, 1993). It is hard to predict the importance and “replaceability” of individual species without

detailed studies, but since we are increasingly faced with the ecosystem consequences of accelerating biodiversity loss (Redford, 1992), an improved ability to predict and protect keystones may help alleviate some of these consequences.

An indisputable role of species richness comes in the guise of the “sampling effect” (Wardle, 1999), i.e. the more species that are present in a community, the higher the probability of having a species that will have a significant ecological impact. This is particularly important when there is a major perturbation to the system. With more species present, there is a higher probability of a formerly “insignificant” species being able to respond to this disturbance and maintain ecosystem function (Ives and Cardinale, 2004), thereby increasing “resilience” (Elmqvist *et al.*, 2003). The “insurance hypothesis” is an analogous way to think about this phenomenon (Yachi and Loreau, 1999). Yachi and Loreau (1999) showed that in a fluctuating environment, species richness can insure against a decline in ecosystem functioning by both buffering (reducing the temporal variance of productivity) and by enhancing ecosystem performance (increasing the mean of productivity).

Even though in many communities only a few species have strong effects, the weak effects of many species can add up to a substantial stabilizing effect and “weak” effects over broad scales can be strong at the local level (Berlow, 1999). In other studies, communities with higher species richness of functional groups had reduced probabilities of cascading extinctions following the removal of a species (Borrvall *et al.*, 2000). Such communities also retained higher portions of species following extinction events

(Ebenman *et al.*, 2004). Thus, increased species richness can insure against sudden change, which is now a global phenomenon (Parmesan and Yohe, 2003; Root *et al.*, 2003).

### **2.3 Body size of birds**

Large and highly mobile bird species are often important mobile links (Lundberg and Moberg, 2003), top consumers, and keystones (Raffaelli, 2004). These species are relatively few and have small populations in relation to the avifauna in general. The very factors that make them particularly valuable to ecosystems also make these birds vulnerable to human impact. Bigger species, with correspondingly more ecological influence, are much more likely to be hunted for their meat. Birds with bigger home ranges, since they sample larger areas, are likely to encounter more threats. Furthermore, large species' life histories, characterized by long life spans, small clutch sizes, infrequent breeding, and low population densities (e.g. albatrosses), also mean that they are far more sensitive to adult mortality, from which they may never recover. That people are selectively doing more damage to the very bird species that often contribute most to ecosystem function means that ecosystem consequences of avian declines and extinctions are likely to be more severe than suggested by random models of extinction. (Zavaleta and Hulvey, 2004).

### **2.4 Birds as mobile links**

From an ecosystem functional perspective, birds are mobile links (Gilbert, 1980; Lundberg and Moberg, 2003) that is crucial for maintaining ecosystem function,

memory and resilience (Nyström and Folke, 2001). The three main types of mobile links, namely genetic, process, and resource linkers (Lundberg and Moberg, 2003), encompass all major avian ecological functions. Seed dispersing frugivores and pollinating nectarivores are genetic linkers that carry genetic material to habitat suitable for regeneration or from an individual plant to another plant, respectively. Trophic process linkers are grazers such as geese (Maron *et al.*, 2006), and predatory birds, such as antbirds and eagles that influence the populations of plant, invertebrate, and vertebrate prey and often provide natural pest control (Molsand Visser, 2002).

Scavenging birds, such as vultures are crucial process linkers that hasten the decomposition of potentially disease-carrying carcasses (Prakash *et al.*, 2003). Piscivorous (fish-eating) birds provide good examples of resource linkers that transport nutrients from water to land in their droppings and often contribute significant resources to island ecosystems (Anderson and Polis, 1999). Woodpeckers act both as trophic process linkers and as physical process linkers or “ecosystem engineers” (Jones *et al.*, 1994). Many woodpeckers and other bird species engineer ecosystems by building nest holes used by a variety of other species (Daily *et al.*, 1993). Mobile link categories are not mutually exclusive (e.g. seabirds are both process linkers as predators of fish and resource linkers as transporters of nutrients from sea to land in their guano).

## 2.5 Typical avian ecosystem services

### 2.5.1 Seed dispersal

Currently, over a quarter of all frugivorous bird species are near threatened, threatened, or extinct. Avian seed dispersal is complex and variable, and changes in the populations of frugivorous birds will result in equally varied and often unpredictable changes in plant communities. The extent to which remaining species may compensate for disperser losses is unknown. Extinctions of seed dispersing birds are likely to reduce heterogeneity (Traveset *et al.*, 2001) and species richness (Tabarelli and Peres, 2002) of plant communities. As is the case with bird declines in general, the effects of seed dispersal will not be uniform and will be particularly felt in certain tropical taxa, such as Lauraceae, Burseraceae, and Sapotaceae that have large seeds with few large avian dispersers. These large frugivorous birds are significantly more threatened than average, which can have significant consequences for tropical forest communities with many shade-tolerant, late successional and dominant tree species with large seeds (Foster and Janson, 1985).

Large birds can disperse seeds dozens if not hundreds of kilometers away (Holbrook *et al.*, 2002). Since it is relatively rare and difficult to observe, the importance of long-distance dispersal by birds, especially over evolutionary time scales, has been underappreciated. Long-distance dispersal is now thought to be crucial (Cain *et al.*, 2000; Nathan, 2005), especially over geological time scales during which some plant species have been calculated to exhibit colonization distances 20 times higher than would be possible without vertebrate seed dispersers (Cain *et al.*, 2000). In this era of

rapid climate change, long-distance seed dispersal by birds is becoming a necessity for more and more plant species, but this ecosystem service may be rapidly eroding in parallel with bird populations, especially of large species. As the dispersers of large seeds disappear, small-seeded, vagile species, already better colonizers that are more adapted to disturbed, rapidly changing environments (Howe and Smallwood, 1982; Foster and Janson, 1985), will have fewer competitors in deforested areas, and will establish themselves “by default” (Terborgh *et al.*, 2002).

Furthermore, avian seed dispersers can contribute to the spread of such invasive species with generalized dispersal mechanisms (Renne *et al.*, 2002). Therefore, biotic homogenization via the replacement of specialist birds with generalist birds may contribute to increases in invasive plants. Losses of frugivorous birds will have significant implications for the ecology of forests and may result in the domination of many areas by short-lived pioneer species, with long-term effects cascading through the community.

### **2.5.2 Pollination**

Although it is not as common as seed dispersal by birds, avian pollination has ecological, economical, evolutionary, and conservation significance, especially in certain species-rich communities, such as tropical forest understory herbs, Australian sclerophyllous plants, and Andean cloud forest shrubs. There has been little research on the economic importance of avian pollination, but birds are thought to pollinate at least 3.5% and up to 5.4% of more than 1500 species of crop or medicinal plants, three

quarters of which cannot self-pollinate (Nabhan and Buchmann, 1997). Bird pollination of a number of economically important species has been demonstrated in Indomalayan (Narang *et al.*, 2000) and other (Nabhan and Buchmann, 1997) regions.

Reductions in avian pollinators will inevitably favor some plant species over others, as demonstrated by Bahama swamp-bush (*Pavonia bahamensis*), which experienced significant seed set reduction as a result of avian pollinator limitation following Hurricane Lili that also created sites for plant recruitment (Rathcke, 2000). Such changes in population dynamics caused by species' interactions are likely to lead to modifications in community composition in the short-term, and to have evolutionary consequences for plant lineages in the long-term (Thompson, 1996).

Birds are particularly important pollinators for sparsely distributed plant species with isolated populations (Ford, 1985) that suffer from increased pollen limitation (Groom, 2001). Both traits increase extinction likelihood, so it would be safe to say that declines in avian pollinators can have serious consequences for many rare plant species.

In fact, the extinction risk of Hawaiian native plants is associated with rarity and with bird pollination (Sakai *et al.*, 2002). If the extinctions of 31 species of Hawaiian Campanulaceae as a result of the disappearance of their avian pollinators (K. Wood pers. comm. in Cox and Elmqvist, 2000) is any indication; hundreds of plant species may have gone extinct on Pacific islands following extensive bird extinctions (Pimm *et al.*, 2006; Steadman, 1997). Introduced Polynesian rats (*Rattus exulans*) on the Easter

Island may have contributed to the extinction of the *Jubaea* palm (on which islanders depended for constructing fishing boats) by causing the extinction of its psittacid pollinator as well as by consuming *Jubaea* seeds (references in Cox and Elmqvist, 2000).

Even though nectarivores are currently among the least threatened of bird functional groups partially due to many hummingbird species' ability to utilize open habitats, this may change in the future since many of these species also have small global ranges. If the expected extinctions of nectarivorous birds do materialize, not only may we lose some of the most specialized and spectacular of bird species, but we may also be faced with the disappearances of their plant mutualists, which would have significant ecological and evolutionary repercussions.

### **2.5.3 Predation and pest control**

Comprising by far the most diverse avian functional group, insectivorous birds are ubiquitous, abundant, and essential components of most terrestrial ecosystems. Not only do these birds often have considerable influences on the behavior, evolution, ecology, and population sizes of their invertebrate prey, they can also modify the population dynamics and even evolution of plants through indirect effects. Furthermore, as invertebrate pests develop resistance to chemicals that often eliminate invertebrate predators, as increasing numbers of farmers switch to organic agriculture, and as pesticide use is curbed by public attitudes, environmental regulations, and consumer trends (Naylor and Ehrlich, 1997; Mourato *et al.*, 2000; Mols and Visser, 2002),

insectivorous birds will increase in significance as providers of natural pest control, components of integrated pest management, and indicators of healthy agroecosystems.

Therefore, it is rather disconcerting that many insectivorous birds in the USA are in decline (Sauer *et al.*, 2003) and that 12%-51% of all bird species feeding on invertebrates are expected to be functionally deficient by 2100. Although less threatened than the global average, insectivorous birds include far more extinction-prone species than any other group and widespread declines in tropical forest insectivorous birds (Thiollay, 1997; Sekercioglu, 2002a, b; Sodhi *et al.*, 2004), 26% of which are extinction-prone, should be a cause for concern. Extreme specializations of many insectivorous birds, especially in the tropics (Sherry, 1984; del Hoyo *et al.*, 2003), make it unlikely that other taxa can replace these birds' essential ecological services.

Although raptors as a group have a lower percentage of extinction-prone species than most other functional groups, large raptor species are more sensitive to disturbance and are more threatened than average. Furthermore, the expected functional extinctions of 13%-22% of raptor species may lead to trophic cascades in some ecosystems, particularly in the tropics where most of these extinctions are expected to take place. Declines in the largest tropical forest raptors, such as Crowned Eagles (*Harpyhaliaetus coronatus*, vulnerable), Harpy Eagles (near threatened), New Guinea Eagles (*Harpyopsis novaeguinae*, vulnerable), and Phillipine Eagles (*Pithecophaga jefferyi*, critically endangered), may have significant impacts on the numbers (Mitani *et al.*,

2001) and behavior (Cordeiro, 1992) of their prey, with further changes possible at lower trophic levels (Terborgh *et al.*, 2001).

Birds of prey often feed on many species and are well-connected hubs. Human-caused extinctions usually select against such large top predators (Ebenman *et al.*, 2004) and food webs are very vulnerable to the selective losses of hubs (Allesina and Bodini, 2004). Consequently, as populations of raptors, particularly large, tropical species decline and disappear, not only are we deprived of the thrill of observing some of the most majestic, inspirational, and symbolic creatures in existence, but we may also have to deal with the ecological and economical consequences of eliminating the drivers of crucial ecosystem processes.

#### **2.5.4 Birds as scavengers**

Scavengers, especially the obligate scavengers consisting of the Old and New World vultures (Houston, 1979), provide one of the most important yet under-appreciated and little-studied ecosystem services of any avian group due to the difficulty of and human aversion towards studying rotting substances (DeVault *et al.*, 2003). Compared to other avian functional groups, the obligate scavenger guild is tiny, comprised of only a few dozen species whose food consumption is predominantly based on scavenging. As such, even the declines or extinctions of a small number of species can result in significant reductions in avian scavenging; especially when one considers that in any one part of the world there are at most seven species of vultures.

Their scavenging nature requires that these birds represent the epitome of animal flight, and, ecologically and evolutionarily, vultures are in a unique and highly threatened class of their own. From prehistoric Africans likely following vultures to obtain carcasses to Andean and Californian natives revering condors to Neolithic Anatolians and present-day Parsis leaving their dead on *dakhmas*, vultures' unique status in ecosystems has always been paralleled in their special place in the human cultural landscape. It is now upon us to make sure that these majestic birds can continue to play their crucial roles in the biosphere and in the human psyche for the millennia to come.

#### **2.5.5 Nutrient deposition by birds**

Avian allochthonous inputs, particularly by seabirds, can provide substantial nutrient subsidies that are especially valuable in nutrient-poor ecosystems. Although in some guano-rich ecosystems, such as the Pacific coast of North America, guano-derived nutrients may be of limited consequence (Wootton, 1991) and excessive inputs can lead to pollution and eutrophication (Post *et al.*, 1998), on many low productivity islands the terrestrial ecosystem is largely subsidized by avian inputs (Sánchez-Piñero and Polis, 2000). On oceanic islands, many of which are nutrient poor (Anderson and Polis, 1999), nutrient inputs from sea to land can greatly increase nitrogen and phosphorous concentrations in soils, enriching plants and consequently, affecting the entire food web on these islands (Anderson and Polis, 1999).

Nutrient deposition by seabirds can be so important that seabird losses can trigger trophic cascades and ecosystem shifts (Croll *et al.*, 2005). Besides enriching soils,

seabirds may even create them. In polar areas with low levels of biological activity, seabirds may be the main agents of soil formation, as exemplified by Adelie Penguin (*Pygoscelis adeliae*) rookeries on Cape Bird, Antarctica (Heine and Speir, 1989). Guano production by seabirds also constitutes a significant socio-economic resource (Haynes-Sutton, 1987), especially for impoverished communities that cannot afford commercial fertilizers. Therefore, reductions in seabird guano, in addition to affecting natural communities, can also have agro-economical consequences for many people, particularly in the developing world.

Unfortunately, seabirds are among the most threatened of all avian taxa. Half of all species whose primary habitat is the sea are extinction-prone (Sekercioglu *et al.*, 2004), a proportion that is by far the largest among all habitat types. The unprecedented population crash of pelagic birds is one of the most important bird conservation crises of our time and will only get worse if the world fishing community and fish consumers are not fully engaged in finding and enforcing solutions.

#### **2.5.6 Ecosystem engineers**

Birds have a plethora of other roles in ecosystems that cannot be pigeon-holed into the main categories above. For example, grazing birds, such as geese and ducks can have significant impacts on the vegetation of some areas, particularly in wetlands and coastal areas where anatids are often concentrated. Although intensive grazing can lead to the degradation of some areas, such as the salt marshes on the shores of Hudson Bay damaged by Snow Geese (Kerbes *et al.*, 1990), ducks and geese can also reduce

agricultural residues in an environmentally-compatible manner, as opposed to open-field burning that has been restricted by legislation (Bird *et al.*, 2000).

Perhaps the least appreciated ecological contribution of birds is as ecosystem engineers (Jones *et al.*, 1994). This is partly because avian engineering rarely has the very visible effects of more prominent engineers such as beavers or trees, but nevertheless, some birds are ecosystem engineers, and sometimes in more ways than one (Daily *et al.*, 1993). Another reason for the relative lack of awareness is that ecosystem engineering itself has received little recognition until recently (Jones *et al.*, 1994). By definition: “Ecosystem engineers are organisms that directly or indirectly modulate the availability of resources (other than themselves) to other species, by causing physical state changes in biotic or abiotic materials. In so doing they modify, maintain, and/or create habitats” (Jones *et al.*, 1994).

Given that birds have limited capacity to change their surroundings physically (as opposed to corals, earthworms, or prairie dogs for example), some of the best examples of avian engineering come from bird nests. Even small bird nests often house beetles, moths, and other invertebrates (Collias and Collias, 1984). At the other extreme, colonial Social Weavers (*Phalacrocorax socius*) construct the largest nest of any bird species. In addition to providing a dwelling to many other organisms, such as snakes, Pygmy falcons (*Polyborus semitorquatus*), and countless invertebrates, these massive structures can even bring down trees. Even though not as extreme, there are various

other examples of large avian nests, particularly of raptors, weavers, and oropendolas, that have effects that go beyond the original nest builder.

Burrow-nesting European Bee-eaters (*Merops apiaster*) are allogenic ecosystem engineers in arid environments, since they remove large amounts of soil, increase the rate of soil loss, create nest burrows often used by other species, and attract burrow using invertebrates which are consumed as food by various birds (Casas-Crivillé and Valera, 2005). Trogons engineer in tropical forests (Valdivia-Hoeflich *etal.* 2005) and burrow-nesting seabird colonies can change soil fertility and lead to massive erosion (Furness, 1991).

The best examples of nest construction resulting in ecosystem engineering come from woodpeckers. Their unique behavior of drilling nest holes is arguably a more important contribution to ecosystems than the insectivorous habits they share with many other species, although woodpeckers' superior ability to extract invertebrates certainly benefits many trees. Because they drill nesting cavities which are later used by other, secondary cavity-nesting species, woodpeckers provide novel resources to other species by changing the physical structure of their environment and therefore, are ecosystem engineers par excellence. Since cavity nesting bird species often have higher nesting success (Knutson *et al.*, 2004), woodpeckers are important components of many avian communities.

Therefore, it is encouraging that woodpeckers (Picidae) comprise the only avian family that contains significantly fewer threatened species than expected (Bennett and Owens, 1997). This resilience may be a consequence of woodpeckers' ability to extensively engineer their habitats. Some woodpeckers assume further ecological importance as "double keystone" species, as in the case of sapsuckers (*Sphyrapicus* spp.), which provide bird and mammals with nest cavities as well as making nutritious sap available to dozens of vertebrate and invertebrate species (Daily *et al.*, 1993). Avian provisioning of sap is not limited to woodpeckers and is also seen in Akiapolaau (*Hemignathus munroi*), an endangered Hawaiian honeycreeper, whose decline may have adverse effects on the species that benefit from this sap (Pejchar and Jeffrey, 2004).

Possibly an important bird ecosystem engineer and perhaps one of the most significant of avian ecological factors may also be the one that has received the least recognition. The Passenger Pigeon (*Ectopistes migratorius*) is often presented as an example of a bird species, maybe the world's most abundant, whose decline from billions of birds in the mid 19th century to none by 1914 had no measured effects on its ecosystem (Simberloff, 2003). Unfortunately, no one thought to study the northern red oak (*Quercus rubra*) and white oak (*Quercus alba*) forests before Passenger Pigeons went extinct. It is likely that Passenger Pigeons, which preferred northern red oaks, had a diverse range of ecological effects on this forest via physical disturbance, nutrient deposition, and acorn consumption (Ellsworth and McComb, 2003).

Tree branch and stem breakage by billions of roosting birds, in addition to changing the forest structure, also built up fuel loads, and likely led to increased fire frequency and intensity in northern red oak forests. This, in combination with the consumption of vast numbers of acorns, may explain the dominance of white oaks in the range of Passenger Pigeons before their extinction, which possibly facilitated the range expansion of northern red oaks (Ellsworth and McComb, 2003).

#### 2.5.7 Seed consumers

Although birds may well be the most important seed dispersers, especially in the tropics, some granivorous birds, such as Passenger Pigeons, finches, and parrots, can be significant seed predators. Red Crossbills (*Loxia curvirostra*) in Spain consume more than 80% of the ripening seeds of relict Scots pines, whose regeneration is limited by the high rate of seed predation (Castro *et al.*, 1999). Avian seed predation may increase in tropical forest fragments since many tropical granivorous birds are more common in forest fragments and outside forests than in extensive forest. In the forest fragments of southeast Brazil, where rodent seed predators have declined and granivorous birds have increased, birds have become the most important, if not the main, seed predators of *Croton priscus* (Euphorbiaceae) (Pizo, 1997). In fact, granivorous birds are the most important avian pests of agriculture, although damage estimates are often exaggerated and often not collected in a scientific manner (Weatherhead *et al.*, 1982). Weatherhead *et al.* (1982) derived corn damage estimates by Red-winged Blackbirds (*Agelaius phoeniceus*) by combining energetics and life history information with a study of captive birds. The resulting damage estimate of 0.41% of total production agreed with

the range of 0.25-0.80% obtained by extensive damage sampling in nine other regions and was well below a 1975 government estimate.

The most notorious example of an avian seed predator is the Red-billed Quelea (*Quelea quelea*). It is the world's most numerous birds with 1-3 billion individuals (Elliott & Lenton, 1989) and the predominant avian pest in Africa. Nevertheless, detailed studies indicate that although local damage may be high, the impact on continental food production is negligible, with losses to cereal crops amounting to less than 1% of the production (Elliott and Lenton, 1989). This is in the region of losses caused by bird pests in other parts of the world (Weatherhead *et al.*, 1982; Elliott and Lenton, 1989). Also, considering the important ecological roles played by Red-billed Queleas as predators of insects, including pest species, as providers of nutrients that also fertilize fields and orchards, and as important food sources for many birds, mammals, and people (Elliott and Lenton, 1989), the extensive environmental damage and non-target deaths caused by explosives, fire bombs, and especially aerially-sprayed fenthion (Meinzingen *et al.*, 1989) cannot be justified. Fenthion has especially severe effects on aquatic species found in water bodies near quelea roosting sites and on predatory and scavenging birds (McWilliam and Cheke, 2004). Birds of prey can reduce quelea populations significantly (Bruggers and Elliott, 1989), but many of them die after spraying operations (Meinzingen *et al.*, 1989). Furthermore, many Africans collect and consume queleas killed by avicides and, are thus routinely exposed to dangerous chemicals (Jaeger and Elliott, 1989).

Mass killing of the other super-abundant granivorous bird, the Passenger Pigeon, may have had public health consequences as well. Oak masts are known to cause population explosions in white-footed mice (*Peromyscus leucopus*) (Blockstein, 1998), which reduce songbird populations directly through nest predation and indirectly by increasing avian predator populations (Schmidt and Ostfeld, 2003). It is likely that the consumption of a large portion of the oak mast by 2-3 billion Passenger Pigeons had limited white-footed mice numbers in the past. Most disconcertingly, white-footed mouse and the black-tailed deer (*Odocoileus hemionus*) are both vectors for Lyme ticks. The increase in the oak crop available to these mammals after the pigeons went extinct disease carrying may have increased their populations, contributing to the increased frequency of Lyme disease we observe today (Blockstein, 1998).

## **2.6 Bird services beyond ecosystems**

Beyond the typical avian ecosystem services, however, birds provide various other “indirect” services, ranging from the aesthetic to the critical to the esoteric, which contribute to human needs in meaningful ways (Filion, 1987). These cover the spectrum from Common Cranes (*Grus grus*) inspiring crane dances, the evidence for which goes back more than 8000 years at the Neolithic site of Çatalhöyük, Turkey (Russell and McGowan, 2003) to White-throated Dippers (*Cinclus cinclus*) serving as indicators of stream water quality (Ormerod and Tyler, 1993) to the economical contributions of millions of people who spend significant amounts of money and time to study, observe, photograph, and enjoy the birds of the world (Sekercioglu, 2002c).

### 2.6.1 Environmental monitors

Perhaps birds' most important indirect function in relation to human-dominated ecosystems is as environmental monitors. Their history here is long, particularly if one uses a liberal definition of environmental monitoring. Back in ancient Rome, domestic geese had a guarding function since they would make quite a racket in response to intruders, a service these birds still provide in a few remote places, such as the Kars province of Turkey. The classic example of avian environmental monitoring, however, is the use of caged canaries in coal mines to warn against the accumulation of toxic gases. These birds are much more sensitive than people to the build-up of carbon monoxide, and give distress signals or keel over before men can detect its presence. It was 1986 before some 200 canaries were phased out of the mining pits in Britain, where two per pit had been required since 1911, to be replaced by electronic gas detectors. At the time, the BBC commented that miners, who grew fond of the birds, "are said to be saddened by the latest set of redundancies in their industry, but do not intend to dispute the decision" (Anon. 1986). Birds have far more and ongoing significance, however, as indirect monitors. Indeed, the beginnings of the modern environmental movement in the USA can be traced to Rachel Carson's classic book, *Silent Spring* (Carson, 1962). The title alludes to the catastrophic impacts of broadcast DDT spraying on bird populations in the United States – presaging springs without birdsong. Carson's work had a catalytic effect on the environmental movement, rapidly creating public awareness and political action that culminated in the first Earth Day less than a decade later.

Since Silent Spring, birds have remained the leading indicators of environmental disruption in the eyes of both scientists and the general public. Scientists employ birds as monitors of various environmental factors, including overuse of pesticides, radionuclide contamination, fisheries stocks, marine pollution, streamwater quality, and wetland acidification (Diamond and Fillion, 1987; Furness and Greenwood, 1993; Bryce *et al.*, 2002). In addition, because so many people are devoted birdwatchers or maintain bird feeders, changes in avian population sizes and distributional status are detected early on and often highly publicized, particularly so with the rapid growth of “citizen science” projects involving bird enthusiasts (Anon. 2003a).

The immense publicity in the United States surrounding the decline of the Northern Spotted Owl (*Strix occidentalis occidentalis*), the extinction in the wild and captive breeding of the California Condor, and the recent rediscovery of the Ivory-billed Woodpecker (*Campephilus principalis*) (Fitzpatrick *et al.*, 2005) are cases in point. In New South Wales, Australia, there are road signs pointing out breeding areas for the endangered Regent Honeyeater (*Xanthomyza phrygia*). The status of rare and endangered bird species are now regularly detailed in journals such as *Bird Conservation International* and *Bulletin of the British Ornithologists' Club*. This interest in birdwatching is just one example of the intangible but integral services birds provide for people as sources of entertainment, wonder, and connecting with nature.

### **2.6.2 Bird watching and conservation**

Birds generate substantial income via birdwatchers that make significant economic contributions to many communities around the world (Sekercioglu, 2002c), not to mention creating a market that fuels the production of high-quality ornithological literature. Birdwatchers are one of the best sources of ecotourism income since they form the largest single group of ecotourists, are educated and have above-average earnings (Ceballos-Lascuráin, 1996; Cordell and Herbert, 2002; Sekercioglu, 2002c). Because of the zeal of many birdwatchers and the resources these people are willing to invest in this activity, birdwatching is becoming the most rapidly growing and most environmentally conscious segment of ecotourism and provides economic hope for many natural areas around the world.

The high expectations of many birdwatchers, combined with their high average incomes, often result in large financial contributions to the localities visited, especially in the case of self-reliant and independent birdwatchers (Kerlinger and Brett, 1995). In addition, information gathered by birdwatchers, such as during breeding bird surveys, Christmas bird counts and other “citizen science” projects (Anon. 2003b) can contribute substantially to ornithological knowledge, especially in tropical areas with few researchers (Mason, 1990).

Birdwatchers’ knowledge of birds and expectations of seeing a variety of species provide a direct link between avian biodiversity of a region and local income. Although birdwatchers are sometimes criticized for commodifying nature through “twitching” or

“listing”, this commodification actually makes it possible for local communities in areas with many and/or rare bird species to generate more income from hosting birdwatchers than other tourists. Because most birdwatchers know what they want to see and have high expectations of seeing certain species, they are likely to spend more money in order to see bird species in their natural environment than the average ecotourist who is not particularly interested in birds.

The consequent increase in the local awareness of the value of bird biodiversity may be key to preserving many natural areas near human population centers. Local people who observe the direct monetary benefits of biodiversity as a result of showing various species to birdwatchers are more likely to conserve ecosystems that harbor unusual birds. Better ecological knowledge and higher expectations of birdwatchers also result in the preservation of many patches of native habitat that host rare birds but do not have official protection.

In many places, indigenous people lack the education and essential financial resources required to invest in ecotourism and they usually qualify for the most menial and low-paid jobs (King and Stewart, 1996). Guiding for birdwatchers, however, values knowledge of natural history, has minimal language requirements, and is less demanding and better paid than jobs requiring hard labor. Birdwatching is a most promising branch of ecotourism because birdwatchers comprise a large and growing pool of educated and relatively wealthy individuals who desire to observe birds in their native habitats and whose activities have relatively low environmental impact. Among

various kinds of ecotourism, bird watching has the highest potential to contribute to local communities, educate locals about the value of biodiversity, and create local and national incentives for the successful protection and preservation of natural areas.

### 2.6.3 Birds as inspiration

As millions of birdwatchers would attest, birds have long been a source of wonder and curiosity for *Homo sapiens*, if for no other reason than their seemingly miraculous ability to fly. The legend of Daedalus and Icarus trying to escape the labyrinth of King Minos of Crete by imitating birds is a classic example and many ancient religions had gods embodied as raptors and other birds (Diamond, 1987b). Medieval Europeans were puzzled about where the birds went in the winter, and even came up with the idea that they dove into the sea and spent the season underwater. Owls symbolize wisdom in one culture, but were considered evil omens in others especially in Ghana. There may well be more folklore associated with Strigiformes than with any other bird order, and some of the best examples can be found in the owl family accounts in HandBook of the Birds of the World (HBW) (Bruce, 1999; Marks *et al.*, 1999).

Ancient Egyptians associated various birds with gods, with the sun god Horus typically represented as a falcon, Lappet-faced Vulture (*Torgos trachliotus*) pendants being placed in pharaonic graves, and Sacred Ibises (*Threskiornis aethiopicus*) being raised for sale to pilgrims to be placed in tombs as offerings. Birds of prey have had prominent roles as symbols of martial might far back into antiquity. In our own time, eagles still play that role as symbols of the United States and other armed forces, as well as of

nations such as Albania and Germany. The legendary beauty of some birds has been a major interest of people for virtually as long as records have been kept. Their feathers have long adorned everything from the warrior headdresses of Papua New Guinea to the robes of Hawaiian kings to the hats of Victorian ladies. Birds have been frequently featured both in secular and religious art avian mating displays have inspired various forms of human dancing (Russell and McGowan, 2003), and John James Audubon's bird paintings are so admired that some of his original prints now sell for over 100,000 Euros. To constantly benefit from these significant ecological functions of birds and beyond there is the need to protect and conserve birds.

## **2.7 Effects of disturbance or loss of tropical rainforest on birds**

Extensive tropical deforestation is a major threat to bird biodiversity. Approximately 50% of the area originally covered by tropical forest has now been cleared, and much of what remains is being rapidly degraded (Wright, 2005). This habitat loss is the primary cause of species endangerment and local extinctions (e.g. Brash, 1987, Castelletta *et al.*, 2000, Trainor, 2007). Given that 70% of the world's threatened bird species occur in lowland and montane tropical forests (Birdlife International, 2008), deforestation remains a major threat. It has been predicted that most of the currently threatened bird species could disappear by the end of this century if the present rate of deforestation continues (Pimm *et al.*, 2006). Although species disappearance is an expected consequence of outright habitat loss, much remains to be learned about the extinction process and how forest disturbance contributes to the decline of tropical birds.

### **2.7.1 Forest loss and avian endangerment**

Humans have affected the structure and function of ecosystems around the world, but the threat to tropical forest is of primary conservation concern, because they contain at least half of the Earth's biodiversity (Dirzo and Raven, 2003). Deforestation continues to accelerate in tropical countries, particularly in tropical Asia and Africa (Matthews, 2001, Hansen and DeFries, 2004). Countries with the largest annual net forest losses (e.g. Brazil and Indonesia) are located in the tropics, where collective losses averaged 8.2 million ha annually between 2000 and 2005 (Food and Agriculture Organization, 2005). Global forest-loss trends over the past decade and a half reveal that deforestation has been more pronounced and widespread in the tropics, regardless of forest cover type examined (i.e. total, natural or primary). There are also higher numbers of threatened and data-deficient birds in the tropics particularly in south-east Asia. These results broadly reinforce the connection between high tropical deforestation and increased avian endangerment suggested by other studies (e.g. Brooks *et al.*, 1997, Bird Life International, 2008).

### **2.7.2 Avian extinctions**

Human actions have raised the rate of bird extinctions by several orders of magnitude, and rates are predicted to rapidly increase (Sekericioglu *et al.*, 2004; Pimm *et al.*, 2006). As much as 67% of local tropical-forest avifauna has been reported to disappear following deforestation (Sodhi *et al.*, 2004), though species often persist for long periods in forest remnants, which leads to a "time lag" between the deforestation event and extinction (Brooks *et al.*, 1999). Bird communities in forest fragments are predicted

to undergo half the total number of extinctions they are likely to experience within 50 years of isolation (Brooks *et al.*, 1999). This time lag may also account for the lower-than-expected number of global extinctions attributable to deforestation that has been recorded thus far, particularly in continental systems (Brooks and Balmford, 1996). However, analyses have shown that the number of bird species expected to become extinct from deforestation is similar to the actual numbers of species classified as threatened (Brooks and Balmford, 1996, Brooks *et al.*, 1997).

Extinction risk is not distributed equally among bird species (Bennett and Owens, 1997, Sekercioglu *et al.* 2004, Sodhi *et al.*, 2004), but there has been little examination of which traits make tropical birds vulnerable. Various global analysis points to intrinsic biological traits e.g. slow life history, large body size (Gaston and Blackburn, 1995; Bennett and Owens, 1997) and extrinsic factors that result in small populations e.g. geographic range size; (Blackburn and Gaston, 2002) as being associated with high extinction risk. In addition, rare and specialized birds are particularly vulnerable to extinction following habitat loss (Owens and Bennett, 2000; Sekercioglu *et al.*, 2004; Sodhi *et al.*, 2004). Other analyses have, however, shown that even species that are flexible in their habitat choice (e.g. can inhabit secondary forests) do not survive extensive deforestation (Harris and Pimm, 2004).

### **2.7.3 Altered communities**

Disturbance and degradation alter forest communities and, thus, affect the survival of forest bird species in several ways. Increased access of open-country species to forests

can lead to greater competition for resources and greater predation pressure (Yap and Sodhi, 2004). Nest predation is also higher at the interface of forest and disturbed habitat (Gibbs, 1991; Burkey, 1993; Cooper and Francis, 1998), where certain predators may be more efficient in detecting nests. The loss of large predatory species associated with overexploitation in deforested areas (Daily *et al.*, 2003; Wright, 2003) may increase populations of small and medium-sized mammals (i.e. mesopredator release) and, thus, exacerbate birds' vulnerability to predation.

Typically, these mesopredators become more abundant following the decline of top predators and, thus, predation rates on avian young and eggs increase (Terborgh, 1992; Crooks and Soule, 1999). Therefore, elevated mesopredator population densities may explain some species extinctions in forest fragments (Sieving, 1992). Although some evidence points to predation pressure generally being lower in less disturbed forests (Cooper and Francis, 1998; Wong *et al.*, 1998), patterns across the tropics vary depending on the local fauna and the extent of disturbance (e.g. Carlson and Hartman, 2001; Posa *et al.*, 2007).

#### **2.7.4 Altered processes**

Declining bird population in the tropics have great implications for ecosystem processes, especially given that extinction threat is not uniformly distributed among avian functional groups, and some key groups such as scavengers, frugivores and insectivores are more threatened than the global average (Sekercioglu *et al.*, 2004).

Disruptions of ecological processes through species loss in degraded forests may also lead to cascading and catastrophic co-extinctions (Koh *et al.*, 2004). For instance, frugivory, a key interaction linking plant reproduction and dispersal with animal nutrition is placed in jeopardy by habitat degradation. Because many tropical trees have evolved to produce large, lipid-rich fruits adapted for animal dispersal (Howe, 1984), the demise of avian frugivores may have serious consequences for forest regeneration. Several examples exist (Brash, 1987; Cordeiro and Howe, 2001, 2003) of fruiting tropical trees that either failed to become re-established after harvest or become less numerous in fragments where the frugivorous bird responsible for the dispersal of their seeds has declined or disappeared. In turn, the declining availability of fruits in disturbed tropical forests that results from disrupted avian-mediated seed dispersal may prevent colonization and persistence of certain frugivores in disturbed habitat (Lambert, 1991; Zakaria and Nordin, 1998).

The biological control of herbivorous insects by birds may be of value in both anthropogenic and natural forest settings (Tscharnkte *et al.*, 2008). However, although it is clear that insectivorous birds play an important role in controlling outbreaks of herbivorous insects in agroforests (Perfecto *et al.*, 2004), there are fewer studies with comparable results in natural forest stands (Van Bael *et al.*, 2003; Sekercioglu, 2006).

Generally, insect herbivores inflict high damage in both the canopy and understory of forest stands that lack avian insectivores (Van Bael *et al.*, 2003; Van Bael and Brawn, 2005; Dunham, 2008); this ability of birds to control herbivorous insects complements

that of other insectivorous predators (Greenberg *et al.*, 2000), understory insectivores and frugivores are predicted to decline with increased disturbance and fragmentation of the tropical forest (Sekercioglu *et al.*, 2002); thus, the potential implications of the loss of birds of these two key trophic guilds for tropical forest productivity must be carefully examined. Although frugivory and insectivory are becoming better understood, more data are needed on how forest disturbance affects other avian functions such as pollination, vertebrate predation, and scavenging.

## **2.8 Knowledge on the effects of deforestation and its associated drivers on forest birds**

### **2.8.1 Forest fragmentation**

Currently, about 45 million hectares of tropical forest exist as fragments in the world's humid tropical regions (Achard *et al.*, 2002) that are scattered among urban areas, pastures, agricultural areas, and other types of land uses. Numerous studies document avian losses and population declines in tropical fragments (reviewed in Turner, 1996) and suggest that area isolation, and quality of fragments all influences the rate and order of species disappearance. Also, several studies have found that traits related to population size and recovery rate, such as rarity (Newmark, 1991), high population variability (Karr, 1982), low annual survival rates, and low fecundity (Karr, 1990; Sieving and Karr, 1997), may predict or account for species loss in fragments.

Terrestrial insectivores are now widely recognized as a fragmentation-sensitive guild (Karr, 1982, Kattan *et al.*, 1994; Stouffer and Bierregaard, 1995; Lambert and Collar,

2002, Sekercioglu *et al.*, 2002; Sigel *et al.*, 2006). Their limited dispersal abilities, high habitat-specificity, and dietary specialization are thought to underlie their propensity to disappear from fragments. For instance, Stratford and Stouffer (1999) found a 74% extinction rate for ground-foraging insectivores in Manaus, Brazil, even though some fragments were connected to contiguous forest by secondary growth. Species with specialized ecology, such as obligate ant-followers, are among the first to be lost from recently isolated fragments (Stouffer and Bierregaard, 1995). Because they require a large foraging area, birds that forage in mixed-species flocks are also adversely affected (Stouffer and Bierregaard, 1995; Sigel *et al.*, 2006, Van Houtan *et al.*, 2006).

Large-bodied frugivores are similarly fragmentation-sensitive, especially at higher elevations (Kattan *et al.*, 1994; Renjifo, 1999). Despite the typically high dispersal ability of canopy species, large frugivores are likely to depend on patchily distributed trees that fruit at different times, and the lowered vegetation diversity in small fragments may not support them (Willis, 1979). Similarly, forest-interior raptors that require large tracts of forest are sensitive to fragmentation (Kattan *et al.*, 1994; Thiollay 1996; Renjifo, 1999). Moreover, large-bodied frugivores and forest raptors may also be subjected to human persecution in open habitat because of their size (Peres, 2001).

Species persistence in fragmented landscapes is influenced by both patch-level and landscape-level factors. Forest-interior species are more affected by patch characteristics such as area, shape, plant species composition, vegetation structure, and extent of microclimatic change (Graham and Blake, 2001).

Edge-avoidance response has been found to be typical of Neotropical insectivores (Lindell *et al.*, 2007), such that certain species are reluctant to cross even relatively narrow roads (Laurance, 2004). For less restricted species, survival in fragments seems to be best predicted by their presence in the matrix of modified habitat surrounding the fragments (Gascon *et al.*, 1999; Renjifo, 2001; Sekercioglu *et al.*, 2002). The type and quality of the matrix, largely determined by the history and intensity of land use, can strongly influence processes within the fragments (Marzluff and Ewing, 2001; Kupfer *et al.*, 2006). Some matrices can provide foraging or breeding habitats (Sekercioglu *et al.*, 2007); structurally complex natural or anthropogenic matrices (i.e. tree plantations) have been found to provide the best fragment-connectivity (Gascon *et al.*, 1999; Renjifo, 2001). If suitable connecting habitat is present, it can allow individuals to recolonize fragments and even restore pre-isolation abundance of some species (Stouffer *et al.*, 2006). In remnants that are completely isolated, however, species richness erodes over time because of continued loss of species and lack of recolonization (Diamond *et al.*, 1987; Robinson, 1999; Sodhi *et al.*, 2006).

Our understanding of the effects of tropical fragmentation is still incomplete, because temporal observations have been recorded only for relatively short periods about 20 years; (Sodhi *et al.*, 2005; Stouffer *et al.*, 2006). Similarly, results inferred from comparing patches with contiguous forests do not paint a complete picture, because sensitive species may already have been extinct before the research was initiated (Graham and Blake, 2001; Manu *et al.*, 2007). To what degree fragmentation

exacerbates outright habitat loss is not well understood, but it is theorized to have a greater effect in the tropics than in temperate systems (Andren, 1994; Fahrig, 2003).

Modeling the effects of area and isolation on extinction and colonization dynamics; Ferraz *et al.*, (2007) found a stronger effect of area, suggesting that species are absent from small, isolated patches not because they are unable to colonize them but because they rarely occupy small patches, even in contiguous forest. Indeed, Van Houtan *et al.*, (2007) showed that tropical forest birds may be better dispersers than assumed but also preferentially disperse from smaller to large patches. It has been proposed that a critical threshold of 20 – 30% of habitat cover exists, below which the relative importance of habitat configuration for species persistence increases (Andren, 1994; Fahrig, 2003).

This is supported by a study that showed spatial organization to be important in sustaining source-sink dynamics and the retention of broader population structure in the face of some short-term local extinction in the highly fragmented Brazilian Atlantic forest (Develey and Metzger, 2006). Nonetheless, the general nature of this threshold needs to be verified, because minimum viable population sizes may depend on the level of connectivity in the landscape (Traill *et al.*, 2007; Brook *et al.*, 2008).

Since many frugivorous birds range widely to track highly variable fruit resources, forest areas below a certain size may not have enough fruiting trees to support somewide-ranging species, especially in the tropics. As a result, frugivorous birds, particularly large species, often decline in forest fragments (Kattan *et al.*, 1994). These

declines can exacerbate the manifold effects of fragmentation (Laurance & Bierregaard, 1997) and result in regional plant extinctions. In Spain, *Juniperus thurifera* declined in fragmented forest as a result of a nine-fold increase in rodent seed predators (*Apodemus sylvaticus*) coupled with a five-fold decrease in thrushes (*Turdus* spp.), whose seed dispersal services could not be replicated in fragments by less effective mammalian seed dispersers. In Australia, most avian providers of highest quantity and quality of dispersal, including of large seeds, had reduced abundance outside extensive forest. In central Amazonia, seedling establishment of *Heliconia acuminata* was 1.5-6 times higher in continuous forest than in 1 ha or 10 ha fragments. In Tanzania's East Usambara Mountains, Cordeiro and Howe (2001) showed that reductions in the numbers of frugivorous birds and primates in small forest fragments resulted in a three-fold decrease in the recruitment of the seedlings and juveniles of 31 animal-dispersed tree species, compared to no reductions in the recruitment of wind and gravity-dispersed species.

Furthermore, recruitment was 40 times lower for ten of the animal-dispersed species that were endemic to the area. Even generalist avian frugivores can decline significantly in fragments (Cordeiro and Howe, 2003), and combined with limited frugivore movement between fragments, this can result in severe reductions in seed dispersal. Avian seed dispersal in forest fragments may significantly favor introduced species over native ones, further modifying natural communities.

The increased mobility of avian seed dispersers with respect to mammals, as well as birds' higher capacity to travel through human-dominated rural landscapes (Graham and Blake, 2001) can enable better gene flow between increasingly fragmented plant populations. In fragmented ecosystems, particularly in the tropics, many specialized bird species can not leave forest fragments (Sekercioglu *et al.*, 2002) and avian seed dispersal declines rapidly away from forests. In such areas, even modest efforts like planting native trees to act as stepping stones or changing the geometry of clearings can significantly improve seed dispersal, increase connectivity of bird and plant populations, facilitate recolonization, and may help encounter the genetic effects of reduced pollination caused by fragmentation. These trees can also help sustain populations of some resilient native frugivores (Luck and Daily, 2003), such as African Pied Hornbills (*Tockus fasciatus*) in Ivory Coast. These birds, as the only large seed dispersers crossing open areas and moving between forest fragments, transport seeds up to 3.5 km away and facilitate the regeneration of and genetic exchange between fragmented forest plant populations.

### **2.8.2 Timber harvesting practices**

Selective logging is practiced in many tropical countries, where gaps between successive harvests of timber species are meant to allow forest to regenerate, resulting in a forest structure with a mix of tree sizes and ages that mimics natural stands. Available data for tropical birds indicate that many forest species continue to survive in, or use, selectively logged forest. Although some species vacate an area when logging begins but returns to it after it has been logged, this pattern is not universal (Thiollay,

1992; Dranzoa, 1998), and some communities remain distinct from the original for periods of 10 – 15 years (Johns, 1996; Thiollay, 1997, 1999). Logging can also results in significant changes in the relative abundances and composition of the avifauna, with an increase of widespread generalists or forest-edge species, compared with pristine forest (Johns, 1996; Thiollay, 1997; Dranzoa, 1998; Aleixo, 1999). This influx often accounts for the higher species richness in logged areas.

Selective logging affects various guilds differently. Some understory insectivores, as well as mixed-species flock members, are intolerant of the changes in microclimate and vegetation that occur after logging, because of their physiology and foraging-habitat specializations (Johns, 1986; Mason, 1996; Dranzoa, 1998; Marsden, 1998; Thiollay, 1999). However, in other cases, such species can benefit from understory regrowth (Cleary *et al.*, 2007). Guilds such as bark-associated insectivores and large-canopy frugivores (e.g. hornbills) decline after large trees are lost (Johns, 1989; Cleary *et al.*, 2007).

On the other hand, some studies report that nectarivores, generalist frugivores, omnivores, and gap or edge specialist seem to benefit from logging-related changes in vegetation (Lambert, 1992; Johns, 1996; Mason, 1996; Dranzoa, 1998; Owiunji and Plumptre, 1998; Thiollay, 1999). A global meta-analysis showed that insectivores and frugivores decrease after moderate disturbance of tropical forest, but patterns for carnivores, omnivores, and nectarivores differ among tropical regions (Gray *et al.*, 2007). There is little evidence that logging disproportionately threatens rare species or

those with restricted ranges (Thiollay, 1997; Marsden, 1998). There are, however, indications that populations that do not experience natural disturbance (e.g., hurricanes) may be more sensitive to logging (Aleixo, 1999).

Many logging concessions are in proximity to pristine forest from which birds can disperse, which may account for the minimal species loss and occurrence of some forest-dependent species in logged areas. The magnitude of impact on the avifauna can also depend on the management regime adopted by timber companies (Frumhoff, 1995; Mason, 1996; Sekercioglu, 2002). If harvest regimes do not allow logged forest to regenerate naturally, isolate them from unlogged compartments, or change regeneration dynamics, bird communities are unlikely to regain their pre-logging composition. However, one of the serious consequences of logging is increased access through roads, which can lead to hunting and a higher probability of further forest clearance (Thiollay, 1999; Asner *et al.*, 2006; Sodhi and Brook, 2006).

### **2.8.3 Infrastructure and urbanization**

Cities are expanding worldwide, and it is expected that more than half the world's total human population will be living in them by 2030 (Palmer *et al.*, 2004). Unlike other land uses, urbanization makes natural successional recovery difficult or impossible; thus, the effects on biodiversity are long-term. Urbanization increases biological homogenization, causing the extirpation of native species and promoting the establishment of non-native, urban-adaptable species that are becoming increasingly widespread and locally abundant across the planet (McKinney, 2006). There is a near-

complete absence of forest species in tropical urban areas, and human commensals such as Rock Doves (*Columba livia*) and House Crows (*Corvus splendens*) can attain high densities (Sodhi *et al.*, 1999; Lim and Sodhi, 2004; Pauchard *et al.*, 2006; Posa and Sodhi, 2006).

Some less sensitive native species, such as frugivores that can feed on fruit-bearing ornamental plants (Petit *et al.*, 1999; Lim and Sodhi, 2004; Posa and Sodhi, 2006), are able to persist in city parks and low-density housing areas. The presence of remnant natural habitats may be the most important determinant of forest bird diversity in tropical cities (Sodhi *et al.*, 1999; Lim and Sodhi, 2004). Therefore, it is unfortunate that cities in developing tropical countries typically do not maintain natural elements in the urban environment (Pauchard *et al.*, 2006; Posa and Sodhi, 2006). Understanding of the effects of urbanization in regions of high avian diversity such as the tropics is still rudimentary (Chace and Walsh, 2006), but measures for urban conservation will be crucial in the coming decades as urban sprawl is set to replace native and rural habitats.

#### **2.8.4 Agricultural practices**

The term “countryside habitat” has been used to encompass the diverse array of active agriculture, plantation or managed forests, fallow land, gardens, and small remnants of native vegetation in human-dominated landscapes (Daily *et al.*, 2001). Surveys in these landscapes have indicated that they can harbor a substantial proportion of the regional avifauna, forest species included (Estrada *et al.*, 1997; Daily *et al.*, 2001; Hughes *et al.*, 2002; Sodhi *et al.*, 2005). However, the value of the different uses for maintaining avian

biodiversity varies considerably (Peh *et al.*, 2005; Posa and Sodhi, 2006; Soh *et al.*, 2006).

Conversion of forest into pasture for cattle grazing has had the greatest impact, resulting in a near-total absence of birds in the heavily modified landscapes of some regions (Saab and Petit, 1992; Estrada *et al.*, 1997; Petit *et al.*, 1999). Low species richness is also observed in other intensively managed plantations, especially in monocultures of non-arboreal annual crops (Estrada *et al.*, 1997; Matlock *et al.*, 2002; Waltert *et al.*, 2004). Open-country species dominate these habitats, because forest birds are sensitive to the extreme climate conditions there. Arboreal crops such as shade coffee (*Coffea spp.*), Cacao (*Theobroma cacao*), and Cardamom (*Elettaria cardamomum*) support a greater number of forest bird species, particularly if natural vegetation is allowed to grow (Estrada *et al.*, 1997; Greenberg *et al.*, 1997; Shahabuddin, 1997; Petit *et al.*, 1999).

Remnant forest trees and riparian strips can be disproportionately important for forest birds persisting in tropical countryside (Sekercioglu *et al.*, 2007). Some primary-forest birds can use older plantations of exotic trees that allow secondary growth (Mitra and Sheldon, 1993) or traditional agroforests that are diverse and structurally complex (Thiollay, 1995); however, species richness and diversity are still lower than in primary forest. Similarly, the successional vegetation that results from practices such as shifting cultivation (i.e., slash-and-burn) or from the abandonment of “permanent” agriculture can be colonized by forest birds. Species richness and abundance have been found to

parallel recovery of vegetation (Bowman *et al.*, 1990; Blankespoor, 1991; Andrade and Rubio-Torgler, 1994; Raman *et al.*, 1998).

Secondary forest regrowth from agricultural fallows can contain a significant proportion of forest avifauna, as well as secondary-growth specialists (Blankespoor, 1991; Raman *et al.*, 1998). However, these habitats are still suboptimal for forest-dependent species (Raman, 2001), whereas traditional systems of shifting agriculture practiced on small scales, with long intervals between burning and recropping, may minimally affect the avifauna (Zhijun and Young, 2003).

The degree of similarity between species assemblages in countryside habitats and in pristine forest appears to depend on land-use patterns and landscape context (Luck and Daily, 2003). Pesticides adversely affect insectivores, as does the lack of leaf litter and low vegetational diversity in agriculture (Shahabuddin, 1997), but the same birds benefit from insect pests in timber plantations (Mitra and Sheldon, 1993). Although large frugivores generally do not benefit from the dominating crop trees of agroforests and are absent from plantations in some areas (Thiollay, 1995; Shahabuddin, 1997), they have been observed in other mixed rural habitats (Sodhi *et al.*, 2005). However, such patterns may be attributable to the proximity of pristine forest to study areas (Barlow *et al.*, 2007).

## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1 Study sites

The study was conducted in the Eastern Region of Ghana between January and March 2011. The agro-ecosystems were the Oil palm plantation of the Ghana Oil Palm Development Company (GOPDC) Limited at Kwaie in the Kwaebibirem District near Kade and the Cocoa farms of the Ghana Cocoa Board (COCOBOD) Cocoa Research Seed Production Unit at Pankese in the Birim District near Nkawkaw; the Esukawkaw Forest Reserve (EFR) near Kadewaso served as the natural forest.

##### **Kwaie estate**

Kwaie Estate lies on the latitude  $6^{\circ} 15' 0''$  North, and longitude  $0^{\circ} 59' 60''$  East covering a total concession of 8,953 ha of which approximately 5,205 ha were developed. It lies at an altitude of 221 meters and  $6^{\circ}$  North and  $0^{\circ} 58' 0''$  West (Fig.1). The entire catchment area for the GOPDC Ltd. is as shown in Fig. 2. Fig.3. shows years of establishment of the GOPDC limited plantation. The land mass is flat and the vegetation is the moist semi-deciduous type and characterized by tall trees with an average height of about 40 metres.

##### **Pankese seed production unit**

The geographical coordinates of Pankese are  $6^{\circ} 31' 0''$  North and  $0^{\circ} 51' 0''$  West, lying between latitude  $-6.5166667^{\circ}$  and longitude of  $-0.85^{\circ}$ . It occupies an area of about 70

ha. The land mass is flat and the vegetation is the moist semi-deciduous type and characterized by tall trees with an average height of about 40 metres. Obviously the area is devoid of any closed forest except the nearby forest reserves namely, Mamang, Bediako, Aiyala, Nsuenasa, Gyaadi, Akyikyiresu and the University of Ghana Agricultural Research Center Forest Reserve, all of which have been grossly modified as a result of years of selective logging. The cocoa farms with clusters of tall emergents give an appearance of a closed forest.



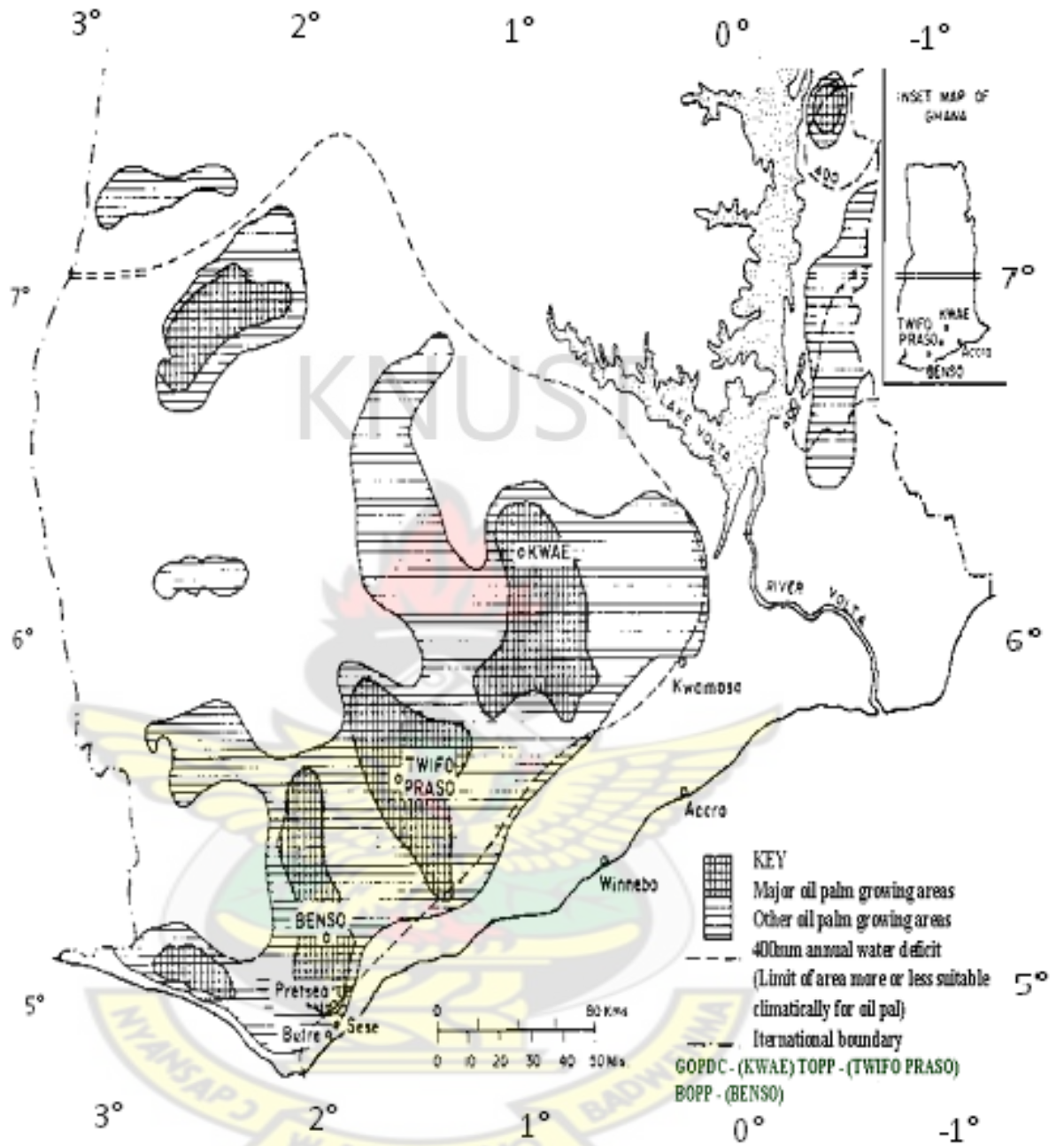
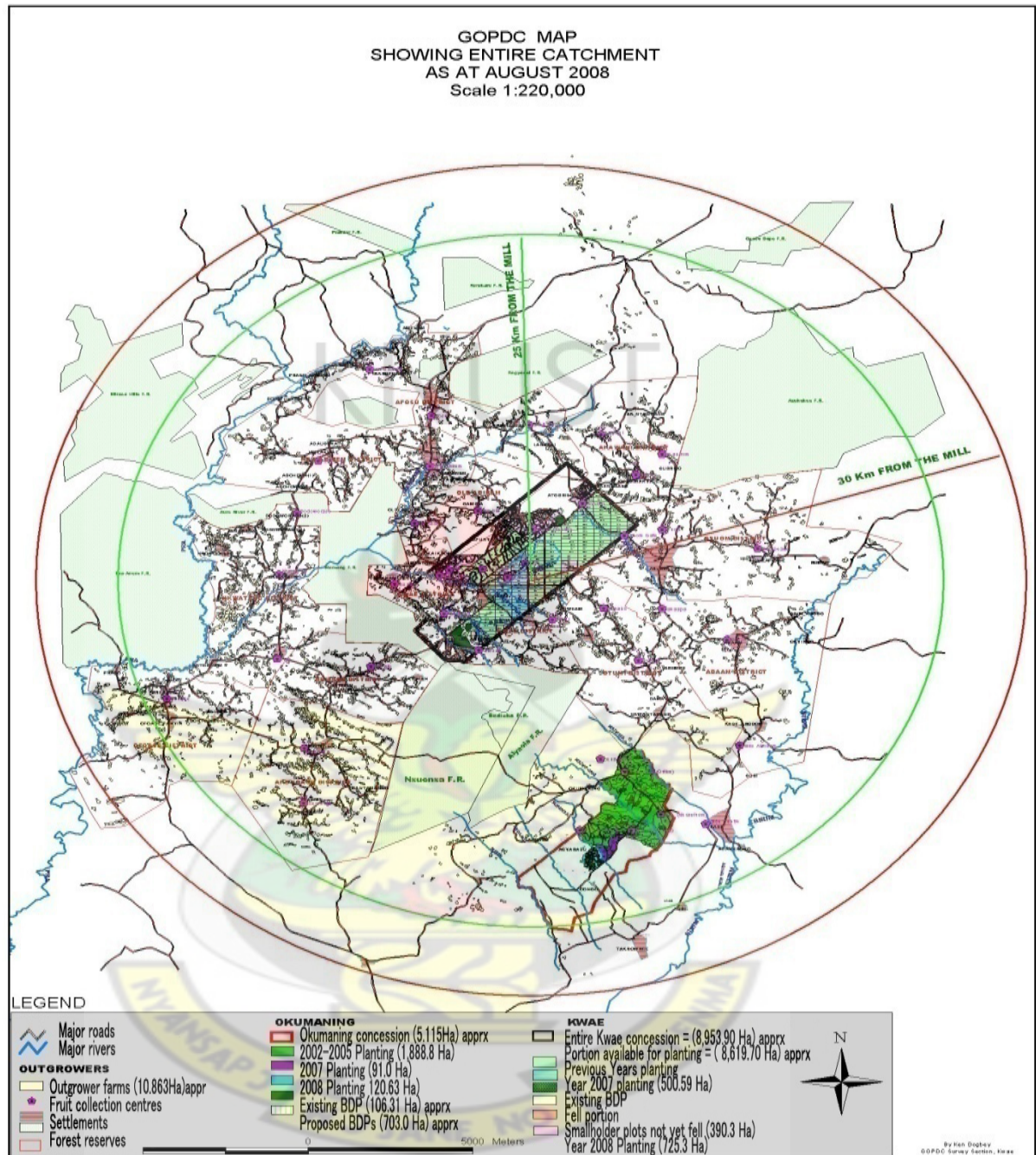


Figure 1: Map of southern Ghana showing the location of Kwae.



**Figure 2: Ghana Oil Palm Development Company (GOPDC) ltd. map showing the entire catchment area as at august, 2008.**

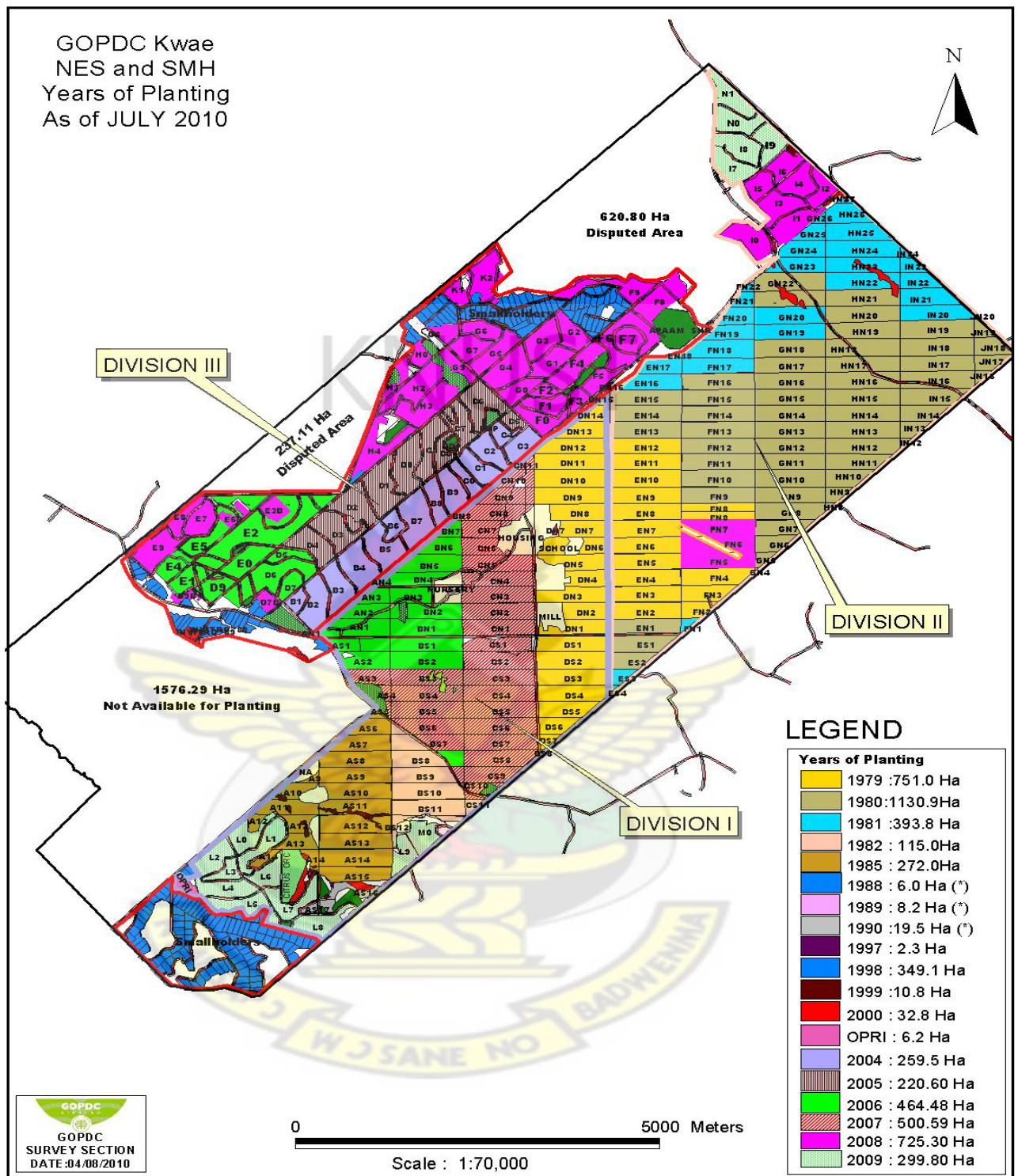


Figure 3: Ghana oil palm development company (GOPDC) ltd. Kwaie, years of planting as of July, 2010.

### **Esukawkaw forest reserve**

Esukawkaw Forest Reserve (EFR) lies between latitude 6 °18' and 6 °26' North and longitudes °

KNUST



EFR is traditionally and predominantly Akyem Abuakwa with settler groups of predominantly Krobos/Adangbes, Ewes and the Kyerepong/Anums.

### 3.2 Methods

Line transect survey technique (Seber, 1973; Eberhardt, 1978 and Burnham *et al.* 1980) was used in the bird species survey in the three study sites. The procedure involved a slow walk along four one-km transects into which the areas were divided. During the survey, notes were taken on visual observations of bird species and bird vocalisation with a critical assumption that birds were not counted more than once. Field binoculars (Olympus 8 X 45 WP1) were used to assist in the observation of bird species. Nomenclature of birds was after Borrow and Demey, (2004). In the survey areas, transects were walked along existing tracks that were cut for harvesting and transport of Oil Palm fruits, and Cocoa pods. Field work was carried out from early in the morning at 6:00 am until 10:00 am and again from 4:00 pm until 6:00 pm in the evening each day.

### 3.3 Data analysis and calculation of community parameters

All records were in a tabular form in the excel data sheet and analysed. The following formulae were used for calculating;

#### 1. Relative Dominance:

$$\text{Relative Dominance} = \frac{n_i}{N} \times 100;$$

Where  $n_i$  = the number of individuals of a species,

$N$  = total number of individuals of all the species seen during the study period.

2. Abundance = number of individuals/km.
3. Frequency of occurrence =  $\frac{\text{number of transects in which a species is found}}{\text{total number of transects}} \times 100$
4. Shannon – Weiner diversity index ( $H = - \sum p_i \ln p_i$ ) was calculated for each site; where  $p_i$  is the proportion of individuals found in the  $i$ th species (Magurran, 1988).
5. One – way analysis of variance (ANOVA) was used to test for differences between sites in species richness and diversity values.

Values calculated by these indices were then used to perform t – tests (95% confidence) comparing diversity among the three habitat types. Spearman’s rank correlation was used to test for any relationship between bird numbers and habitat types.

For the purpose of this study, the relative status of each species based on the frequency of occurrence was classified as follows:

- Abundant: species occurring from 76-100%
- Common: species occurring from 51%-75%
- Uncommon: species occurring from 26%-50%
- Rare: species found from 1%-25% of the transects

All computations were done using Microsoft Excel and statistical software Minitab 14.1 (2003).

## CHAPTER FOUR

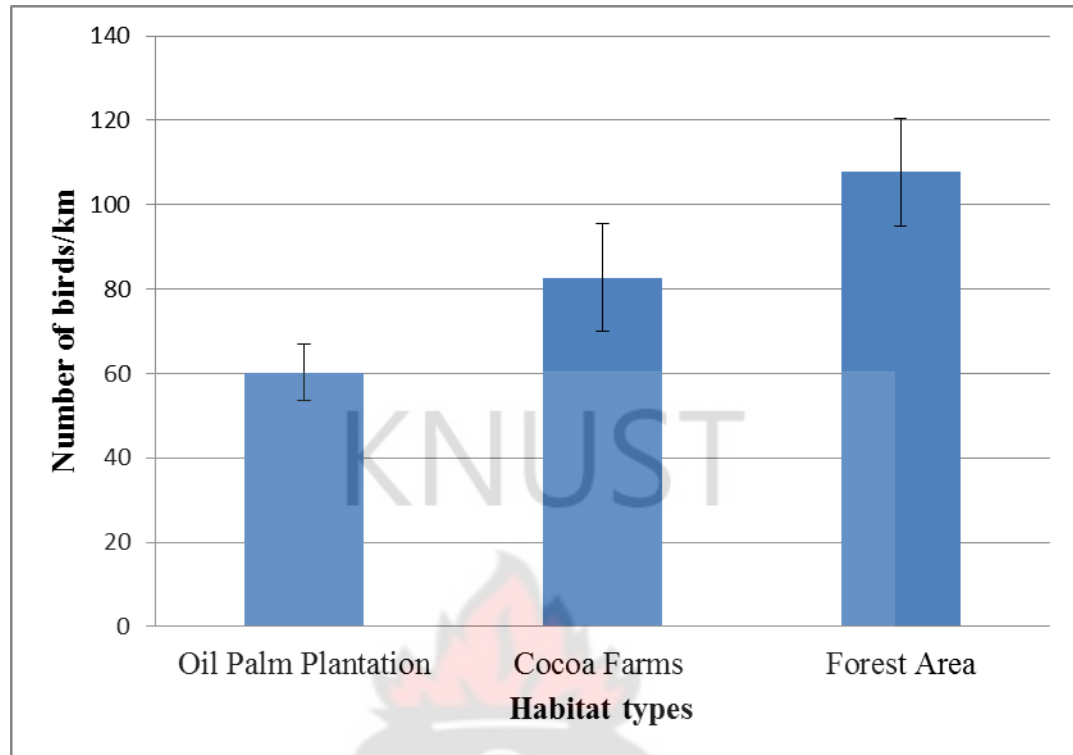
### RESULTS

#### 4.1 Species composition and density

The total number of birds encountered was 240 at a mean of 60.25 (SD = 6.65) per km at the Kwae habitat type. At Pankese the total number of birds was 330 at a mean of 82.75 (SD = 12.79) per km and 431 birds were encountered at the Esukawkaw Forest reserve at mean number of 107.75 (SD = 12.84) per km (Figure 4).

Analysis of variance was conducted to evaluate the hypothesis that species abundance of birds occurring in the three habitat types of oil palm plantations (Kwae), cocoa farms (Pankese) and forest area (Esukawkaw forest reserve) were the same. At 0.05 alpha level the difference of means of all the populations were significant at  $p < 0.05$  ( $F = 3.96$ ,  $df = 2$ ,  $p = 0.02$ ) and Levene's test for equal variance also indicated a significant difference between the variance of all the species populations. This then rejects the hypothesis.

When Mann-Whitney U-test was used to evaluate the differences of the abundance of birds between any two habitat types, it was found that the number of birds in the oil palm plantation did not differ from the number of birds in cocoa farms as  $p > 0.05$  ( $U = 5592$ ,  $p = 0.2348$ ) but differed significantly from the forest area as  $p < 0.05$  ( $U = 2283$ ,  $p = 5.345E-16$ ). In addition, the number of birds in the cocoa farm also differed from the forest area as  $p < 0.05$  ( $U = 3189$ ,  $p = 5.299E-10$ ).

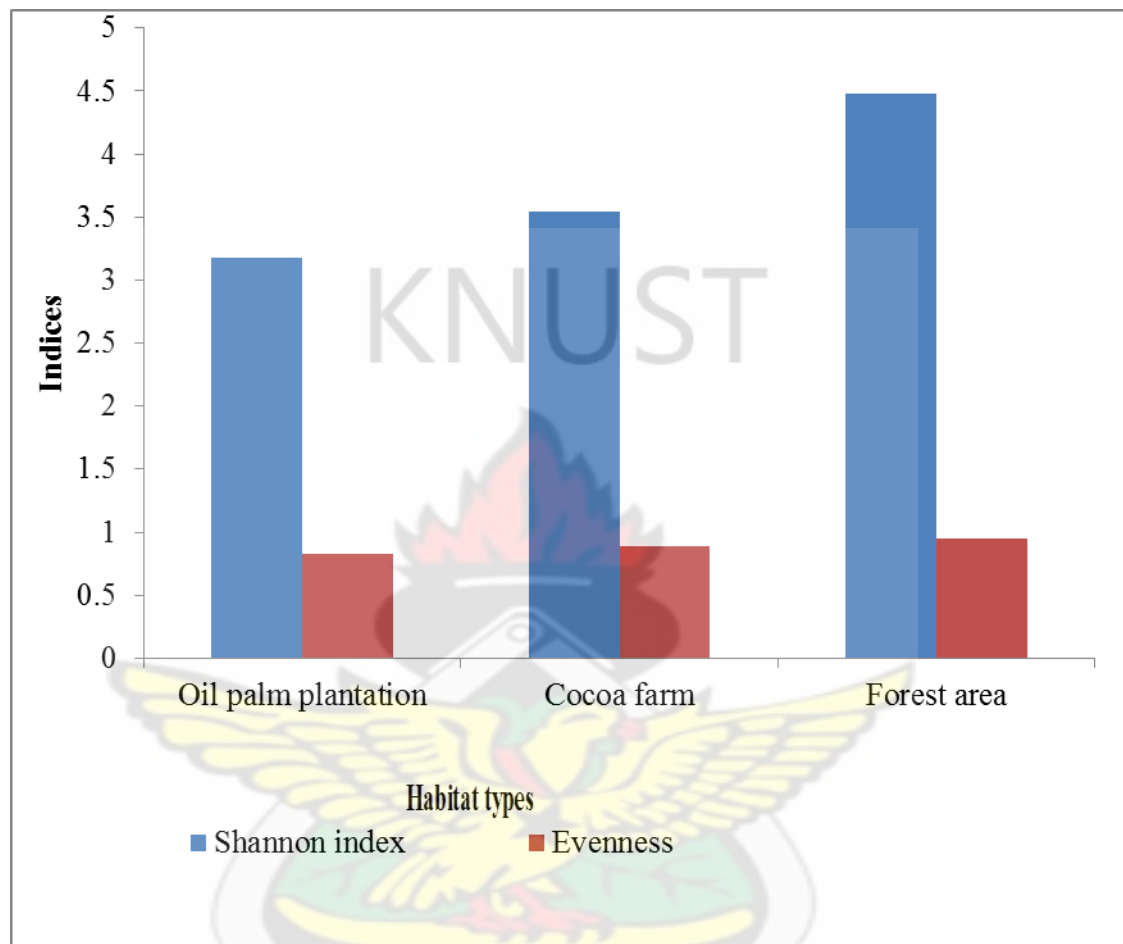


**Figure 4: Density of birds occurring in the three habitat types.**

#### **4.2 Diversity of birds occurring in oil palm plantation, cocoa farm and forest area**

The Shannon diversity index of bird species surveyed in the oil palm plantation was 3.18 (3.97, 4.19 at 95% confidence limit (C.L.)) and evenness of 0.83 (0.92, 0.95 at 95% C.L.); in the cocoa farms it was 3.54 (4.03, 4.23 at 95% C.L.) and evenness of 0.89 (0.91, 0.94 at 95% C.L.) and in the forest area it was 4.48 (4.11, 4.28 at 95% C.L.) and evenness of 0.95 (0.91, 0.94 at 95% C.L.). This has been graphically shown in Figure 5. Diversity t test was conducted to test the hypothesis that diversity of birds within any two habitat types was the same. Results indicated that diversity of birds in the oil palm plantation differed from that of cocoa farms as  $p < 0.05$  ( $t = -4.0149$ ,  $p = 6.963E-5$ ) and also from the forest area since  $p < 0.05$  ( $t = 15.3150$ ,  $p = 0.00000$ ). On the other hand,

diversity of birds found in the cocoa farms differed from that of the forest as  $p < 0.05$  ( $t = -14.063$ ,  $p = 1.0836E-38$ ).



**Figure 5: Graphical representation of bird diversity and evenness of the three habitat types.**

#### 4.3 Bird abundance, dominance and frequency of occurrence

In the forest area the number of birds (abundance) ranged from a minimum of 0.3bird/km to a maximum of 5.0 birds/km with the median being 0.8 bird/km. *Gymnobucco calvus* was the only species with maximum abundance of 5.0 but the abundance of others like *Treron calva*, *Torcu fasciatu*, *Andropadus latirostris* were

relatively high whereas species like *Buteo auguralis*, *Halcyon badia*, *Pogoniulus scolopaeceus* occurred in relatively smaller numbers. On equitability of habitat sharing species such as *Gymnobucco calvus* (4.6%), *Hedydipna collaris* (2.6%), *Treron calva* (2.6%), *Torcuafasciatus* (2.3%) were dominating as opposed to species such as *Accipiter toussenelii* (0.2%), *Macrosphenus flavicans* (0.2%), *Halcyon badia* (0.2%) (Table 1). On status of birds seen during the survey 36% were rare, 30.6% as uncommon, 17.1% as common and 16.3% as abundant.

**Table 1: List of birds found in the Esukawkaw forest reserve. (Numbers are based on recordings on 4km transects)**

| FAMILY       | COMMON NAME              | SCIENTIFIC NAME                 | Abundance<br>(individual/km) | Dominance<br>(%) | Frequency of<br>occurrence<br>(%) |
|--------------|--------------------------|---------------------------------|------------------------------|------------------|-----------------------------------|
| Accipitridae | African Harrier Hawk     | <i>Polyboroides typus</i>       | 0.8                          | 0.7              | 75.0                              |
| Passeridae   | African Goshawk          | <i>Accipiter toussenelii</i>    | 0.3                          | 0.2              | 25.0                              |
| Falconidae   | Red-necked Buzzard       | <i>Buteo auguralis</i>          | 0.3                          | 0.2              | 25.0                              |
| Collumbidae  | Red-eyed Dove            | <i>Streptopelia semitoquata</i> | 0.5                          | 0.5              | 25.0                              |
| Collumbidae  | Tambourine Dove          | <i>Turtur tympanistria</i>      | 0.8                          | 0.7              | 75.0                              |
| Collumbidae  | Blue Headed wood Dove    | <i>Turtur brehmeri</i>          | 2.3                          | 2.1              | 100.0                             |
| Collumbidae  | African Green Pigeon     | <i>Treron calva</i>             | 2.5                          | 2.3              | 100.0                             |
| Musophagidae | Yellow Billed Turaco     | <i>Tauraco macrorhynchus</i>    | 2.0                          | 1.9              | 100.0                             |
| Cuculidae    | Olive Long-Tailed Cuckoo | <i>Cercococcyx olivinus</i>     | 1.0                          | 0.9              | 25.0                              |
| Cuculidae    | Didric Cuckoo            | <i>Chrysococcyx caprius</i>     | 0.5                          | 0.5              | 50.0                              |
| Cuculidae    | Klaas Cuckoo             | <i>Chrysococcyx klaas</i>       | 0.5                          | 0.5              | 25.0                              |
| Cuculidae    | African Emerald Cuckoo   | <i>Chrysococcyx cupreus</i>     | 0.5                          | 0.5              | 50.0                              |
| Cuculidae    | Black Cuckoo             | <i>Cuculus clamosus</i>         | 0.3                          | 0.2              | 25.0                              |
| Cuculidae    | Yellow Bill              | <i>Ceuthmochares aereus</i>     | 2.0                          | 1.9              | 75.0                              |
| Alcedinidae  | Woodland Kingfisher      | <i>Halcyon badia</i>            | 0.3                          | 0.2              | 25.0                              |

| Table 1 cont'd       |                             |                                 |     |     |       |
|----------------------|-----------------------------|---------------------------------|-----|-----|-------|
| <b>Coraciidae</b>    | Blue-Throated Roller        | <i>Eurystomus gularis</i>       | 0.8 | 0.7 | 50.0  |
| <b>Phoeniculidae</b> | White-Headed Wood Hoopoe    | <i>Pheoniculus bollei</i>       | 1.5 | 1.4 | 75.0  |
| <b>Phoeniculidae</b> | Forest Wood-Hoopoe          | <i>Pheoniculus castaneiceps</i> | 0.5 | 0.5 | 25.0  |
| <b>Bucerotidae</b>   | African Pied Hornbill       | <i>Torqus fasciatus</i>         | 2.8 | 2.6 | 100.0 |
| <b>Bucerotidae</b>   | Piping Hornbill             | <i>Bycanistes fistulator</i>    | 1.5 | 1.4 | 75.0  |
| <b>Capitonidae</b>   | Necked-Faced Barbet         | <i>Gymnobucco calvus</i>        | 5.0 | 4.6 | 100.0 |
| <b>Capitonidae</b>   | Bristle-Nosed Barbet        | <i>Gymnobucco peli</i>          | 1.0 | 0.9 | 50.0  |
| <b>Capitonidae</b>   | Speckled Tinker Bird        | <i>Pogoniulus scolopaeus</i>    | 0.5 | 0.5 | 50.0  |
| <b>Capitonidae</b>   | Red-Rumped Tinker Bird      | <i>Pogoniulus atroflavus</i>    | 1.5 | 1.4 | 50.0  |
| <b>Capitonidae</b>   | Yellow Throated Tinker Bird | <i>Pogoniulus subsulphureus</i> | 1.0 | 0.9 | 25.0  |
| <b>Capitonidae</b>   | Yellow Spotted Barbet       | <i>Buccanodon duchailui</i>     | 0.5 | 0.5 | 25.0  |
| <b>Capitonidae</b>   | Hairy-Breasted Barbet       | <i>Tricholaema hirsuta</i>      | 1.0 | 0.9 | 50.0  |
| <b>Capitonidae</b>   | Yellow-Billed Barbet        | <i>Trachylaemus purpuratus</i>  | 0.5 | 0.5 | 25.0  |
| <b>Indicatoridae</b> | Cassin's Honey Bird         | <i>Prodotiscus insignis</i>     | 0.5 | 0.5 | 50.0  |
| <b>Picidae</b>       | Little Green Wood Pecker    | <i>Campethera maculosa</i>      | 0.5 | 0.5 | 25.0  |
| <b>Picidae</b>       | Buff-Spotted Wood Pecker    | <i>Campethera nivosus</i>       | 0.8 | 0.7 | 75.0  |
| <b>Picidae</b>       | Gabon woodpecker            | <i>Dendropicos gabonensis</i>   | 0.8 | 0.7 | 50.0  |
| <b>Picidae</b>       | Fire-Bellied Wood Pecker    | <i>Dendropicos pyrrhogaster</i> | 1.0 | 0.9 | 50.0  |
| <b>Eurylaimidae</b>  | Rufous-sided Broadbill      | <i>Smithornis rufolateralis</i> | 0.8 | 0.7 | 50.0  |
| <b>Campephagidae</b> | Blue Cuckoo-Shrike          | <i>Coracina azurea</i>          | 0.8 | 0.7 | 25.0  |
| <b>Pycnonotidae</b>  | Common Bulbul               | <i>Pycnonotus barbatus</i>      | 1.8 | 1.6 | 75.0  |
| <b>Pycnonotidae</b>  | Little Greenbul             | <i>Andropadus virens</i>        | 2.0 | 1.9 | 100.0 |
| <b>Pycnonotidae</b>  | Little Greybul              | <i>Andropadus gracilis</i>      | 1.5 | 1.4 | 75.0  |

| Table 1 cont'd      |                            |                                   |     |     |       |
|---------------------|----------------------------|-----------------------------------|-----|-----|-------|
| <b>Pycnonotidae</b> | Ansorge's Greenbul         | <i>Andropadus ansorgei</i>        | 0.8 | 0.7 | 50.0  |
| <b>Pycnonotidae</b> | Cameroon Sombre Greenbul   | <i>Andropadus curvirostris</i>    | 1.3 | 1.2 | 100.0 |
| <b>Pycnonotidae</b> | Slender-billed Greenbul    | <i>Andropadus gricilirostris</i>  | 1.5 | 1.4 | 50.0  |
| <b>Pycnonotidae</b> | Yellow-whiskered Greenbul  | <i>Andropadus latirostris</i>     | 2.5 | 2.3 | 75.0  |
| <b>Pycnonotidae</b> | Honeyguide Greenbul        | <i>Baeopogon indicator</i>        | 1.0 | 0.9 | 50.0  |
| <b>Pycnonotidae</b> | Simple leaflove            | <i>Chlorochicla simplex</i>       | 1.0 | 0.9 | 100.0 |
| <b>Pycnonotidae</b> | Swamp Palm Bulbul          | <i>Thescelocichla leucopleura</i> | 2.0 | 1.9 | 100.0 |
| <b>Pycnonotidae</b> | Icterine Greenbul          | <i>Phyllastrephus icterinus</i>   | 2.5 | 2.3 | 100.0 |
| <b>Pycnonotidae</b> | White-Throated Greenbul    | <i>Phyllastrephus albigularis</i> | 0.5 | 0.5 | 25.0  |
| <b>Pycnonotidae</b> | Grey-Headed Bristledbill   | <i>Bleda canicapillus</i>         | 2.0 | 1.9 | 100.0 |
| <b>Pycnonotidae</b> | Spotted Greenbull          | <i>Ixonotus guttatus</i>          | 1.5 | 1.4 | 50.0  |
| <b>Pycnonotidae</b> | Western Nicator            | <i>Nicator chloris</i>            | 1.0 | 0.9 | 50.0  |
| <b>Turdidae</b>     | Forest Robin               | <i>Stiphrornis erythrothorax</i>  | 0.3 | 0.2 | 25.0  |
| <b>Sylviidae</b>    | Yellow-Browed Camaroptera  | <i>Cameroptera superciliaris</i>  | 0.5 | 0.5 | 25.0  |
| <b>Sylviidae</b>    | Olive-Green Camaroptera    | <i>Cameroptera chloronota</i>     | 0.5 | 0.5 | 50.0  |
| <b>Sylviidae</b>    | Rufous-Crowned Eremomela   | <i>Eremomela badiceps</i>         | 1.3 | 1.2 | 50.0  |
| <b>Sylviidae</b>    | Green Crombec              | <i>Sylvietta virens</i>           | 0.8 | 0.7 | 50.0  |
| <b>Sylviidae</b>    | Grey Longbill              | <i>Macrosphenus concolor</i>      | 0.5 | 0.5 | 25.0  |
| <b>Sylviidae</b>    | Yellow Longbill            | <i>Macrosphenus flavicans</i>     | 0.3 | 0.2 | 25.0  |
| <b>Sylviidae</b>    | Green Hylia                | <i>Hylia prasina</i>              | 1.3 | 1.2 | 25.0  |
| <b>Muscicapidae</b> | Ussher's Flycatcher        | <i>Muscicapa ussheri</i>          | 1.3 | 1.2 | 50.0  |
| <b>Muscicapidae</b> | Fraser's Forest Flycatcher | <i>Fraseria ocreata</i>           | 1.0 | 0.9 | 75.0  |
| <b>Muscicapidae</b> | Grey-Throated Flycatcher   | <i>Muscicapa griseigularis</i>    | 0.5 | 0.5 | 25.0  |
| <b>Monarchidae</b>  | Chestnut-capped Flycatcher | <i>Erythrocercus mccallii</i>     | 1.8 | 1.6 | 75.0  |

| Table 1 cont'd        |                                 |                                |     |     |       |
|-----------------------|---------------------------------|--------------------------------|-----|-----|-------|
| <b>Monarchidae</b>    | Red-Bellied Paradise Flycatcher | <i>Terpsiphone rufiventer</i>  | 0.8 | 0.7 | 50.0  |
| <b>Platysteiridae</b> | Common Wattle-Eye               | <i>Platysteira Cyanea</i>      | 1.0 | 0.9 | 50.0  |
| <b>Muscicapidae</b>   | Black and White Flycatcher      | <i>Bias musicus</i>            | 0.8 | 0.7 | 75.0  |
| <b>Muscicapidae</b>   | Shrike Flycatcher               | <i>Megabyas flammulatus</i>    | 0.8 | 0.7 | 50.0  |
| <b>Timaliidae</b>     | Blackcap Illadopsis             | <i>Illadopsis cleaveri</i>     | 0.8 | 0.7 | 50.0  |
| <b>Timaliidae</b>     | Brown Illadopsis                | <i>Illadopsis fulvescens</i>   | 0.8 | 0.7 | 25.0  |
| <b>Paridae</b>        | Tit-hylia                       | <i>Pholidornis rushiae</i>     | 0.8 | 0.7 | 75.0  |
| <b>Nectariniidae</b>  | Collared Sunbird                | <i>Hedydipna collaris</i>      | 2.3 | 2.1 | 100.0 |
| <b>Nectariniidae</b>  | Fraser's Sunbird                | <i>Deleornis fraseri</i>       | 1.5 | 1.4 | 100.0 |
| <b>Nectariniidae</b>  | Green Sunbird                   | <i>Anthreptes rectirostris</i> | 0.5 | 0.5 | 25.0  |
| <b>Nectariniidae</b>  | Buff-Throated Sunbird           | <i>Chalcomitra adelberti</i>   | 0.8 | 0.7 | 25.0  |
| <b>Nectariniidae</b>  | Blue-Throated Brown Sunbird     | <i>Cyanomitra cyanolaema</i>   | 0.3 | 0.2 | 25.0  |
| <b>Nectariniidae</b>  | Johanna's Sunbird               | <i>Cinnyris johannae</i>       | 0.5 | 0.5 | 25.0  |
| <b>Nectariniidae</b>  | Tiny Sunbird                    | <i>Cinnyris minullus</i>       | 0.5 | 0.5 | 25.0  |
| <b>Nectariniidae</b>  | Olive Sunbird                   | <i>Cyanomitra olivaceus</i>    | 1.5 | 1.4 | 75.0  |
| <b>Nectariniidae</b>  | Little Green Sunbird            | <i>Anthreptes seimundi</i>     | 1.3 | 1.2 | 100.0 |
| <b>Laniidae</b>       | Red-billed Helmet-Shrike        | <i>Prionops caniceps</i>       | 1.0 | 0.9 | 50.0  |
| <b>Oriolidae</b>      | Western Black-Headed Oriole     | <i>Oriolus brachyrhynchus</i>  | 0.5 | 0.5 | 50.0  |
| <b>Oriolidae</b>      | Black-winged Oriole             | <i>Oriolus nigripennis</i>     | 1.0 | 0.9 | 50.0  |
| <b>Emberizidae</b>    | Velvet-Mantled Drongo           | <i>Dicrurus modestus</i>       | 0.5 | 0.5 | 50.0  |
| <b>Emberizidae</b>    | Shining Drongo                  | <i>Dicrurus attripennis</i>    | 0.5 | 0.5 | 25.0  |
| <b>Sturnidae</b>      | Splendid Glossy Starling        | <i>Lamprotornis splendidus</i> | 1.5 | 1.4 | 75.0  |
| <b>Sturnidae</b>      | Forest Chestnut-winged Starling | <i>Onychognathus fulgidus</i>  | 0.5 | 0.5 | 25.0  |
| <b>Ploceidae</b>      | Maxwell's Black Weaver          | <i>Ploceus albinucha</i>       | 1.5 | 1.4 | 75.0  |

| Table 1 cont'd      |                                  |                                |     |     |       |
|---------------------|----------------------------------|--------------------------------|-----|-----|-------|
| <b>Ploceidae</b>    | Preuss's (Golden-Backed) Weaver  | <i>Ploceus preussi</i>         | 0.5 | 0.5 | 25.0  |
| <b>Ploceidae</b>    | Yellow-Mantled Weaver            | <i>Ploceus tricolor</i>        | 2.3 | 2.1 | 100.0 |
| <b>Ploceidae</b>    | Crested Malimbe                  | <i>Malimbus malimbicus</i>     | 0.3 | 0.2 | 25.0  |
| <b>Ploceidae</b>    | Blue-Billed Malimbe              | <i>Malimbus nitens</i>         | 0.5 | 0.5 | 25.0  |
| <b>Ploceidae</b>    | Red-Headed Malimbe               | <i>Malimbus rubricollis</i>    | 1.3 | 1.2 | 75.0  |
| <b>Ploceidae</b>    | Red-Vented Malimbe               | <i>Malimbus scutatus</i>       | 1.3 | 1.2 | 50.0  |
| <b>Estrildidae</b>  | Chestnut-Breasted Negrofinch     | <i>Nigrita bicolor</i>         | 0.3 | 0.2 | 25.0  |
| <b>Estrildidae</b>  | Grey-Headed (crowned) Negrofinch | <i>Nigrita canicapilla</i>     | 0.5 | 0.5 | 25.0  |
| <b>Estrildidae</b>  | White-Breasted Negrofinch        | <i>Nigrita fusconota</i>       | 0.8 | 0.7 | 50.0  |
| <b>Dicruridae</b>   | Forked-Tailed Drongo             | <i>Dicrurus adsimilis</i>      | 1.0 | 0.9 | 100.0 |
| <b>Silviidae</b>    | Kemp's Longbill                  | <i>Macrosphenus kempii</i>     | 0.3 | 0.2 | 25.0  |
| <b>Phasianidae</b>  | Ahanta Frankolin                 | <i>Frankolinus alantensis</i>  | 1.0 | 0.9 | 75.0  |
| <b>Laniidae</b>     | Common Fiscal                    | <i>Lanius collaris</i>         | 0.3 | 0.2 | 25.0  |
| <b>Collumbidae</b>  | Green fruit Pigeon               | <i>Treron calva</i>            | 0.3 | 0.2 | 25.0  |
| <b>Capitonidae</b>  | Red-Fronted Tinkerbird           | <i>Pogoniulus pusillus</i>     | 0.5 | 0.5 | 50.0  |
| <b>Collumbidae</b>  | Blue-Headed Wood Dove            | <i>Turtur brehmeri</i>         | 0.3 | 0.2 | 25.0  |
| <b>Rallidae</b>     | Nkulengu Rail                    | <i>Hinantornis haematopus</i>  | 0.8 | 0.7 | 75.0  |
| <b>Cuculidae</b>    | Black-Throated Coucal            | <i>Centropus leucogaster</i>   | 0.3 | 0.2 | 25.0  |
| <b>Meropidae</b>    | Little Bee Eater                 | <i>Merops pusillus</i>         | 1.3 | 1.2 | 100.0 |
| <b>Meropidae</b>    | White-Throated Bee Eater         | <i>Merops albicollis</i>       | 1.3 | 1.2 | 100.0 |
| <b>Cuculidae</b>    | Dusky-Long Tailed Cuckoo         | <i>Cercococcyx mechowi</i>     | 0.5 | 0.5 | 50.0  |
| <b>Oriolidae</b>    | Western Black-Headed Oriole      | <i>Oriolus chinensis</i>       | 0.3 | 0.2 | 25.0  |
| <b>Nectarinidae</b> | Superb Sunbird                   | <i>Cinnyris superbus</i>       | 0.5 | 0.5 | 50.0  |
| <b>Nectarinidae</b> | Splendid Sunbird                 | <i>Cinnyris coccinigastrus</i> | 0.5 | 0.5 | 50.0  |
| <b>Mesophagidae</b> | Green Turaco                     | <i>Tauroco persa</i>           | 0.3 | 0.2 | 25.0  |

In the oil palm plantation, the number of birds (abundance) ranged from a minimum of 0.3bird/km to a maximum of 11.5 birds/km with the median being 0.5 birds/km. *Pycnonotus babatus* was the bird species with the maximum number per km but the number of others like *Milvus migrans*, *Bubulcus ibis*, *Streptopelia semitoguata*, *Tockus fasciatus*, *Pycnonotus babatus*, *Ploceus cucullatus*, *Estrilda melpoda*, *Spermestes cucullata*, *Corvus albus* were also high; others like *Treron calva*, *Falio tinnunculus*, *Egretta garzatta*, *Treron calva*, *Centropus leocogaster* occurred in relatively low numbers. On the dominance, *Pycnonotus babatus* (19.2%), *Corvus albus* (10.0%) *Streptopelia semitoguata* (5.8%), *Tockus fasciatus* (5.8%), *Pycnonotus babatus* (5.8%), *Ploceus cucullatus* (5.8%), *Estrilda melpoda* (6.7%) dominated as opposed to species like *Muscicapa striata*, *Muscicapa comitata*, *Terpsiphone refiventer*, *Melaenornis pallidus*, *Nectarinia adelberti*, *Ploceus tricolor*, *Muscicapa striata*, *Muscicapa comitata*, *Terpsiphone refiventer* etc. occurring at 0.4% (Table 2). In the oil palm plantations 24.4% of the birds were classified as abundant, 22.2% as common, 13.3% as not common and 40.1% as rare.

**Table 2: List of birds found in the oil palm plantation (Numbers are based on recordings on 4km transects in the Kwaie oil palm plantation)**

| Family              | Common name            | Scientific name                 | Abundance<br>(individuals/km) | Dominance<br>(%) | Frequency of<br>occurrence(%) |
|---------------------|------------------------|---------------------------------|-------------------------------|------------------|-------------------------------|
| <b>Accipitridae</b> | Lizard buzzard         | <i>Kaupifalco monogrammicus</i> | 0.5                           | 0.8              | 50.0                          |
| <b>Falconidae</b>   | Common Kestrel         | <i>Falio tin nunculus</i>       | 0.3                           | 0.4              | 25.0                          |
| <b>Falconidae</b>   | Black Kite             | <i>Milvus migrans</i>           | 3.3                           | 5.4              | 100.0                         |
| <b>Ardeidae</b>     | Little Egret           | <i>Egretta garzatta</i>         | 0.3                           | 0.4              | 25.0                          |
| <b>Ardeidae</b>     | Cattle Egret           | <i>Bubulcus ibis</i>            | 2.3                           | 3.8              | 100.0                         |
| <b>Collumbidae</b>  | Red-eyed Dove          | <i>Streptopelia semitoguata</i> | 3.5                           | 5.8              | 100.0                         |
| <b>Collumbidae</b>  | Tambourine Dove        | <i>Turtur tympanistria</i>      | 1.0                           | 1.7              | 75.0                          |
| <b>Collumbidae</b>  | African Green Pigeon   | <i>Treron calva</i>             | 0.3                           | 0.4              | 25.0                          |
| <b>Collumbidae</b>  | Blue Spotted Wood Dove | <i>Turtur afer</i>              | 0.5                           | 0.8              | 75.0                          |
| <b>Cuculidae</b>    | Senegal Coucal         | <i>Centropus senegalensis</i>   | 1.5                           | 2.5              | 75.0                          |
| <b>Cuculidae</b>    | Black Throated Coucal  | <i>Centropus leocogaster</i>    | 0.3                           | 0.4              | 25.0                          |
| <b>Cuculidae</b>    | Black Coucal           | <i>Centropus grillii</i>        | 0.3                           | 0.4              | 25.0                          |
| <b>Cuculidae</b>    | Yellow Bill            | <i>Ceuthmochares aereus</i>     | 1.0                           | 1.7              | 75.0                          |
| <b>Cuculidae</b>    | White Browed Coucal    | <i>Centropus superciliasus</i>  | 0.3                           | 0.4              | 25.0                          |
| <b>Cuculidae</b>    | African merald Cuckoo  | <i>Chrysoccyx cupreus</i>       | 0.0                           | 0.0              | 0.0                           |
| <b>Alcedinidae</b>  | Woodland Kingfisher    | <i>Halcyon senegalensis</i>     | 0.0                           | 0.0              | 0.0                           |
| <b>Bucerotidae</b>  | African Piedhornbill   | <i>Tockus fasciatus</i>         | 3.5                           | 5.8              | 100.0                         |
| <b>Capitonidae</b>  | Speckled Thinkerbird   | <i>Pogoniulus scolopaeceus</i>  | 0.3                           | 0.4              | 25.0                          |

| Table 2 cont'd        |                                    |                                       |      |      |       |
|-----------------------|------------------------------------|---------------------------------------|------|------|-------|
| <b>Pycnonotidae</b>   | Western nicator                    | <i>Nicator chloris</i>                | 0.3  | 0.4  | 25.0  |
| <b>Pycnonotidae</b>   | Little Greenbul                    | <i>Andropadus virens</i>              | 1.5  | 2.5  | 75.0  |
| <b>Pycnonotidae</b>   | Common Bulbul                      | <i>Pycnonotus babatus</i>             | 11.5 | 19.2 | 100.0 |
| <b>Pycnonotidae</b>   | Swamp-palm<br>Cireenbul            | <i>Thescelocichla<br/>leucopleura</i> | 0.3  | 0.4  | 0.0   |
| <b>Pycnonotidae</b>   | Simple Leaflove                    | <i>Chlorocichla<br/>simplex</i>       | 0.3  | 0.4  | 25.0  |
| <b>Sylvidae</b>       | Green Crombec                      | <i>Sylvietta virens</i>               | 0.3  | 0.4  | 25.0  |
| <b>Sylvidae</b>       | Grey Back<br>Camaroptera           | <i>Camaroptera<br/>brachyuran</i>     | 1.3  | 2.1  | 75.0  |
| <b>Sylvidae</b>       | Kemp's Longbill                    | <i>Macrosphenus<br/>flavicans</i>     | 0.3  | 0.4  | 25.0  |
| <b>Sylvidae</b>       | Olive Green<br>Camaroptera         | <i>Camaroptera<br/>chloronota</i>     | 1.0  | 1.7  | 75.0  |
| <b>Sylvidae</b>       | Tawny Franked<br>Prinia            | <i>Prinia subflava</i>                | 1.3  | 2.1  | 75.0  |
| <b>Muscicapidae</b>   | Spotted Flycatcher                 | <i>Muscicapa striata</i>              | 0.3  | 0.4  | 25.0  |
| <b>Muscicapidae</b>   | Dusky-blue<br>Flycatcher           | <i>Muscicapa comitata</i>             | 0.3  | 0.4  | 25.0  |
| <b>Monarchidae</b>    | Red-bellied<br>Paradise Flycatcher | <i>Terpsiphone<br/>refiventer</i>     | 0.3  | 0.4  | 25.0  |
| <b>Platysteiridae</b> | Pale Flycatcher                    | <i>Melaenornis<br/>pallidus</i>       | 0.3  | 0.4  | 25.0  |
| <b>Platysteiridae</b> | Blackand White<br>Flycatcher       | <i>Bias musicus</i>                   | 0.0  | 0.0  | 0.0   |
| <b>Nectariniidae</b>  | Collared Sunbird                   | <i>Anthreptes collaris</i>            | 0.5  | 0.8  | 50.0  |
| <b>Nectariniidae</b>  | Western Olive<br>Sunbird           | <i>Nectarinia<br/>Olivacea</i>        | 0.5  | 0.8  | 50.0  |
| <b>Nectariniidae</b>  | Superb Sunbird                     | <i>Cinnyris suberbus</i>              | 1.5  | 2.5  | 75.0  |
| <b>Nectariniidae</b>  | Buff Throated<br>Sunbird           | <i>Nectarinia<br/>adelberti</i>       | 0.3  | 0.4  | 25.0  |
| <b>Nectariniidae</b>  | Variable Sunbird                   | <i>Cinnyris venustus</i>              | 0.5  | 0.8  | 50.0  |
| <b>Sturnidae</b>      | Splendid glossy<br>starling        | <i>Lamprotomis<br/>splendendus</i>    | 1.0  | 1.7  | 75.0  |

| Table 2 cont'd     |                                 |                               |     |      |       |
|--------------------|---------------------------------|-------------------------------|-----|------|-------|
| <b>Ploceidae</b>   | Preuss's (Golden-Backed) Weaver | <i>Ploceus preussi</i>        | 0.0 | 0.0  | 0.0   |
| <b>Ploceidae</b>   | Yellow Mantled Weaver           | <i>Ploceus tricolor</i>       | 0.3 | 0.4  | 25.0  |
| <b>Ploceidae</b>   | Vieillot's Black Weaver         | <i>Ploceus nigerrimus</i>     | 0.0 | 0.0  | 0.0   |
| <b>Ploceidae</b>   | Red Headed Malimbe              | <i>Malimbus rubricollis</i>   | 0.0 | 0.0  | 0.0   |
| <b>Ploceidae</b>   | Spectacled Weaver               | <i>Ploceus ocularis</i>       | 1.0 | 1.7  | 50.0  |
| <b>Ploceidae</b>   | Village Weaver                  | <i>Ploceus cucullatus</i>     | 1.0 | 1.7  | 100.0 |
| <b>Ploceidae</b>   | Orange Checked Waxbill          | <i>Estrilda melpoda</i>       | 4.0 | 6.7  | 100.0 |
| <b>Estrildidae</b> | Bronze Mannikin                 | <i>Spermestes cucullata</i>   | 1.8 | 2.9  | 100.0 |
| <b>Apodidae</b>    | African Palm Swift              | <i>Cypsiurus parvus</i>       | 0.8 | 1.3  | 50.0  |
| <b>Corvidae</b>    | Pied Crow                       | <i>Corvus albus</i>           | 6.0 | 10.0 | 100.0 |
| <b>Meropidae</b>   | White Throated Bee-eater        | <i>Merops albicollis</i>      | 1.5 | 2.5  | 100.0 |
| <b>Passeridae</b>  | Northern Grey Headed Sparrow    | <i>Passer griseus</i>         | 1.5 | 2.5  | 100.0 |
| <b>Phasianidae</b> | Ahanta Francolin                | <i>Francolinus ahantensis</i> | 0.5 | 0.8  | 25.0  |

In the cocoa farm area, the maximum number of species was 7.5 birds/km and the minimum was 0.3 bird/km. *Vidua macroura* (7.5), *Merops albicollis* (3.0) *Passer griseus* (5.0), *Gymnobucco calvas* (2.0) etc. recorded relatively higher number of birds per km. The species that dominated included *Tricholaema hirsute* (6.7%), *Dendropicos*

*pyrrhogaster* (6.7%), *Pycnonotus babatus*(4.7%), *Cinnyris minullus* (4.0%). 26.8% of species was abundant, 21.4% common, 25.0% uncommon while 26.8% was rare (Table 3).

**Table 3: List of birds found on the cocoa farm. (Numbers are based on recordings on 4km transects in Pankese cocoa farm).**

| Family              | Common name             | Scientific name                  | Abundance (individuals/ km) | Dominance (%) | Frequency of occurrence (%) |
|---------------------|-------------------------|----------------------------------|-----------------------------|---------------|-----------------------------|
| <b>Accipitridae</b> | Lizard buzzard          | <i>Kaupifalco monogrammicus</i>  | 1.3                         | 1.7           | 75.0                        |
| <b>Accipitridae</b> | Beaudouin's Snake Eagle | <i>Circaetus beadouini</i>       | 0.5                         | 0.7           | 25.0                        |
| <b>Ardeidae</b>     | Little Egret            | <i>Egretta garzatta</i>          | 0.3                         | 0.3           | 25.0                        |
| <b>Ardeidae</b>     | Cattle Egret            | <i>Bubulcus ibis</i>             | 0.0                         | 0.0           | 0.0                         |
| <b>Collumbidae</b>  | Red-eyed Dove           | <i>Streptopelia semitogata</i>   | 0.5                         | 0.7           | 50.0                        |
| <b>Collumbidae</b>  | Tambourine Dove         | <i>Turtur tympanistria</i>       | 1.3                         | 1.7           | 75.0                        |
| <b>Collumbidae</b>  | African Green Pigeon    | <i>Treron calva</i>              | 2.3                         | 3.0           | 100.0                       |
| <b>Collumbidae</b>  | Blue Spotted Wood Dove  | <i>Turtur afer</i>               | 0.8                         | 1.0           | 75.0                        |
| <b>Collumbidae</b>  | Laughing Dove           | <i>Streptopelia senegalensis</i> | 0.3                         | 0.3           | 25.0                        |
| <b>Cuculidae</b>    | Klass' Cuckoo           | <i>Chrysococcyx klass</i>        | 0.3                         | 0.3           | 25.0                        |
| <b>Cuculidae</b>    | Didric Cuckoo           | <i>Chrysococcyx caprius</i>      | 0.3                         | 0.3           | 25.0                        |
| <b>Cuculidae</b>    | African Emerald Cuckoo  | <i>Chrysococcyx cupreus</i>      | 0.3                         | 0.3           | 25.0                        |

| Table 3 cont'd      |                             |                                  |     |     |       |
|---------------------|-----------------------------|----------------------------------|-----|-----|-------|
| <b>Bucerotidae</b>  | African Piedhornbill        | <i>Tockus fasciatus</i>          | 0.0 | 0.0 | 50.0  |
| <b>Bucerotidae</b>  | Piping Hornbill             | <i>Bycanistes fistulator</i>     | 0.0 | 0.0 | 50.0  |
| <b>Bucerotidae</b>  | White-Crested Hornbill      | <i>Tropicranus albocristatus</i> | 0.0 | 0.0 | 50.0  |
| <b>Capitonidae</b>  | Speckled Thinkerbird        | <i>Pogoniulus scolopaeceus</i>   | 0.3 | 0.3 | 25.0  |
| <b>Capitonidae</b>  | Red Rumped Thinkerbird      | <i>Pogoniulus atroflavus</i>     | 0.8 | 1.0 | 50.0  |
| <b>Capitonidae</b>  | Yellow Throated Thinkerbird | <i>Pogoniulus subsulphureus</i>  | 0.3 | 0.3 | 25.0  |
| <b>Capitonidae</b>  | Naked-Faced Barbet          | <i>Gymnobucco calvas</i>         | 2.0 | 2.7 | 75.0  |
| <b>Capitonidae</b>  | Hairy-breasted Barbet       | <i>Tricholaema hirsute</i>       | 5.0 | 6.7 | 100.0 |
| <b>Picidae</b>      | Fire-bellied Woodpecker     | <i>Dendropicos pyrrhogaster</i>  | 5.0 | 6.7 | 100.0 |
| <b>Picidae</b>      | Cardinal Woodpecker         | <i>Dendropicus fuscescens</i>    | 1.3 | 1.7 | 50.0  |
| <b>Pycnonotidae</b> | Western nicator             | <i>Nicator chloris</i>           | 0.3 | 0.3 | 25.0  |
| <b>Pycnonotidae</b> | Little Greenbul             | <i>Andropadus virens</i>         | 0.3 | 0.3 | 25.0  |
| <b>Pycnonotidae</b> | Common Bulbul               | <i>Pycnonotus babatus</i>        | 3.5 | 4.7 | 100.0 |
| <b>Sylvidae</b>     | Grey Back Camaroptera       | <i>Camaroptera brachyuran</i>    | 0.8 | 1.0 | 50.0  |
| <b>Sylvidae</b>     | Yellow Browed Camaroptera   | <i>Camaroptera superciliaris</i> | 1.5 | 2.0 | 50.0  |

| Table 3 cont'd        |                                 |                               |     |     |       |
|-----------------------|---------------------------------|-------------------------------|-----|-----|-------|
| <b>Sylvidae</b>       | Kemp's Longbill                 | <i>Macrosphenus flavicans</i> | 0.3 | 0.3 | 25.0  |
| <b>Sylvidae</b>       | Olive Green Camaroptera         | <i>Camaroptera chloronota</i> | 0.0 | 0.0 | 0.0   |
| <b>Sylvidae</b>       | Tawny Franked Prinia            | <i>Prinia subflava</i>        | 0.0 | 0.0 | 0.0   |
| <b>Sylvidae</b>       | Green Hylia                     | <i>Hylia prasina</i>          | 1.5 | 2.0 | 75.0  |
| <b>Sylvidae</b>       | Spotted Flycatcher              | <i>Muscicapa striata</i>      | 0.0 | 0.0 | 0.0   |
| <b>Muscicapidae</b>   | Ashy Flycatcher                 | <i>Muscicapa caerulescens</i> | 0.3 | 0.3 | 25.0  |
| <b>Muscicapidae</b>   | Dusky-blue Flycatcher           | <i>Muscicapa comitata</i>     | 0.0 | 0.0 | 0.0   |
| <b>Muscicapidae</b>   | Red-bellied Paradise Flycatcher | <i>Terpsiphone refiventer</i> | 2.0 | 2.7 | 100.0 |
| <b>Monarchidae</b>    | African Paradise Flycatcher     | <i>Terpsiphone viridis</i>    | 1.8 | 2.3 | 100.0 |
| <b>Monarchidae</b>    | Pale Flycatcher                 | <i>Melaenornis pallidus</i>   | 0.0 | 0.0 | 0.0   |
| <b>Platysteiridae</b> | Black and White Flycatcher      | <i>Bias musicus</i>           | 0.3 | 0.3 | 25.0  |
| <b>Platysteiridae</b> | Collared Sunbird                | <i>Anthreptes collaris</i>    | 0.5 | 0.7 | 50.0  |
| <b>Nectariniidae</b>  | Superb Sunbird                  | <i>Cinnyris suberbus</i>      | 0.8 | 1.0 | 50.0  |
| <b>Nectariniidae</b>  | Johanna's Sunbird               | <i>Cinnyris johannae</i>      | 2.0 | 2.7 | 100.0 |
| <b>Nectariniidae</b>  | Olive-Bellied Sunbird           | <i>Cinnyris chloropygius</i>  | 1.0 | 1.3 | 50.0  |
| <b>Nectariniidae</b>  | Tiny Sunbird                    | <i>Cinnyris minullus</i>      | 3.0 | 4.0 | 100.0 |

| Table 3 cont'd       |                                           |                                    |     |     |       |
|----------------------|-------------------------------------------|------------------------------------|-----|-----|-------|
| <b>Nectariniidae</b> | Western black<br>Headed Oriole            | <i>Oriolus<br/>brachyrhynchus</i>  | 1.3 | 1.7 | 100.0 |
| <b>Oriolidae</b>     | Black-winged<br>Oriole                    | <i>Oriols nigripennis</i>          | 0.8 | 1.0 | 75.0  |
| <b>Oriolidae</b>     | Velvet-<br>mantled<br>Drongo              | <i>Dicrurus modestus</i>           | 0.8 | 1.0 | 75.0  |
| <b>Dicruridae</b>    | Forked Trailed<br>Drongo                  | <i>Dicrurus adsimilis</i>          | 0.8 | 1.0 | 50.0  |
| <b>Sturnidae</b>     | Splendid<br>glossy starling               | <i>Lamprotomis<br/>splendendus</i> | 2.3 | 3.0 | 75.0  |
| <b>Ploceidae</b>     | Preuss's<br>(Golden-<br>Backed)<br>Weaver | <i>Ploceus preussi</i>             | 0.3 | 0.3 | 25.0  |
| <b>Ploceidae</b>     | Yellow<br>Mantled<br>Weaver               | <i>Ploceus tricolor</i>            | 1.5 | 2.0 | 75.0  |
| <b>Ploceidae</b>     | Vieillot's<br>Black Weaver                | <i>Ploceus nigerrimus</i>          | 0.5 | 0.7 | 50.0  |
| <b>Ploceidae</b>     | Red Headed<br>Malimbe                     | <i>Malimbus<br/>rubricollis</i>    | 2.5 | 3.3 | 100.0 |
| <b>Ploceidae</b>     | Grey-headed<br>Negro-finch                | <i>Nigrita canicapilla</i>         | 0.8 | 1.0 | 75.0  |
| <b>Estrildidae</b>   | Bronze<br>Mannikin                        | <i>Spermestes<br/>cucullata</i>    | 0.0 | 0.0 | 0.0   |
| <b>Estrildidae</b>   | African Palm<br>Swift                     | <i>Cypsiurus parvus</i>            | 0.0 | 0.0 | 0.0   |
| <b>Apodidae</b>      | Pied Crow                                 | <i>Corvus albus</i>                | 1.3 | 1.7 | 75.0  |
| <b>Corvidae</b>      | White<br>Throated Bee-<br>eater           | <i>Merops albicollis</i>           | 3.0 | 4.0 | 100.0 |

| Table 3 cont'd     |                                    |                                   |     |      |       |
|--------------------|------------------------------------|-----------------------------------|-----|------|-------|
| <b>Meropidae</b>   | Northern Grey<br>Headed<br>Sparrow | <i>Passer griseus</i>             | 5.0 | 6.7  | 100.0 |
| <b>Passeridae</b>  | Ahanta<br>Francolin                | <i>Francolinus<br/>ahantensis</i> | 0.0 | 0.0  | 0.0   |
| <b>Phasianidae</b> | Pearl Spotted<br>Owlet             | <i>Glaucidium<br/>perlatus</i>    | 0.5 | 0.7  | 25.0  |
| <b>Tytonidae</b>   | Pinktailed<br>Whydad               | <i>Vidua macroura</i>             | 7.5 | 10.0 | 100.0 |
|                    |                                    |                                   |     |      |       |

#### 4.4 Relationship between bird numbers and habitat types

The Spearman's rank correlation was used to evaluate the influence of the habitat types on the number of birds. There was positive relationship between the number of birds and habitat types i.e. as the habitat type approaches the nature of forest bird numbers increase. This was significant at  $P < 0.05$  ( $\rho = 0.90$ ,  $p = 5.6413 \times 10^{-5}$ ). This implies that, habitat types influence about 90% of the bird numbers.

## CHAPTER FIVE

### DISCUSSION

#### 5.1 Esukawkaw forest reserve

The record of 216 different species of birds during the survey period for the three habitat types is an indication of high avifauna diversity. The species diversity index and evenness of habitats during the entire period revealed that the Esukawkaw Forest Reserve (EFR) habitat had the highest species diversity of 4.48 and evenness of 0.95.

The large and natural state of EFR habitat as compared to the other sites might have contributed to the highest bird species diversity and evenness. This is because of the availability of multiple and variety of alternative food sources for the birds. Most of the large area of the EFR is inaccessible to people, contributing to a favourable condition for breeding, feeding and nesting sites.

The Kwae oil palm plantation and the Pankese Cocoa farms are exposed to the local people for cultivation and cutting of the vegetation. As a result, birds which depend on these sites for feeding, nesting, hiding and breeding are affected. In natural habitats where the intervention of humans is less and minimum, the diversity as well as the evenness of species is higher than the fragmented ones where intensive farming is carried out (Rana, 2005). Differences in feeding habits and habitats could also increase diversity, evenness and species richness (Smith, 1992).

The distribution and abundance of many bird species are determined by the composition of the vegetation that forms a major element of their habitats. As vegetation changes along complex geographical and environmental gradients, a particular bird species may appear, increase or decrease in number and disappear as the habitat changes (Lee and Rotenberry, 2005). Therefore, in this survey, the highest frequency of occurrence of birds (26.8%) was found in the Pankese Cocoa farms, followed by the Kwaie Oil Palm plantation (24.1%) and the EFR habitat with the least value of 16.3%.

## **5.2 Pankese cocoa farms habitat type**

The Cocoa farms habitat type recorded a relatively high species diversity of 3.54 and evenness of 0.95. This is because cocoa (*Theobroma cacao*) crops are generally planted under forest trees in the new World tropics, and high bird diversities have been documented in many cocoa landscapes (Greenberg *et al.*, 2000; Reitsma *et al.*, 2001; Estrada and Coastes-Estrada, 2005; Faria *et al.*, 2006; Gonzalez and Harvey, 2007). Thus, cocoa farms appear to provide additional habitat for some bird populations that continue to lose forest habitats.

The vegetation in shaded cocoa farms has simplified structure and taxonomic diversity relative to forest vegetation, and thus may provide habitat for only certain guilds of birds. For example, management regimes in cocoa farms include the removal of understorey herbs and shrubs, thinning of canopy trees, removal of lianas and epiphytes, and replacement of naturally occurring trees with planted species that provide useful

fruits or wood. This simplified system may preclude the use of cocoa farms for forest birds that depend on specific foraging niches.

In previous studies of shade agro-systems, greater species diversity of forest organisms has been found where management of canopy vegetation is least intense (Greenberg *et al.*, 1997; Mas and Dietsch, 2003; Anderson and Gradstein, 2005; Cruz-Angon and Greenberg, 2005). At one extreme, where cocoa is grown in sparse shade of only a couple of tree species in Indonesia, cocoa farms support low diversity compared to primary and secondary forests (Waltert *et al.*, 2004). In contrast, often cocoa is grown under diverse shade conditions in Central America. Similar to the findings of Reitsma *et al.* (2001) in Costa Rica, greater bird diversity with increasing shade tree species diversity was found.

The diversity of forest organisms using shaded agroforests is likely to be highly dependent on the landscape matrix in which the agroforests exist. For example, Greenberg *et al.* (2000) found low bird diversity in Mexican cocoa farms and suggested that distance from forest was an important factor. While Reitsma *et al.* (2001) found no correlation between bird diversity in cocoa farms and distance to forest edge in Costa Rica; Faria *et al.* (2006) documented greater bird diversity in Brazilian cocoa farms that were surrounded by forests than in farms where agriculture dominated the landscape.

### 5.3 Kwae oil palm plantation habitat type

Kwae oil palm plantation showed a relatively low species diversity of 3.18 and evenness of 0.83 as compared with the two other sites. This is because oil palm plantations are reputed to be harsh on biodiversity, diminishing richness of several groups such as beetles, butterflies and birds (Chung *et al.*, 2000; Koh, 2008a). Fortunately, Kwae oil palm plantation practise organic farming using the legume, *Calopogonium sp.* serving as an understorey. The existence of this well developed understorey might reduce this impact, contributing to conserve some biodiversity (Aratrakorn *et al.*, 2006).

Understorey vegetation beneath oil palms by several authors (eg. Aratrakorn *et al.*, 2006) in fact promotes bird richness and abundance. This was vividly collaborated by this current research where species abundance of this habitat type was found to be the highest (i.e. 0.3 – 11.5 birds/km) among the three habitat types. Understorey could be providing food source, refuge and breeding sites for birds and other species, as occurs in other commercial plantations such as coffee, pine, eucalyptus, cocoa and rubber. At these plantations, understorey is also suggested as a significant source of food and shelter for species thus enhancing biodiversity in these productive areas (Greenberg *et al.*, 1997; Grez *et al.*, 2003; Aratrakorn *et al.*, 2006; Harvey and Gonzalez-Villalobos, 2007).

At El Estor, the undergrowth and the resources it might be providing benefits even vulnerable species such as *Turdus assimilis* and *Malacoptile panamensis*. These two birds are reported to live in primary forests only (Elsermann and Avendano, 2006).

Commercial plantations support only a fraction of biodiversity that was once held in the natural ecosystems they replaced. Oil palm for instance supports about 10% of the original assemblage (Donald, 2004; Aratrakorn *et al.*, 2006; Koh and Wilcove, 2008). The dominance of insectivorous species (70% of species feed on insects) could be a key issue to promote the development of understorey vegetation in oil palm plantations. Allowing the spontaneous development of understorey vegetation might also contribute to insect control as bird richness and abundance are enhanced in such plantations. Birds do reduce insect abundance (eg. Koh, 2008b), hence as with other plant species, insectivorous birds might contribute to the natural pest control, strengthening justifications for conserving biodiversity in this agricultural landscape (Koh, 2000b).

Further, oil palm plantations with enhanced understorey might even function as corridors between natural ecosystems; thus, leaving or building up understorey vegetation at oil palm plantations should be encouraged.

## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 Conclusion

Birds are well known indicator taxon due to their sensitivity to environmental perturbations, relevant to ecosystem functioning (eg. pollination and seed dispersal) and relative ease in sampling. Deforestation and forest disturbance have negative effects on birds including declines in diversity and abundance, changes in species assemblages, loss of species guilds and extinction.

Bird diversity was much higher in the forest area (4.48) than in the cocoa farms (3.54) and the oil palm plantation (3.18). Bird diversity in the forest area was 1.30 higher than that in the oil palm plantation and 0.94 higher than in the cocoa farms.

Similarly, bird density was highest in the forest area than the other two habitat types. While forest area recorded 107.75 bird density, cocoa farms and oil palm plantation registered 82.75 and 60.25 bird density respectively. There was a positive relationship between the number of birds and the habitat types i.e. as habitat type approaches the nature of forest, the bird numbers also increase. Therefore, intensive agro-ecosystems have negative effects on the diversity and distribution of avifauna.

## 6.2 Recommendations

The study revealed that intensive land use systems of agriculture have negative effects on bird diversity and populations. With a large portion of the tropical landscape deforested for agriculture and other land uses, it is critical that strategies are developed that would preserve the remaining forests' bird diversity and prevent further losses. It is therefore recommended that intensive land use systems should incorporate in the planting of forest trees by intensive agricultural land users in Ghana. In addition, large continuous blocks of primary forests and extensive fragments should be conserved for the conservation of tropical forest birds by the district assemblies.

Furthermore, oil palm plantations with enhanced understorey might even function as corridors between natural ecosystems: thus, living or building up understorey vegetation at oil palm plantations should be encouraged.

Further studies by researchers should be conducted on a long term basis to differentiate between birds of residence and migrant birds in future.

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## APPENDIX 1: Details of statistics

- a. Diversity t-test comparing Kwaie habitat type to either forest or Pankese habitat types.

| Habitat types      | T       | P          | Remarks     |
|--------------------|---------|------------|-------------|
| Kwaie and Pankese  | -4.0149 | 6.963E-5   | Significant |
| Kwaie and forest   | 15.3150 | 0.00000    | Significant |
| Pankese and forest | -14.063 | 1.0836E-38 | Significant |

- b. Mann-Whitney U-tests comparing the differences of occurrence of species in any two of any two habitat types.

| Site comparison    | U    | P         | Remarks         |
|--------------------|------|-----------|-----------------|
| Kwaie and Pankese  | 5592 | 0.2348    | Not significant |
| Pankese and Forest | 3189 | 5.299E-10 | significant     |
| Kwaie and Forest   | 2283 | 5.345E-16 | significant     |

c. Details of ANOVA

|                | Sums of Squares | DoF | Mean Square | F     | P       |
|----------------|-----------------|-----|-------------|-------|---------|
| Between groups | 171.89          | 2   | 85.9489     | 3.957 | 0.02003 |
| Within groups  | 7167.75         | 330 | 21.7204     |       |         |
| Total          | 7339.65         | 332 |             |       |         |

