FORAGING ECOLOGY AND RESOURCE PARTITIONING AMONG PALEARCTIC MIGRANTS AND RESIDENT BIRD SPECIES IN NORTHERN GHANA

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CONSERVATION SCIENCE OF THE UNIVERSITY OF GHANA

BY:

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DECLARATION

This is to certify that this thesis is the result of research undertaken by me, Adeniji Elijah Gbemiga towards the award of an MPhil degree in Zoology (Biodiversity option) at the Department of Animal Biology and Conservation Science, University of Ghana. This thesis has not been submitted either in part or in whole for any degree and all references to other people's work has been duly acknowledged.

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DEDICATION

I dedicate this work to the Almighty God for his continual grace upon my life. This work is also dedicated to my family especially my mum, Lardi Kunola and siblings, Elisha Adeniji, Christiana Adeniji and Judith Adeniji who have also helped in diverse ways for the completion of this thesis.

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LIST OF ABBREVIATIONS

UNEP --- United Nations Environment Programme

FT --- Foraging techniques

FL --- Foliage-Gleaning

G --- Gleaning

HG --- Hover gleaning

SA --- Sallying

HK --- Hawking

PR --- Probing

HT --- Habitat Type

OG --- Open Grassland

TH --- Thicket

NBF --- Non-Burnt Farmland

BF --- Burnt Farmland

FL --- Fallow Land

FH --- Foraging Height

MW ---Melodious Warbler

WW --- Willow Warbler

PF --- Pied Flycatcher

NC --- Northern Crombec

RC --- Rufous Cisticola

SE --- Senegal Eremomela

MP --- Presence of Migrants

MA --- Absence of Migrants

t Test --- Statistical Test

ABSTRACT

In the Palearctic-African bird migration system, some studies have addressed the question of coexistence of Palearctic breeding birds with Afrotropical species in the former's wintering grounds, however, conclusions are often drawn in a speculative way. These studies have led to some generalizations concerning habitat selection and foraging ecology about the traits that might enable migrants to coexist with residents. Migrants are often assumed to be more diverse in their habitat selection, forage in higher up in the vegetation than residents are, and more flexible in foraging behaviour by using a wider range of foraging techniques, though some studies revealed contradicting results. I studied the foraging ecology and resource partitioning of Palearctic migrants and resident birds in Northern Ghana, with emphasis on spatial partitioning, foraging techniques and habitat preference. I compared the ecology of three Palearctic breeding species: *Ficedula hypoleuca*, *Hippolais polyglotta* and *Phylloscopus trochilus*, with three resident species: *Cisticola rufus*, *Eremomela pusilla* and *Sylvietta brachyura*. All migrating species were more flexible in foraging behaviour as compared to their Afrotropical counterparts. The present study suggests that migrants partition resources with residents and, therefore, coexist with Afrotropical species. The generalization that migrants forage higher up in the vegetation strata was also confirmed. However, with respect to habitat usage, I could not fully confirm the above-mentioned generalization, since Rufous cisticola showed higher diversity in habitat usage than the Melodious warbler, showing that care has to be taken into account when drawing general conclusions from few studies for a whole migration system on a huge continent.

Differences in habitats used by resident warblers during the presence and absence of migrants were significant. Similarly, Northern crombec and Rufous cisticola were found to forage higher in the vegetation when migrants were present than when they were absent. This difference could be as a result of niche shift induced by the arrival of migrants. However, it is not known which mechanism facilitates this separation because interference competition was not observed. A social survey conducted on the study site suggested that certain activities of local inhabitants could pose a threat to the survival of migrants.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

It is estimated that at least 5 billion individual birds migrate each year from the Palearctic region to tropical Africa south of the Sahara to spend the winter (Moreau 1972). Migrant birds fly distances of hundreds or even thousands of kilometers in order to find the best ecological conditions and habitats for foraging and breeding purposes. All birds migrating to tropical Africa have to adapt morphologically and physiologically to, for example, the trans-Saharan flight, and ecologically to competition with resident species or to habitat changes on their winter grounds (Huston 1994). The main characteristic of migrating birds is the use of resources which are sporadic in space and time. The majority of migrants occur in seasonal savannas and open woodland, mostly using temporarily and locally abundant food sources generally unused by residents (Huston 1994).

When the geographic range of a species expands over a period of time, the biologist is provided with an opportunity to study the dynamic changes in foraging behaviour and habitat utilization as well as the interactions with resident local species. Such changes in range inevitably bring different species of birds into contact, thereby providing information on synecological changes among interacting species, such as changes in foraging patterns, habitat utilization and competitive interactions (Eckhardtr 1979, Rusterholkz 1981). These interactions are particularly interesting when the species are completely different ecologically and morphologically and occupy similar habitats within their historical ranges (Lack 1990). Previously, it was thought that tropical bird community niches were so tightly packed that there was no vacant space for migrants at all (McArthur 1972, Diamond 1975, Rabøl 1993). Lack (1983) assumed that migrants can only occur where food is superabundant. Recent publications, however, see migrants as integral parts of tropical avian communities, which are absent temporarily, and sometimes discuss their co-evolution with residents (Salewski 1999, Berthold 2000).

Food is probably the most important resource affecting migrants in their winter quarters (Sherry & Holmes 1996). There is no intra- or interspecific competition for mates or breeding sites, therefore, potential niche partitioning should involve mainly habitat and microhabitat selection and foraging ecology (Salewski et. al 2002b). Migrants partition resources with resident birds in order to maintain coexistence (Salewski et. al 2002b). Since resident birds play host to and are used to prevailing conditions on the wintering grounds, they are often superior to migrants in utilization of resources. Therefore, Palearctic migrants, in order to coexist with residents and effectively utilize resources in that seemingly new environment, may have to diversify their foraging strategies. Migrants are assumed to forage higher up and in more peripheral parts of the vegetation and, generally also in more open habitats as compared to their resident counterparts (Lack 1990, Leisler 1992). They are also assumed to be more flexible and opportunistic in their utilisation of resources, using a wider range of foraging techniques, and using a higher foraging speed than their Afrotropical counterparts in their respective guilds (Lövei 1989, Leisler 1992 and 1993).

Another resource which is of immense importance to the migrants and hence requires partitioning for migrants to effectively coexist with residents is the choice of habitats. Habitat selection of migrants in their wintering quarters appears to be less restrictive than on their temperate breeding grounds. Several factors determine habitat selection by birds in their winter quarters. Competitors and food availability have always been regarded as important factors in habitat selection (Leisler 1992). Afrotropical Palearctic migrants generally occupy a wider range of habitats than their tropical equivalents, i.e. they are more eurytopic (Lack 1986, Leisler 1990), a pattern that has also been observed in the Neotropics (Greenberg 1986). Migrants are also expected to be more successful in exploring alternative habitats and exploiting seasonal resources which are not regularly used by African species (Morel & Morel 1978, Sinclair 1978, Lack 1983, 1990).

Despite the difficulties associated with directly measuring interspecific competition (Huston 1994), the sudden arrival of large numbers of migrants in wintering areas already occupied by resident species may have significant potential for competition (Lack 1971, Greenberg 1986, Leisler 1992). However, the inference often made from migrants' foraging behaviour is that it permits avoidance of competition with resident species (Lack 1971, Bilcke 1984, Rabøl 1987).

The nature of the mechanisms that may structure animal communities is much debated and the role of interspecific competition in particular is difficult to detect in the field (Huston 1994). In many situations it is only possible to monitor putative mechanisms of niche partitioning that might enable species to coexist. The role of the interspecific interactions that occur when large numbers of migrant birds join resident communities in their winter quarters has been reviewed by Greenberg (1986) and Leisler (1992), who suggested that competition might result in spatial separation and niche shifts of resident species, but direct evidence of such processes are weak.

Populations of migratory birds have suffered sustained and often severe declines over the past few decades (Tucker & Heath 1994, BirdLife International 2004). One recent analysis of continent-wide survey data from the database Birds in Europe for the period between 1970 and 2000 has highlighted this decline (Sanderson et al. 2006). Over the 30 year study period, 48 (40%) of 119 afro-Palearctic migrant species (i.e. long-distance migrants that breed in Europe and winter in sub-Saharan Africa) exhibited substantial negative population trends. Long-distance migratory birds appear to be the group most affected by population declines, as no such patterns are apparent for short-distance migrants and residents, breeding in the same habitats in Europe.

There is evidence that reduced over-winter survival in dry, open habitats in sub-Saharan Africa may be a contributing factor to the decline (Sanderson et al. 2006, Ian 2002). Habitat destruction, desertification and lower resource availability on the wintering grounds due to reduced rainfall and increased agricultural intensification may partly explain these lower over-winter survival rates. Between 1970 and 2000, agricultural practices intensified at a high rate; the area of land in sub-Saharan Africa utilized for agriculture increased by only 4%, but fertilizer consumption almost trebled and pesticide imports increased five-fold (Tilman et al. 2002). As global food demand is predicted to double over the next 50 years, agricultural intensification is likely to increase even further, so the threat it poses to migrant species is likely to continue c. Climate change may also affect some populations by uncoupling the timing of resource availability from the timing of migration (Schaub et al. 2005). Long-distance migrants are most likely to be affected by such asynchrony in phenology, as evidence suggests they may be less able to adapt to change than resident non-migratory species due to their smaller brain sizes and lower problem-solving abilities (Schultz et al. 2005, Sol et al. 2005).

1.2 JUSTIFICATION

Over the years, millions of birds migrate from the Palearctic regions to tropical Africa south of the Sahara during winter. When they arrive, they face a problem of meeting resident birds with which they might have to compete for food and space (Salewski et al. 2002a). Relatively, limited information exists on how Palearctic passerines facilitate their coexistence with resident birds and the strategies they use to assess the available resources during these periods. My work will add up to the basic knowledge on how migrants forage and how they partition resources with resident birds.

Most studies on migrant ecology of birds in sub-Saharan Africa have been conducted in the eastern and southern parts of the continent (Pearson & Backhurst 1976, Leisler et al.1983, Lack 1986, Herremans 1993) but seldom in West Africa (Morel & Morel 1992) where most migrants from Central and Western Europe overwinter (Bairlein 1985, Zink 1973–1985). Moreover, there are few recent African studies (Salewski et al. 2002b, Jones et al. 2010) and virtually none recent from West Africa, although millions of birds are believed to over-winter in West Africa from Europe. To increase our basic knowledge on migrant-resident bird interactions, particularly with emphasis on foraging behaviour and resource partitioning, it is imperative to include studies of this kind from the West African region, hereunder Ghana.

Recent research has established clearly that the population of African-Eurasian migrant birds keeps on declining (BirdLife International 2008). Our knowledge about the ecology of migrant birds in their wintering grounds in West Africa is limited; therefore needs more observation to help explain their recent decline; hence the need for this study.

Food conditions may change seasonally in the wintering grounds and these changes may produce variations in foraging behavior (Salewski et al. 2002a). Of particular interest to the present study is also, the way in which the migrant birds encounter and use food resources and habitats – ecological conditions that inevitably affect their survival at the wintering grounds. Indeed such ecological aspects remains poorly understood, particularly in the West African sub-region.

1.3 SCOPE OF THE STUDY

The term foraging behaviour as used in this study is defined as behavioural responses or sequences associated with eating, including modes of eating, rhythmic patterns of eating, and time intervals. It involves searching for and exploiting food resources (Danchin et al. 2008). Resource or niche partitioning is a process which allows two species to divide certain resources (such as food, habitat) so that one species does not out-compete the other as dictated by the competitive exclusion principle; thus, coexistence is obtained through the differentiation of their realized ecological niches. Niche partitioning may not occur if there is sufficient geographic and ecological space for organisms to expand into (Sahney et al. 2010).

The present study involves three each of resident birds (Warblers: Sylviidae and Cisticolidae) and three Palearctic migrant passerine birds (Warblers: Sylviidae, and Flycatchers: Muscicapidae). It focuses mainly on the species' foraging techniques, foraging height, habitat usage, type of prey captured and is quantified by the time spent performing each foraging activity. The type of prey is categorized into insect or larva. The foraging technique was also categorized into 'gleaning', 'hawking', 'hover-gleaning', 'sallying' and 'probing'. Some emphasis was also placed on a social survey conducted to assess local inhabitants' knowledge about migrant birds and how their activities may affect migrant ecology and conservation.

1.4 MAIN OBJECTIVE

The aim of this research is to increase our understanding of the foraging behaviour of some Palearctic migrants (Melodious warbler, Willow warbler and Pied flycatcher) and resident birds (Rufous cisticola, Northern crombec and Senegal eremomela) in Ghana, and in particular how these species partition resources by trophic and spatial niche dimensional segregation.

1.4.1 Specific objectives

1. To determine how migrant and resident birds partition resources with emphasis on:

- Foraging techniques
- Habitat type
- Foraging height
- Food type

2. To determine whether the foraging behaviour of resident birds differs during the presence and absence of migrant birds
3. To assess local inhabitants' knowledge about migrant birds and how their activities may affect migrant ecology and conservation.

1.5 WORKING HYPOTHESES AND EXPECTED RESULTS

The main working hypothesis of this study is that Palearctic migrants are more flexible and opportunistic in their utilization of resources (Leisler 1993); they use a wider range of foraging techniques (Lack 1986, Lövei 1989), forage higher up in the vegetation (Lack 1990, Rabøl 1993) and generally, in more habitat types compared to their resident counterparts (Lack 1986). It is also hypothesized that the foraging behaviour of residents during the presence of migrants will be different when migrants are absent (Leisler 1990).

It is predicted that there will be an overlap in the foraging behaviour between migrant and resident birds, but that this overlap portrays differential niche segregation and is therefore consistent with principles of coexistence (Leisler 1993). In effect it means that the birds may overlap in the usage of some resources however, they still will be able to co-exist because the combined multidimensional overlap is coherent with coexistence (Leisler 1993).

CHAPTER TWO

LITERATURE REVIEW

2.1 SPECIES DESCRIPTION

2.1.1 Migrants

2.1.1.1 The Willow Warbler

The Willow warbler (*Phylloscopus trochilus*) is typically 11–12.5 cm long and 7–15 g weight (BirdLife International 2004). It is greenish brown above and off-white to yellowish below; the wings are plain greenish-brown with no wing bars. Juveniles are more yellowish below than adults (Hoyo et al. 2006, Snow & Perrins 1998). It is very similar to the Common chiffchaff (*Phylloscopus collybita*), but non-singing birds can be distinguished from Chiffchaffs by their paler pinkish-yellow legs (dark brown to blackish in Chiffchaff), longer paler bill, more elegant shape and longer primary projection (wing tip). Its song is a simple repetitive descending whistle, while the contact call is a disyllabic 'hoo-eet', distinct from the more monosyllabic 'hweet' of Chiffchaffs (Hoyo et al. 2006, Baker 1997, Snow & Perrins 1998).

The Willow warbler is a common and widespread leaf-warbler which breeds throughout northern and temperate Europe and Asia. Willow warblers breed from Ireland east to the Anadyr River basin in eastern Siberia (Hoyo et al. 2006). They are birds of open woodlands with trees and ground cover for nesting, including most importantly birch, alder, and willow habitats (Baker 1997). They prefer young, open, scrubby woodland with small trees, including human-altered habitats such as coppice and young plantations of up to 10–20 years old (Snow & Perrins 1998). High amounts of birch, alder and willow, with good lichen amounts, fields with large amounts of bracken and mosses are also preferred. Like most Old World warblers these small passerines are insectivorous (Baker 1997). These birds are strongly migratory, with almost all of the population wintering in sub-Saharan Africa.

Approximate timings of migration for the warbler are:

- October to March: wintering in sub Saharan Africa.

- Mid-March to mid-May: migrates and arrives in the breeding range.
- Late April to August: breeding season, usually only one brood but rarely two.
- August to October: migrates back to Africa (Snow & Perrins 1998)

The resident counterparts of Willow warbler and Melodious warbler are the Northern crombec, Rufous cisticola and Senegal eremomela. They are all warblers and belong to the order Passeriformes (perching birds). They are not necessarily closely related to one another, but share some characteristics, such as being fairly small, vocal, and insectivorous. They tend to be more easily heard than seen. Identification can be difficult and may be made on the basis of song alone (Wilson et al. 1973).

2.1.1.2 The Melodious Warbler

The Melodious warbler (*Hippolais polyglotta*) is an Old World warbler in the tree warbler genus Hippolais. It is a medium-sized warbler, 12–13 cm in length and 8-14g in weight, and similar to its eastern counterpart, Icterine warbler. The adult has a plain brown back and wings, and yellowish underparts (BirdLife International 2012). On the wings, secondaries and tertials are edged brownish-yellow, like the greater wing-coverts (but to lesser degree). On the tail, all rectrices are edged and tipped whitish. The sexes are identical, as with most warblers, but young birds are paler on the belly. On the head, is a short, indistinct pale yellow supercilium (Hoyo et al. 2006). The bill is greyish with pinkish-yellow lower mandible and cutting edges. The eyes are dark brown. Legs and feet are greyish-brown to pinkish-grey. The juvenile shows more conspicuous pale wing panel and paler underparts. Like most warblers, it is insectivorous, but will take other small food items, including berries. Its song is a rapid, sustained and varied babble, sometimes including imitations (Borrow & Demey 2004). This small passerine bird mostly prefers open woodland with bushes. 3-5 eggs are laid in a nest in a tree or a bush. Both sexes are similar. It breeds in south-west Europe (BirdLife International 2012). It is migratory, wintering in sub-Saharan Africa. In Europe, the breeding population is estimated to number 1.0-3.0

million breeding pairs, equating to 3.0-9.0 million individuals (BirdLife International 2004). Europe forms 75-94% of the global range, so a very preliminary estimate of the global population size is 3.19-12.0 million individuals, although further validation of this estimate is needed. On the breeding grounds, it prefers orchards, large gardens, scrub, dense thorny bushes in meadows and riverine forest (Hoyo et al. 2006)

Approximate timings of migration for Melodious warbler are:

- September to late February/April: wintering in sub Saharan Africa.
- Late April/May: migrates and arrives in the breeding range.
- May to September: breeding season.
- Late July to early September: migrates back to Africa (BirdLife International 2004)

2.1.1.3 The Pied Flycatcher

The Pied flycatcher (*Ficedula hypoleuca*) is a small passerine bird in the Old World flycatcher family, one of the four species of Western Palearctic black-and-white flycatchers. It breeds in most of Europe and western Asia. It is migratory, wintering mainly in western Africa (BirdLife International 2004). This 12-13.5 cm long bird (Parkin 2003) weighs about 13 grams. The breeding male is mainly black above and white below, with a large white wing patch, white tail sides and a small forehead patch, above their beak. The size of these spots directly correlates with a male's attractiveness to a female. The size also indicates the male's immune competence, and larger patches are correlated with fewer trypanosome infections (Morales et al. 2007, Sanz 2001). Usually males are the only ones with white forehead patches, but in some populations females may have them as well, and the patch is a sign of ageing, rather than health (Morales et al. 2007). The plumage of males which often reflects ultraviolet light darkens as they age, until they reach a jet black color. During nesting, brooding females have an incubation patch which can be used to determine sex (Siitari 2002). Pied flycatcher has a black bill which is broad but pointed in shape typical of aerial insectivores. Non-breeding males, females and juveniles have the black replaced by a pale brown, and may be very difficult to distinguish from other *Ficedula* flycatchers, particularly the Collared flycatcher (*Ficedula albicollis*) with which this species hybridizes to a limited extent (Parkin 2003).

Pied flycatchers are insectivorous and eat many types of invertebrates, including beetles, spiders and ants. They also eat flies, bees, wasps and moths (Eeva et al. 2005, Lyytinen et al 2003). As well as taking insects in flight (sallying-hawking) and from the ground (Lundberg 2010), this species within its breeding range preys on caterpillars amongst the foliage (Parkin 2003), and will take berries.

In the breeding seasons Pied flycatchers are found in forests, and forest composition varies by region. In central Europe, they prefer high altitude beech and spruce forests. They are also found at middle altitude levels, where beech and spruce mix with deciduous forest (Adamik & Bures 2007, Huhta et al. 1998). After breeding, Pied flycatchers leave Europe in a south-westerly direction (Winkel & Frantzen 1991). In Spain and Portugal, where migration peaks in September (Veiga 1986), they occupy temporary foraging territories for up to nine days (Bibby & Green 1980) which might be re-used in subsequent winters (Veiga 1986). During this time they prepare their onward migration (Bibby & Green 1980). After arriving south of the desert, they continue to the final wintering grounds to occupy and defend a territory where they stay during the whole European winter.

Below is the approximate migratory timing of the Pied flycatcher;

- Mid-September to mid-April: lives in sub-Saharan Africa
- Mid April to end of May: migrates and arrives in north and north-western Europe.
- June to August: breeding season, one brood only
- August to mid-September: flies back to sub-Saharan Africa (BirdLife International 2004).

The birds are territorial and intraspecific relationships are mostly expressed by territorial behaviour (Salewski 2002b). The singing male defends the area, but if several nests are close to each other, they defend the territory communally. They are monogamous and pair-bonds last about one breeding season. The Pied Flycatcher predominately practices a mixed mating system of monogamy and polygyny (von

Haartman 1951). Within the polygyny system, the males leave their home territory once their primary mates lay their first eggs. Males then create a second territory, presumably in order to attract a secondary female to breed. Even when they succeed at acquiring a second mate, the males typically return to the first female to exclusively provide for her and her offspring (Silverin 1980). Males will sometimes care for both mates if the nests of the primary and secondary female are close together. Insectivores, like Pied flycatchers, generally have intermediate basal metabolic rates (BMR) when compared to similar birds eating different diets (McNab 2009). They average about 0.84 kJ/h in BMR.

Pied flycatchers are subject to a range of parasitic infections. The white patches on their foreheads and wings lack the protection of melanin, so those areas are more prone to breakage, bacterial infection, and lice infestations. They carry infestations of mites and fleas (Merino & Potti 1996). Nestlings are parasitized by blow fly larvae (*Protocaliphora azurea*). Well-fed nestlings are more resistant to parasitism. Blood parasite infections increase in parents with large clutches. Blood parasites, *Haemoproteus balmorali* affects males more, while *Haemoproteus pallidus* affects females. The increased infection rate is probably due to the birds spending their energy on feeding their young at a cost to their immune systems (Haemig 1999, Merino & Potti 1998). Pied flycatchers have a varying relationship with northern wood ants (*Formica aquilonia*). When they nest in trees containing these ants, their nests are at risk of predation from the ants. However, when there is another predator which may eat the nestlings, like Eurasian jays (*Garrulus glandarius*), Pied flycatchers may choose to nest in trees with wood ants because they help to defend against jays (Haemig 1999).

2.1.1.4 The Northern Crombec

The Northern crombec (*Sylvietta brachyura*) is a very small warbler of bush and woodland habitat with a tailless appearance (Stevenson & Fanshawe 2002). It was formerly placed in the massively paraphyletic Sylviidae, however, it is now considered to belong to a newly-recognized, as yet unnamed lineage (BirdLife International 2004). It measures about 8cm and weighs about 6.5g. It is uniform grey above with a whitish face and throat giving a pale-faced appearance. It also has a dark eye-line and buffy cinnamon underparts (Stevenson & Fanshawe 2002).

It is insectivorous and takes a range of insect prey. Northern crombec is very active and feeds in the canopy and in bushes, either as singles or pairs, or sometimes in mixed species flocks (Hoyo et al. 2006). It mostly prefers dry savanna to semi-arid scrub (Clements 2009). Breeding is seasonal and usually timed to coincide with the end of the dry season and beginning of the rainy season. Northern crombec is monogamous and build simple cup-shaped nests in dense vegetation. Both parents typically help in raising the young, which are able to fly at around two weeks of age (Alström et al. 2006).

Northern crombec has an extremely large range, and hence does not approach the thresholds for Vulnerable under the range size criterion hence the species is evaluated as Least Concern (BirdLife International 2012). The global population size has not been quantified, but the species is described as common over most of it range, although locally common to uncommon in West Africa (Hoyo et al. 2006).

2.1.1.5 The Rufous Cisticola

Rufous cisticola (*Cisticola rufus)* is a small insectivorous bird formerly classified in the Old World warbler family Sylviidae, but now considered to be in the family Cisticolidae (Ryan 2006). This small size (about 10cm) warbler is easily heard than seen. It has dull rust brown upperparts (BirdLife International 2000) and faint yellow and white under-parts. Its natural habitats are subtropical or tropical dry shrubland and subtropical or tropical dry lowland grassland. It can also be found in human-modified habitats such as road verges, cultivation, weedy areas or pasture (Ryan 2006). Male Rufous cisticolas are polygamous. The female builds a discreet nest deep in the grasses, often binding living leaves into the soft fabric of felted plant down, cobweb, and grass. The average clutch is about 4 eggs, which take about 2 weeks to hatch (Nguembock et al. 2007). It is non-migratory and often found within its range.

Rufous cisticola has a very large range, and hence does not approach the thresholds for Vulnerable under the range size criterion (Dowsett & Forbes-Watson 1993, Sibley & Monroe 1990).The population trend appears to be stable, and hence the species does not approach the thresholds for Vulnerable under the population trend criterion (>30% decline over ten years or three generations). The population size has not been quantified, but it is not believed to approach the thresholds for Vulnerable under the population size criterion (<10,000 mature individuals with a continuing decline estimated to be >10% in ten years or three generations, or with a specified population structure). For these reasons the species is evaluated as Least Concern.

2.1.1.6 The Senegal Eremomela

The Senegal eremomela (*Eremomela pusilla*) is another sylvid. These 10.5 cm long warblers weigh about 9.0g and have olive upperparts and yellow underparts. The throat is white and sexes are similar in size and plumage (Madge 2006). They are intermediate in appearance between crombecs and apalis. Like most warblers, the Senegal eremomela is insectivorous and nest low in vegetation (Ryan 2006). Its call is a squeaky "tuuu" and the song is a trill.

It prefers open woodland, savanna and semi-arid scrub habitats. It can also be found in human-modified habitats such as road verges, cultivation, weedy areas or pasture. It is usually seen alone, in pairs, or in family groups as it forages on the ground or in foliage for insects and other small invertebrates. Sometimes, they are difficult to see, so their song is often used as an identification guide (Hoyo et al. 2006).

The global population size of the Senegal eremomela has not been quantified, but the species is described as the commonest member of its genus throughout the West African Guinea and Sudan savannah belts (Hoyo et al. 2006). This species is not believed to approach the thresholds for international status as Vulnerable under the population size criterion (<10,000 mature individuals with a continuing decline estimated to be >10% in ten years or three generations, or with a specified population structure). For these reasons the species is evaluated as Least Concern (BirdLife 2000, 2004, 2008).

2.2 FORAGING ECOLOGY OF MIGRANTS AND RESIDENT BIRDS

A study conducted in Zimbabwe on habitat use and densities of co-existing migrant Willow warbler with resident Senegal eremomela revealed that, Willow warblers occupied more habitat types and occurred at higher densities than the ecologically-similar resident Eremomela spp. (Jones et al. 2010).

Another study conducted in three woodland habitats in Zimbabwe to assess how immigrant Palearctic Willow warblers partitioned resources with two ecologically similar resident warblers revealed that, unlike either Eremomela species, Willow warblers occurred in all three habitat types (Salewski et al. 2002b). In acacia woodlots, Willow warblers showed a significantly greater diversity of foraging techniques, perhaps reflecting a greater diversity of prey taken, compared to the Burnt-necked Eremomela (*Eremomela usticollis*). In mopane woodland, where eremomelas hardly occurred, Willow warblers showed the highest diversity of foraging techniques (Salewski et al. 2002b) and may be able to exploit resources there that eremomelas cannot.

Habitat selection and coexistence of migrant warblers and afrotropical resident birds was investigated in Kenya by Leisler (1992). The results of the study showed that, migrant birds were more eurytopic (able to tolerate a wide range of ecological conditions and habitats) and exploited more open parts of the habitats than ecologically similar tropical species. In some guilds, the foraging speed and rate of migrants were higher and they used their wings more often for hovering than the resident birds. There was, however, weak evidence that niche shift of resident birds was induced by the arrival of migrants. The study suggested that residents were dominant and that migrants adjusted their foraging ecology by filling out unexploited niches or overlapped in many niche dimensions.

A comparative ecological study of Willow warblers and resident birds in Kenya (Rabøl 1987, 1993) and Ivory Coast (Salewski 1999) also revealed that Willow warblers foraged more within the vegetation and used their wings more often for hovering than the ecologically similar resident Green-backed Eremomela *(Eremomela canescens)*. Rabøl (1987) suggested that the arrival of Willow warblers led to microhabitat displacements among Afrotropical species but he later rejected his earlier conclusions and stated that interspecific competition played a lesser role than he previously thought.

A study on the morphology and foraging behaviour of Siberian phylloscopus warblers revealed a striking correlation between morphology and foraging techniques (Forstmeier 2001). Species with large hind limbs and short wings foraged in dense vegetation near the ground using gleaning techniques. In contrast, species with long wings and large bills favoured open vegetation, and foraged by sallying manoeuvres. Independently of these trends, small species foraged at higher levels in the vegetation, and used hover flight more often than did larger species. Foraging methods were also highly correlated with vegetation structure (Forstmeier 2001). Coniferous trees were exploited using hover flight when they had short needles and gleaning when needles were long. Sallying predominated in light deciduous vegetation whereas gleaning was used most in dense, deciduous bushes. After controlling for the effects of vegetation structure on foraging behaviour, species differences became less pronounced, but were still significant. It is therefore concluded that morphology may be regarded as having adapted to enable more efficient exploitation of certain microhabitats. Morphology may therefore partly determine a species' ability to colonise new habitats.

Furthermore, the wintering strategies of pied flycatchers and willow warblers were compared in Ivory Coast, and it was revealed that habitat and microhabitat choice of these species were similar but in foraging ecology, they differed by a higher diversity of foraging substrates and foraging techniques of pied flycatchers. The differences in the winter strategies were explained by the ability of Pied flycatchers to defend a territory because of their diversity in foraging behaviour, whereas Willow warblers were more specialized and therefore obligated to be more mobile in order to find their patchily distributed food (Salewski et al. 2002a).

There are also studies on foraging interactions among resident and migrant birds outside the African-European (Afrotropical-Palearctic) region. A study aimed at examining the foraging behaviour of a resident bird species, the Rufous-capped warbler (*Basileuterus rufifrons)* in Mexico (the New World), revealed that the resident birds did not move to other habitats when migrants were present. Rufous-capped warblers (RCWAs) foraged almost equally in both vegetative layers (canopy and understory) during the wet season although they were more successful foraging in the canopy. In the dry season, migrants foraged primarily in the canopy and RCWAs shifted so that 80% of RCWA foraging manoeuvres were in the understorey. At that time RCWAs foraged less successfully in both vegetative layers (Jedlicka et al. 2006).

Resource partitioning within an assemblage of seven species of insectivorous birds inhabiting remnant Melaleuca woodland on Rottnest Island off the coast of Western Australia was studied during May-July 1993. The significance of total foraging niche overlap between species and sexes (defined as overlap > 60%) was low in May (only 14% of all total foraging overlaps) but increased slightly in June and July (25 and 29% of all total foraging niche overlaps respectively). Foraging habits were associated significantly both with bird species and month of observation, indicating that foraging niche partitioning occurred and that its pattern varied circannually. The diversity of foraging habits displayed by each bird species in each foraging niche dimension varied widely (Wheeler & Calver 1996).

A study on the foraging and habitat relationships of insect-gleaning birds in a Sierra Nevada mixed-conifer forest showed that tree species and, to a lesser extent, foraging heights were used selectively by the guild. Of four measured foraging niche components (dimensions), the use of foraging site (consisting of air or tree part) showed the greatest difference between species, followed by tree species, foraging techniques, and foraging height. Resident and migrant species groups showed few fundamental differences in foraging patterns, except that migrants tended to use a greater proportion of deciduous foliage than residents (Danielle & Reginald 1985).

In summary, it is clear that some of the studies conducted in the African-European region did point out to the existence of differences in the foraging behaviours (habitat selection, foraging technique, and foraging height) between migrants and residents. Migrants occupied more habitats and used a higher diversity of foraging techniques than the residents (Jones et al. 2010, Salewski et al. 2002b).
However, some gaps have been identified in the literature reviewed. Most of the comparative ecological studies conducted in Africa, have over the years focused on the willow warbler, giving little attention to the Pied flycatcher. Also, there is no known comparative ecological study on the foraging ecology of melodious warblers and resident species in Africa, a subject that warrants research. Furthermore, previous studies on migrant-resident foraging interactions did not focus on the extent of overlap between migrants and residents on their niche gradients, and how these overlaps could influence their co-existence. Also most of the previous studies reviewed, did not increase our understanding on spatial resource partitioning between migrants and residents, however much attention was rather paid to habitat type and foraging techniques. This study however, aims at filling out some of the gaps by focusing simultaneously on four factors of resource partitioning: 1) Habitat type (Major), 2) Foraging height, 3) Foraging technique (Major), 4) Food type (Minor) and extent of niche overlap among migrant and resident bird species.

2.3 OVERVIEW OF MIGRANT BIRDS

2.3.1 Bird Migration

Bird migration is the regular and seasonal movement of whole or part of populations, characterised by many species of birds. Such predictable movements (journeys) include those made in response to changes in food availability, habitat or weather. In some instances, the journeys are not regarded as "true migration" because they are irregular and unpredictable (i.e. nomadism, invasions, irruptions) or in only one direction (i.e. dispersal = movement of young away from natal area). Migration is marked by its annual seasonality (Berthold et al. 2001). Approximately 1800 of the world's 10,000 bird species are long-distance migrants, thus they travel several thousands of kilometres (Sekercioglu 2007). The main motivation for migration seems to be food; for example, some hummingbirds choose not to migrate once those humming birds are fed throughout the winter (Sekercioglu 2007). Locating suitable resources during migration may enhance an individual's survivorship and subsequent reproductive output.

In addition to resource availability, another factor that appears to influence migratory behaviour is the size of foraging groups. Boyle and Conway (2007) found that species of birds that are solitary foragers are much more likely to be migratory than species that forage in pairs or groups. A likely explanation for this relationship between foraging behaviour and tendency to migrate is that, foraging with conspecifics likely improves foraging efficiency.

Palearctic migrants are among other birds that embark on journeys to wintering grounds for conducive ecological conditions. They are known to use urban habitats as stopover sites and often occur in cities at exceptional density (Chad et al. 2010).These migrants face several challenges along the flyways and stop over sites which could lead to substantial mortality (Ketterson & Nolan 1982). For example, Strandberg et al. (2010) used satellite telemetry to monitor four species of raptors crossing the Sahara Desert while attempting to migrate from Europe to Africa and found that 31% of all juveniles and 2% of adults died en-route. Also, Newton (2007) summarized previously documented cases of bird mortality during migration and examples included more than 10,000 magnolia warblers (*Dendroica magnolia*) and other warblers killed in a rainstorm off the Texas coast in 1981.

Along the flyways, the migrants could find themselves in an unfamiliar area and as such may not be able to find adequate food to meet the high energy demands (Loiua & Moore 1990). Other problems which migrants face on the flyways are predators and unpredictable weather, and competition with other migrants as well as residents for potentially limited resources (Huito 1985). All these challenges must be overcome to successfully complete migration.

Finding and consuming food and water to offset high stress, physical exertion costs, and other risks of migration may therefore, be a considerable cost for an individual during migratory periods. As fat deposits are depleted during flight, passerines can restore lipid reserves at rates approaching 10% body mass per day (Rappole & Warner 1976, Biebach et al. 1986, Moore & Kerlinger 1987).

Migratory birds exhibit great variation in the distance of their migratory journeys, with some short-distance migrants moving just a few hundred kilometers and some long-distance migrants traveling several thousand kilometers. Several factors can contribute to this variation in migration distance among different species and populations. For example, migration distance among some birds appears to be influenced by food habits, with insectivorous species tending to migrate longer distances than frugivorous species (Boyle & Conway 2007). Migration distances can also be influenced by the presence of ecological or geographical barriers, such as large bodies of water, deserts, and mountain ranges (Alerstam 2001).

For most birds, migration is divided into alternating periods of flight and stopovers, with time at stopover sites spent foraging to deposit fuel for the subsequent flight (Schaub et al. 2008). The time spent at stopover sites is influenced by a bird’s condition when arriving at a site and by conditions, such as food availability and weather, at the site. The overall speed of migration is greatly influenced by the time spent at stopover sites, and this speed can be of critical importance because it determines when migrants arrive at breeding and wintering sites. Stopover duration is short if foraging success is poor and fuel deposition rates are low or negative (Yong & Moore 1993).

2.3.2 Migratory Flyways

Flyways have been defined as “the entire range of a migratory bird species (or groups of related species or distinct populations of a single species) through which it moves on an annual basis from the breeding grounds to non-breeding areas, including intermediate resting and foraging places as well as the area within which the birds migrate” (Boere & Stroud 2006).

Typically, migratory journeys follow a predominantly north-south axis, linking breeding grounds in arctic and temperate regions with non-breeding sites in temperate and tropical areas. Recent research has identified eight such pathways: the East Atlantic, the Mediterranean/Black Sea, the East Asia/East Africa, the Central Asia, the East Asia/Australasia, and three flyways in the Americas and the Neotropics (Boere & Stroud 2006). The Mediterranean/Black Sea Flyway is one of three Palearctic-African flyways connecting Europe with Africa. Collectively, these constitute the world’s largest bird migration system.

The scale of the avian movement is truly awesome with over two billion passerines and non-passerines, 2.5 million ducks and two million raptors migrating from their breeding grounds in Europe and central and western Asia to winter in tropical Africa. The majority of those coming from western Siberia and central and eastern Europe do so along the Mediterranean/Black Sea Flyway which stretches south from the Russian arctic (Boere & Stroud 2006).

2.3.3 Timing of Migration

The primary physiological cue for migration is the changes in the day length. These changes are also related to hormonal changes in the birds. In the period before migration, many birds display higher migratory restlessness or *Zugunruhe* (German) as well as physiological changes such as increased fat deposition (Diego et al. 2004). The occurrence of Zugunruhe even in cage-raised birds with no environmental cues (e.g. shortening of day and falling temperature) has pointed to the role of circannual endogenous programs in controlling bird migrations. Caged birds display a preferential flight direction that corresponds with the migratory direction they would take in nature, even changing their preferential direction at roughly the same time their wild conspecifics change course (Diego et al. 2004).

Many factors can influence the timing of migration, including genetic factors (Berthold 1998). Berthold (1990) found that the onset of migratory activity in captive birds (characterized by migratory restlessness, or zugunruhe) maintained under controlled conditions was highly correlated with that of birds in the wild, suggesting that the timing of migration has a genetic, or innate, component. However, the extent of genetic control probably varies among species, with such control more likely in species, such as long-distance migrants, that breed in highly seasonal environments where environmental conditions are predictable within and across years (Ogonowski & Conway 2009) and when wintering and breeding areas are far apart and conditions in one location provide no evidence of conditions at the other location.

2.3.4 Ecological and Cultural Significance of Migrant Birds

Migratory birds perform important ecological regulating services. They play a vital role in seed dispersion and flower pollination (Whelan et al. 2008). Seed dispersal through migrants' activities is an important process influencing the distribution of plant species in the environment (Schupp 1993) and can help in forest restoration process (Reid et al. 2008, Lindell et al. 2012). Moreover, seed dispersal may exert selective pressures on plants, and these pressures directly affect their reproductive success (Thompson & Wilson 1979).

Migratory birds are potentially very effective indicators of environmental changes that affect us all, for example, climate and habitat change (UNEP/CMS 2012). Migratory birds play other important roles in the ecosystems. They eat insects and rodents which save farmers money they would otherwise spend on pesticides and crop protection measures (UNEP/CMS 2012). By acting as natural controls, migrants help regulate pests by reducing populations of potentially harmful insects such as caterpillars, weevils, cutworms, beetles and flies. In the UK, major plagues of caterpillars resulted from the persecution of birds that were thought to eat much-needed grain and fruit during World War 1 (Collar et al. 2008). Each year in September-October, at the end of the wet season, migratory birds such as Abdim's storks (*Ciconia abdimi)*, black kites (*Milvus migrans)* and cattle egrets (*Bubulcus ibis)* converge on the Diffa region in South-East Niger, to feed on millions of Senegalese grasshoppers (*Oedaleus senegalensis)*. Due to their grasshopper devouring capacities, Abdim's storks and cattle egrets are held in high esteem by local farmers. Other insectivorous migratory birds in all parts of the world provide similar functions (UNEP/CMS 2012). Migratory species also have great significance in many cultures – in legends, stories, religions, medicine and customs. They even play a major role in the way we measure time and experience seasons. Nowadays humans also benefit from them for recreational activities and educational purposes (UNEP/CMS 2012).

2.3.5 Economic Importance of Migrant Birds

In local and global economies, too, migratory birds play an important role: through subsistence, recreational and commercial hunting, providing food and income. More recently they have become prime attractions for eco-tourists. There is no doubt, however, that migratory birds contribute much to bird-watching and eco-tourism businesses all over the world (UNEP/CMS 2012). Bird watching is a highly popular recreational activity and greatly contributes to the growing global eco-tourism industry (UNEP/CMS 2012). Birding is the most rapidly growing sector of eco-tourism, a billion dollar industry, which again makes migratory birds economically important for human beings. Hundreds of thousands of birdwatchers travel to various places in the world to watch birds, hoping to glimpse rare species. Considerable economic benefit is achieved by disbursing funds for travelling, accommodation and entrance fees. On a South African site, two 'birding routes' are generating an estimated revenue of US$ 6.4 million annually for local people. Tourists are provided with route descriptions that take them to a number of bird-watching areas, where they can watch intra-African and Palearctic migrants (UNEP/CMS

2012). Costa Rica in 1999 received US$ 1 billion from eco-tourism, of which 41% stemmed from bird-watching eco-tourists (Collar et al. 2008). Mostly this was related to resident birds perhaps, but some also related to altitudinal migrants and long-distance migrants. A survey by the United States Fish & Wildlife Service puts the annual economic value generated by bird watchers (or 'birders') and other wildlife watchers at around US$ 32 billion per year in the United States alone. This amount corresponds to the gross domestic product (GDP) of Costa Rica, which, coincidently, is a popular destination for US birders (UNEP/CMS 2012). In Scotland, the Royal Society for the Protection of Birds (RSPB) found out in 2011 that US$ 8 - 12 million is spent annually by tourists wishing to see White-tailed eagles on the Isle of Mull alone. 4 per cent of jobs in Scotland associated with wildlife tourism are supported by this expenditure every year. Economic benefits delivered by White-tailed Eagles on the Isle of Mull have more than tripled since 2005 (UNEP/CMS 2012).

Also, the production of birding equipment such as binoculars and cameras is an important multi-million dollar industry. In 2001, migratory bird hunting trip and equipment for migratory bird hunting generated estimated revenue of $6.57 million and $7.32 million to the US economy (UNEP/CMS 2012). A great diversity of bird watching literature helps birdwatchers and interested lay people to explore the fascinating world of migratory birds. This type of eco-tourism educates people about the importance of migratory birds and ecosystems. Ecotourism can help conserve important habitats that helps preserve not just migrating birds but biodiversity on a much greater scale.

The trade in wild live birds, including some migratory ones, is still an important, but controversial, economic activity. Many bird species are kept as pets for their beauty and their song. In the period 2000-2003, three million wild birds (and 800,000 captive bred ones) were imported into the European Union (BirdLife International 2008). In Asia as well, there is an enormous trade in wild birds. These are mainly sedentary birds, but a considerable percentage consists of migratory species. In West Asia there is also a market for stuffed birds, many of which are migratory. The same can be said for other parts of the world (BirdLife International 2008).

Also, migratory birds help save farmers money they would have otherwise used in fighting pest. For instance, in 2001, it was estimated that birds reduced insect damage to forest and agriculture in the USA by 44% and that saved the US economy US$ 440 million in that year and many of these birds are migratory insectivores (Collar et al. 2008).

2.3.6 Ecological Effects of Bird Migration

The migration of birds enhance the dispersal of other species, including those of ectoparasites such as ticks and lice which in turn may carry micro-organisms including those of concern to human health (Smith et al. 1996). Considerable interest has been taken due to the global spread of avian influenza, however migrant birds have not been found to be a special risk, with import of pets and domestic birds being a greater threat (Rappole et al. 2006). Some viruses that are maintained in birds without lethal effects, such as the West Nile Virus may however be spread by migrating birds. Birds may also have a role in the dispersal of propagules of plants and plankton (Figuerola & Green 2002).

2.3.7 Adaptations of Migrant Birds

Migrant birds alter their metabolism in order to meet the demands of migration. The storage of energy through the accumulation of fat and the control of sleep in nocturnal migrants require special physiological adaptations (Hedenström 2008). Since there is an increased food requirement, during pre-migration, it is expected that more time will be invested on foraging at the expense of other activities. Recently, a radar study quantified bird migration and demonstrated that almost all passerines cross the Western Sahara with an intermittent strategy, thus they fly during the night and rest during the day (Jedlicka et al. 2006). According to the study, before crossing the desert, most passerines accumulate fat stores because they will not find appropriate resting sites for foraging in the Sahara. However, it was also reported that birds use the vegetation around oases for refueling. Since birds resting at oases had smaller fat deposits than birds resting in the open desert, it was hypothesized that mainly lean birds or fall-outs use the oases for foraging (Jedlicka et al. 2006). In addition, the feathers of a bird suffer from wear-and-tear and require to be moulted. The timing of this moult - usually once a year but sometimes two - varies with some species moulting prior to moving to their winter grounds and others moulting prior to returning to their breeding grounds. Apart from physiological adaptations, migration sometimes requires behavioural changes such as flying in flocks to reduce the energy used in migration or the risk of predation (Weber 2009).

2.3.8 Global and Regional Solutions for Endangered Migrants

Migrant birds in their innumerable forms are an irreplaceable part of the earth's natural system, which must be conserved for the good of mankind. Therefore, each generation of man holds the resources of the earth for future generations and has an obligation to ensure that this legacy is conserved and, where utilized, is used wisely. Conserving migratory animals such as birds, and their habitats helps to preserve entire ecosystems, thus supporting life on Earth. As an environmental treaty under the aegis of the United Nations Environmental Program, the Conservation of Migratory Species of Wild Animals (CMSWA) provides a global platform for the conservation and sustainable use of migratory animals and their habitats (CMS 2008). The convention brings together the states through which migratory animals pass, and lays the legal foundation for conservation measures throughout the species' migratory range. Measures are embedded in detailed conservation and management plans. Migratory species threatened with extinction are listed on Appendix I of the convention on migratory species of wild animals (CMSWA). States are entreated to strictly protect these animals, conserving or restoring their habitats, mitigating obstacles to migration and controlling other factors that might endanger them. They are also to prevent, remove, compensate for or minimise as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent the migration of migratory species.

The convention also promotes concerted action among the range states of many of these species to with one mind, protect the migrants. Migratory species that need or would significantly benefit from international co-operation are listed in Appendix II of the CMSWA convention (CMS 2008). CMSWA promotes collaborative research and conservation projects on migratory animals worldwide. The spectrum of activities is wide, ranging from population counts to the evaluation of the quality of habitats and threats, as well as the use of satellite telemetry to identify migration routes. Other projects focus on studies of breeding habits, fencing of nesting areas, site identification and mapping, or the genetic analysis of tissue samples (CMS 2008).

One typical example of a migrant bird that enjoys protection under the convention is the Aquatic warbler (*Acrocephalus paludicola*). The Aquatic warbler *(Acrocephalus paludicola)* is the rarest and the only internationally threatened passerine bird found in mainland Europe. This small migratory water bird is estimated to have declined sharply at a rate equivalent to 40 per cent in the last 10 years (CMS 2010). As of May 2010, its global population of only 10,200-13,800 males is confined to less than 40 sites in only six countries, with four sites supporting over 80% of the global population (CMS 2010). Its dependence on a specialised and vulnerable breeding habitat (for example marshes, fen mires) means it has become globally threatened, as its habitats have been suffering from constant decline. This decline is especially due to human induced changes in the hydrological regime in key sites (both drainage and flooding), changes in land use and habitat fragmentation due to infrastructure building. As part of international efforts to conserve the Aquatic warbler, range states under the CMSWA decided to work closely together to improve the conservation status of the Aquatic warbler throughout its breeding, migrating and wintering range. To that end they will, individually or collectively provide strict protection for the Aquatic warbler and identify and conserve the wetland habitats essential for its survival. Range countries will also facilitate the expeditious exchange of scientific, technical and legal information needed to coordinate conservation measures, and cooperate with recognized scientists of international organizations and other range States in order to facilitate their work conducted in relation to the conservation of the Aquatic warbler (CMS 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Location

The study area is the Damongo Dam Area which is situated in Damongo, within the Northern Region of Ghana (Fig. 1). Its geographical coordinates are 9°3' 20" North, 1° 45' 30" West. The study area stretches over an area of about 11.2 km^2. The site is situated at the outskirt of Damongo township, about 600m away from the town and about 900 km from Accra. Damongo is the district capital of the West Gonja District. The dam in the study area is locally referred to as the ‘Akpeteshie dam’ and it provides food resources to several bird species in the area.

3.1.2 Climate

The annual climatology is mainly influenced by two major wind or air mass systems, the South-western Maritime Air and the North-eastern Continental Air. Rainfall is bimodal with the average annual precipitation being 1144mm. From 2005-2011, annual rainfall ranged from 973.3mm to 1377.9mm (Ghana Meteorological Agency 2011).The rainfall pattern is erratic, beginning in late April to late October. The peak of the rainfall is in June/July with prolonged dry spell in August. The rains are stormy and torrential, up to 300mm per hour. Erosion and floods are common due to the torrential nature of the rains. Temperatures are generally high with the maximum occurring in the dry season, between March/April and are lowest between December/January. The mean monthly temperature is 27°c (Ghana Meteorological Agency 2011). The dry season is characterised by the Harmattan wind, which is dry, dusty and cold in the morning and very hot at noon. Evapotranspiration is very high causing soil moisture deficiency. Humidity is very low causing dry skin and cracked lips to human beings. The vegetation is characterized by trees being sufficiently widely spaced so that the canopy does not close. The open canopy allows sufficient light to reach the ground to support an unbroken herbaceous layer consisting primarily of grasses. The vegetation is therefore, intermediate between grasslands and forests vegetation. The dominant vegetation in the study area is mostly of a height of about 0.5-15m. The ground vegetation and foliage are mostly below 3m, so birds are easy to watch as they forage from conspicuous perches in the tree canopy.

3.1.3 Flora and Fauna

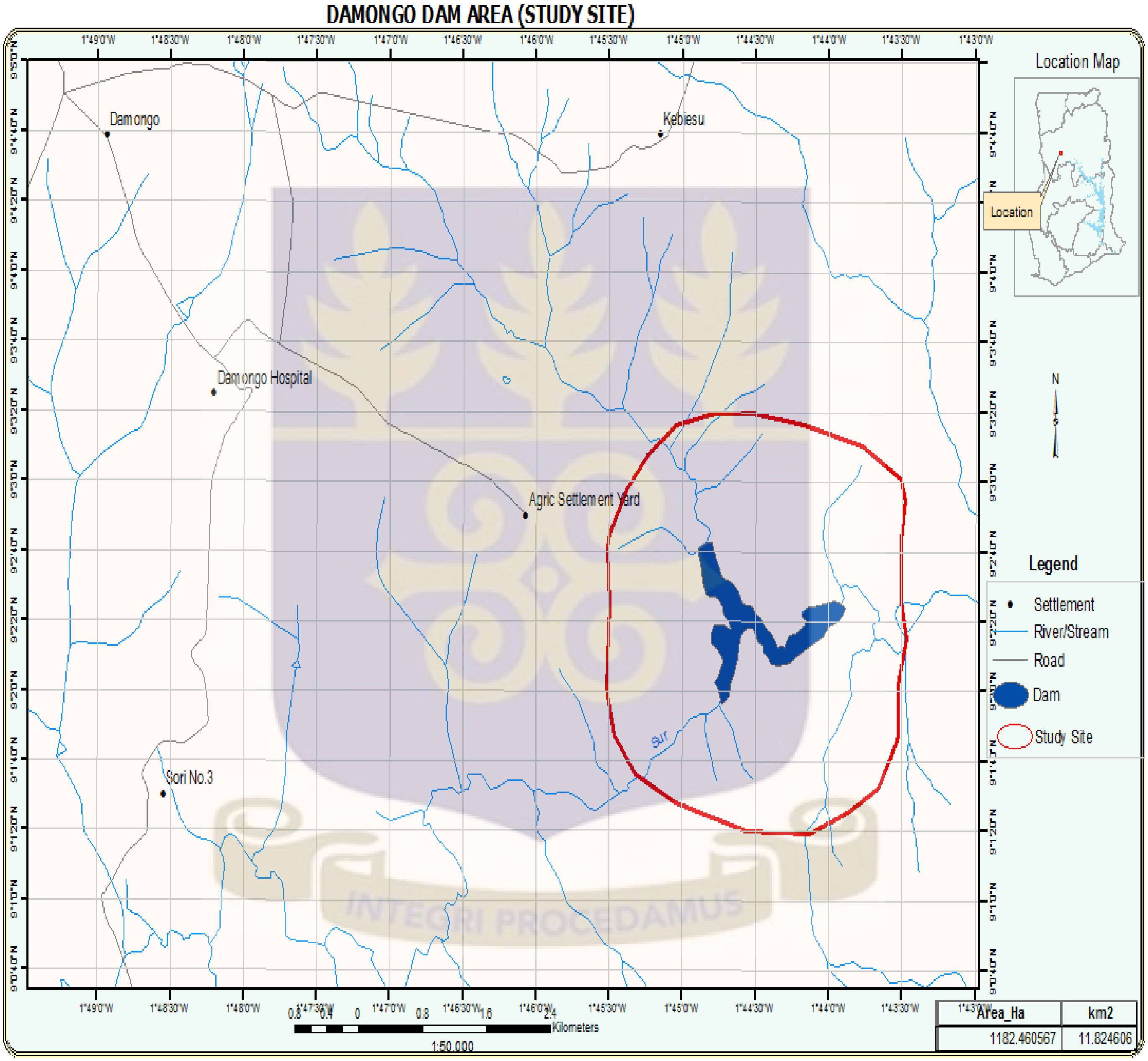
The natural vegetation in the study area is the Guinea Savanna. The composition of trees in this guinea savannah varies but generally consists mostly of *Acacia sp.*, *Searinega virosa*, *Combretum sp.*and *Crotalaria refusa*. The understory is made up of long grasses, shrubs and herbs, including elephant grass (*Pennisetum purpureum*) which can grow to be 3 or 4 meters tall.There are also farmlands of various sizes with different plantations. Some of the cash crops planted are the cashew (*Anacardium occidentale*) and mango (*Mangifera indica)*. The presence of animals such as grasscutters (*Thryonomyidae swinderianus*), hares (Lepus capensis) and squirrels (*Xerus erythropus*) often attracts hunters to the site whose activities often leave the vegetation destroyed by setting the vegetation ablaze. The birds found in the area also includes laughing dove (*Streptopelia segalensis*), Northern grey-headed sparrow (*Passer griseus*), Red-winged warbler (*Heliolais erythropterus*), Common fiscal (*Lanius collaris*), Senegal Coucal (*Centropus senegalensis*)

3.1.4 Population and Land Tenure

From the results of the 2000 population and housing census, Damongo had a population of about 14,442 (GSS 2005). Majority of the residents are subsistent farmers. Besides farming, the women are mostly engaged in petty trading. Gonjas are the dominant tribe in the area whiles the Yagbon-wura is the paramount chief of the Gonja traditional area. Other minority tribes such as the Dagombas, Frafras and Mamprusis are also found in the area.

Land tenure refers to the terms and conditions on which land is held, used and transacted (Adams et al. 1999). The type of land tenure system practiced in Damongo is the communal ownership of land. The land is vested in the paramount chief who holds it in trust for his people. This tenureship of land rights is passed down to community level through sub-chiefs. Thus actual ownership or allodial rights are held by the community as a whole, granting rights of use to individual family lineages. Family groups have rights to use the land for building their own dwellings and for cultivating the crops which form their subsistence base (Odonkor & Mason 1994). Land has always been an important component of development in Damongo hence making a living requires some access without which the livelihoods of many would be in jeopardy (Yaro & Abraham 2009). However, land under the customary system of ownership is sometimes abused by family groups that own them. These family groups sometimes engage in bad farming practices such as continuous cropping, deforestation and bush burning leading to habitat degradation and loss of micro-organisms.

Fig 1: Topographical map of the study area



3.2 MATERIALS AND METHODS

3.2.1 Field Studies of Birds

3.2.1.1 Foraging Techniques

Data was collected from January 2011 to March 2011 and subsequently from November 2011 to May 2012.The foraging data was obtained by taking a transect walk through the study area to observe and record different birds in the area. Transects were cut, with each transect measuring about 200m×20m. For each day, an average of 10 transects were walked looking for the target species. In all 200 transects were cut during the entire study period. Transects were not used more than once during each study period so that the likelihood of the same individuals being observed during each study period was minimized. Transects were laid across the different vegetation. Observations were made in the early morning starting at sunrise and lasting about four hours (06h00-10h00) and in the late afternoon over a two to three hours period before sunset (15h00-18h00). Data was taken only on target birds that were actively foraging. The observation method was scan sampling. Each bird was observed using a pair of binoculars (10×40) until the bird was lost out of sight or until a maximum of three minutes spent per bird, whichever came first (Thompson 2002). Each foraging technique was measured with a stop watch. The minimum observation time and minimum distance of observing the birds without disturbing their activities were 30 seconds and 10 metres respectively. In cases where I repeatedly lost and re-located the same individual (for example, due to being temporarily obscured by foliage or branches) this was noted and later treated as one observation (once the foraging time spent by the bird did not exceed 3 minutes). For each prey item taken by a bird, the foraging technique, foraging height and habitat type were recorded.

Five foraging techniques (FT) observed were:

- **Foliage-gleaning (FL)**: Referred to as a systematic examining of foliage, small twigs and branches by moving quietly using feet and wing movements, small jumps and circuits. During this technique, adult insect, larval, pupae and eggs are mainly taken (Dunn & Garreth 1997).

- **Hover-gleaning (HG)**: Referred to as the systematic examining of substrates by hovering (fast wing beats enabling the bird to be stationary in the air for several seconds) close to it without using legs to hold on to the substrate (Dunn & Garreth 1997). This behaviour makes birds to feed on outer vegetation otherwise difficult to reach.
- **Sallying (SA)**: The sudden pursuit and pounces on flying or stationary insects (adults or larval) for short distances and returning to mostly the same perching vantage point (Raffaele 1989).
- **Hawking (HK)**: The sudden pursuit and pounces of particularly flying insects for longer distances and then returning to mostly a different perch (Ford et al. 1988)
- **Probing (PR)**: Referred to as the penetration of a substrate with the beak in pursuit of sub-surface prey, for example, in bark and crevices. Particularly larval preys, pupae and eggs are targeted (Barker et al. 2001).

3.2.1.1.1 Foraging Behaviour of Residents during the Absence and Presence of Migrants

In order to examine the effect of migrants' presence, the foraging behaviour of residents was examined during the presence and absence of the migrants. The foraging behaviour of residents during the absence of migrants where observed from March-May 2012, whiles the foraging behaviour of residents during migrants presence was observed from January-March 2011, and November 2011- March 2012.

3.2.1.2 Habitat Preference

Basically, five different habitat types (HT) were assessed during the study. These habitat types provided shelter and food resource for both migrant and resident birds. The five habitat types were chosen because they each have different vegetation complexity; therefore, it was important to observe how the birds will forage in each of the habitat types. Moreover, disturbance factor in the habitat types especially with respect to the burnt farm lands and non-burnt farm lands are different, and that can influence the foraging behaviour of the birds in those habitats, as such there was the need to include the burnt farmland and non-burnt farmland in the study to observe how the birds will feed in each of those habitats. Also since foraging height preference of the birds is a major objective of this study, it was imperative to select habitat types with different vegetation height in order to know which habitat type the birds will prefer most. The habitat types were as follows;

- **Open grassland (OG):** Areas dominated by grasses rather than large shrubs or trees (Piperno & Sues 2005). In other words, it is a biological community that contains few trees or shrubs. It is characterized by mixed herbaceous (non-woody) vegetation cover.
- **Thicket (TH):** Thick growth of bushes, dense or tangled growth of small trees (Everard 1987).
- **Non-burnt Farmland (NBF):** Cultivated land that has not been subjected to burning.
- **Burnt Farm Land (BF):** Areas of land that is burnt for farming purposes.
- **Fallow land (FL):** Less disturbed area with more bushes and compact ground or an uncultivated or ploughed area that is left to regrow (Aweto 2013).

3.2.1.3 Foraging Height

Foraging height (FH) is the height above ground level at which a bird species takes a prey item. All foraging heights were estimated to the nearest 1 meter. The foraging heights were put into five different categories as follows;

- **Very Low**: Foraging in vegetation less than 3 m of height, mainly in bushes, grasses and weeds.
- **Low**: Foraging in vegetation between 3-6m above the ground.
- **Medium**: Foraging in vegetation between 6-9m above the ground.
- **High**: Foraging in vegetation between 9-12m above the ground.
- **Very high:** foraging height of between 12-15m and more above the ground.

3.2.2 Quantifying Dimensional Niche Occupation: Habitat type, Foraging techniques and Foraging height

The time spent in each foraging height contra, foraging technique and habitat type was calculated after which the proportional time (in %) spent by each bird in each niche dimension could also be calculated. Quantifying the time spent in each niche dimension provides a good ground for assessing niche overlap among the birds.

3.2.3 Diagrammatic Representation of Foraging Techniques

The foraging techniques used by both migrant and resident birds were represented in a pentagonal structure with each axis of the pentagon representing a foraging technique. Lines, representing the proportion of time each bird species spent performing a foraging technique were drawn to the axis of the pentagon (Wiens 1997). If the length of the lines drawn to the axis are equal, it implies that the species is a generalist; an organism that makes use of a variety of food sources (Krebs & Davies 1993), hence uses different foraging techniques at equal rate, however if the length of one of the lines to the axis is far longer than the rest, then it implies that the species is a specialist; organism that has a limited diet (Krebs & Davies 1993).

3.2.4 Insect Collection

A sweep net was used to sample insects over the lower portions of the vegetation in the study area. After making the last sweep, the opening of the sweep net was firmly held to prevent insects from flying out. Insects were killed by gently pressing on them with a rug, and gently transferred into a container containing 70% ethanol for preservation. The insects were then identified and classified in the laboratory after being observed under a light microscope. The purpose of this activity was to know the kind of insect species found in the study area and by extension, give an idea of insect species which could be fed upon by the six insectivorous birds targeted in this study.

3.2.5 Collection of Plant Species

Plant species were collected by plucking the leaves of the plants making sure that all the features which could help in identifying the plant species such as the flowers were attached. With some of the shrubs, a whole branch was plucked. The plant species were identified with the help of a botanist from the botany department of the University of Ghana. The purpose of this activity was to know the kind of plant species providing shelter for both insect and bird species in the study area.

3.3 SOCIAL SURVEY

A social survey was conducted to assess local inhabitants' knowledge about migrant birds. The survey was also to ascertain whether the hunters, farmers and fuel wood harvesters within the study area were aware of the threat that their activities could pose to both resident and migrant birds. Pictures of the bird species from a field guide were shown to the informants before administering an open ended questionnaire (Appendix 12). Informants where interviewed in either the Ghanaian language (Dagbani or Twi) or English, whichever they understood.

3.4 DATA ANALYSIS

STATA 11 was used in analysing the data. Stata is a general-purpose statistical software package used in data analysis among others. Stata 11, although similar to some statistical packages, such as Microsoft Excel, is much more powerful and allows the user to store all commands in a log file often called a .do file, after its program extension (Nicholas 2011). Stata 11 can generate tables, graphs and can be used to apply various statistical packages.

In the data analysis, a two sample test of proportion comparing the various species under each niche dimension (foraging technique, foraging height and habitat type) was done to determine whether there was significant differences (P value) among the species under each of the niche dimensions. This was done under a confidence interval of 95% (CI=95%) and 5% level of significance ($\alpha = 0.05$).

3.4.1 Chi-square Goodness of Fit Test

The Chi-square test (Snedecor & Cochran 1989) was used to determine whether foraging behaviour of residents during the presence of migrants differ significantly from residents foraging behaviour during the absence of migrants.

The chi-square goodness of fit test takes the following form;

H_0: The data follow a specified distribution.

H_a: The data do not follow the specified distribution.

Test Statistic: The test statistics is a chi-square random variable (X^2) defined by the following equation;

$$\lambda^2 = \sum (O - E)^2 / E \text{ .... (1),}$$

O is the observed frequency (foraging behaviour of residents in the presence of migrants) and E is the expected frequency (foraging behaviour of residents in the absence of migrants).

3.4.2 Determination of Dimensional Niche Overlap

Niche overlap gives an idea of the extent to which two species utilise similar resources.

For each of the three niche dimensions: (A) five habitat types (horizontal spatial); (B) five foraging heights (vertical spatial); (C) five foraging techniques, the relative time (in %) spent on each niche dimension was calculated for each species (means +/- STD). Hereafter pair-wise dimensional niche-overlap was calculated using the Morisita-Horn similarity index (Morisita 1959), where %-occupation on each niche gradient (e.g. foraging height, n = 5; foraging techniques, n = 5; and habitat type, n = 5) replaces number of individuals of the two compared species, and the two compared species replaces habitats A and B in the formula listed below;

$C_{MH} = 2 \cdot \Sigma(an_i \cdot bn_i)/(da + db) \cdot aN \cdot bN$ ………………………..(2)

Where, aN, bN = total number of individuals in site A, B

ani, bni = number of observations on each niche gradient in the i'th species (niche dimension) in site A, B (species A and B compared)

$da = \Sigma\, an_i^2/aN^2$

$db = \Sigma\, bn_i^2/bN^2$

The Morisita-Horn index is based on the assumption that increasing the size of the samples will increase the diversity because it will include different habitats (i.e. different faunas). If the two samples are completely different, and if the species occur in the same proportions in both samples (total similarity), then the index = 1. If overlap is non-existent then the value is 0 (total dissimilarity or complementarity).Unlike the other similarity indices it is recommended that the Morisita-Horn index be used to avoid the complex dealings with effects of sample size and diversity (Henk 1981).

3.4.3 Diversity of Niche Dimensional Occupation: Habitat Type, Foraging Techniques and Foraging Height

To assess how each species occupy the niche dimensional gradients, the Shannon-Wiener diversity index (H) was applied to habitat type, foraging technique and foraging height (n = 5 for each). The Shannon-Wiener index was used because it is moderately sensitive to sample size (Magurran 1988) and increases with numbers of categories (Krebs 1999).The index weigh all components of niche dimensions proportionately to their frequencies in the sample, rather than favouring common or rare components, as do the Simpson index or species richness indices. It assumes that individuals are randomly sampled from an independently large population. It also assumes that all the species are represented in the sample.

In estimating the diversity index, %-occupation or proportion of the birds on each niche gradient (e.g. foraging height, n = 5; foraging techniques, n = 5; and habitat type, n = 5) replaces number of individuals in the Shannon-Wiener equation, and the three niche dimensions replaces species.

The %-occupation or proportion of species (p_i) in each niche gradient is then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by -1: Thus;

$$H' = -\sum p_i \times \ln (p_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Shannon entropy is then converted to true diversity (or effective species number), EXP (H'), because EXP (H') shows the true reflection of diversity better than the simple entropy (H'). This quantity has a unique ability to weigh elements precisely by their frequency, without disproportionately favoring either rare or common elements (Jost 2007).

The Shannon-Wiener entropy is represented as follows;

$$\mathrm{EXP}\left(-\sum p_i \ln p_i \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Plate 1: Observing the foraging behaviour of birds in the fallow land

Plate 2: Northern Crombec foraging by foliage-gleaning in a tree (height = 5m) in the non-burnt farm habitat

CHAPTER FOUR

RESULTS

4.1 FORAGING TECHNIQUES

4.1.1 Foraging Techniques of Migrant and Resident Birds

Other migrants and resident birds were also observed at the study site, however 882 target birds were observed. Out of that, 588 (66.7%) were migrant birds whiles 294 (33.3%) were resident birds. The target migrant species, Willow warbler (*Phylloscopus trochilus)*, Melodious warbler (*Hippolais polyglotta*) and Pied flycatcher (*Ficedula hypoleuca*) used all five foraging techniques towards a prey item. Resident species, however, did not use all five foraging techniques. Rufous cisticola (*Cisticola rufus)* and Senegal eremomelas (*Eremomela pusilla*) used four techniques, whereas Northern Crombec (*Sylvietta brachyura*) used three techniques (Figure 2). Clearly, foraging technique diversity was highest among migrant birds particularly for the Melodious warbler and Pied flycatcher (MW=1.1, WW=0.9, PF=1.1; Table 1). Diversity was however lower among residents with Northern crombec recording the least (RC=0.8, NC=0.4, SE=0.6, Table 1). There was significant difference in the foraging techniques used by the migrant warblers and those used by the resident warblers (P<0.01, Table 2).

All the six species used foliage-gleaning, hover- gleaning and sallying to capture their prey, with foliage-gleaning being the major technique except for the Pied flycatcher which were more adapted to hawking hence had to fly more frequently in order to catch their prey. Foliage-gleaning was used, even to a higher degree when foraging at very low heights (0-3m). However, hawking was not a common maneuver observed among the migrant and resident warblers. Though the cisticola and eremomela species devoted less than 10% of their foraging strategy to hawking, Northern crombec never engaged in hawking (Fig. 2). Probing was the foraging technique least used by the migrant birds (less than 3%), none of the resident birds probed. Hover- gleaning and sallying were common among the Rufous cisticola as compared to the rest of the bird species, using 24% on hover-gleaning and 22% sallying (figure 2).

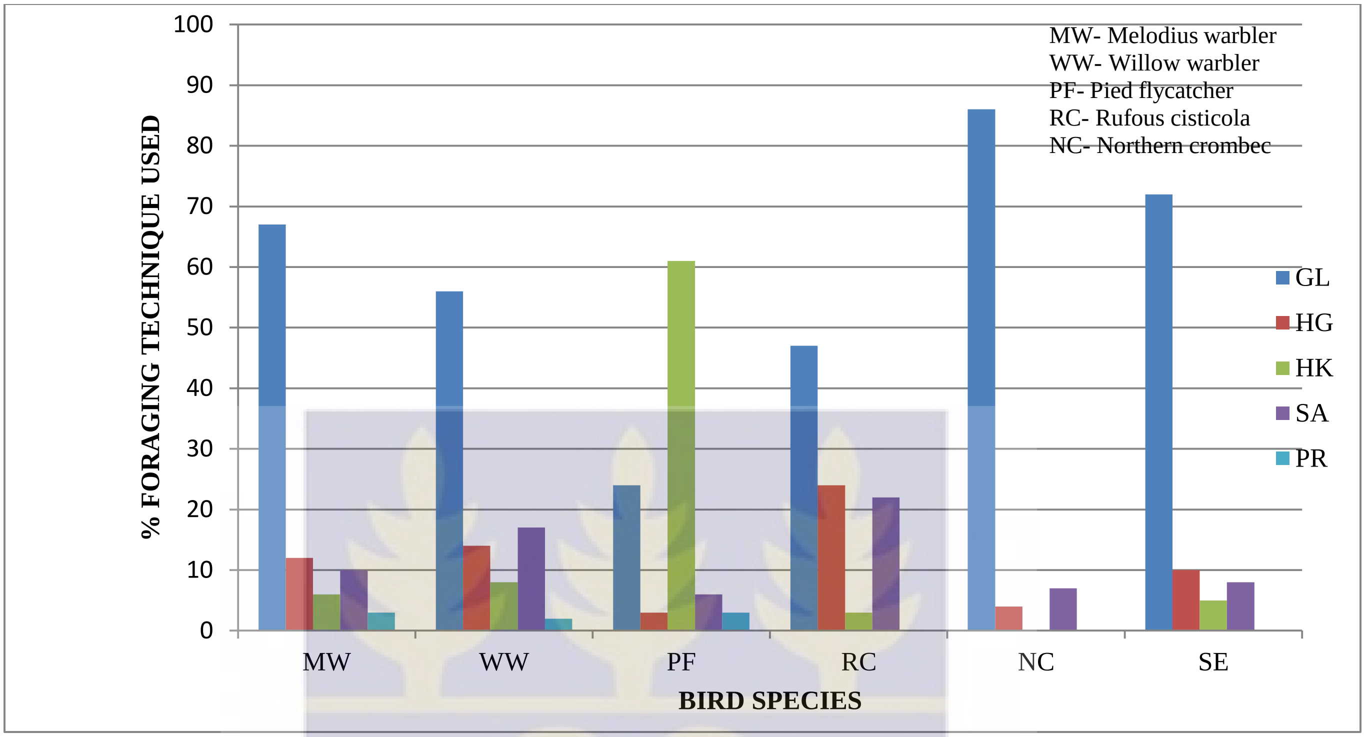


FIG 2: Percentage of foraging techniques used by migrant and resident birds (when migrants were present)

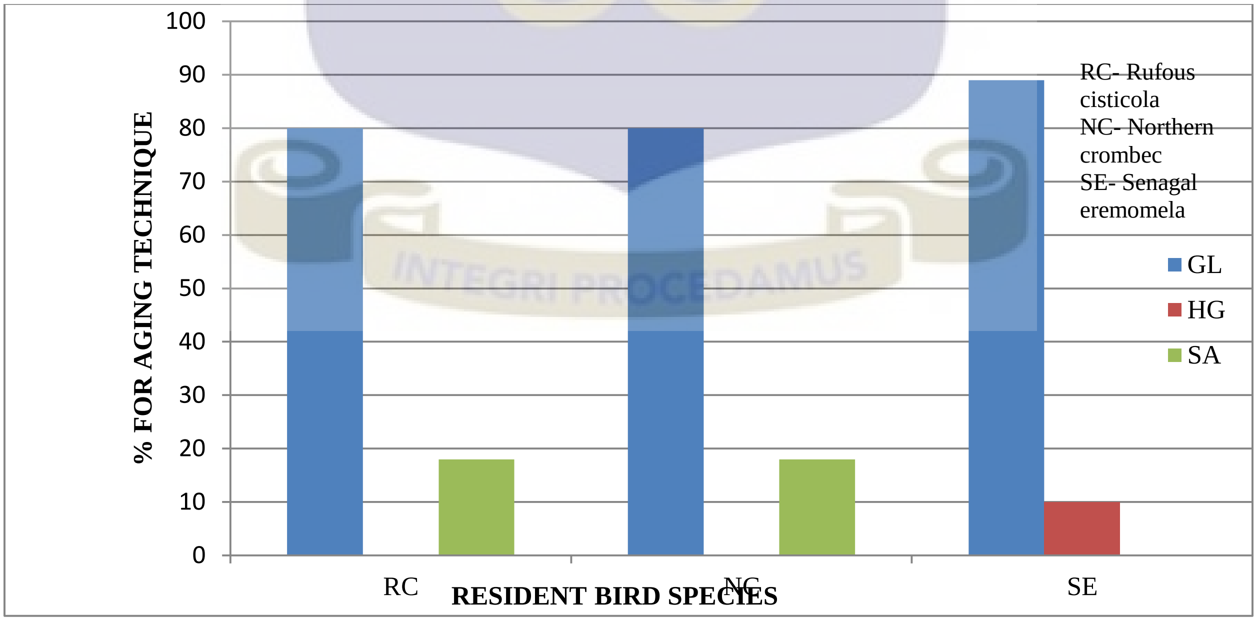


FIG 3: Percentage of foraging techniques used by resident birds in the absence of migrants

Table 1: Diversity of niche dimensional occupation for migrants and residents (during migrants' presence (MP) and absence (MA)

SPECIES	**DIVERSITY OF RESIDENTS (EXP(H'))**					
	FORAGING TECHNIQUE (FT)		FORAGING HEIGHT (FH)		HABITAT TYPE (HT)	
	MP	MA	MP	MA	MA	MP
RC	2.2	1.7	4.1	1.5	3.3	1.3
NC	1.5	1.3	2.2	1.7	2.2	1.2
SE	1.8	1.5	3.3	1.5	1.6	1.3
	DIVERSITY OF MIGRANTS (EXP(H'))					
	FT		FH		HT	
MW	3.0		4.1		3.0	
WW	2.5		3.3		4.1	
PF	3.0		4.1		3.3	

Table 2: Statistical test (t test) when comparing species pairwise with respect to foraging techniques usage

SPECIES	DIFFERENCE IN PROPORTION	P VALUE	95% CI (%)
WW & NC	27.5	<0.001	19.2-35.8
WW & RC	20.9	<0.001	12.8-29.0
WW & SE	26.3	<0.001	18.1-34.5
MW & NC	19.1	0.001	10.7-27.6
MW & RC	12.5	0.006	4.2-20.8
MW & SE	17.9	0.001	9.4-26.3
PF & RC	-12.6	0.1	-21.5-3.6
PF & SE	-7.2	0.27	-16.2 - 1.8
PF & NC	-5.9	0.3	-15.0-3.2

4.1.2 Foraging Techniques of Resident Birds in the Absence of Migrant Birds

It was revealed that in the absence of the migrants, resident birds used fewer foraging techniques. Each resident species used two foraging techniques, with foliage-gleaning being the dominant (Fig 3). Besides foliage-gleaning, Rufous Cisticola and Northern Crombec sallied whiles Senegal Eremomela hover-gleaned. None of the birds used hawking and probing in capturing their prey.

Comparatively, resident birds showed a relatively lower foraging techniques diversity when migrants where absent (EXP (H'): RC = 1.7, NC: H'= 1.3 and SE: H'= 1.5; Table 1), than when they were present (EXP (H'): RC = 2.2, NC: H' = 1.5 and SE: H'= 1.8; Table 1), with Northern crombec recording the least.

When the niche dimensions of Rufous cisticola during the presence of the migrants was compared with its niche dimensions during the absence of the migrants, it was revealed that, there were significant differences (P<0.0001; Table 3) in the foraging techniques, foraging heights and habitats used by the Rufous cisticola. Also, the foraging heights and habitats used by Northern crombecs during the presence of migrants were also significantly different (P<0.0001; Table 3) from what they used when migrants were absent, however, their foraging techniques was an exception (P=0.2; Table 3). These difference was also observed in the foraging techniques and habitats used by Senegal eremomela (P<0.0001), however, their foraging height was an exception (P=0.3; Table 3).

Table 3: Chi-square goodness of fit test results comparing the niche dimensions of each of the resident birds during the presence and absence of the migrant birds

	p value		
Resident Species	Foraging technique	Foraging height	Habitat selection
RC	<0.0001	<0.0001	<0.0001
NC	0.2	<0.0001	<0.0001
SE	0.001	0.3	<0.0001

4.1.3 Foraging Techniques Used in the Various Habitats

Hover-gleaning was the dominant foraging technique among both resident and migrant warblers foraging across all five habitat types (Table 4). However, this was not the case for the Pied flycatcher where hawking was mostly used in the fallow, burnt and non-burnt farm habitats. All five foraging techniques were used by migrant warblers in fallow land habitats. Migrants also used four and two different foraging strategies in the thicket and burnt-farm habitat types respectively. In the thicket habitat type, migrants used foliage-gleaning, hover-gleaning, sallying and hawking in capturing their prey, whiles in the burnt-farms, only foliage-gleaning and sallying were used. Though the resident warblers never foliage-gleaned in the grasslands, cisticolas did. Cisticolas sallied in all habitats except in the grassland, whereas Northern crombec and Senegal Eremomela sallied only in the fallow habitat. Eremomelas were seen hawking in only the thicket habitat type.

Table 4: Foraging techniques used by the birds in the various micro-habitats

Foraging Technique	**MELODIOUS WARBLER** **% foraging technique used in Habitat Type**				
	GR	TH	FB	FNB	FF
GL	2.44	6.91	4.07	6.50	47.56
HG	0.81	2.03	0	0.81	9.35
HK	0	2.44	0	0.41	4.47
SA	1.63	0.41	2.03	0	5.69
PR	0	0	0	0	2.44
	WILLOW WARBLER **% foraging technique used in Habitat Type**				
	GR	TH	FB	FNB	FF
GL	3.16	3.80	7.59	10.76	31.64
HG	0	0.63	0	3.80	10.44
HK	0	0.32	0	1.27	7.28
SA	1.90	0.63	1.27	4.11	10.13
PR	0	0	0	0.95	0.32
	PIED FLYCATCHER **% foraging technique used in Habitat Type**				
	GR	TH	FB	FNB	FF
GL	3.33	0	0	6.67	16.67
HG	0	0	0	0	6.67
HK	3.33	0	6.67	16.67	33.33
SA	0	0	0	0	3.33
PR	0	0	3.33	0	0
	RUFOUS CISTICOLA **% foraging technique used in Habitat Type**				
	GR	TH	FB	FNB	FF
GL	0.89	7.42	7.42	17.90	36.68
HG	0	2.62	0.87	4.80	6.55
HK	0	0.87	0	0	1.31
SA	0	1.75	2.18	4.80	3.96
PR	0	0	0	0	0
	NORTHERN CROMBEC **Habitat Type(% foraging technique used)**				
	GR	TH	FB	FNB	FF
GL	0	0	8.11	1.35	78.38
HG	0	0	0	0	4.05
HK	0	0	0	0	0
SA	0	0	0	0	8.11
PR	0	0	0	0	0

Continuation of Table 4

Foraging Technique	**SENEGAL EREMOMELA Habitat Type (%)**				
	GR	TH	FB	FNB	FF
GL	0	20.24	0	2.38	52.38
HG	0	4.76	0	0	7.14
HK	0	3.57	0	0	0
SA	0	0	0	0	9.53
PR	0	0	0	0	0

4.1.4 Diagrammatic Representation of the Foraging Techniques of both Migrant and Resident Birds

The foraging techniques and foraging time spent performing each technique can be represented diagrammatically. Since the total number of foraging techniques observed in the study was five, a pentagonal structure was suited, with each axis of the pentagon representing a foraging technique. The length of the lines to an axis is proportional to the amount of foraging time devoted to that foraging technique (Wiens 1997). When the length of the lines to an axis for any two techniques is the same, it implies that equal amount of time was devoted performing those techniques. Where a bird performs all five foraging techniques, all the five axis of the pentagon are labelled with each of the foraging techniques performed. However, where the bird performs less than five foraging techniques, only those techniques performed are represented on the axis. In Figure 5, 6, 7, 8 and 9 migrant and resident warblers spent over 50% of their foraging time foliage-gleaning; therefore, the length of the line to their foliage-gleaning axis is relatively longer. In Figure 4, a greater proportion of the Pied flycatcher's time was spent hawking, hence the length of line to the hawking axis is also relatively longer than the length of the lines to the axis of the other foraging techniques.

Below are diagrammatic representations of the foraging techniques of some migrant and resident birds (after Wiens 1997);

The length of lines indicates percentage time spent on each technique.

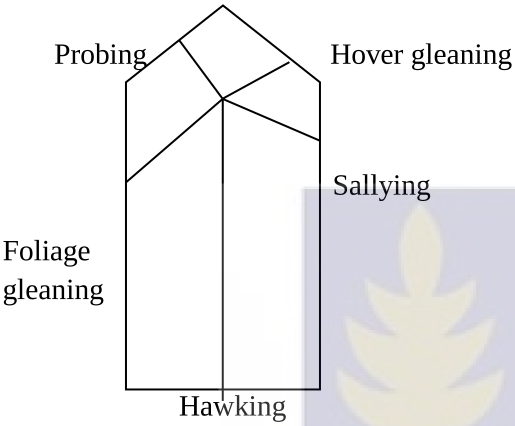


Fig 4: Foraging techniques of Pied flycatcher
(A typical hawker)

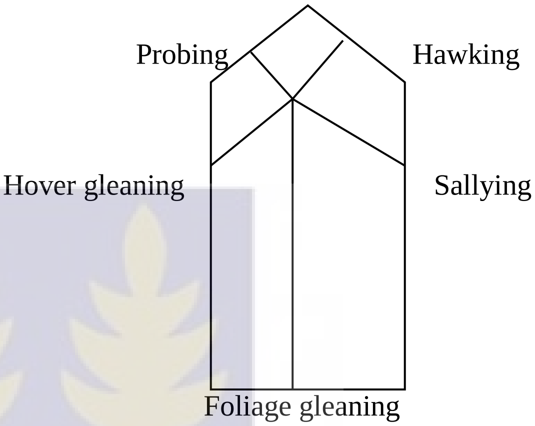


Fig 5: Foraging techniques of Willow warbler
(A typical foliage gleaner)

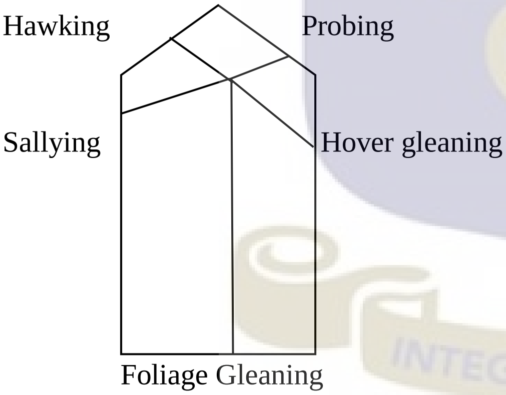


Fig 6: Foraging techniques of Melodious warbler
(A typical foliage gleaner)

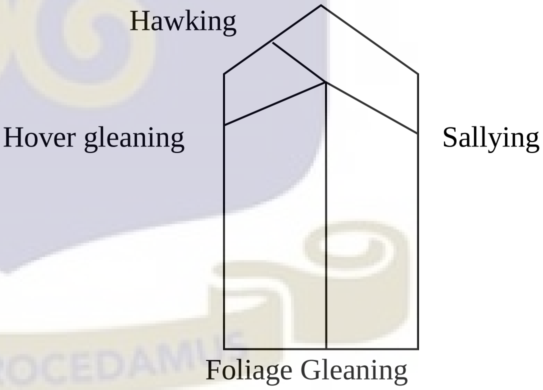


Fig 7: Foraging techniques of Rufous cisticola
(A typical foliage gleaner)

Below are diagrammatic representations of the foraging techniques of Northern crombec and Senegal eremomela (after Wiens 1997);

The length of lines indicates percentage time spent on each technique.

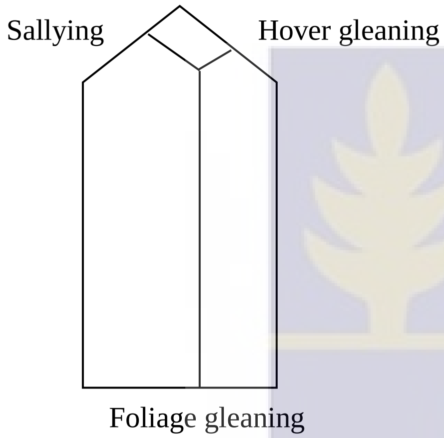


Fig 8: Foraging techniques of Northern crombec (A typical foliage gleaner)

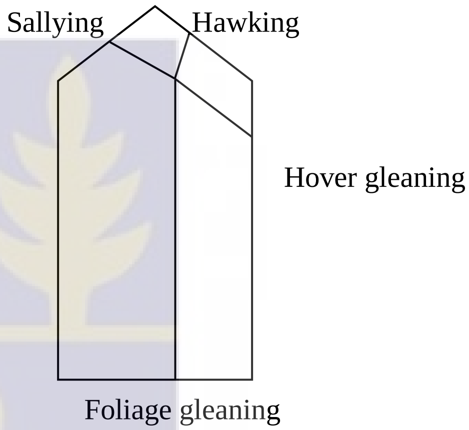


Fig 9: Foraging techniques of Senegal eremomela (A typical foliage gleaner)

4.2 HABITAT SELECTION

4.2.1 Habitat Selection of Migrants and Resident Bird Species

Migrant warblers and Cisticolas foraged in all five habitat types including the grasslands, where resident Northern crombec and Senegal eremomela were not found. Resident warblers used three habitats each (Figure 14 and Fig 15) but at different rates. Clearly, habitat diversity was higher in migrants compared to residents, except the Cisticola (EXP (H'): MW= 3.0; WW=4.1; PF=3.3; RC=3.3; SE=1.6; NC=2.2, Table 1).

Difference in habitat type used, between migrants and resident warblers was significant (MW&NC, P=0.007; MW&SE, P=0.008; WW&NC, P=0.002; WW&SE, P=0.003; Table 5), except for the cisticola (MW&RC, P=0.6; WW&RC, P=0.9; Table 5).

Most of the prey the birds preyed upon were found in the fallow habitat type and as such, foraging activities of all the species were mostly concentrated in the fallow habitat type. Though Pied flycatchers foraged in most of the habitats, they were not seen foraging in the thickets, where migrant warblers had successful maneuvers. All residents, except Northern crombecs foraged in the thickets. The Non-burnt farms witnessed more birds foraging in there than the burnt farm habitats (Fig. 10, 11, 12, 13 and 15). This was however, the reverse for the Northern crombec, which often foraged in the burnt farmlands than in the non-burnt farm lands (Fig 14). The grassland habitat type also witnessed migrants and cisticolas foraging in there, but at relatively smaller rates, however, Senegal eremomela and Northern crombec never foraged in such habitats.

Interestingly, all residents foraged only in the fallow habitat type after the departure of the migrants from the wintering grounds; none of the residents were seen foraging in any other habitat type (Fig. 16). Habitat type utilisation of residents during the presence of migrants were significantly different from those habitat types utilised when migrants were absent (P<0.001, Table 3).

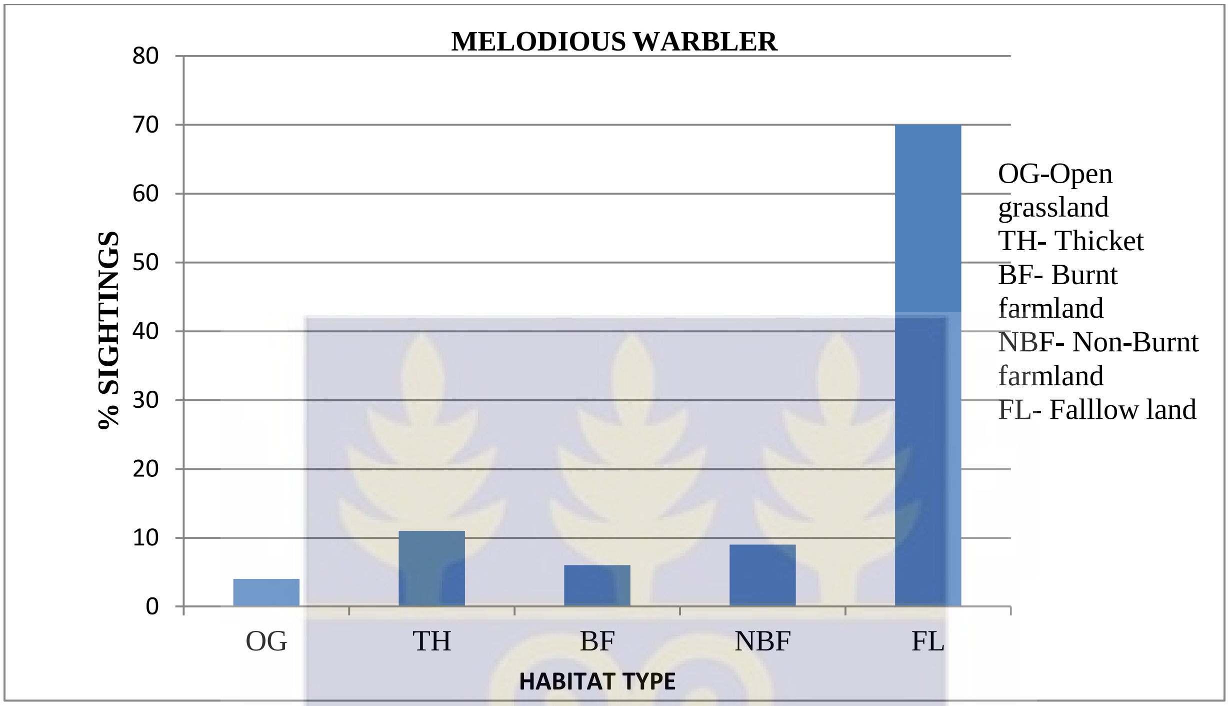


FIG 10: Percentage sightings of Melodious warbler in different vegetation

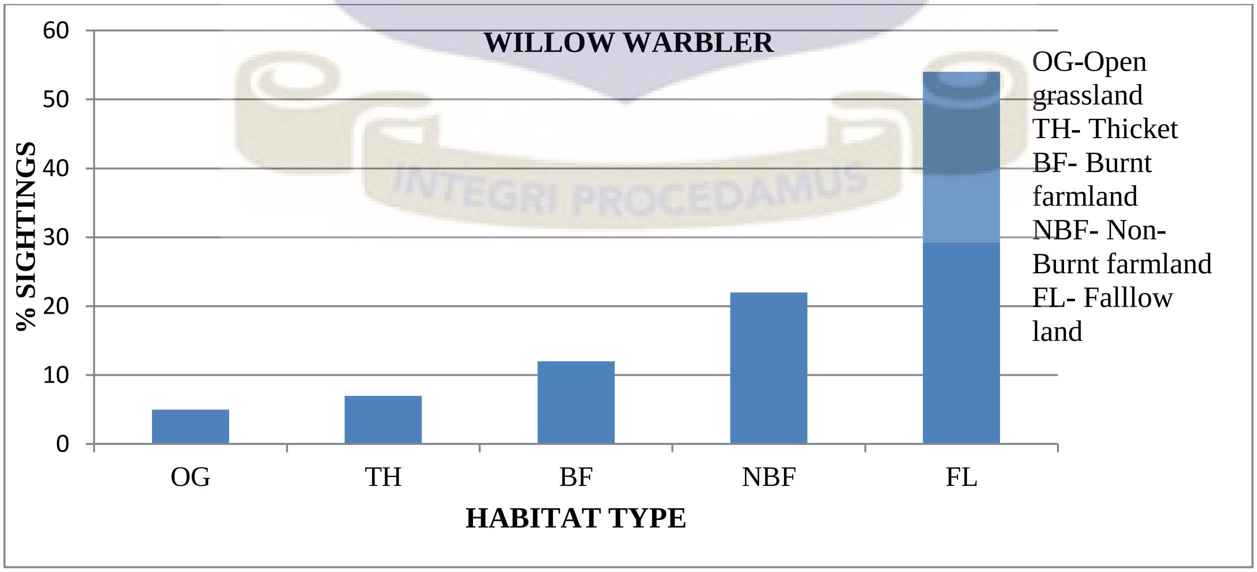


FIG 11: Percentage sightings of Willow warbler in different vegetation

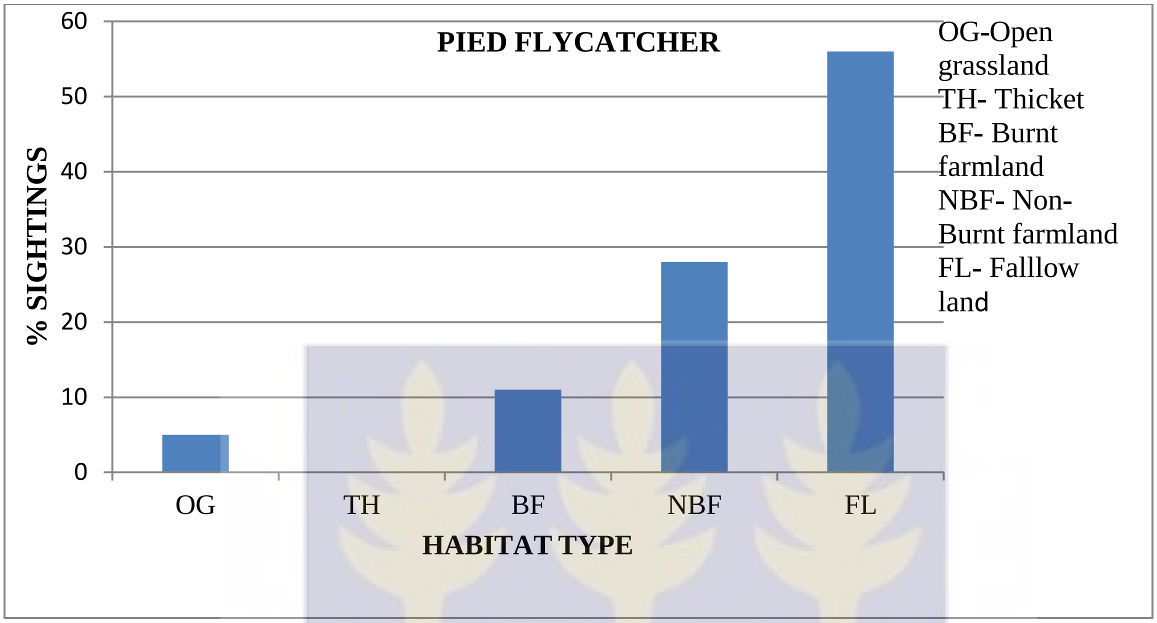


FIG 12: Percentage sightings of Pied flycatcher in different vegetation

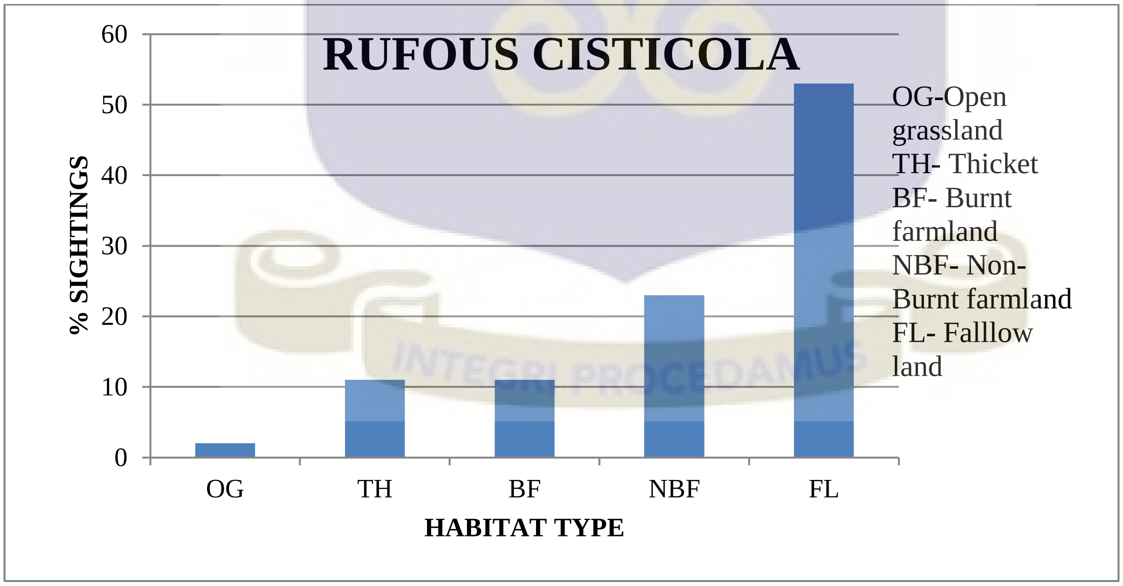


FIG 13: Percentage sightings of Rufous cisticola in different vegetation

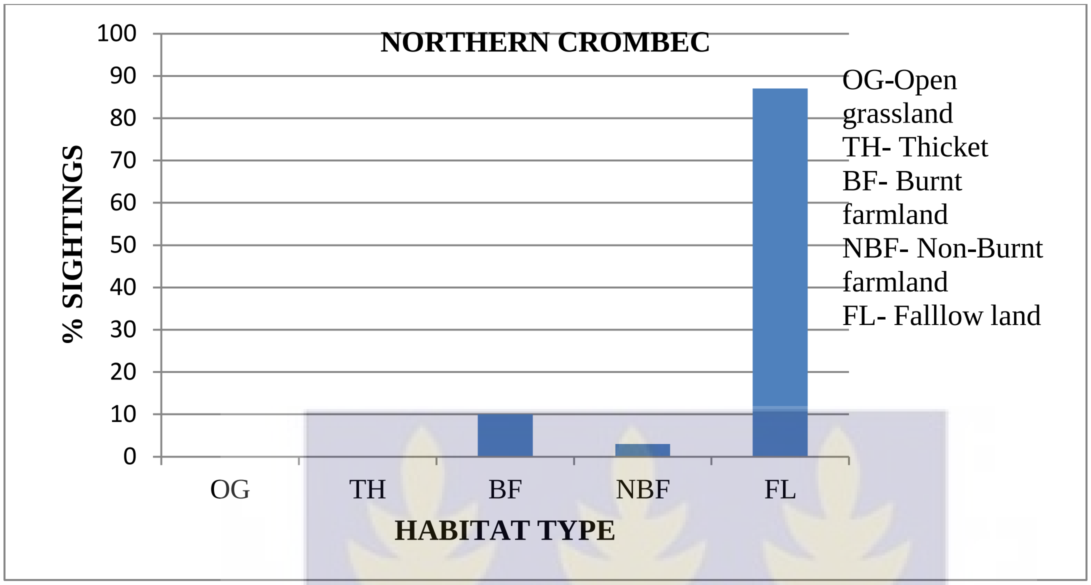


FIG 14: Percent sightings of Northern crombec in different vegetation

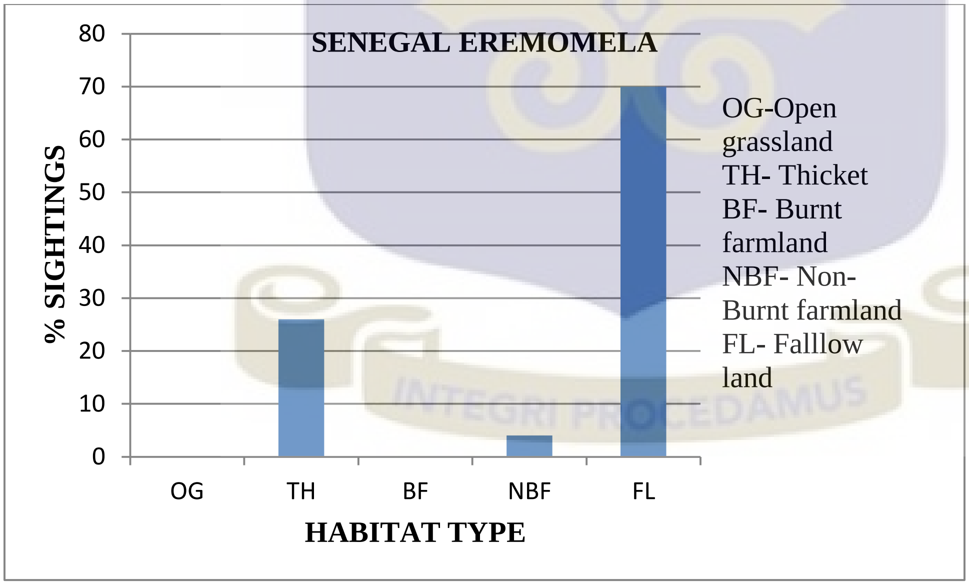


FIG 15: Percentage sightings of Senegal eremomela in different vegetation

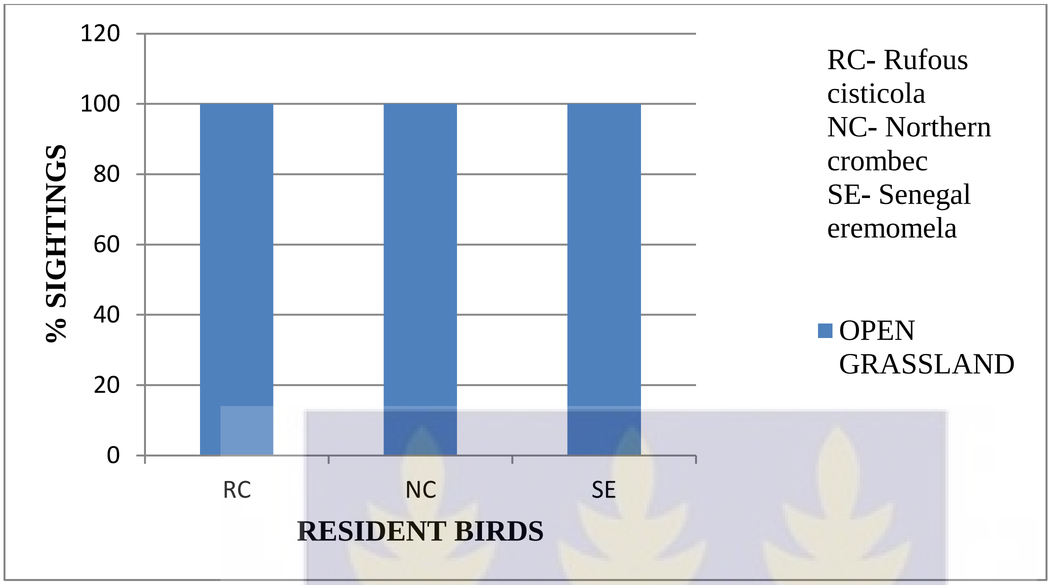


FIG 16: Percentage sightings of resident birds in different vegetation during the absence of migrants

Table 5: Statistical test (t test) when comparing species pairwise with respect to habitat type usage

SPECIES	DIFFERENCE IN PROPORTION	P VALUE	95% CI (%)
WW & NC	19.7	0.002	10.1-29.2
WW & RC	0.4	0.9	-8.6 - 9.4
WW & SE	18.5	0.003	9.0-28.1
MW & NC	17.1	0.007	7.4-26.7
MW & RC	-2.2	0.6	-11.3-6.9
MW & SE	15.9	0.008	6.3-25.5
PF & RC	-24.7	0.02	-34.4 -14.9
PF & SE	-6.6	0.4	-16.8 - 3.7
PF & NC	-5.4	0.4	-15.7-4.9

4.3 FORAGING HEIGHT

4.3.1 Foraging Height of Migrants and Resident Bird Species

Foraging among the birds occurred at heights of 0-15m (Fig.17), with most of the foraging maneuvers concentrated at heights of 3-9m. No bird species was observed foraging at heights higher than 15m even though some vegetation was higher. Migrant warblers were often seen foraging from both low (<6m) and high parts (>9m) of the vegetation. They foraged at high heights where resident warblers were often not seen. Cisticolas were the only resident species that had successful maneuvers observed at heights above 12m (RC=4%, Fig 17). Notwithstanding, the proportion of Cisticolas foraging at heights above 12m was smaller as compared to that of the migrants (MW=7%, WW=6%, PF=9%, Fig 17). Rufous cisticola had the highest number of successful maneuvers occurring at heights of 0-3m in the vegetation strata.

Diversity of foraging height was highest in Melodious warbler, Flycatcher and Cisticola followed by Eremomela and Willow warbler, with Northern crombec recording the least (MW=4.1, PF=4.1, RC=4.1, WW=3.3, SE=3.3, NC=2.2; Table 1). There was significant difference in foraging heights used between Northern crombec and Willow warbler, Melodious warbler and Eremomela and between Flycatcher and Cisticola (NC & WW: P=0.004; MW & SE: P=0.001; PF & RC: P=0.007, Table 6).

In the absence of the migrants, resident birds were mostly observed foraging at the lower parts of the vegetation. They all foraged at heights below 9m in the vegetation strata (Fig 18). As such, they recorded lower diversities in feeding heights (RC=1.5, NC=1.7, SE=1.5, Table 1) when migrants were absent as compared to when migrants were present (RC=4.1, NC=2.2, SE=3.3, Table 1). The heights at which cisticolas and Northern crombecs captured their prey when migrants were present were significantly different from those heights at which they captured prey when migrants had left their wintering grounds (For RC, P<0.0001; for NC, P<0.0001, Table 3). However, there was no significant change in the foraging height of Eremomela when migrants departed from their wintering ground (P=0.001).

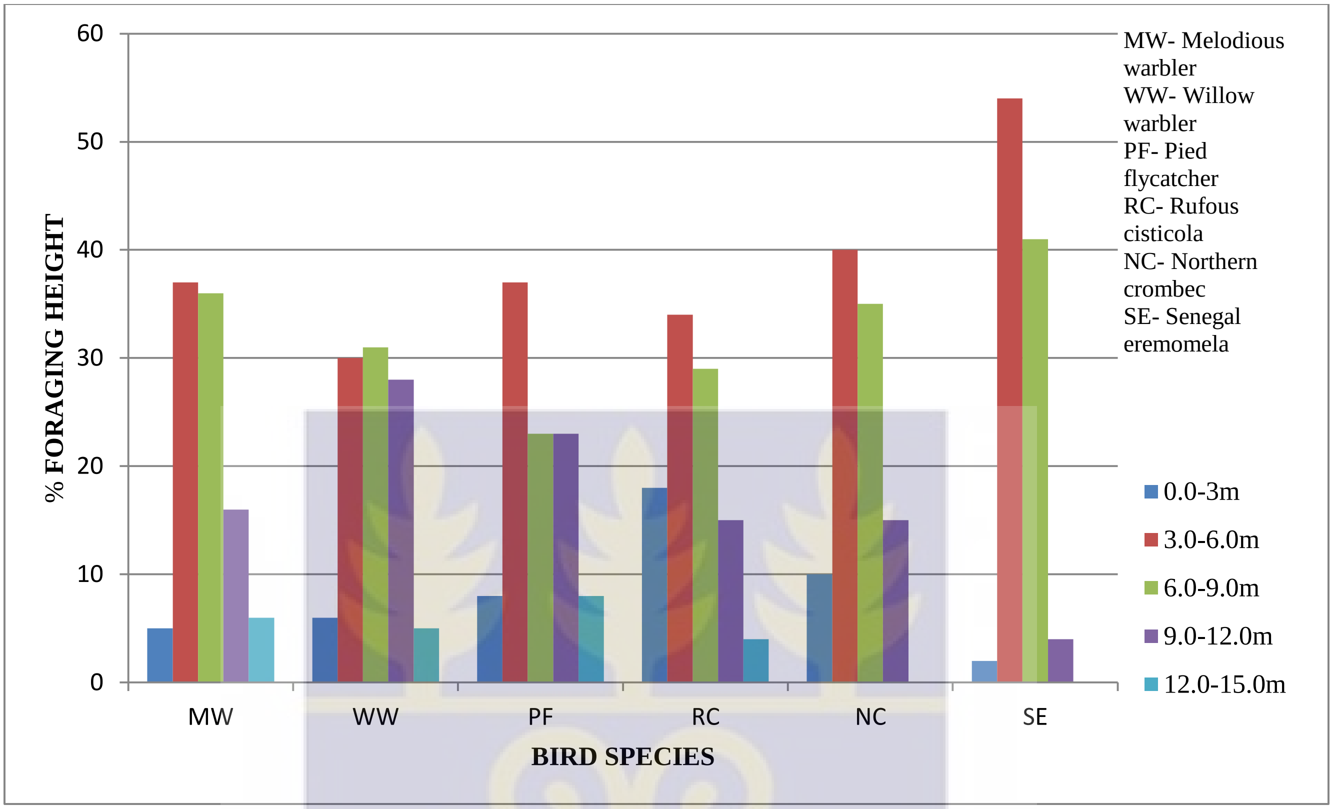


FIG 17: Foraging heights used by migrant birds and resident birds

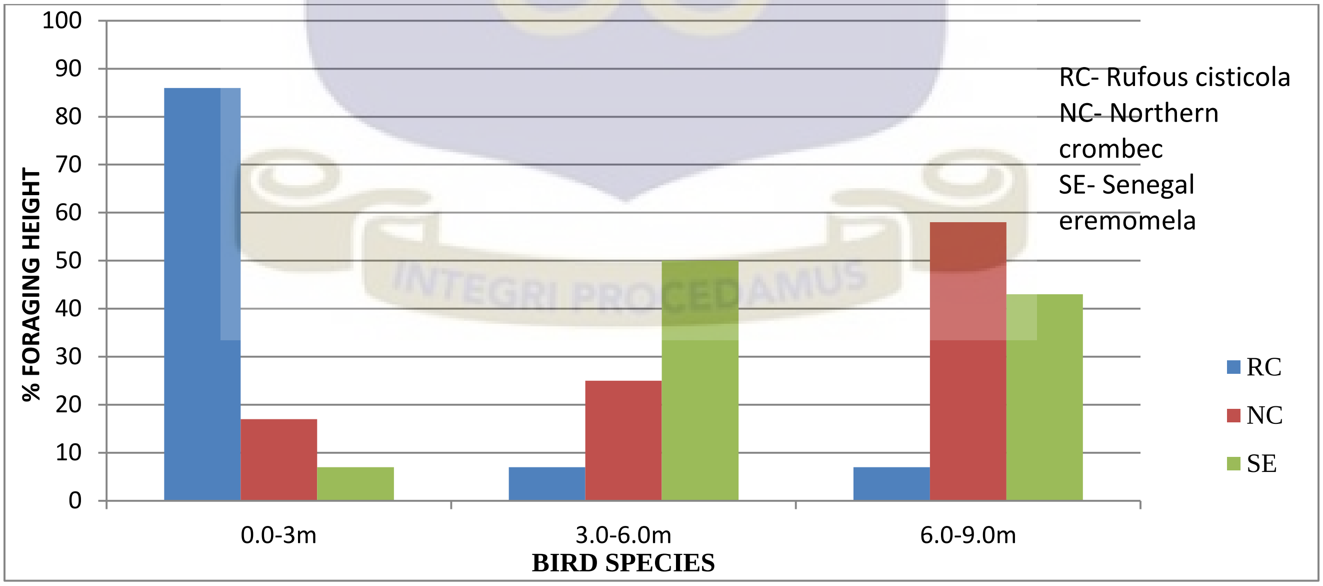


Fig 18: Foraging Height used by resident birds in the absence of migrant birds

Table 6: Statistical test (t test) when comparing species pairwise with respect to foraging height usage

SPECIES	**DIFFERENCE IN PROPORTION**	**P VALUE**	**95% CI (%)**
WW & NC	15.6	0.004	7.0-24.1
WW & RC	-2.0	0.6	-9.9 – 5.9
WW & SE	14.6	0.1	1.2-28.0
MW & NC	-2.5	0.5	-10.4-5.4
MW & RC	-2.0	0.6	-9.9 - 5.9
MW & SE	17.6	0.001	9.1-26.0
PF & RC	-26.8	0.007	-35.4 - 18.2
PF & SE	-6.7	0.3	-15.8 – 23.7
PF & NC	-5.9	0.3	-15.0-31.8

4.3.2 Foraging Height in Specific Habitat Types

In the grassland habitat type, the migrant warblers foraged at heights of 3-15m (Appendix 2 and 3), whereas in the thicket and fallow habitat types, foraging activities took place at heights of 0-12m and 0-15m respectively. Though Melodious warblers did not forage at heights of 12-15m in the burnt farm habitat types, the Willow warblers did (Appendix 2 and 3). It was revealed that, in the grassland habitat type where the resident birds scarcely occurred, Pied flycatchers and Cisticolas' foraging heights were limited to 6-9m and 0-3m respectively (Appendix 4 and 5). However, in the thicket, burnt farm and non-burnt farm habitat types, cisticolas foraged at heights of 0-15m (Appendix 5). Senegal Eremomelas and Northern crombecs were mostly observed foraging at a height of 0-12m in the fallow habitat types (Appendix 6 and 7). Foraging in the non-burnt farm areas were however, from heights of 0-3m for

Eremomelas and 3-6m for Northern crombecs. In the absence of migrants, residents foraged only in the fallow habitat type at heights of less than 9m (Appendix 8, 9, 10)

4.4 NICHE OVERLAP BETWEEN MIGRANTS AND RESIDENTS

4.4.1 Foraging Techniques

Niche overlap was observed between migrant warblers and resident species in their foraging techniques. Overlap was highest between the Melodious warbler and the Rufous cisticola (C_{MH} = 0.99; Table 7), however, overlap between the Pied flycatcher and resident species were low (C_{MH}= 0.49 for PF & RC; C_{MH}= 0.44 for PF & SE; C_{MH}=0.42 for PF & NC; Table 7), with Northern crombec recording the least overlap with the Pied flycatcher. Eremomela and Cisticola showed an almost complete overlap when the migrants were absent from their wintering grounds (C_{MH} =0.99, Table 7), however, overlap between the two were relatively low when migrants were present (C_{MH} =0.95). Eremomela and Northern crombec rather showed a higher overlap when migrants were present than when they were absent (migrants present, C_{MH}= 0.96; migrants absent, C_{MH} =0.99), though this difference is minimal.

Overlap in foraging height occurred among all the bird species (C_{MH}>0.6). Overlap between the Pied flycatcher and the Northern crombec was the highest (C_{MH}=0.98) whereas overlap between the Willow warblers and Northern crombecs was the least (C_{MH}=0.66, Table 7). Niche overlap between residents were relatively lower when migrants departed from the wintering grounds, with Rufous cisticola and Northern crombec recording the least (C_{MH}= 0.37)

Overlap in habitat type usage was high between migrants and the Rufous cisticola (C_{MH}: MW&RC= 0.94, WW&RC=0.93, PF&RC=0.97; Table 7). Though, resident warblers overlapped greatly with Melodious warblers (C_{MH}: MW&NC=0.94, MW&SE=0.96) and Pied flycatchers (C_{MH}: PF&SE=0.83 and PF&NC=0.85, Table 7), overlap with Willow warblers was low for both Northern crombec (C_{MH}=0.66) and Eremomela (C_{MH}=0.68). In the absence of the migrants, there was a complete overlap between the

Rufous cisticola and Senegal Eremomela (C_{MH}=1), however overlap between the Northern crombec and each of the other resident species were the same (C_{MH}=0.93).

Table 7: Niche overlap among the various bird species

	MORISITA HORN INDEX (C_{MH})– FORAGING TECHNIQUE					
SPECIES	**MW**	**WW**	**PF**	**RC**	**SE**	**NC**
MW		0.98	0.54	0.99	0.96	0.92
WW			0.52	0.98	0.98	0.96
PF				0.49	0.44	0.42
RC					0.95	0.91
SE						0.98
	MORISITA HORN INDEX (C_{MH})– FORAGING HEIGHT					
	MW	**WW**	**PF**	**RC**	**SE**	**NC**
MW	-	0.86	0.98	0.96	0.88	0.97
WW			0.76	0.83	0.66	0.80
PF				0.95	0.91	0.98
RC					0.87	0.97
SE						0.93
	MORISITA HORN INDEX (C_{MH})– HABITAT TYPE					
	MW	**WW**	**PF**	**RC**	**SE**	**NC**
MW		0.79	0.94	0.94	0.96	0.94
WW			0.93	0.93	0.68	0.66
PF				0.97	0.83	0.85
RC					0.87	0.84
SE						0.93

CONTINUATION OF TABLE 7

	Niche overlap among the resident birds in the absence of migrants, with respect to foraging technique (FT), foraging height (FH) and habitat (H)								
	RC			**SE**			**NC**		
	FT	FH	H	FT	FH	H	FT	FH	H
RC				0.99	0.20	1	0.97	0.37	0.93
SE							0.96	0.88	0.93

4.5 TYPE OF PREY FED UPON BY THE BIRD SPECIES

There were basically two types of prey observed, namely the larva and the adult insect. Different amount of insects and larva were captured by each of the bird species (Table 9). All the birds except Northern Crombec and Pied flycatcher foraged on both insect and larval prey. Whiles Northern crombec foraged exclusively on larva (100%), Pied flycatcher fed exclusively on adult insect (100%). Willow warblers fed equally on both adult insects and larva (adult insect=50%, larva=50%; Table 8). Melodious warbler, Rufous cisticola, Northern crombec and Senegal eremomela fed mostly on larva than on adult insects, however, equal number of Willow warbler fed on insects and larva. The dominant prey captured by the resident birds in the absence of the migrants was larva (RC=80%, SE=82%, NC=100, Table 8).

Table 8: % number of prey taken by each species

PREY	**PRESENCE OF MIGRANTS**						**ABSENCE OF MIGRANTS**		
	% Number of Prey						**% Number of Prey**		
	MW	WW	PF	RC	SE	NC	RC	SE	NC
INSECT	33	50	100	47	4	0	20	18	0
LARVA	67	50	0	53	96	100	80	82	100
TOTAL	100	100	100	100	100	100	100	100	100

4.6 INSECT SPECIES IN THE STUDY AREA

There were several species of insects observed in the study area. The birds depended on an unknown number of insect species for food. The specific species of insects which the birds foraged on could not be observed in the study, since this may require gut analysis. However, insects were sampled in the study area which presumably could be some of the insects the birds foraged on. Some of the sampled insect species belonged to the families Formicidae, Aphididae, Gryllidae, Acrididae and Charanomidae (Table 9).

Table 9: Sampled insect species in the study area

NAME	ORDER	FAMILY
Tetramodium sp.	Hymenoptera	Formicidae
Camponotus sp.	Hymenoptera	Formicidae
Crematogaster sp.	Hymenoptera	Formicidae
Aphis gossypii	Homoptera	Aphididae
Gryllus sp.	Orthoptera	Gryllidae
Chorthippus curtipenis	Orthoptera	Acrididae
Charanomis plumosus	Diptera	Charanomidae
Bibio albipennis	Diptera	Charanomidae
Reduvius sp.	Hemiptera	Reduviidae

4.7 TREES USED BY THE BIRD SPECIES

Several tree species were observed during the study. The trees provided shelter for the migrants, residents and the insects. The trees also served as nesting sites for the resident species. The insects captured by the birds were mostly found on the trees. Below are some of the tree species used by the bird species;

Table 10: Some species of trees used by the bird species

Plant species	**FAMILY**
Crotalaria refusa	Fabaceae
Annona senegalensis	Annonaceae
Leptadenia hastate	Asclepiadaceae
Acacia sp.	Fabaceae
Combretum sp.	Combretaceae
Hyptis suaveolens	Lamiaceae
Vittelaria paradoxa	Sapotaceae
Sida acuta	Malvaceae
Securinega virosa	Euphorbiaceae
Pennisetum purpureum	Poaceae
Parkia biglobosa	Fabaceae

4.8 SOCIAL SURVEY

From the questionnaire administered to ninety local inhabitants, more than half of the respondents (58%) were aware of the presence of migrant birds in the area yet none of them knew the names of neither the migrants (in their local dialect) nor where they migrated from (Table 11). All the respondents admitted that the migrant birds visit their farms to feed. They (100%) also admitted to burning their farms, although it is often controlled so that the fire wouldn't spread to non-target areas. Some of respondents (50%) did not know whether their burning or farming activities could pose a threat to the migrants.

Table 11: Respondents knowledge (n=90) about migrant birds and their activities at the study area

Parameter	Response	Percentage (%)
Knowledge about the presence of migrants in the area	Yes	58
	No	42
Knowledge about where they Migrate from	Don't know	100
Knowledge about the local names of migrants in the area	Don't know	100
Visit of migrants to farms	Yes	100
	No	0
Purpose of visit	To feed	100
Do farming activities, logging, hunting pose any threat to migrants	Yes	25
	No	25
	Don't know	50
Use of chemicals (pesticides) on the farms	Yes	100
Burning on the farms	Yes	100
	No	0
Do bush burning pose any threat To the migrants	Yes	25
	No	25
	Don't know	50
Frequency of burning in a year	Once	50
	Several	50
Purpose of burning	Farming	82
	Hunting	18
Reason for controlling of burning	Prevent spread to non-target areas	100
Season that burning often occur	Dry season	90
	Anytime	10

4.8.1 Some plates showing the negative impact of bush burning, logging and fire wood harvesters in the study Area

Plate 3: Bush burning at the burnt farm habitat type

Plate 4: Logging activities in the fallow habitat type

Plate 5: logging activities in the fallow habitat type

Plate 6: Women carrying fuel wood after harvesting it from the fallow habitat type

Plate 7: Destruction of the vegetation for farming purposes (Burnt farm habitat type)

CHAPTER FIVE

DISCUSSION

5.0 FORAGING BEHAVIOURAL SEGREGATION

5.1 Foraging Techniques of Birds

Niche partitioning was detected between Palearctic migrants and Afrotropical species (Rabøl 1987, 1993, Waide1981, Salewski 2002b). Niche partitioning was mainly expressed by differences in foraging techniques, foraging height and habitat preference. Foliage gleaning and aerial insectivores that take fairly large prey from the ground were particularly well represented among the insectivorous migrants. Palearctic migrants showed the highest diversity in foraging techniques. This confirms assumptions that migrants in general are less specialized in their foraging habits than are residents (Leisler 1993, Lövei 1989, Lack 1986), which is also the case, in the Neotropics (Greenberg 1986). However, the findings of my work contradicted previous studies conducted by Lack (1986) in Kenya, where Palearctic warblers were more specialised in food selection than residents and hence did not display more techniques in their resource utilisation. This contradiction could be as a result of difference in food supply. Where food is abundant, migrants could specialize in using fewer techniques however the reverse is the case when food is limited.

The migrant birds showed the highest diversity in feeding techniques because of their opportunistic nature. Moreover, residents are familiar with food sources throughout the year and can specialise on such using fewer foraging techniques, whereas migrants need to adapt to changes in habitats (food sources) as they move from place to place, hence the need to use more foraging techniques. According to Lovette and Holmes (1995), different feeding techniques reflect different kind of prey taken, therefore, I assume that migrants have a wider range of prey that they utilize opportunistically and this enables them to forage successfully and might not contest residents for food, thereby coexisting with species of very similar foraging ecology.

Palearctic migrants used all five foraging techniques, Rufous cisticolas and Eremomela spp. used four whiles Northern crombecs used three foraging techniques. None of the resident birds used probing. I suggest it was because they were not as flexible or opportunistic as the migrants in their resource utilisation, a pattern that was also observed by Salewski et al. (2002b). The residents were not as flexible as the migrants probably because they were familiar with the environment hence can specialise on few foraging techniques to obtain food, whereas migrants might be unfamiliar there, hence needs to use more feeding techniques to obtain food. The flexibility among the migrants might be a factor that enabled them to establish themselves in the wintering grounds in different habitats (Salewski et al. 2002b). This suggestion is consistent with a study conducted by Lefebvre et al. (1998) where they revealed that behavioral flexibility was associated with learning ability, and behavioral flexibility allowed animals to respond more rapidly to changes in the environment.

The high foraging technique diversity of migrants could lead to reduced competition between residents and migrant birds (Lack 1971, Blicke 1984, Rabøl 1987), although differences in foraging behaviour do not necessarily equate to differences in diet or resources used. Though the suggestion that these differences are in order for migrants to avoid resident competitors through increased movement remains unproven, the use of removal experiments (though it may not be so feasible) would presumably help clarify this issue.

Rufous cisticolas and Senegal eremomelas used more foraging techniques during the presence of the migrants than in their absence. This could be as a result of changes in food supply due to weather changes or habitat changes caused by habitat destruction. Also, if food is scarce and competition is high during migrants' presence, more opportunistic foraging may be required hence more foraging techniques may be used, however, if migrants are not present, residents can specialize on fewer techniques. But it could also be that certain foods were more readily available at a particular time hence the best foraging technique was adopted, according to optimal foraging theory (Begon et al. 2006). Moreover, the absence of the migrants may induce competitive release such that food becomes easier to obtain and each species can afford to specialize on most abundant food by adopting fewer techniques.

In the resident warblers' guild, the Cisticolas were distinctly separated by habitat type used and foraging height from the other species. It usually foraged from either great or low height in different vegetation, which explains the higher feeding technique diversity as compared to the rest of the resident species.
Of all the five foraging techniques used by the migrants and resident warblers, foliage-gleaning was the most dominant, indicating the effectiveness of utilising that foraging method. Perhaps, it required less energy foliage-gleaning as compared to the other techniques. Also, probably there were more insects on the branches and leaves hence the need to glean. In foliage-gleaning, the birds feed mostly on hidden and cryptic preys that do not move frequently, such as larva (Amano & Eguchi 2002). Moreover, the dominant prey captured by most of the warblers was larva, and as such, it may require using more of foliage-gleaning in capturing the larva than using other foraging techniques such as hawking or sallying.

Pied flycatchers did not glean as much as the warblers due to their morphological adaptation. Clearly, hawking was often used by the flycatchers in capturing their prey because of their morphological adaptation; hence insects were the dominant prey captured by the flycatchers. Their broad and pointed beaks with many bristle feathers enable them to catch their prey in the air. Their pointed wings generate more lift and less drag during hawking and enable the bird to fly fast, turn quickly and smoothly in mid-glide (Behrstocky et al. 2001). When a bird hawks insects, the prey must be substantial enough to pay off in terms of a biological energy budget (Burton 1990).

The least used foraging technique was probing. Probing is mostly done in soft or decaying wood or in tree barks. Since there were tree harvesting in the area, such older trees with loose bark were scarce. All the bird species except Northern crombec performed hover-gleaning, their small size made hovering possible. Though hover-gleaning is energy demanding, the warblers were more methodical in their approach to hovering even seeming lethargic as they perched upon and deliberately pick over foliage. Most birds that hover have high aspect ratio wings that are suited to low speed flying but fast wing flapping (Shyy et al. 2007). One major exception to this is the humming bird, which is among the most accomplished hoverers among all birds. Though Northern crombecs were not observed hover-gleaning, it does not mean they cannot do so. Perhaps in my study area, it was not feasible or they did so in areas that I ignored.

Difference in abundance and availability of food can influence the foraging strategies of the birds. Insects may be abundant but cryptic and difficult to locate in certain vegetation types and heights, therefore, various foraging strategies needs to be adapted to acquire food. Also, insects may be abundant and easy to locate in all vegetation and heights, then, fewer foraging strategies needs to be used to capture them.

5.2 Spatial Partitioning (Foraging height)

A higher proportion of migrants were found foraging higher up in the vegetation (9-15m) than the resident birds. This observation supports previous observations by Lack (1990), Leisler (1992) and Rabøl (1993) that Palearctic migrants foraged higher up in the vegetation canopy than their resident counterparts. The results of my study however, contrast with earlier study conducted by Salewski et al. (2002b) in Zimbabwe, where Willow warblers foraged in lower parts of trees than did burnt-necked Eremomela, *Eremomela usticollis.* However, generalization that migrant are more diverse in foraging heights than residents (Leisler 1992) could not be fully confirmed since Rufous cisticolas showed higher foraging height diversity than Willow warblers.

Besides foraging at greater heights, migrants foraged at low heights as well. This flexibility in foraging height allows migrants to partition resources with residents (Salewski et al. 2002b). The migrants fed from both high (9-15m) and low heights (0-6m) canopy due to their opportunistic behaviour. Moreover, residents are permanent in the area and can specialize on niches (narrow niches) whereas migrants' needs to cope with changing conditions and may fill out gaps unexploited by residents. Also, there are indications that migrants adjust their behavior to food availability; therefore, they are driven to heights where they may find more prey to feed on. Therefore, flexibility in foraging height is an important feature for migrants to cope with unfavorable situations to which they are otherwise not adapted to.

It has been stated that migrants forage higher in vegetation as an adaptation to permit coexistence with residents by using untapped resources that are only seasonally available (Salewski & Peter 2006), though results from the study of the role of competition in shaping migrant-resident communities remain largely unconvincing (Salewski & Peter 2006).

The Pied flycatcher had the highest proportion of birds foraging from a height of 12-15m. The Pied flycatchers fed from relatively higher trees than the rest of the bird species probably because, they need perching vantage points with good view in order to scan in all directions and enable them to sally, hawk and pounce.

The significant differences in feeding heights between Northern crombecs and Willow warblers, Melodious warblers and eremomelas and between flycatchers and cisticolas could be as a result of the flexibility of the migrants, which enabled them move to different foraging heights.

Northern crombec and Cisticola were found to forage higher up in the vegetation strata when migrants were present than when they were absent. This difference could be as a result of niche shift induced by the arrival of migrants (Rabøl 1987, 1993, Waide1981). Contrary to conventional knowledge that resident birds out-compete migrants, these resident resource generalists may be able to shift to under-exploited niches to avoid resource competition when migrants are very abundant (Jedlicka et al. 2006). Moreover, in the absence of migrants, residents fed from relatively lower heights, probably because of the availability of more food at those heights.

5.3 Habitat Type Preference

The migrant warblers occupied a wider range of habitats than their tropical equivalents (Northern crombec and Senegal eremomela), thus they were more eurytopic (Lack 1986, Leisler 1990). They may be more successful in exploring different habitats and exploiting seasonal resources not regularly used by the resident species. The migrant warblers occurred in all five habitat types but at different frequencies, they had a wider niche. Diversity in habitat type usage was relatively higher in migrants compared to the eremomelas and northern crombecs probably because the two residents were specialists and required more specific habitat conditions than did migrants (Stotz et al. 1996; Leisler 1990; Greenberg 1986). Moreover, the residents are familiar with the environment hence can specialise on niches (habitats), whereas migrants might be unfamiliar there, hence needs to cope with changing conditions and may fill out gaps (habitats) unexploited by residents. This is consistent with earlier observations made by Salewski et al. (2002b) in Zimbabwe, where migrant willow warblers showed high habitat diversity than resident eremomelas. The migrants had to increase their foraging habitats in order to obtain enough food. However, Rufous cisticola showed more habitat diversity than the Melodious warbler. Therefore, generalisations that migrants are more diverse in their habitat selection than residents could not be fully confirmed, showing that care has to be taken into account when drawing conclusions from few studies for a whole migration system on a huge continent.

In the grassland habitat type where the residents hardly occurred, the migrants showed a relatively higher diversity of foraging techniques, therefore may be able to exploit food resources that the resident species cannot. Pied flycatchers were not found foraging in the thicket habitat type; probably, they needed a clear aerial view to catch their prey (Lövei 1989). Moreover, more open habitats favour Palearctic birds (Jones 1998). Also, foraging within a habitat is often associated with behavioural and morphological adaptations; hence since Pied flycatchers are morphologically adapted to flycatching, they may not be successful in catching insects in the thickets since the dense vegetation could hinder surveillance abilities and flight maneuvers.

Besides not foraging in the grassland habitat type, Northern crombecs and Eremomelas were not observed foraging in the thickets and burnt farms habitat types respectively. It is possible that both species found sufficient food elsewhere hence where not detected in those habitats. Also, Northern crombecs were not observed in the thickets probably due to their secretive nature. It is important to note that, cryptic and secretive species are easier to overlook or miss in more dense habitats. Their secretive and shy nature makes them difficult to be observed in thick vegetation.

There was significant difference in the habitat type used by resident birds during the presence and the absence of migrants. In the absence of the migrants, residents foraged only in fallow habitat type, they were not found in any other habitat type, and hence habitat diversity was relatively lower, however, in the presence of migrants, diversity of habitat type used by residents was relatively higher. I suggest that the presence of migrants possibly led to some amount of habitat displacement of resident warblers, resulting in residents feeding from various habitats. In the presence of the migrants, the residents might have to increase their foraging habitats in order to obtain enough food. However, the absence of the migrants, might have led to a 'competitive' release making it possible for residents to obtain enough food in the fallow habitats without moving to other habitats. Hence, previous suggestions of habitat displacement of Eremomelas by Willow warblers could be confirmed (Salewski 1999, Rabøl1987). However, it is not known which mechanism facilitates this separation because direct interspecific interactions were not observed, hence I cannot assess whether my observations resulted from active displacement of one species by the other. My inability to observe direct interspecific interactions in various habitat types and foraging heights is seen as a challenge and constraint in my methodology.

The findings of my study also agrees with earlier observations made in Zimbabwe by Salewski et al. (2002b), where burnt-necked Eremomelas, foraged more in the center of the vegetation in monospecific flocks during the absence of Willow warblers than when Willow warblers were present, indicating a possible habitat displacement, therefore, large numbers of migrants will have an influence on tropical communities (Jones 1998, Rabøl 1987). In Kenya, however, Rabøl (1993), correcting Rabøl (1987), found no displacement of residents by willow warblers or vice versa.

Generally, the foraging activities of the birds were concentrated in the fallow habitats. The fallow habitats had more vegetation than the other habitats hence may provide more micro-habitats for insects and bird species. Unlike the fallow habitat type, the burnt and non-burnt farm habitats had much of their vegetation destroyed through slash-and-burn, logging and charcoal burning activities and this could lead to a possible decline in the insect population in those regions, hence the limited foraging activities.

5.4 Niche Overlap

None of the migrants had a complete overlap (100% overlap) with the residents on any niche dimension. It is worthwhile to note that, though migrants may show a high overlap with residents on a niche dimension, they could still co-exist because they probably used similar resources, but at different times of the day. Competitive exclusion takes place only when resources are limited and the niche overlap is great in all dimensions.

Although on the average, willow warblers showed the greatest overlap with the resident species in foraging techniques, they did not overlap to a great extent (overlap<77%) with the residents in habitat selection and foraging height. Therefore, the Willow warbler will be able to co-exist with the resident species due to the overall small niche overlap with respect to spatial partitioning. Moreover, the multi-dimensional overlap between the willow warbler and the resident species is less than 0.77, hence they can co-exist. Also, they will be able to co-exist because of the use of similar foraging techniques and resources (prey) in different habitats. Also, though the Pied flycatcher showed the highest overlap with the resident birds in foraging height, it recorded the lowest overlap with residents with respect to foraging techniques used. Therefore, the Pied flycatcher might be the greatest competitor to the resident birds in terms of foraging height, yet they could still co-exist because of the use of different foraging techniques in obtaining prey at those similar heights. In other words, a great overlap in foraging height is compensated by a low overlap in foraging techniques. Moreover, the multi-dimensional overlap between the Pied flycatcher and the residents is less than 0.50, so they will be able to co-exist.

Migrants have been thought to avoid resource competition while in the tropics by foraging for resources under-used by resident species and under-represented in their foraging habitats (Lack 1986, Leisler 1992, O'Connor 1981).

In the absence of the migrants, the resident birds mostly congregated at the same habitats where there were more food resources, which possibly led to the high overlaps. However, the low overlap among the residents in the absence of the migrants indicates that food may be abundant in all vertical strata as such the residents moved to different heights to obtain food, without having to congregate at same heights. Previous studies conducted in Africa might give clue to inter-specific competition between migrants and residents. Moreau (1972) stated that 28% of migrant species are potential competitors to residents. In Kenya, Leisler et al. (1983) found competition between wintering migrants and residents expressed by interspecific aggression over territories in which the migrant species were inferior to the resident ones. Nonetheless, the flexibility of Palearctic migrants in feeding ecology might allow them to utilize resources that are not available for residents, and they might therefore be able to coexist in the same habitats (Salewski 2000b).

5.5 Threats to Resident and Migrant Birds

The results of the interviews with ninety farmers, hunters and fuel wood harvesters clearly suggest that their activities could pose a threat to the survival of the bird species in the area. All the ninety respondents admitted to burning the bush within the study area, especially during the dry season (November to March) and this suggests that a great deal of the vegetation cover, micro-organisms and insect species could be destroyed, and if nothing is done to remedy the situation the entire area might one day be completely degraded, limiting continued support for high diversity of flora and fauna. This is particularly problematic if enough fallow lands are not left long enough to develop a complex vegetation stratification to support a variety of foraging techniques among various bird species. Increasing human population growth will definitely result in such consequences if farming practises and fuel wood dependence is not changed.

Furthermore, trees are often harvested for commercial purposes by the local inhabitants, leaving the area with few trees, especially during the dry season when there are few farming activities. If not curbed, the continual destruction of insect resource has a potential of triggering competition among the bird species (Leisler 1990, 1992, Rabøl 1987), hence could also affect the foraging behavior and survival of migrants.

People were also observed shooting the birds with catapult. This practices if not checked can reduce the population of migrants and resident birds' species in the area. Insecticides used on the farms could also pose a great threat to the migrants, since migrants sometimes feed on those farms. The threat on the migrants could be both in terms of bio-accumulation of DDT, and reduced insect abundance due to the spraying.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The results of this study support the claim of Jedlicka et al. (2006) and Salewski et al. (2002b) that migrants partition resources with small, insectivorous residents. Higher foraging heights and more diverse foraging techniques could be a relatively widespread mechanism for migrant birds to coexist with resident species, a subject that warrants further research. The flexibility of Palearctic migrants in foraging ecology might allow them to utilize resources that are not available for residents, and enable them to coexist with residents in the same habitats. Therefore, previous suggestions that Palearctic migrants are more flexible and use a wide variety of foraging techniques (Leisler 1992, 1993) could be confirmed. However, claims that migrants are more diverse in their habitat selection and foraging height preference (Leisler 1992) could not be fully confirmed, since the Rufous cisticola showed more versatility in habitat selection than Melodious warbler. Likewise the cisticolas were more diverse in foraging height than the Willow warblers.

In the presence of migrants, residents changed their foraging behaviour in a more specialised way, probably, to reduce competition with migrants. There were indications of displacements of residents in habitat selection and foraging height therefore, previous suggestions of habitat displacement of residents by migrants (Salewski 1999) could be confirmed, however, it is not known which mechanism facilitates this separation because direct interspecific interactions were not observed.

Habitat selection, foraging techniques and foraging height diversity among the residents were relatively low in the absence of migrants. This difference could be as a result of niche shift induced by the arrival of migrants. Residents may shift to under-exploited niches to avoid resource ‘competition’ when migrants are very abundant. Moreover, since residents are permanent around and are familiar with food sources throughout the year, they can specialize on niches (narrow niches), thereby leading to low diversities in niche dimensions.

Niche overlap existed between migrants and residents, but at different rates. None of the migrants had a complete overlap with the residents on any niche dimension. Although some of the migrants showed a high overlap with some residents, they were still able to co-exist because a high overlap in one niche dimension was compensated by a low overlap in another niche dimension.

Even though previous studies conducted in Africa (Huston 1994, Moreau 1972, Leisler 1992) might give clue to inter-specific competition between migrants and residents, I am unable to determine whether interference competition existed between migrants and residents, since it requires direct observations of interactions between birds. Moreover, it is difficult to determine diffuse competition in the field among several species.

Activities such as burning, logging and hunting by the local inhabitants could pose a threat to the survival of the migrant bird community in the area, since these could lead to the loss of micro-habitats and a reduction in insect abundance which supports the bird species. Moreover, destruction of the vegetation cover through burning can deplete the vegetation cover, leading to a decline in insect (prey) population, hence could adversely affect migrants' foraging ecology and population.

6.2 Recommendations

6.2.1 Further Research and Improved Methodology

To further increase our understanding on migrants and residents foraging interactions, further studies should focus strictly on behavioural changes in residential species upon migrant arrival and consider the predatory effects this shift may have on the abundance of organisms at lower trophic levels (arthropods). Further studies should also focus on direct interference competition between migrants and residents and compare areas where migrants are less abundant with respect to food abundance and vertical vegetation complexity. Also, to improve our knowledge on migrants and their conservation needs, further studies comparing seasonal changes, habitat requirements, food abundance and habitat preferences of insect populations should be conducted on the wintering grounds.

6.2.2 Improved Protection and Law Enforcement

Concerted actions by government and the local inhabitant are required to protect the migrants. Buffer zones should be constructed in the study area especially where there is high population of diverse avifauna, restricting burning, logging and hunting of migrants. Also, protected zones that are void of human activities such as cemeteries or other sacred places could be constructed in the study area so as to limit human activities in there. Local community participation in protective measures is very essential as governmental institutions are inadequately equipped and staffed to solely enforce such legislations and regulations. Legislation against fire use in hunting should be enforced.

6.2.3 Conservation Measures Involving Local People Participation

Alternative livelihood and income generating activities such as animal husbandry and bee keeping should be provided to local inhabitants whose major occupation is logging, fuel wood harvesting and bird hunting within the study area so as to mitigate the threat that those activities could pose on the vegetation and the bird community.

Since some of the local inhabitants interviewed did not know whether burning could pose a threat to the birds in the area, I suggest that there should be intensive education and awareness creation at both local and national levels on the need to protect the migrant birds. Wildlife associations at the grassroots level could be formed to help enhance the knowledge of general bird and wildlife conservation issues. Members of such associations could be encouraged to plant more trees at the migratory sites so as to provide more niches for the bird community in the area. Farmers should also be discouraged from farming practices such as slash and burn and rather cultivate perennial crops such as cash crops (cashew, mango) and fuel wood plantation such as teak, acacia and jathropha.

Also, co-operative research and conservation projects should be carried out yearly by governmental and non-governmental organizations on the migratory bird species and their wintering grounds so as to monitor and mitigate the negative effects of human population growth, through conservation efforts. Both local and international collaborative research should be paramount to conservation and educational institutions, in their quest to protect migrants.

REFERENCES

Abrams, P. 1980. Some comments on measuring niche overlap. Ecology 61:44–49.

Adamik, P. & Bures, S. 2007. Experimental evidence for species-specific habitat preferences in two flycatcher species in the hybrid zone. Naturwissenschaften, 94: 859-863.

Adams, M., Sibanda, S. & Turner, S. 1999. Land Tenure Reform and Rural Livelihoods in Southern Africa. ODI Natural Resources Perspectives No 39. Overseas Development Institute, London.

Alerstam, T. 2001. Detours in bird migration. Journal of Theoretical Biology, 209: 319-331.

Alström, P., Ericson, P. G. P., Olsson, U. & Sundberg, P. 2006. Phylogeny and classification of the avian superfamily Sylvioidea. Molecular Phylogenetics and Evolution 38 (2): 381–397.

Amano, E. H. & Eguchi, K. 2002. Foraging niches of introduced Red-billed Leiothrix and native species in Japan. 123-131.

Aweto, A. O. 2013. Shifting cultivation and secondary succession in the tropics. 51-103

Bairlein, F. 1985. Offene Fragen der Erforschung des Zuges paläarktischer Vogelarten in Afrika. Vogelwarte 33: 144–155.

Baker, K. 1997. Warblers of Europe, Asia and North Africa (Helm Identification Guides). 256–259.

Barker, F. K., Clark, G. A. Jr., Grzybowski, J.A., Humann, A., Jaramillo, A., Kricher, J., Reed, J. M., Sargent, M. & Sargent, R. 2001. National Audubon Society - The Sibley Guide to Bird Life & Behavior. Alfred A. Knopf. Pp. 360–361, 377, 390, 404, 427, 435–436, 441, 451, 545

Begon, M., Townsend, C.R. & Harper, J.L. 2006. Ecology: from individuals to ecosystems, 4th edn. Blackwell, Oxford

Behrstocky, R.A., Clark Jr, G. A., Collins, C.T., Sheldon, F.H. & Winkler, D.W. 2001. National Audubon Society – The Sibley Guide to Bird Life & Behavior. Alfred A. Knopf. Pp. 100.

Berthold, P. 1990. Wegzugbeginn und einsetzen der zugunruhe bie 19 vogelpopulationen – eine vergleichende untersuchung. In: Proceedings of the International Centennial Meeting of the DO-G, Current topics in avian biology (R. van den Elzen, K.-L. Schuchmann, and K. Schmidt-Koenig, eds.). 217-222. Bonn, Germany.

Berthold, P. 1998. Bird migration: genetic programs with high adaptability. Zoology 101: 235-245.

Berthold, P. 2000. Vogelzug: Eine aktuelle Gesamtu¨bersicht. Darmstadt: Wissenschaftliche Buchgesellschaft.

Berthold, P., Bauer, H. & Westhead, V. 2001. Bird migration: a general survey. Oxford University Press

Bibby, C.J. & Green, R.E. 1980. Foraging Behaviour of Migrant Pied flycatchers, *Ficedula hypoleuca*, on Temporary Territories. 507-521.

Biebach, H., Friedrich, W. & Heine, G. 1986. Interaction of body mass, fat, foraging and stop-over periods in trans-Saharan migrating passerine birds. Oecologia 69:370-379.

Bilcke, G. 1984. Seasonal-changes in habitat use of resident passerines. Ardea 72: 95–99.

BirdLife International, 2000. Threatened birds of the world. Barcelona and Cambridge, UK: Lynx Edicions.

BirdLife International, 2004. Threatened birds of the world 2004 CD-ROM.

BirdLife International, 2008. Threatened birds of the world 2008 CD-ROM.

BirdLife International, 2012. *Hippolais polyglotta.* IUCN Red List of Threatened Species. Version 2012.1

Boere, G.C. & Stroud, D.A. 2006. The flyway concept: what it is and what it isn't. Waterbirds around the world. Eds. G.C. Boere, C.A. Galbraith & D.A. Stroud. The Stationery Office, Edinburgh, UK. Pp. 40-47.

Borrow, N. & Demey, R. 2004. Birds of Western Africa. Princeton University Press. 335-336.

Boyle, W. A. & Conway, C.J. 2007. Why migrate? A test of the Evolutionary Precursor Hypothesis. American Naturalist 169: 344-359.

Burton, R. 1990. Birdflight: An Illustrated Study of Birds' Aerial Mastery. Facts on file. Pp. 26–44. ISBN 0-8160-2410-3.

Chad, L.S., Eric, J.S. & Christopher, G.G. 2010. Passerine migrant stopover duration and spatial behaviour at an urban stopover site.Volume 36, Issue 5. Pp 484-492.

Clements, J.F. 2009. The Clements Checklist of Birds of the World. 6th ed., with updates to December 2009. Ithaca: Cornell Univ. Press

Collar, N.J., Long, A.J., Robles, G. P. & Rojo, J. 2008. Birds and People. Bonds in a Timeless Journey. CEMEX-Agrupación Sierra Madre-BirdLife International, Mexico City, Mexico. Pp 360.

Convention on the Conservation of Migratory Species of Wild Animals (CMS). 2008.

Convention on the Conservation of Migratory Species of Wild Animals (CMS). 2010.

Danchin, E., Giraldeau, L. & Cezilly, F. 2008. Behavioural Ecology. New York: Oxford University Press.

Danielle, A.A. & Geginald, H.B. 1985. Foraging and habitat relationships of insect- gleaning birds in a Sierra Nevada mixed-conifer forest. The condor 87: 205-216.

Diamond, J.M. 1975. Assembly of species communities. In: Ecology and evolution of communities (Cody ML, Diamond JM, eds). Cambridge: Harvard University Press; 342–444.

Diego, R., Fernando, S. & Nicola, S. 2004. "Protandry and sexual dimorphism in trans-Saharan migratory birds". Behavioral Ecology 15 (4): 592–601.

Dowsett, R. J. & Forbes-Watson, A. D. 1993. Checklist of birds of the Afrotropical and Malagasy regions. Tauraco Press, Li.

Dunn, J. & Garrett, K.1997. Warblers. New York: Peterson Field Guides. Pp. 18, 377, 437, 470, 551.

Eckhardtr, C. 1979. The adaptive syndromes of two guilds of insectivorous birds in the Colorado Rocky Mountains. Ecol. Monogr. 49:129-149.

Eeva, T., Ryoma, M. & Riihimaki, J. 2005. Pollution-related changes in diets of insectivorous passerines. Oecologia, 145: 629-639

Everard, D. A. 1987. A classification of the subtropical transitional thicket in the Eastern Cape based on syntaxonomic and structural attributes. South African Journal of Botany 53: 329-340

Figuerola, O. & Green, A.J. 2002. "Dispersal of aquatic organisms by waterbirds: a review of past research and priorities for future studies". Freshwater Biology 47 (3): 483–494.

Ford, H.A., Bell, H., Nias, R. & Noske, R. 1988. The relationship between ecology and the incidence of cooperative breeding in Australian birds. Behavioral Ecology and Sociobiology 22 (4): 239–249

Forstmeier, W. & Keßler, A. 2001. Morphology and foraging behaviour of Siberian Phylloscopus warblers. – J. Avian Biol. 32: 127–138.

Ghana Meteorological Agency, 2011. Climatological data for Damongo. Pp. 1.

Greenberg, R. 1986. Competition in migrant birds in the non-breeding season. 281–307 in: Johnstone, R. (ed.). Current ornithology. Vol. 3. Plenum Press, New York.

GSS. 2005. 2000 Population and Housing Census of Ghana. Pp. 390

Haemig, P. 1999. Predation risk alters interactions among species: competition and facilitation between ants and nesting birds in a boreal forest. Ecology Letters, 2: 178-184.

Hedenström, A. 2008. Adaptations to migration in birds: behavioral strategies, morphology and scaling effects. Phil. Trans. R. Soc. B 363 (1490): 287–299.

Henk, W. 1981. Similarity indices, sample size and diversity. Vol.50, Issue 3. 296-302.

Herremans, M. 1993. Seasonal dynamics in subkalahari bird communities with emphasis in migrants. Proc. Pan-Afr. Orn. Congr. 8: 555–564.

Huhta, E., Jokimaki, J. & Rahko, P. 1998. Distribution and reproductive success of the Pied Flycatcher Ficedula hypoleuca in relation to forest patch size and vegetation characteristics; the effect of scale. IBIS, 140: 214-222.

Huito, R.T. 1985. Seasonal changes in habitat distribution of transient insectivorous birds in south eastern Arizona: competition mediated? Auk 102: 120-132.

Hoyo, D. J., Elliott, A. & Christie, D. 2006. Handbook of the Birds of the World. Volume 11: Old World Flycatchers to Old World Warblers. Lynx Edicions.

Huston, M. A. 1994. Biological diversity – the coexistence of species in changing landscapes. Cambridge University Press, Cambridge.

Ian, N. 2002. Population limitation in migrants. Volume 146, Issue 2, Pp 197-226

Jedlicka, J.A., Greenberg, R., Perfecto, I., Philpottt, S.M. & Dietsch, T.V. 2006. Seasonal shift in the foraging niche of a tropical avian resident: resource competition at work? Volume: 22: 385-395

Jones, P. 1998. Community dynamics of arboreal insectivorous birds in African savannas in relation to seasonal rainfall patterns and habitat. Pp 422.

Jones, P., Salewski, V., Vickery, J. & Mapaure, I. 2010. Habitat use and densities of co-existing migrant Willow Warblers Phylloscopus trochilus and resident eremomelas Eremomela spp. in Zimbabwe. Volume: 57, Issue: 1. 44-55.

Jost, L. 2007. Partitioning Diversity into independent alpha and beta components. Ecology, 88(10), 2007, pp. 2427–2439.

Ketterson, E.O. & Nolan, J.R. 1982. The role of migration and winter mortality in the history of a temperate-zone migrant, the Dark-eyed Junco, as determined by demographic analysis of winter population. Auk 99:243-259.

Krebs, C. J. 1999. Ecological Methodology. Second edition. Addison-Wesley, California.

Krebs, J. R. & Davies, N. B. 1993. An Introduction to Behavioural Ecology. Wiley-Blackwell. ISBN 0-632-03546-3.

Lack, P.C. 1971. Ecological Isolation in Birds. Blackwell Scientific Publications, Oxford, UK.

Lack, P.C. 1983. The movements of Palearctic landbird migrants in Tsavo East National Park, Kenya. J Anim Ecol 52:513–524.

Lack, P. 1986. Ecological correlates of migrants and residents in a tropical African savanna. Ardea 74: 111–119.

Lack, P. 1990. Palaearctic-African systems. 345– 356 in Keast, A. (ed.). Biogeography and ecology of forest bird communities. Academic Publishing, Hague.

Lefebvre, L., Gaxiola, A., Dawson, S., Timmermans, S., Rosza, L. & Kabai, P. 1998. Feeding innovations and forebrain size in Australian birds. Behaviour 135:1077–1097.

Leisler, B., Heine, G. & Siebenrock, K.H. 1983. Einnischung und interspezifische Territorialität überwinternder Steinschmätzer (Oenanthe isabellina, O. oenanthe, O. pleschanka) in Kenia. J. Ornithol. 124: 393–413.

Leisler, B. 1990. Selection and use of habitat of wintering migrants. In: Gwinner E (ed) Bird Migration. 156–174. Springer-Verlag, Berlin, Germany.

Leisler, B. 1992. Habitat selection and coexistence of migrants and Afrotropical residents. Ibis 134 Suppl. 77-82.

Leisler, B. 1993. Habitat use and coexistence of Palearctic migrants and Afrotropical residents. Ann Mus Roy Afr Cent (Zool) 268:565–570.

Lindell, C.A., Cole, R.J., Holl, K.D. & Zahawi, R.A. 2012. Migratory bird species in young tropical forest restoration sites: effects of vegetation height, planting design, and season. Bird Conservation International, 22:94-105.

Loiua, D. & Moore, F.R. 1990. Energy demands of migration on Red-eyed Vireos (Vireo diauceus). Behay Ecol. 1:24-35.

Lövei, G.L.1989. Passerine migration between the Palearctic and Africa. Curr Ornithol 6:143-174.

Lovette, I.J. & Holmes, R.T. 1995. Foraging behavior of America redstarts in breeding and wintering habitats: implications for relative food availability. Condor 97:782–791.

Lundberg, A. 2010. The Pied Flycatcher. A&C Black. 55–59.

Lyytinen, A., Brakefield, P. & Mappes, J. 2003. Significance of butterfly eyespots as an anti-predator device in ground-based and aerial attacks. Oikos, 100: 373-379.

Madge, S. 2006. "Family Sylviidae (Old World Warblers)", in del Hoyo, J., Elliott, A. & Christie, D. Handbook of the Birds of the World. Volume 11, Old World Flycatchers to Old World Warblers, Barcelona: Lynx Edicions, pp. 683–685.

Magurran, A.E. 1988. Ecological diversity and its measurement. Chapman and Hall, London, 179p.

McArthur, R. 1972. Geographical ecology: patterns in the distribution of species. New York: Harper & Row.

McNab, B. 2009. Ecological factors affect the level and scaling of avian BMR. Comparative Biochemistry and Physiology, Part A 152: 22-45.

Merino, S. & Potti, J. 1996. Weather dependent effects of nest ectoparasites on their bird hosts. Ecography, 19: 107-113.

Merino, S. & Potti, J. 1998. Growth, nutrition, and blow fly parasitism in nestling Pied Flycatcchers. Canadian Journal of Zoology, 76: 936-941.

Moore, F.R. & Kerlinger, P. 1987. Stop over and fat deposition by North American wood-warblers (Parulinae) following spring migration over the Gulf of Mexico. Oecologia 74: 47-54.

Moreau, R. E. 1972. The Palearctic-African Bird Migration Systems. London.

Morel, G.J. & Morel, M.-Y. 1978. Recherches ecologiques sur une savane sahelienne du Ferlo septentrional, Senegal. Etude d'une communaute avienne.Cahier l'ORSTOM Series Biol-ogie 3–24.

Morel, G.J. & Morel, M.-Y. 1992. Habitat use by Palearctic migrant passerine birds in West Africa. Ibis 134 (Suppl. 1):83–88.

Morisita, M. 1959. "Measuring of the dispersion and analysis of distribution patterns". Memoires of the Faculty of Science, Kyushu University, Series E. Biology. 2: 215–235.

Newton, I. 2007. Weather-related mass-mortality events in migrants. Ibis 149: 453-467.

Nguembock, B., Fjeldsa, J., Tillier, A. & Pasquet, E. 2007. A phylogeny for the Cisticolidae (Aves: Passeriformes) based on nuclear and mitochondrial DNA sequence data, and a re-interpretation of a unique nest-building specialization. Molecular Phylogenetics and Evolution 42: 272-286.

Nicholas, P. N. 2011. Introduction to Stata 11, getting started with Stata programming. Pp. 3

O'Connor, R. J.1981. Comparisons between migrantandnon-migrant birds in Britain. 167–195, in Aidley, D. J. (ed.). Animal migration. Cambridge University Press, Cambridge.

Odonkor, M. & Mason, J. 1994. Land, Paramountcy and Conflict in Northern Region: the 1994 Guinea-fowl war. Unpublished confidential report for CIDA, Accra.

Ogonowski, M. S. & Conway, C.J. 2009. Migratory decisions in birds: extent of genetic versus environmental control. Oecologia 161: 199-207.

Parkin, D.T. 2003. "Birding and DNA: species for the new millennium". Bird Study 50 (3): 223–242.

Pearson, D.J. & Backhurst, G. C. 1976. The southward migration of Palaearctic birds over Ngulia, Kenya. Ibis 118: 78–105.

Piperno, D. R. & Sues, H. D. 2005. Dinosaurs Dined on Grass. Science 310 (5751): 1126–8.

Rabøl, J. 1987. Co-existence and competition between overwintering Willow Warblers (*Phylloscopus trochilus)* and local warblers at Lake Naivasha, Kenya. Ornis Scand. 18: 104–121.

Rabøl, J. 1993. Competition between over-wintering Willow Warblers *Phylloscopus trochilus* and local warblers in the acacia-savannah in Kenya. Pp 76–96 in Madsen, J. (ed.). Proc. 7th Nordic Congr. Orn. (1990). Skive, Denmark.

Raffaele, H. A. 1989. A guide to the birds of Puerto Rico and the Virgin Islands. Pp. 103–137

Rappole, J.H. & Warner, D.W. 1976. Relationship between behavior, physiology and weather in avian transients at a migration stop over site. Oecologia 26: 193-212.

Rappole, J.H., Compton, B.W., Leimgruber, P., Robertson, J., King, D. I. & Renner, S.C. 2006. Modelling movement of West Nile virus in the Western hemisphere. Vector-Borne Zoonotic Dis. 6:128–139.

Reid, J.L., Harris, J. B. C., Martin, L. J., Barnett, J. R. & Zahawi, R. A. 2008. Distribution and abundance of Nearctic-Neotropical songbird migrants in a forest restoration site in southern Costa Rica. Journal of Tropical Ecology 24:685-688.

Rusterholkz, A. 1981. Competition and the structure of an avian foraging guild. Am. Nat. 118: 173-190.

Ryan, P. 2006. Family Cisticolidae (Cisticolas and allies). 378–492 in Del, H. J., Elliott, A. & Christie, D.A. 2006. Handbook of the Birds of the World. Volume 11. Old World Flycatchers to Old World Warblers Lynx Edicions, Barcelona.

Sahney, S., Benton, M.J. & Ferry, P.A. 2010. "Links between global taxonomic diversity, ecological diversity and the expansion of vertebrates on land". Biology Letters 6 (4): 544–7.

Salewski, V. 1999. Untersuchungen zur U¨ berwinterungso¨kologie pala¨arktischer Singvo¨gel in Westafrika unter besonderer Beru¨ cksichtigung der Wechselwirkungen zu residenten Arten (PhD dissertation). Oldenburg: Carl v. Ossietzky Universita¨t.

Salewski, V. 2000b. Microhabitat use and feeding strategies of the pied flycatcher and the willow warbler in their West-African winter quarters compared with resident species. Ostrich 71:191–193.

Salewski, V., Bairlein, F. & Leister, B. 2002a. Different wintering strategies of two Palearctic migrants in West Africa- a consequence of foraging strategies? Ibis 2002, 144, 85-93.

Salewski, V., Jones, P. & Vickery, J. 2002b. Niche partitioning between immigrant Palearctic willow warblers Phylloscopus trochilus and resident Afrotropical warblers in three woodland habitats in Zimbabwe. Avian Sci 2:207–215.

Salewski, V. & Peter, J. 2006. Palearctic passerines in Afrotropical environments: A review. J ornithol (2006) 147: 192-201.

Sanderson, F. J., Donald, P. F., Pain, D. J., Burfield, I. J. & van Bommel, F. P. J. 2006. Long-term population declines in Afro-Palearctic migrant birds. Biol Conserv. 131: 93–105.

Sanz, J. 2001. Experimentally reduced male attractiveness increases parental care in the pied flycatcher Ficedula hypoleuca . Behavioral Ecology, 12 (2): 171-176.

Schaub, M., Jenni, L. & Bairlein, F. 2008. Fuel stores, fuel accumulation, and the decision to depart from a migration stopover site. Behavioral Ecology 19: 657-666.

Schaub, M., Kania, W. & Köppen, U. 2005. Variation of primary production during winter induces synchrony in survival rates in migratory white storks Ciconia ciconia. J. Anim Ecol. 74: 656–666.

Schultz, S., Bradbury, R. B., Evans, K. L., Gregory, R. D. & Blackburn, T. M. 2005. Brain size and resource specialization predict long-term population trends in British birds. Proc. R. Soc. Lond. Ser. B 272: 2305–2311.

Schupp, E. W.1993. Quantity, quality, and the effectiveness of seed dispersal by animals. Vegetatio, 107/108:15-29.

Sekercioglu, C.H. 2007. Conservation ecology: area trumps mobility in fragment bird extinctions. Current Biology 17 (8): R283–R286.

Sherry, T.W. & Holmes, R.T. 1996. Winter habitat quality, population limitation, and conservation of Neotropical-Nearctic migrant birds. Ecology 77: 36–48.

Shyy, W., Lian, Y., Tang, J., Viieru, D. & Liu, H. 2007. Aerodynamics of Low Reynolds Number Flyers. Cambridge Aerospace Series. Pp 12

Sibley, C. G. & Monroe, B. L. 1990. Distribution and taxonomy of birds of the world. Yale University Press, New Haven, USA.

Siitari, H., Honkavaara, J., Huhta, E. & Viitala, J. 2002. Ultraviolet reflection and female mate choice in the pied flycatcher, Ficedula hypoleuca . Animal Behavior, 63: 97-102.

Silverin, B. 1980. "Effects of long-acting testosterone treatment on freeliving pied flycatchers, Ficedula hypoleuca, during the breeding period". Animal Behaviour 28 (3): 906–912.

Sinclair, A.R.E. 1978. Factors affecting the food supply and breeding season of resident birds and movements of Palaearctic migrants in a tropical African savannah. Ibis 120: 480-497

Smith, R.P., Lacombe, P.W., Morris, E.H., Holmes, S.R. & Caporale, D.W. 1996. "Role of bird migration in the long-distance dispersal of Ixodes dammini, the vector of Lyme disease". J. Infect. Dis. 174 (1): 221–4.

Snow, D. W. & Perrins, C. M. 1998. The Birds of the Western Palearctic (Concise Edition ed.). Oxford: Oxford University Press.

Snedecor, G. W. & Cochran, W.G. 1989. Statistical Methods, Eighth Edition, Iowa State University Press.

Sol, D., Lefebvre, L. & Rodríguez-Teijeiro, J. D. 2005. Brain size, innovative propensity and migratory behaviour in temperate Palearctic birds. Proc. R. Soc. Lond. Ser. *B* 272: 1433–1441.

Stevenson, T. & Fanshawe, J. 2002. The Birds of East Africa. Pp 374

Stotz, D. F., Fitzpatrick, J. W., Parker, T. A. & Moskovits, D. K. 1996. Neotropical birds: ecology and conservation. Chicago, IL: University of Chicago Press.

Strandberg, R., Klaassen, R. H. G., Hake, M. & Alerstam, T. 2010. How hazardous is the Sahara Desert crossing for migratory birds? Indications from satellite tracking of raptors. Biology Letters (online early).

Thompson, J. N. & Wilson, M. F. 1979. Evolution of temperate fruit/bird interactions: phenological strategies. Evolution, 33:973-982.

Thompson, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. The Auk 119:18–25.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. & Polasky, S. 2002. Agricultural sustainability and intensive production practices. Nature 418: 671–677.

Tucker, G. M. & Heath, M. F.1994. Birds in Europe: their conservation status. Cambridge, UK: BirdLife International (BirdLife Conservation Series 03).

UNEP/CMS. 2012. A brief tour by the Convention on the Conservation of Migratory Species of Wild Animals. Second edition.

Veiga, J.P. 1986. Settlement and fat accumulation by migrant Pied Flycatchers in Spain. Ring. Migr. 7: 85–98.

von Haartman, L. 1951. "Successive Polygamy". Behavior 3 (4): 256–274.

Waide, R.B. 1981. Interactions between resident and migrant birds in Campeche, Mexico. Trop. Ecol. 22: 134- 154.

Weber, J.M. 2009. "The physiology of long-distance migration: extending the limits of endurance metabolism". J. Exp. Biol. 212 (Pt 5): 593–597.

Wheeler, A.G. & Calver, A.G.M. 1996. Resource partitioning in an island community of insectivorous birds during winter. Volume: 96, Issue: 1: 23 – 31.

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

Wiens, A. J. 1997. The ecology of bird community. Volume 1. Pp 167

Wilson, O.E., Winslow, R.B., Richard, E.D., Robert, L.M., Richard, D.O., Millard, S. & William, E. 1973. Life on Earth. Sinaur Associates Inc. Pp 857

Winkel, W. & Frantzen, M. 1991. Ringfund-Analyse zum Zug einer niedersächsischen Population des Trauerschnäppers Ficedula hypoleuca. Vogelkundl. Ber. Nieders. 23: 90–98.

Yaro, J.A. & Abraham, Z. 2009. Customary land tenure, Investment and livelihoods adaptation in Northern Ghana. Ogua Journal of Social Science (JOSS), Vol. 4. No.3.Pp. 59-82.

Yong, W. & Moore, F.R. 1993. Relation between migratory activity and energetic condition among thrushes following passage across the Gulf of Mexico . Condor 95: 934 - 943.

Zink, G. 1973–85. Der Zug EuropäIischer Singvögel, Vol. I and II. Wiesbaden: Aula-Verlag.

APPENDIX

Appendix 1: Shannon-Wiener evenness of the birds (considering foraging technique)

SPECIES	**E_H**
MW	0.68
WW	0.56
PF	0.68
RC	0.50
NC	0.25
SE	0.37
Shannon-Wiener evenness considering foraging techniques used by resident birds in the absence of the migrant birds	
RC	0.31
NC	0.19
SE	0.25

Appendix 2: Proportion of MW foraging from various heights in each habitat type

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0.014	0.011	0.007	0.004
TH	0.007	0.025	0.05	0.007	0
FB	0	0.011	0.028	0.014	0
FNB	0.007	0.028	0.014	0.028	0
FF	0.032	0.241	0.278	0.135	0.057

Appendix 3: Proportion of WW foraging from various heights in each habitat type

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0.004	0.012	0.016	0.008
TH	0.019	0.023	0.016	0.004	0
FB	0	0.019	0.047	0.035	0.004
FNB	0.012	0.07	0.081	0.062	0.012
FF	0.012	0.225	0.22	0.081	0.019

Appendix 4: Proportion of PF feeding from various heights in each habitat type

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0.095	0	0
TH	0	0	0	0	0
FB	0	0.048	0	0.048	0
FNB	0.048	0.048	0.048	0.095	0
FF	0.048	0.238	0.095	0.095	0.095

Appendix 5: Proportion of RC feeding from various heights in each habitat type

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0.008	0	0	0	0
TH	0.08	0.021	0.008	0.017	0.008
FB	0.08	0.008	0	0.025	0.004
FNB	0.173	0.042	0	0.051	0.004
FF	0.35	0.063	0.017	0.038	0

Appendix 6: Proportion of SE foraging from various heights in each habitat type

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0	0	0
TH	0.2	0.047	0.035	0	0
FB	0	0	0	0	0
FNB	0.024	0	0	0	0
FF	0.506	0.07	0.024	0.094	0

Appendix 7: Proportion of NC feeding from various heights in each habitat type

		FORAGING HEIGHT/m			
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0	0	0
TH	0	0	0	0	0
FB	0	0.2	0.2	0	0
FNB	0	0.2	0.2	0	0
FF	0	0.133	0.067	0	0

Appendix 8: Proportion of RC foraging from various heights in each habitat type in the absence of migrants

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0	0	0
TH	0	0	0	0	0
FB	0	0	0	0	0
FNB	0	0	0	0	0
FF	0.84	0.8	0.8	0	0

Appendix 9: Proportion of SE foraging from various heights in each habitat type in the absence of migrants

	FORAGING HEIGHT/m				
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0	0	0
TH	0	0	0	0	0
FB	0	0	0	0	0
FNB	0	0	0	0	0
FF	0.07	0.50	0.43	0	0

Appendix 10: Proportion of NC foraging from various heights in each habitat type in the absence of migrants

FORAGING HEIGHT/m					
HABITAT	0.0-3.0	3.0-6.0	6.0-9.0	9.0-12.0	12.0-15.0
GR	0	0	0	0	0
TH	0	0	0	0	0
FB	0	0	0	0	0
FNB	0	0	0	0	0
FF	0.17	0.25	0.58	0	0

Appendix 11: Rainfall pattern of Damongo from 2005-2011

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2005	2.2	17.8	78.3	104.5	168.8	115.9	143.6	126.3	208.4	101.7	0.0	9.8
2006	0.5	23.0	47.9	48.2	169.7	149.2	151.6	89.0	147.7	146.5	0.0	0.0
2007	0.0	11.3	40.5	120.6	91.2	80.9	113.0	225.4	210.4	92.3	10.7	0.0
2008	0.0	0.0	118.2	84.4	151.9	102.6	326.2	285.9	220.6	85.3	2.8	0.0
2009	0.0	2.5	11.7	103.5	140.7	149.1	208.8	221.3	159.7	139.3	6.1	0.0
2010	0.0	34.0	8.3	118.5	130.3	189.8	90.0	203.9	299.9	215.5	0.0	0.0
2011	0.0	5.4	38.5	24.7	143.7	169.1	146.1	234.3	256.1			

Appendix 12: Questionnaire administered to local inhabitants

Questionnaire

Name is your name?

What is your occupation?

Are you aware of the presence of migrant birds in this area? YES ☐ NO ☐

What time of the year do you often see them around?

Where do they migrate from?

Can you identify any of these migrant birds in the picture? YES ☐ NO ☐

What are the names of the birds?

Do the migrant birds visit your farms? YES ☐ NO ☐

In your opinion, why do the migrant birds visit your farm?

Does your farming/hunting/logging activity pose a threat to the birds? YES NO ☐ ☐

Do you apply insecticides/pesticides on your farm?

Do you burn the bush in the area? YES ☐ NO ☐

Why do you burn the bush?

What period of the year do you often burn the bush?

How frequent do you burn the bush in a year?