

**ASPECTS OF THE ECOLOGY OF THREE COMMUNALLY BREEDING
BIRD SPECIES ON LEGON CAMPUS**

BY

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DECLARATION

I hereby declare that except for references to other peoples' work which have been duly cited, this thesis is entirely my original work which has neither been submitted in whole nor part by any person to any academic institution or University for the same or another degree.

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ABSTRACT

This study compares some ecological aspects (territory size, group size, clutch size and food supply rate) of three communally breeding bird species, namely Yellow-billed Shrike (*Corvinella corvina*), Green Wood-hoopoe (*Phoeniculus purpureus*) and Brown Babbler (*Turdoides plebejus*), on the Legon campus of the University of Ghana. This was in response to the limited literature on communal breeding bird species despite their widespread distribution in Africa. The methodology involved direct observations and the use of the convex polygon method in the determination of the territory sizes in both the wet and dry seasons. In the wet season, a total of 245 Yellow-billed Shrike, 74 Green Wood-hoopoe and 120 Brown Babbler were recorded compared to 281 Yellow-billed Shrike, 59 Green Wood-hoopoe, and 119 Brown Babbler in the dry season. These constituted 31 territories of the Yellow-billed Shrike, 11 territories of the Green Wood-hoopoe and 14 territories of the Brown Babbler. Territorial groups generally exist throughout the year, and each group member helped defend the group's territory and feeding of nestlings/breeding females. The mean territory sizes of the Yellow-billed Shrike were 1.11 ± 0.51 and 1.22 ± 0.52 hectares, the Green Wood-hoopoe were 4.17 ± 1.92 and 3.93 ± 1.35 hectares, and that of the Brown Babbler were 1.71 ± 0.63 and 2.43 ± 0.87 hectares in both the wet and dry seasons respectively. Thus, the territory sizes of all the bird species were similar except the Brown Babbler that had a significantly larger territory size in the dry season ($P < 0.05$). The mean group sizes of the Yellow-billed Shrike were 9.07 ± 3.45 and 9.06 ± 3.40 , the Green Wood-hoopoe were 6.73 ± 3.29 and 7.38 ± 3.78 , and that of the Brown Babbler were 8.57 ± 3.50 and 8.50 ± 3.23 in both the wet and dry seasons respectively. There was no significant difference in the group sizes between the two seasons for any of the three species ($p > 0.05$).

DEDICATION

I dedicate this piece of work to my parents (Mr/Mrs Kwabena Adusei) for their support throughout my education. God richly bless them.

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LIST OF ABBREVIATIONS

CEGENSA:	Centre for Gender Studies and Advocacy
CERSGIS:	Centre for Remote Sensing and Geographic Information Systems
GPS:	Global Positioning Systems
IUCN:	International Union for Conservation of Nature and Natural Resources
LBG:	Legon Botanical Gardens

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Communal or cooperative (social) breeding in birds is defined as the rearing of chicks at one nest by more than two individuals irrespective of the precise genetic mating system (Emlen & Vehrencamp, 1985). Of the over 10,000 bird species occurring worldwide, little over 3% are known to breed communally (Arnold & Owens, 1998). Although there is a collective effort in communal breeding, it is generally the oldest male and female within the group that constitutes the mating pair with the rest acting as ‘helpers’ or subordinates (Cockburn, 1998). Thus, the subordinates’ group members usually forego their own reproduction and assist the breeding pair in the rearing of offspring (Cockburn, 1998). In helping the breeding pairs, the subordinates often boost the reproductive success of communal breeding groups, and some species such as the White-winged Chough (*Corcorax melanorhamphos*) in Australia cannot breed successfully in solitary breeding units (Heinsohn, 1992).

Several reasons are given to explain communal breeding in birds. Among these is the ‘Habitat Saturation Hypothesis’, which explains that individuals sharing their reproductive attempt cannot breed outside their territory because of shortage of breeding opportunities (Brown, 1987). The shortage of breeding opportunities for communally breeding birds is generally attributed to some peculiar features in their breeding ecology. For example, in the Green Wood-hoopoe (*Phoeniculus purpureus*), nesting and roosting holes are thought to limit dispersal and breeding, and thereby enhancing communal breeding (Ligon & Ligon, 1990; Gill, 2007). Another explanation of communal breeding is given by the ‘Life History Hypothesis’, which suggests that, communal breeding tends to occur in species with low

annual mortality (Brown, 1987). This is because the low annual mortality leads to overcrowded populations with little opportunity for the establishment of new breeding territories and thus promoting communal breeding (Rowley & Russell, 1990).

Despite the widespread distribution of communally breeding bird species in Africa (Arnold & Owens, 1998), limited work has been done on these birds particularly in Ghana. Grimes (1980 & 2005) generally remain the major references to communally breeding of bird in Ghana. In his studies, Grimes focused on the group behaviour and breeding biology of the Yellow-billed Shrike (*Corvinella corvina*) on Legon campus and reported the species to live in groups throughout the year. He also observed little changes in the locations, boundaries and areas of the territories occupied by the majority of the social groups. Though Grimes initiated a substantial long-term monitoring work on this species between 1970 and 1974, the Legon campus has witnessed major environmental changes amidst the ever increasing student numbers and there is the need to know whether this bird species continue to exhibit the same behaviour.

This study therefore continues Grimes work on the Yellow-billed Shrike and compare some aspects of the species ecology with two other communally breeding bird species at Legon campus, namely the Brown Babbler (*Turdoides plebejus*) and the Green Wood-hoopoe. These two additional communal breeders are also commonly found on Legon campus and research has shown that they breed all year round, and have overlapping territories with those of the Yellow-billed Shrike (Fry *et al.*, 1988 & 1992).

1.2 JUSTIFICATION

Over the past five decades, there has been an increasing knowledge of the occurrence of communal breeding among many species of birds, from a wide variety of families, in which helpers take part in activities such as territorial defense, nest construction, incubation and feeding of young (Grimes, 1976 & 1980; Cockburn, 1998).

In Ghana, available literature on Yellow-billed Shrike is limited to Grimes' (1980 & 2005) which could not definitively conclude whether seasons affect some aspects of the breeding ecology of this species, with regards to nestling food supply, group size & territory size.

Grimes carried out his work on the Legon campus of the University of Ghana due to the fact that it is one of the few remaining areas in the Accra Municipality which still holds the remnant vegetation of the Accra plains. According to Grimes (2005), the variety and distribution of habitat types remains fairly constant between the 1970s and early 2000 but in recent times many green areas surrounding the campus and interspersing the built ups have been consumed by infrastructural developments and these could affect the ecology of the many bird species including the Yellow-billed Shrike (Gashong *et al.*, 2013).

The Green Wood-hoopoe and Brown Babbler are also communally breeding birds that are common on the Legon campus (Grimes, 2006) but with limited information on their breeding ecology in Ghana. The addition of these two species to Grimes' detailed studies on the Yellow-billed Shrike would add to the information on communal breeding birds in Ghana and enable the assessment of the differences in the social structure among these three communally breeding bird species, that share ecological similarities (all insectivorous) and contrasts (two cup nesters and one hole (or cavity) nester, the Green Wood-hoopoe).

1.3 OBJECTIVES

The main objective of the research was to compare some ecological aspects of three communally breeding bird species on the University of Ghana main campus-Legon.

The specific objectives of this study were to:

- Map out the territory distribution of the three bird species on the campus.
- Determine circannual changes in territory size of each species.
- Determine circannual changes in group size of each species.
- Determine if there is a relationship between group size and territory size of each species.
- Determine if there is a relationship between group size and clutch size of each species.
- Determine if there is a relationship between group size and nestling food supply rate of each species.

1.4 HYPOTHESES

The present study aims at testing these hypotheses (Null hypotheses);

- H_O : There is no circannual change in territory size of any of the three species.
- H_O : There is no circannual change in group size of any of the three species.
- H_O : There is no relationship between group size and territory size of any of the three species.
- H_O : There is no relationship between group size and clutch size of any of the three species.
- H_O : There is no relationship between group size and nestling food supply rate of any of the three species.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL SPECIES DESCRIPTION

2.1.1 Yellow-billed Shrike

2.1.1.1 Physical Description

The Yellow-billed Shrike is a small passerine bird in the family *Laniidae*. Adults are usually about 18cm long with a long tail and short wings. The adults have mottled brown upperparts and streaked buff underparts whilst the juveniles have barred and mottled feathers with no streaks. Every yellow-billed Shrike has a brown eye mask, a rufous wing patch and with a yellow bill. This bird species is noisily conspicuous and gregarious, and sexes are similar (Fry *et al.*, 1992).

2.1.1.2 Habitat, Distribution and Status

The Yellow-billed Shrike is a common resident breeding bird species in tropical Africa. Its distribution ranges from Senegal to Uganda but it can also be found in the Western-most parts of Kenya (Zimmerman *et al.*, 1999). In Ghana, it is mostly found in the northern parts of the country (e.g. Mole, Bole and Gambaga), but also southwards through Kete Krachi to Keta and the Accra Plains (Fry *et al.*, 1992). It inhabits dry, shrubby savanna woodlands, bushy pasture, acacia savanna, cultivation and riverine woods (Fry *et al.*, 1992). This species is evaluated as Least Concern on the IUCN List of Threatened Species (IUCN, 2012).

2.1.1.3 Foraging and Breeding Ecology

The Yellow-billed Shrike feeds on insects which they locate from prominent look-out perches in trees, wires or posts. They also feed on other invertebrates and small lizards that are either

caught by swooping from a perch or by pouncing after a low, short hawking flight. In poor visibility, they feed on the ground, systematically turning over the litter and feeding on invertebrates such as the praying mantis, caterpillars, slugs, worms and spiders (Grimes, 1980). The Yellow-billed Shrike usually lives in small vocal parties and breeds cooperatively. Group members usually roost together and collectively build a cup-like nest in the bush or tree for the breeding female to lay and incubate eggs. Generally, 4 - 5 eggs are laid and are incubated over period of 17 days (Grimes, 1980). Only one female in a group breeds at a given time, with other members providing protection and food (Zimmerman *et al.*, 1999). This species of bird lives in groups throughout the year and clutches are mostly found between January and August in Ghana (Grimes, 1980).

2.1.2 Green Wood-hoopoe

2.1.2.1 Physical Description

The Green Wood-hoopoe is a member of the family *Phoeniculidae*, with adults up to about 44 cm long. It is a near-passerine tropical bird native to Africa. It has a metallic dark green plumage, with a purple back and a very long diamond-shaped purple tail. The Green Wood-hoopoe is also characterized with distinctive white markings on the wings, white chevrons on the tail edges and a long thin curved red bill. Sexes are similar, but the immature have black bills (Hockey *et al.*, 2005).

2.1.2.2 Habitat, Distribution and Status

The Green Wood-hoopoe occurs throughout sub-Saharan Africa, excluding the lowland forest of the DR Congo and West Africa. Within southern Africa it is common in Mozambique, Zimbabwe, eastern South Africa, northern and eastern Botswana, and northern Namibia. In

Ghana, it occurs in every region except the rain forest areas. It generally prefers savannas, palm groves, open woodland, riverine forest in arid thorn bush and wooded gardens (Fry *et al.*, 1988). This species is evaluated as Least Concern on the IUCN List of Threatened Species (IUCN, 2012).

2.1.2.3 Foraging and Breeding Ecology

The Green Wood-hoopoe usually eats insects, foraging mainly on tree trunks and branches, probing and searching for food and occasionally descending to the ground. It sometimes feeds on reptiles, amphibians and seeds (Hockey *et al.*, 2005). This species of bird is a monogamous communal breeder, usually with 1-10 non-breeding nest helpers. Nests are usually located in pre-existing cavities such as tree holes, fence posts or buildings. It lays 2 - 5 eggs, which are incubated for 17 - 18 days (Hockey *et al.*, 2005). In Ghana, its eggs have been found throughout the year (January- December) and usually up to two broods per year in the south. (Fry *et al.*, 1988).The female is the sole incubator, but she is provided with food by the male and the other group members. The chicks are fed by helpers, as well as the breeding male and they fledge when they are 28 - 30 days old, after which they remain in the vicinity of the nest. The parents continue to feed the juveniles for 2 - 3 months after fledging, and once the juveniles are settled in, the adults fly away to roost elsewhere. The juveniles are capable of strong flight 3 - 4 months after leaving the nest, becoming fully independent soon after (Hockey *et al.*, 2005).

2.1.3 Brown Babbler

2.1.3.1 Physical Description

The Brown Babbler is a medium sized babbler in the *Turdoides* family, measuring 22 – 25 cm in length and weighs around 52 – 80 grams. The plumage is grey-brown with a white-streaked throat and breast, and a scaled head. The wings are bronze-brown with a black bill, and the legs dusky black. The irises of the adult's eyes are yellow. The sexes are alike, and juvenile birds are like the adults but with plainer and browner plumage, and brown irises (Collar & Robson, 2007).

2.1.3.2 Habitat, Distribution and Status

The Brown Babbler inhabits the Sahel region between the Sahara Desert and the tropical forests of Western Africa, from southern Mauritania, Senegal and the Gambia to southern Sudan, Uganda and western Kenya. The species lives in open savanna, wooded grasslands, riparian habitat in drier areas, degraded cultivation, farmlands, parks and gardens (Collar & Robson, 2007). It is common across its range and readily lives in human modified habitat (Collar & Robson, 2007). The species is mostly sedentary but is thought to make some seasonal movements based upon local conditions related to the rainy seasons. In Ghana, it is commonly found in the northern part of the country, the Volta region and the South-eastern part of the country (Borrow & Demey, 2010). This species is evaluated as Least Concern on the IUCN List of Threatened Species (IUCN, 2012).

2.1.3.3 Foraging and Breeding Ecology

The Brown Babbler consumes a variety of insects including ants, beetles, termites, and praying mantises, as well as other invertebrates, berries, and fruit. They also opportunistically

take carrion. They generally forage on the ground and in groups of up to 14 individuals (Collar & Robson, 2007). Egg laying in Ghana typically takes place in April-May, July and November, but could be found to breed all year round (Fry *et al.*, 1992). Breeding females lay between 3-5 eggs, and where more than one female lays, the total number of eggs in a nest can reach 13. The largest number of fledglings recorded from one nest is about six (Zahavi, 1990).

2.2 COMMUNAL BREEDING IN BIRDS

The evolution of communal breeding in birds has been a fundamental and persistent problem for evolutionary biologists for the past century. In 1859, Darwin recognized the paradox of apparently altruistic behaviour among individuals subject to natural selection, but the full extent of the problem of communal breeding and its ubiquity in biological systems has only been recently appreciated (West *et al.*, 2007).

Approximately 3% of the extant bird species in the world regularly forgo the opportunity to breed independently and instead breed communally with other conspecifics, either as helpers or co-breeders (West *et al.*, 2007). Reproduction is monopolized by one or few of the adult group members and most adults do not reproduce, but help rear the breeder's offspring. The traditional explanation for communal breeding is that, the opportunities for breeding independently are limited owing to peculiar features of the species' breeding ecology, such as the availability of food. However, it has proved remarkably difficult to find any common ecological correlates of cooperative breeding in birds. This difficulty has led to the formation of various hypotheses by different avian biologists to explain the basis of communal breeding in birds. Two of these hypotheses are supported by most avian biologists, and these are the

‘Habitat Saturation Hypothesis’ and the ‘Life History Hypothesis’ (Brown, 1987; Arnold & Owens, 1998).

The ‘Habitat Saturation Hypothesis’ predicts that, those individuals who forgo or share their reproductive attempt cannot breed elsewhere because of shortage of breeding opportunities and cannot also become floaters owing to a lack of marginal habitats (Brown, 1987). For example, in the Green Wood-hoopoe, nesting and roosting holes are thought to limit dispersal and breeding, and thereby enhancing communal breeding (Ligon & Ligon, 1990; Gill, 2007). Alexander (1974) and Koenig (1981) stress that there are some general classes of elements that select species for communal breeding and these are; (i) predator defence, and (ii) location of a limited resource, such as food or mates (habitat quality) . This last category (as related to habitat) is the one which has taken the form of the ‘Habitat Saturation Hypothesis’, which was first proposed by Selander (1964). It has since received the support of many authors (Brown, 1974, 1987; Stacey 1979; Koenig & Pitelka 1981; Emlen, 1982; Woolfenden & Fitzpatrick, 1984; Koenig & Mumme, 1987). According to this hypothesis, young birds, physiologically capable of reproducing, remain in the territory where they were born because there is a local absence of habitat suitable for breeding. They therefore become adaptive, for both parents and adult offspring, for the latter to remain in the natal unit and help rear younger siblings until a breeding vacancy becomes available (Woolfenden & Fitzpatrick, 1984).

The explanation of the ‘Habitat Saturation Hypothesis’ by virtue of specialized breeding ecology has strong intuitive appeal. However, despite the fact that certain communally breeding species, such as the Green Wood-hoopoe, have obvious peculiar features to their breeding ecology (such as cavity nesting) which may predispose them to communal breeding, the case is not nearly so clear in other species (Smith, 1990). It is shown to be very difficult

to identify any common ecological correlates of communally breeding in birds (du Plessis *et al.*, 1995), or to demonstrate that communal breeding species are more ecologically constrained than non-communal breeding species (Smith, 1990).

The 'Habitat Saturation Hypothesis' has been little tested, in spite of its persuasive appeal, and has recently been questioned for several species where it appears that there are other confounding factors important for shaping their breeding systems (Ford *et al.*, 1988). Due to this, some studies of communal breeding have shifted the emphasis from examination of variation in ecological factors *per se* to variation in life history traits (Rowley & Russell, 1997). Specifically, it has been suggested that communal breeding tends to occur in species with low annual mortality because this leads to overcrowded populations with little opportunity for the establishment of new breeding territories (Rowley & Russell, 1990).

The 'Life History Hypothesis' suggests that, the common feature of communally breeding birds is their great longevity, rather than any particular feature of their breeding ecology (Arnold & Owens, 1998). As the traditional explanation suggests, the breeding habitat of cooperatively breeding species is saturated, but this saturation is not owing to any peculiar feature of the breeding ecology of communal breeders. Rather, the saturation arises because the local population turnover in these species is unusually slow and this is what the 'Life History Hypothesis' predicts (Arnold & Owens, 1998). This 'Life History Hypothesis' is therefore a subtle twist on the traditional explanation of habitat saturation in communally breeding species. Whereas the traditional explanation suggests that breeding opportunities are limited by an absolute shortage of a peculiar form, for example, nesting site, the 'Life History Hypothesis' suggests that breeding habitat saturation occurs because the turnover of territory owners is unusually slow. When comparing avi-faunas of Tropical Africa, Asia and the

Americas, the incidence of communal breeding in corvids (*Corvidae*) is about the same (Cockburn, 1996).

Slow life histories with low clutch sizes and high survival is believed to promote communal breeding, and has been further stimulated by comparative analyses by Arnold & Owens (1998) who showed that the incidence of communal breeding in clades of birds is not associated with ecological factors but increases with clade level estimates of adult survival. It has also been shown that the incidence of communal breeding differs dramatically between clades of birds (Russell, 1989). For example, most communal breeders belong to the oscine passerines (Cockburn, 2004).

In a comprehensive review of communal breeding among Australian passerines, Cockburn (1998) concluded that there is no definite link between life history and communal breeding. Similarly, the only two explicit comparative studies of the 'Life History Hypothesis' were unable to find a consistent difference in life history between communal and non-communal breeding species of Australian passerines (Poiani & Pagel, 1997).

Stacey & Ligon (1991) proposed an alternative hypothesis contrary to the Habitat Saturation and Life History hypotheses to explain communal breeding, which emphasizes the benefits accrued by young helpers remaining in their natal territories, rather than the breeding restrictions resulting from ecological constraints or life histories. This hypothesis which is called the 'Benefits of Philopatry Hypothesis', suggests that it should be advantageous for young birds to remain in their natal units if one or both of the following are true; (1) when the local territories vary greatly in quality and (2) group-living, per se, is important for survival, thus leading to an optimal group size for a given area. If one or both criteria are not met for a

given species, that is, there is no among-territory variance or there are no survival advantages associated with group-living, an individual should always disperse whether or not the habitat is saturated.

The taxonomic diversity of communal breeding systems in birds is impressive and communal breeding is found in 10 orders (e.g. Struthioniformes, Anseriformes & Falconiformes) (Grimes, 1976 a, b). However, it is most conspicuous in the Passeriformes, where they have been recorded in 32 families and subfamilies. The food and foraging methods used by communally breeding birds are diverse (Fry, 1977), and in general, insects are prominent in the diet of most species (Grimes, 1976b), while nectar and fruit specialists are rare. Sexual dimorphism is rare in communal breeding systems and when present is likely to be inconspicuous. Monogamy is common, polygamy is occasional, and promiscuity is rare, as expected by kinship theory (Ricklefs, 1975). The habitats in which communally breeding species live are extremely varied (Fry, 1977). Communal breeding is rare in Europe and North America and common in the tropics and particularly in Australia (Grimes, 1976 a, b). This global distributional pattern of this kind of breeding system which overlaps only marginally with the geographic distribution of scientists explains in part why communal breeding has not fully been investigated in many parts of the world, e.g. in the Afro-tropical region (Brown, 1978).

Communal breeding in birds is characterized by the presence of non-breeding individuals in a social group that help feed and defend young that are not their own offspring. Individual group members obtain one or more variety of benefits by virtue of group living (Koenig & Mumme 1987). Skutch (1961) used the word, ‘helpers’, to refer to birds that assist at nests not belonging to their mates. Helping behaviour can benefit both the parents and other helpers.

Many studies on communal bird associations show a positive correlation between the presence of helpers and the production and survival of nestlings (Brown & Brown, 1981; Koenig, 1981).

2.2.1 Advantages of Communal Breeding in Birds

There are many possible explanations that promote or select for communal rather than solitary breeding. Breeders can benefit if subordinates enhance their reproductive output or survival (Cockburn, 1998). In addition, future benefits may be attained when subordinates inherit the territory, and therefore subordinates may benefit from raising offspring that later become helpers (Cockburn, 1998). Helping is not restricted to groups of closely related members, and it could also be a form of gaining parental experience, acquiring social status or a gateway for future mating opportunities (Wiley & Rabenold, 1984).

Another important advantage of communal breeding is group augmentation. In many species, survival is greater in large groups due to the benefits of large group numbers. Some species may experience passive benefits due to the presence of other group members, such as the dilution effect (e.g. reduced chances of individual predator attacks), while others may experience active benefits that depend on the help that new members might offer (Wiley & Rabenold, 1984). The benefits of cooperative breeding have to be significant as compared to breeding solitary in order to select for this altruistic behavioural pattern (Ligon & Burt, 2004). In this way, helping could evolve through group augmentation if the larger group sizes result in automatic passive benefits to all group members. However without passive benefits, larger groups could still receive active benefits in the form of delayed reciprocity. Therefore it might be advantageous for a subordinate to provide aid to a dominant individual even if it is completely unrelated (Ligon & Burt, 2004).

Helpers also gain benefits by enhancing breeder survivorship through benefits of group living, such as increased predator detection (Roberts *et al.*, 1996). Communal breeders consisting of larger groups may enjoy the same or improved predator detection rate while scanning for predators less frequently (Pulliam, 1973). An individual therefore spends less time scanning for predators and gets more time to do activities such as foraging which can result in increased feeding rate. This phenomena has been demonstrated in the Downy Woodpecker (*Picoides pubescens*), a species that joins mixed-species foraging flocks in the winter (Sullivan, 1985). Foraging efficiency may increase as a result of large group size which is independent of the effect of group size on vigilance for predators. For example, an individual's foraging rate may increase through local enhancement of which group members observe where other animals are feeding and use that information to find food themselves (Krebs *et al.*, 1972).

Helpers may also enhance breeder survivorship by reducing the breeder's energy expenditure during the breeding season. This is usually tested by measuring nestling feeding rates because this is the most conspicuous energy demanding behaviour performed by breeders (Krebs *et al.*, 1972). Moreover, helpers also assist with provisioning and if the total provisioning rate of groups with helpers is statistically equivalent to that of groups without helpers, then one or both breeders are adjusting their effort (in terms of feeding the young) to the presence of helpers. In several species, breeders adjust their workload in the presence of helpers so that the total provisioning rate is unchanged. In other species, total provisioning significantly increases in the presence of a helper, yet one or both breeders reduces its workload (Emlen *et al.*, 1991).

Another advantage of helping is that, it may be a learning experience that benefits an individual once it attains breeder status by improving relevant skills. The 'Skills Hypothesis' predicts that, first-time breeders with helping experience will have higher reproductive success than first-time breeders without helping experience (Lawton & Guindon, 1981). Analyses of benefits of helping experience must first separate helping experience from breeding experience and identify effects of age independent of experience. Helping experience had no effects on subsequent reproductive success of first time breeders in the Western Bluebirds (*Sialia mexicana*) (Dickinson *et al.*, 1996). However, helping experience has strong effects on reproductive success in the Seychelles Warbler (*Acrocephalus sechellensis*), and Long-tailed Tit (*Aegithalos caudatus*) (Komdeur, 1996; Hatchwell *et al.*, 1999).

Helping behaviour may also facilitate the acquisition of a new territory and this may be done in three ways; (i) territorial budding, (ii) territorial inheritance and (iii) territorial dispersal. Territorial budding was first described for the Florida scrub-jay (*Aphelocoma coerulescens*) by Woolfenden (1978). In this species, helpers augment group size such that larger groups increase their territory size and eventually the dominant male helper acquires a small portion of the enlarged parental territory. This mechanism of acquiring a territory is common in the Florida scrub-jay. Thirty eight percent (38%) of male helpers obtain breeding positions in this way (Woolfenden & Fitzpatrick, 1990). Territorial budding has also been described in the Hooded Crow (*Corvus cornix*) in which sixty percent (60%) of two year old birds obtained territories within the boundaries of the parental territory (Grabovsky, 1986).

2.2.2 Disadvantages of Communal Breeding in Birds

The primary disadvantage of communal breeding is the cost of expending energy towards raising the offspring of another individual. A study conducted by Cornwallis *et al.* (2010) showed a strong negative correlation between the evolution of promiscuity (extra-pair copulations) and the evolution of communal breeding, suggesting that communal breeding is more likely to evolve in monogamous populations (Rubenstein, 2007). For species with multiple-mating systems, the time and energy spent raising kin offspring would prove too costly in terms of energy expenditure for communal breeding to be selected for.

Another disadvantage of helping in some birds includes reduced body condition, reduced future survival and fecundity (Davies, 1941). Data from a research done on Stripe-backed Wrens (*Campylorhynchus nuchalis*) showed that, helpers with high provisioning rates have lower survival (Davies, 1942). This means that the decision to help is likely to have cascading effects throughout the individual's life time and not just within one breeding season. This also implies that, all apparent benefits of helping must be discounted by any reduction in future survival or fecundity.

The costs of providing care to offspring have been extensively investigated in the broader literature on parental care (Davies, 1940). Birds are sensitive to their own ability to provide parental care. They adjust their level of investment accordingly to mitigate these costs. Apart from obvious differences such as egg-laying, there are costs to parental care that affect the sexes differently. For example, male great tits (*Parus major*) suffer increased parasite burdens when brood sizes are increased whereas females do not (Reyer & Westerterp, 1985).

2.3 TERRITORIES AND TERRITORIALITY OF BIRDS

Territoriality is widespread among birds and there have been many intensive field studies on avian territoriality. Territories are defined as areas defended over a period of time, that is, by collections of points in space and time which are characterized not only by the presence of the individual but also by the manifestation of a particular pattern of behaviour, such as aggression towards intruders or proclamation of ownership (Emlen, 1957). Territoriality often results in a regular dispersal pattern among such individuals. In many species the defended area is essentially equal to the home range (an area traversed by an animal in its normal activities of food gathering, mating, and caring for young). This may be true only in certain phases of the reproductive sequence in some species, such as the Black-capped Chickadee (*Parus atricapillus*) (Stefanski, 1967). In these species the defended areas abut extensively but do not overlap significantly.

Territory size is an important ecological attribute of populations, and this is because it may determine population density, affect the local distribution and abundance of both intruders and prey (Carpenter, 1987). The adaptive value of territorial behaviour has been related to the defense of resources and reproductive success (Davies, 1978). Territorial boundaries have been shown to shift from one day to the next, due to the stage of the breeding cycle of the birds and time of day (Stefanski, 1967; Weeden, 1965). It may also vary with changes in dominance relations and the physiological conditions of the territory owners.

In the tropics, the predominant territorial system is year-round defence of feeding and nesting territories (Stutchbury & Morton, 2008). Year-round territoriality is typical of tropical insectivorous birds (Buskirk & Buskirk, 1976) and arthropod resources are defensible because they are more or less evenly distributed spatially and temporally (Stutchbury & Morton,

2008). However, territorial size may change over the season independently of food abundance (Duca *et al.*, 2006).

The benefit of territoriality relies in the owners having either more a particular resource or better resources than they would have otherwise. According to Perrins & Birkhead (1983), the main resources that birds may defend in territories include food, nesting sites and mates. In a comparative study where birds were defending food resources within territories, territory size was directly related to body weight of the birds (Schoener, 1968). The main disadvantage of territoriality compared to non-territoriality is that more energy is expended in order to demarcate (e.g. songs) and defend territories actively. Also, another disadvantage of territoriality in birds is the increase in competition of available food in their territories.

In estimating abundance and density of birds, a survey technique called territory mapping is used (Bibby *et al.*, 2000). This method is based on counting territories of all species within a defined study plot. Locations of all birds, particularly singing males, are mapped on paper replicas of the plot during repeated visits preferably in the breeding season. Data for each visit are transcribed to species specific sheets, and territory boundaries are identified for clustered multiple registrations at the end of the census. Territory mapping can also be done by observing the movements of birds in their territory and noting the outermost points from their nest. The territory area can then be measured by the convex polygon method (Odum & Kuenzler, 1955), which consists in joining the outermost observation points for each bird with a straight line. The largest polygon obtained is taken as the bird territory size. Although this method has been criticized (Worton, 1987), it is normally used because of its simplicity and most often sufficient for cooperative studies (Ribeiro *et al.*, 2002).

Studies have shown that various bird species have different territory sizes. According to Radford & du Plessis (2004), Green wood-hoopoes inhabited home ranges with a mean available area of 23.59 ± 1.7 ha and the mean territory size defended within these areas is 15.59 ± 1.1 ha in their study area. Grimes (1980) also documented that the Yellow-billed shrikes on the University of Ghana campus defended an average area of approximately 16.6 ha.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The Legon campus of the University of Ghana (05°39'03"N 00°11'13"W) lies about 13 km north-east of Accra, the capital of Ghana and has an altitude of between 91.44 m and 121.99 m (Figure 1). The Legon campus lies within the coastal savanna zone of Ghana (www.ghanadistricts.com). Its mean monthly temperature varies between 20° C and 30° C, with the lowest in August and the highest in March/April (www.ghanadistricts.com). The rainfall pattern is bimodal with two peaks, usually in June and October. The major rainy season occurs from April to the end of July, while the period from September to late October is the minor wet season, and the annual rainfall ranges from 635 mm to 1,140 mm with an average of 887.5 mm (www.ghanadistricts.com).

North of the Legon campus is the Legon Botanical Gardens (LBG). The LBG covers an area of approximately 25 hectares which supports educational and scientific research purposes. Characteristic vegetation includes grasses such as *Heteropogon sp*, shrubs and trees including Neem (*Azadirachta indica*), Kapok (*Ceiba pentandra*) and Antiaris (*Antiaris toxicaria*). There are also cash crops like Mango (*Mangifera indica*) and Cocoa (*Theobroma cacao*), and a large collection of West African orchids and palms. The LBG has a good representation of ecological zones which include closed canopy gallery forest, marshy grassland, wooded grassland, riparian vegetation and dense thickets (www.ug.edu.gh). The Southern part of the campus is a built-up area comprising the lecture halls, departments and residential areas.

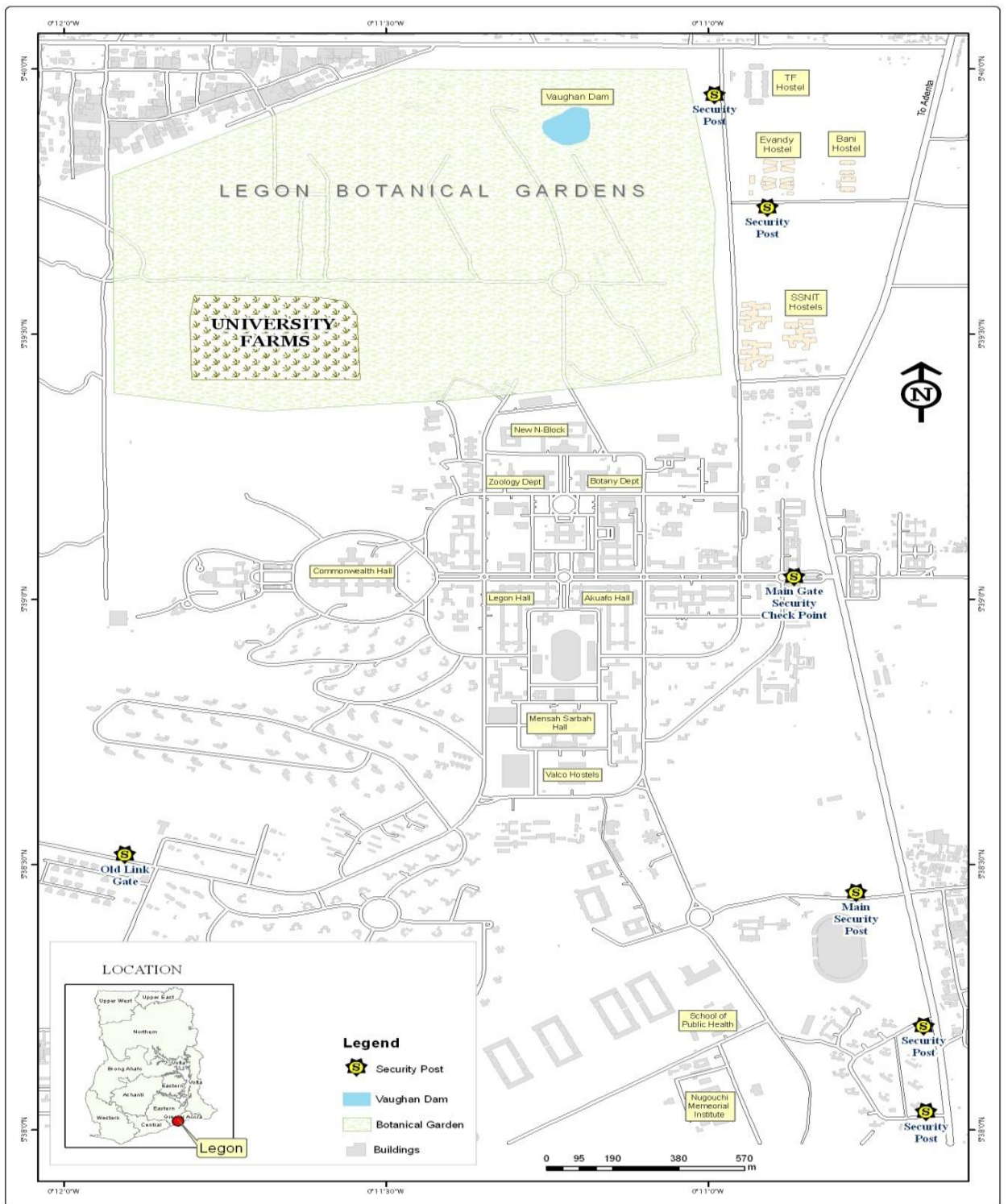


Figure1: Map of the University of Ghana Main Campus

(Source: Centre for Remote Sensing and Geographic Information Systems (CERSGIS), University of Ghana).

3.2 DATA COLLECTION

3.2.1. Identification and Counting of Territories

Between June and August 2012, the number of territories of each of the three bird species (Yellow-billed Shrike, Green Wood-hoopoe and Brown Babbler) was obtained by surveying the campus during the day. Identification of territories followed the procedure described by Ligon & Ligon (1978) and Grimes (1980). Individuals of each of the three bird species were considered to form a territory if the area they inhabited had a nest, nestlings or fledglings (Ligon & Ligon, 1978; Grimes, 1980). Nest sites were located by following birds returning with food for the breeding female (Radford, 2004) or by looking for the source of food-solicitation calls produced by breeding females of all the bird species in the vicinity of the nest (Ligon & Ligon, 1978).

3.2.2 Determination of Territorial Group Size

For each species-specific territory, groups of birds associated with these territories were followed for 30-45 minutes to determine the group sizes. During this period, repeated counts were made to accurately determine the number of individuals in the group as previously carried out by Grimes (1980). Determination of the group sizes were done in the minor rainy season (September-October, 2012) and in the dry season (January-February, 2013).

3.2.3 Determination of Territory Size

Bird movements around nests were observed to demarcate the territorial boundaries as previously described by Jullien & Thiollay (1998), Wiklander *et al.* (2001) and Ribeiro *et al.* (2002). The observations were done for about 3-4 hours for each territory during both wet and dry seasons. During each observation period, the birds in a group were observed and their

positions were recorded with a portable GPS (Garmin eTrex). Changes in the location of the birds within the observation periods were also noted and the geographical coordinates recorded accordingly. Similarly, the geographical coordinates of the locations where disputes arose between groups were taken with a portable GPS (Garmin eTrex). All the geographical coordinates of the locations of birds in each group were electronically plotted on a scaled map (scale; 1 cm: 142 m, provided by CERSGIS) and a convex polygon was created by connecting the outermost locations (Minimum Convex polygon method; Odum & Kuenzler, 1955). The polygon obtained was taken as the group territory size for each bird species, and the size was estimated using a computer-based program (ArcView 3.2). Although this method has been criticized, it was chosen due to its simplicity and wide use in ornithology (Ribeiro *et al.*, 2002), and the fact that it was merely used for intraspecific comparative purposes within and between seasons. The territory sizes for each bird species group were determined for both the minor rainy season (September-October) and the dry season (January-February).

3.2.4 Food Supply Rate for Nestlings and Breeding Females

During the breeding periods of each territory group, three hours were spent to record the rate at which food was brought to the nestlings and breeding females. This was done by counting the number of times food was brought to the nest by members of the group in the early morning (6am-9am) and late afternoons (3pm-6pm) when feeding activities are known to be high (Wright, 1997). Observations were made between 20 and 30 meters from the nest, using binoculars when necessary, to avoid disturbing the birds (Wright, 1997).

3.2.5 Determination of Clutch Size

The clutch sizes of each bird species were noted within the two seasons surveyed (rainy/dry). Within the minor rainy season (September-October), as well as the dry season (January-

February), the clutch sizes of all nest sites were counted. For the Yellow-billed Shrike and Brown Babbler, clutch size was estimated from eggs or nestlings observed directly with the use of an inspection mirror inclined on a long stick. This improvised instrument enabled inspection of nests up to a height of 3m. To determine the clutch size of the Green Woodhoopoe, fledglings were counted instead of the eggs/nestlings, since their nest content were not easily accessible (cavity nesters, normally placed high up in trees).

3.3 DATA ANALYSIS

Data sets were first subjected to normality test, to subsequently select parametric or non-parametric test statistics. The parametric tests were used since the data was normal. To determine if there was a significant change in territory size and group size between dry and wet seasons, a paired t-test was used. The Pearson's correlation coefficient was used to determine the relationships between group size and: (i) territory size; (ii) clutch sizes (iii) Food supply rate.

The GenStat software (9th edition) and Microsoft Excel (2007) were used for the statistical analysis.

CHAPTER FOUR

RESULTS

4.1 TERRITORY DISTRIBUTION AND SIZE

4.1.1 Yellow-billed Shrike

4.1.1.1 Territory Distribution

In all, thirty one (31) groups of the Yellow-billed Shrike were found to inhabit the Legon campus during the study period (Fig. 2). Details on the location of each group is presented in Appendix 1. Out of this number, twenty seven (27) groups were recorded in both seasons whilst four additional groups (Groups 1, 11, 29 and 31; Table 1) were seen only during the dry season. Each group defended an area where nest, eggs, or fledglings were found and groups either shared boundaries or were distantly separated from each other. Members of the individual groups chased intruders away or displayed agonistic behaviours (mainly vocally) when some individuals of other groups intruded their defended area. Figure 2 further showed that many of the groups, which were generally small and densely packed, are concentrated in the central part of the campus where infrastructure is found.



Figure 2: Territory distributions of the Yellow-billed Shrike for both wet and dry seasons on Legon campus.

DS = dry season (red dots and lines); WS = wet season (green dots and lines). The dots are the GPS position of the locations of the observed birds in each group, and the lines show the boundaries. The attached figures to the dots indicate each group. The middle dots are their nest locations.

4.1.1.2 Circannual Changes in Territory Size

The territory sizes of the individual groups of the Yellow-billed Shrike are presented in Table 1. The territories ranged from 0.30 hectares (Group 20) to 2.69 hectares (Group 23) with both the smallest territory and the largest territory sizes occurring in the wet season (Table 1). The mean territory size of the Yellow-billed Shrike in the wet season (1.11 ± 0.51) and dry season (1.22 ± 0.52) were statistically similar ($t=1.39$, $p= 0.18$, $n=27$) indicating that the territory sizes remain fairly stable.

Table 1: Territory sizes of the Yellow-billed Shrike groups in the wet and dry seasons.

GROUPS	TERRITORY SIZES (HECTARES)	
	WET SEASON	DRY SEASON
1	-	0.41
2	0.58	0.59
3	0.74	1.31
4	0.74	0.87
5	0.94	0.52
6	0.91	1.13
7	1.46	0.76
8	1.09	1.83
9	0.89	0.89
10	1.16	2.39
11	-	0.76
12	1.53	2.33
13	1.54	1.12
14	1.59	1.64
15	1.29	1.36
16	1.73	1.21
17	0.69	1.37
18	1.23	1.26
19	0.57	1.08
20	0.30	0.80
21	1.10	1.46
22	1.02	1.12
23	2.69	1.68
24	0.42	1.32
25	0.55	0.93
26	1.79	1.81
27	0.94	0.83
28	0.93	0.35
29	-	0.83
30	1.46	1.71
31	-	1.98
MEAN±SD	1.11± 0.51	1.22± 0.52

4.1.2 Green Wood-hoopoe

4.1.2.1 Territory distribution

The territory distributions of the Green Wood-hoopoes were associated with areas containing lots of tall trees with dead branches, loose bark and cavities (holes and crevices), predominantly in the central portions of the Legon campus (few outlying territories). They were also found to nest under the roofs of some buildings in the study area. Details on the location of each group are presented in Appendix 2. The territories were very large (up to over 7 ha) and 2-3 times the size of the two other species. Many territories are distant and others were abutting, although not overlapping. Eleven (11) groups of the species were found to inhabit the study area (Fig. 3). In contrast to the yellow billed-shrikes, three groups were not found in the dry season but only in the wet season, and two of these were found nesting on roof tops (Group 2 & 8; Table 2). The nesting tree of Group 1 was destroyed as a result of road construction in that area. Though this species is territorial, it only actively defends its territories when breeding. Thus, during the breeding season, individuals in a group chase away all conspecifics from other social groups as well as other species, but in the non-breeding seasons, only other group members of the same species were chased away. Individuals were always located close to their nest (about 60 m away) during the breeding season but in the non-breeding seasons, they were only seen around their nests in the morning and evenings.

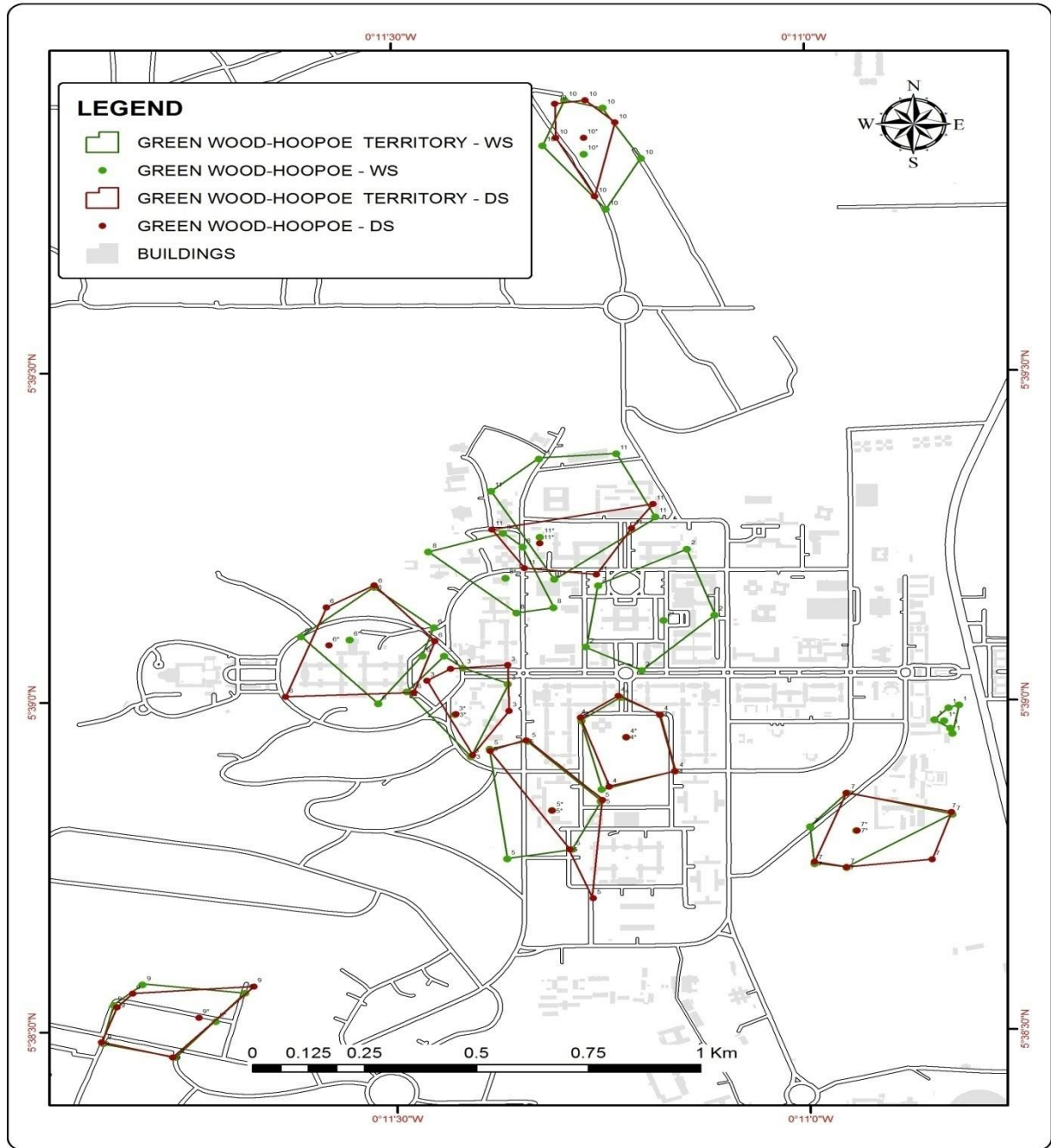


Figure 3: Territory distributions of the Green Wood-hoopoe for both wet and dry seasons on Legon campus.

DS = dry season (red dots and lines); WS = wet season (green dots and lines). The dots are the GPS position of the locations of the observed birds in each group, and the lines show the boundaries. The attached figures to the dots indicate each group. The middle dots are their nest locations.

4.1.2.2 Circannual Changes in Territory Size

The territory sizes of the individual groups of the Green Wood-hoopoe are shown in Table 2. The lowest and highest territory sizes were 0.20 and 7.74 hectares respectively and both occurred in the wet season (Table 2). Similar to the Yellow-billed Shrike, there was no significant difference between the territory sizes of the Green Wood-hoopoe in the wet (4.17 ± 1.92) and dry (3.93 ± 1.35) seasons ($t = 1.06$, $p = 0.32$, $n = 8$), and thus, indicating that territory sizes remain fairly stable throughout the year.

Table 2: Territory sizes of the Green Wood-hoopoe groups in the wet and dry seasons.

GROUPS	TERRITORY SIZES (HECTARES)	
	WET SEASON	DRY SEASON
1	0.20	-
2	6.05	-
3	3.20	2.83
4	3.65	3.50
5	5.34	4.05
6	5.04	6.76
7	3.69	4.39
8	3.14	-
9	4.08	3.84
10	3.68	2.16
11	7.74	3.88
MEAN $\pm$ SD	4.17 ± 1.92	3.93 ± 1.35

4.1.3. Brown Babbler

4.1.3.1 Territory Distribution

Fourteen (14) groups were identified on Legon campus throughout the study period and all were seen in both seasons (Fig.4). Generally, the territorial boundaries remained stable throughout the study period, indicating site specificity throughout the year. Figure 4 further shows that the Brown Babbler displayed a wide distribution on the Legon campus, and apparently had no preference for central or more outlying portions of the study area (widely distributional pattern). The territories were mostly well-spaced out with a very few of them congregated, and also with no intraspecific overlap between the separate groups and only one abutting (Fig. 4). Details on the location of each group are presented in Appendix 3.

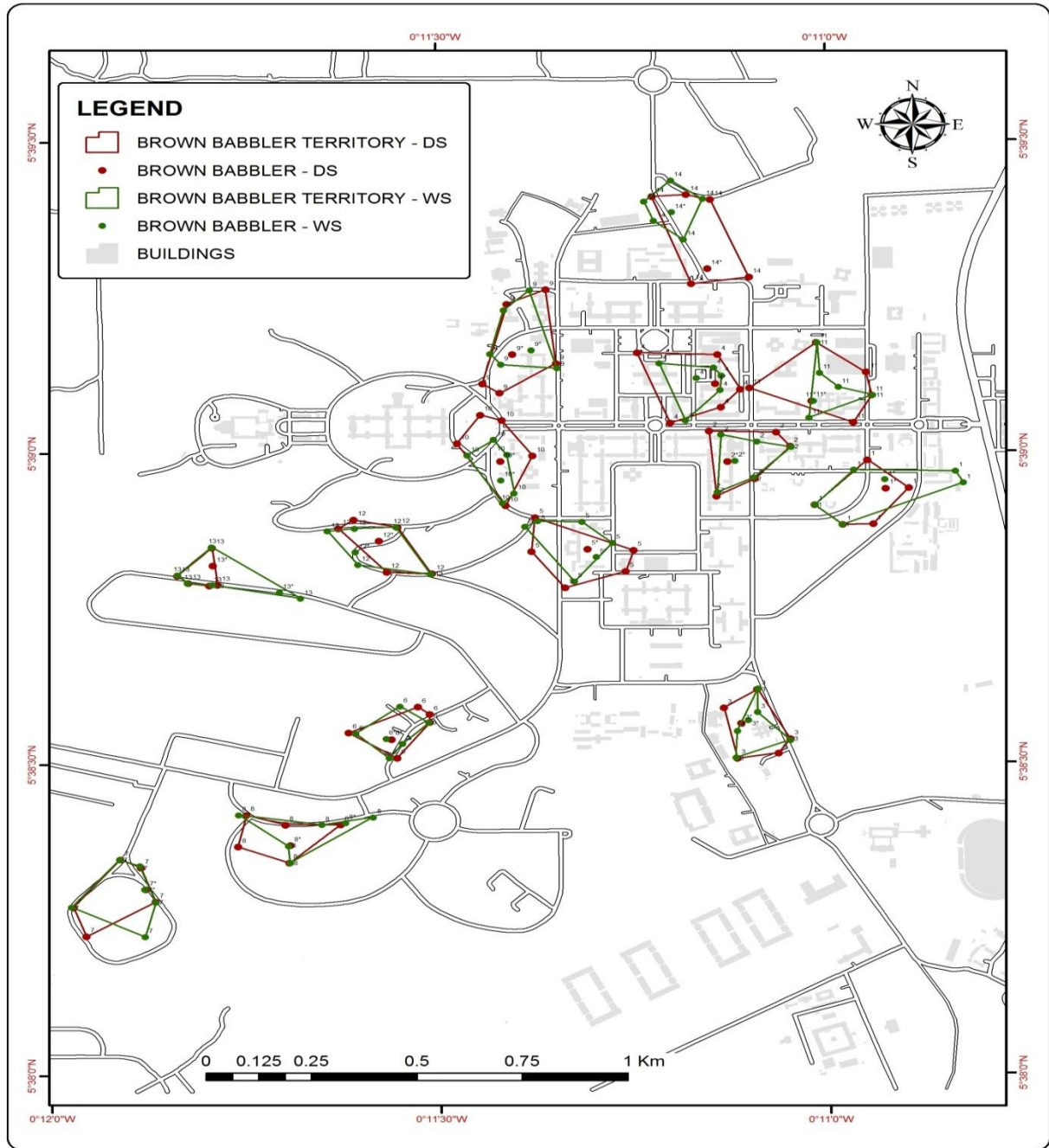


Figure 4: Territory distributions of the Brown Babbler for both wet and dry seasons on Legon campus.

DS = dry season (red dots and lines); WS = wet season (green dots and lines). The dots are the GPS position of the locations of the observed birds in each group, and the lines show the boundaries. The attached figures to the dots indicate each group. The middle dots are their nest locations.

4.1.3.2 Circannual Changes in Territory Size

The lowest territory size recorded for the Brown Babbler was 0.60 hectares and the highest was 3.69 hectares being the highest (Table 3). Both the lowest and highest territory sizes occurred in the dry season contrary to that of the Yellow-billed shrike and the Green Wood-hoopoe. The mean territory size of the dry season (2.43 ± 0.87) was significantly higher (t -value = 2.46, $p = 0.03$, $n=14$) than the wet season (1.71 ± 0.63). This indicates that, the Brown Babbler defended a larger area in the dry season than the wet season.

Table 3: Territory sizes of the Brown Babbler groups in the wet and dry seasons.

GROUPS	TERRITORY SIZE (HECTARES)	
	WET SEASON	DRY SEASON
1	3.20	2.38
2	1.62	2.36
3	1.08	2.01
4	1.44	3.31
5	1.97	2.94
6	1.26	1.41
7	2.55	2.37
8	1.55	1.87
9	2.18	3.32
10	1.08	2.50
11	0.95	3.69
12	1.97	1.82
13	1.70	0.60
14	1.37	3.49
MEAN $\pm$ SD	1.71 ± 0.63	2.43 ± 0.87

4.2 CIRCANNUAL CHANGE IN GROUP SIZE

4.2.1 Yellow-billed Shrike

The group sizes of the species ranged from 4 - 21 individuals and all members of a group actively defended their territory and helped in feeding the nestlings. The mean group size of the wet season was 9.07 ± 3.45 and that of the dry season was 9.06 ± 3.40 (Table 4). There was no significant difference in group size between the wet and dry seasons ($t=0.97$, $p=0.34$, $n=27$).

Table 4: The group sizes of the Yellow-billed Shrike in both wet and dry seasons.

GROUPS	NUMBER OF INDIVIDUALS	
	WET SEASON	DRY SEASON
1	-	4
2	5	7
3	8	9
4	7	5
5	8	10
6	9	10
7	12	12
8	9	7
9	7	7
10	12	13
11	-	4
12	10	8
13	9	10
14	14	13
15	9	9
16	7	8
17	11	13
18	12	13
19	5	5
20	4	4
21	9	10
22	11	11
23	9	10
24	5	6
25	6	6
26	21	19
27	8	8
28	7	7
29	-	9
30	11	11
31	-	13
MEAN	9.07±3.45	9.06±3.40

4.2.2 Green Wood-hoopoe

The group sizes of the Green Wood-hoopoe ranged from 3 - 14 individuals. The group size of the wet season was 6.73 ± 3.29 and that of the dry season was 7.38 ± 3.78 (Table 5). There was no significant difference between the group sizes of the Green Wood-hoopoe for both the dry and wet seasons ($t=0.22$, $p=0.84$, $n=8$).

Table 5: The group sizes of the Green Wood-hoopoe in both wet and dry seasons.

GROUPS	NUMBER OF INDIVIDUALS	
	WET SEASON	DRY SEASON
1	3	-
2	7	-
3	4	4
4	7	5
5	2	2
6	9	9
7	11	14
8	4	-
9	6	7
10	12	10
11	9	8
MEAN $\pm$ SD	6.73 ± 3.29	7.38 ± 3.78

4.2.3 Brown Babbler

Half of the total groups of the Brown Babbler identified on campus had the number of individuals in the group remaining stable in both seasons (Table 6). There were little changes in the group sizes of the remaining groups over the two seasons. The mean group size in the wet season was 8.57 ± 3.50 and that of the dry season was 8.50 ± 3.23 . There was no significant difference in the group sizes between the wet and dry seasons ($t=0.17$, $p=0.87$, $n=14$), since $p > 0.05$.

Table 6: The group sizes of the Brown Babbler in both wet and dry seasons.

GROUPS	NUMBER OF INDIVIDUALS	
	WET SEASON	DRY SEASON
1	6	6
2	9	9
3	8	7
4	11	11
5	13	9
6	15	14
7	6	6
8	8	8
9	5	6
10	4	4
11	13	15
12	5	5
13	6	9
14	11	10
MEAN±SD	8.57±3.50	8.50±3.23

4.3 THE RELATIONSHIP BETWEEN GROUP SIZE AND TERRITORY SIZE

4.3.1 Yellow-billed Shrike

There was a positive correlation ($r^2=0.32$, $p < 0.05$, $n=27$) between the group size and territory size of the Yellow-billed Shrike during the wet season (Fig.5). This positive correlation was also significant ($r^2=0.32$, $p < 0.05$, $n=31$) during the dry season (Fig.6).

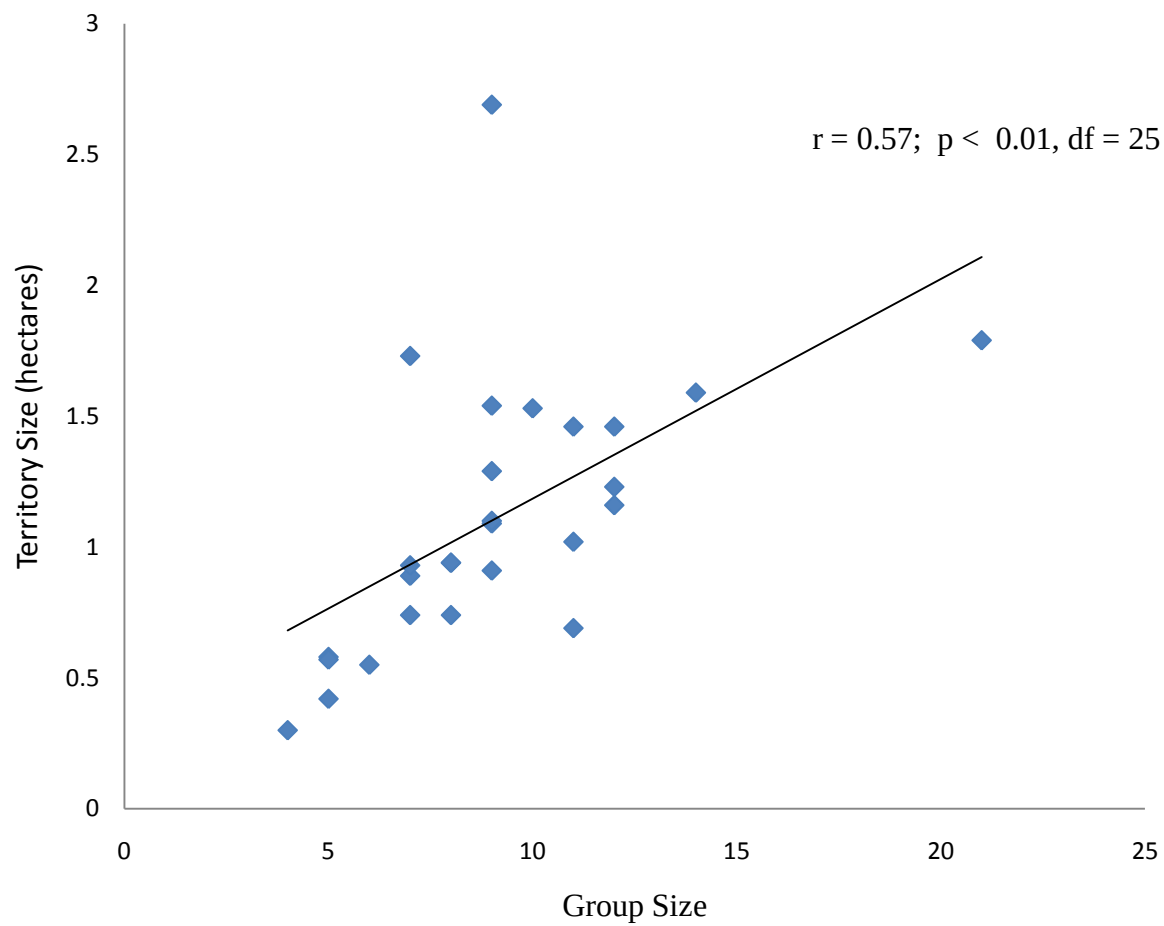


Figure 5: The relationship between group and territory sizes of the Yellow-billed Shrike in wet season.

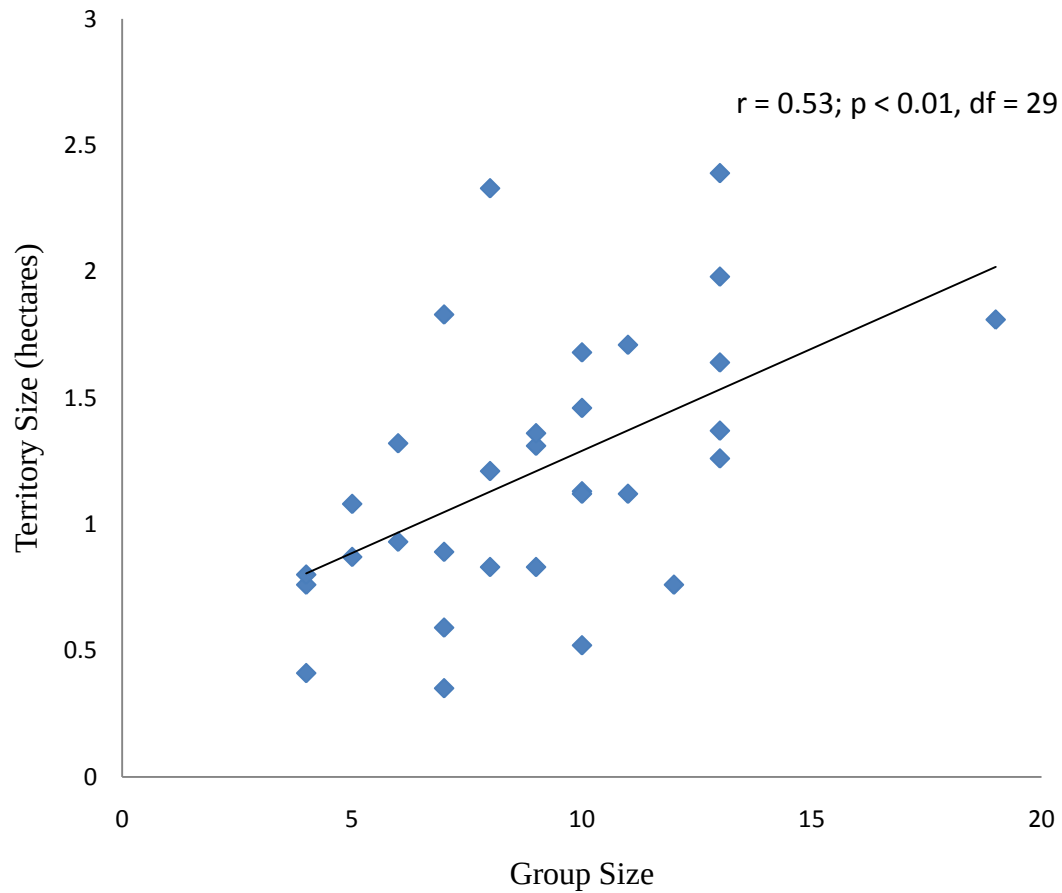


Figure 6: The relationship between group and territory sizes of the Yellow-billed Shrike in dry season.

4.3.2 Green Wood-hoopoe

There was no significant positive correlation ($r^2=0.11$, $p > 0.05$, $n=11$) between the group and territory sizes of the Green Wood-hoopoe during the wet season (Fig.7). Similarly to the Yellow-billed Shrike, the correlation ($r^2=0.04$, $p > 0.05$, $n=8$) between the group and territory sizes of the Green Wood-hoopoe during the dry season was not significant (Fig.8). Thus,

territory size of the Green Wood-hoopoe is not affected in any way by group size and vice versa.

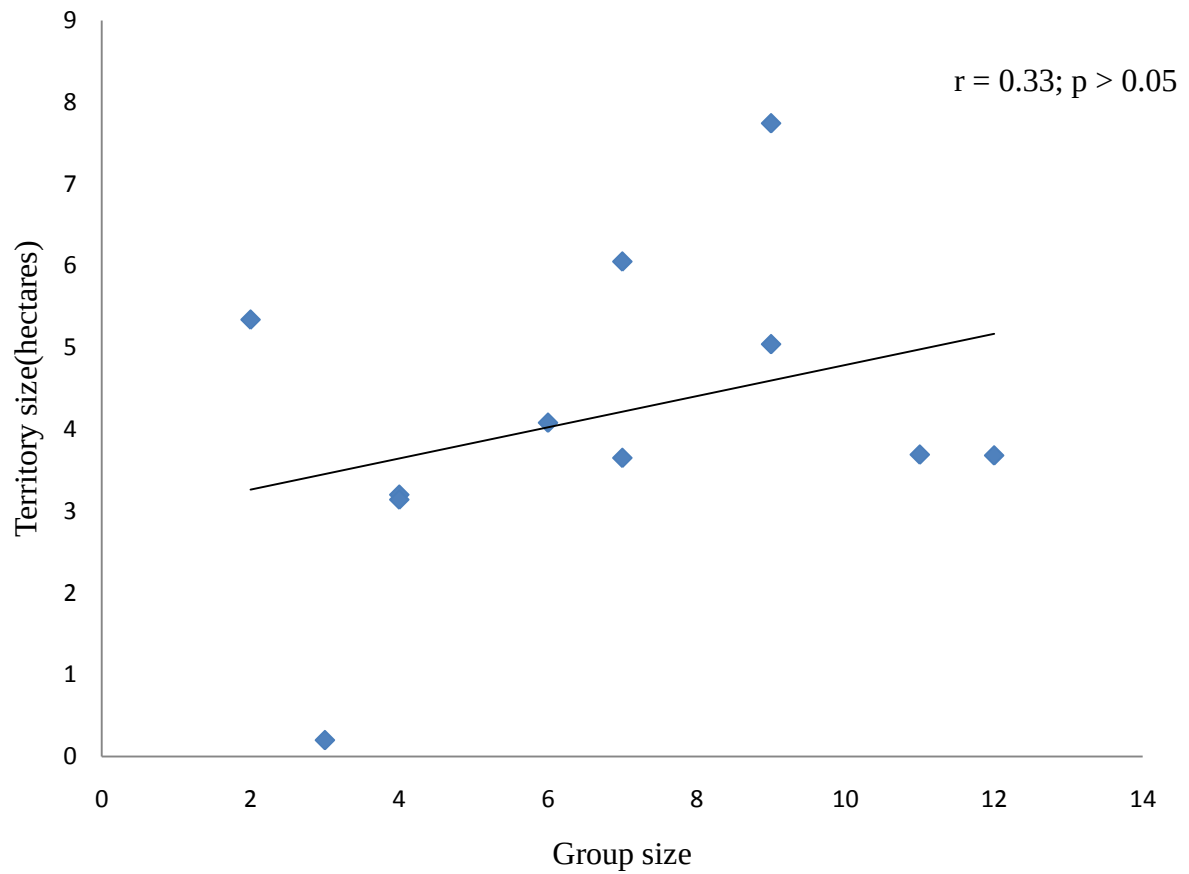


Figure 7: The relationship between group and territory sizes of the Green Wood-hoopoe in the wet season.

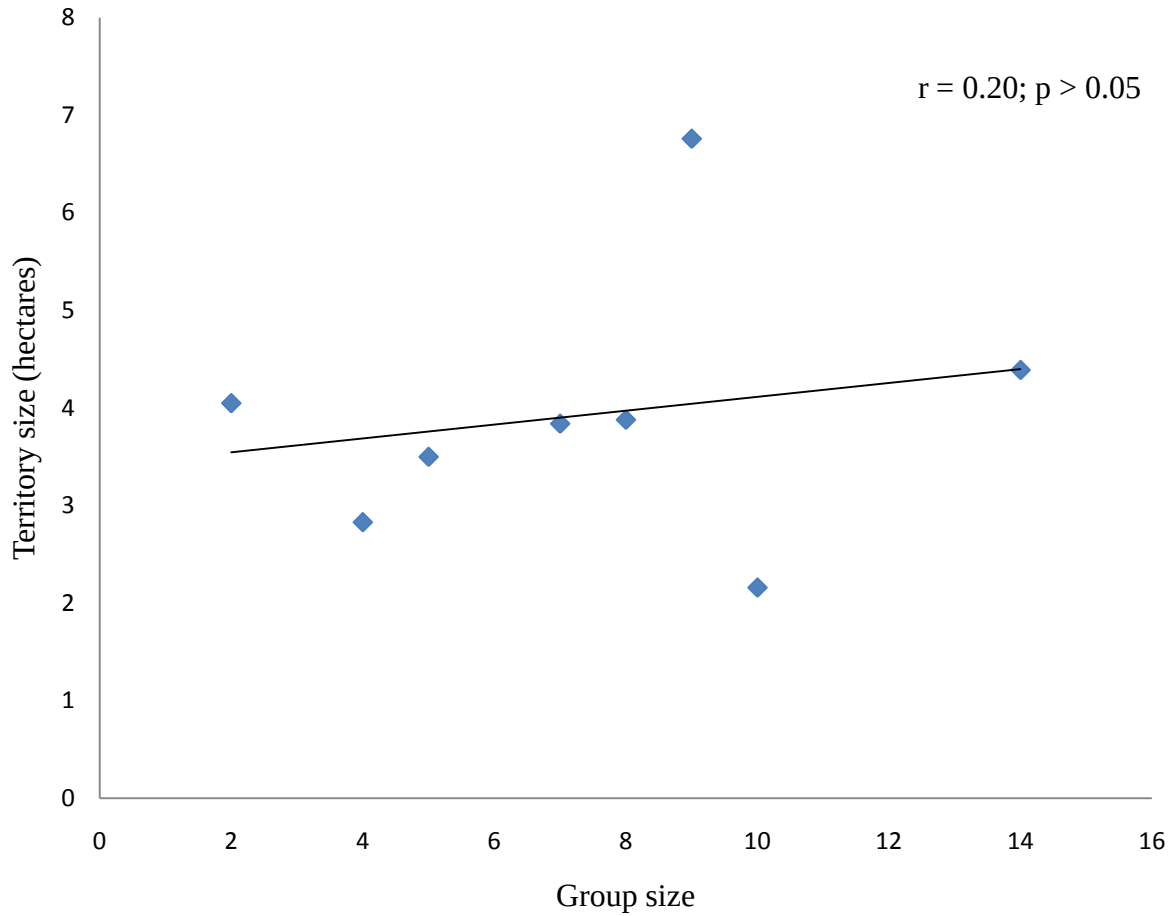


Figure 8: The relationship between group and territory sizes of the Green Wood-hoopoe in the dry season.

4.3.3 Brown Babbler

There was a weak negative correlation (Fig.9) between the group and territory sizes of the Brown Babbler during the wet season but statistical analysis showed that the relationship was not significant ($r^2 = 0.17$, $p > 0.05$, $n = 14$) between the territory and group size, since $p > 0.05$. This relationship was even more spurious in the dry season (Fig.10), and rather showing

a positive trend though it was not also significant ($r^2 = 0.03$; $p > 0.05$, $n = 14$), since $p > 0.05$.

Thus, territory size is unaffected by group size and vice versa in the Brown Babbler.

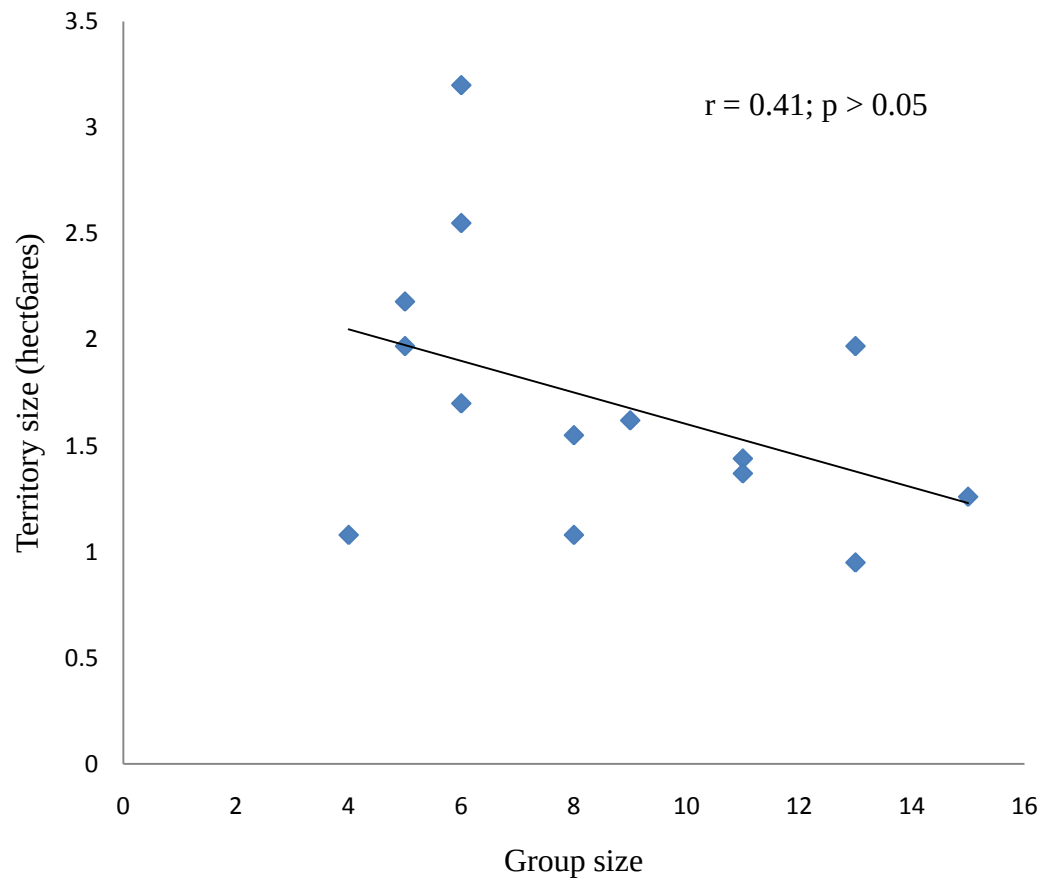


Figure 9: The relationship between group and territory sizes of the Brown Babbler in the wet season.

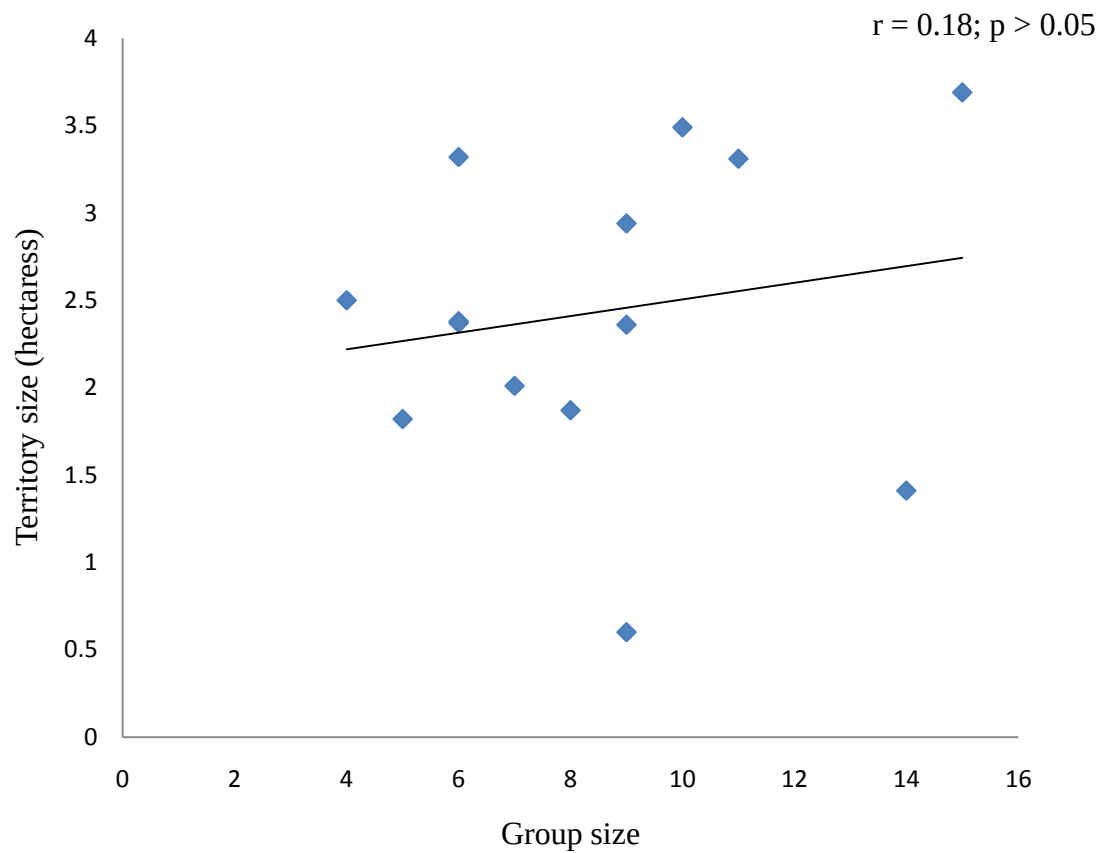


Figure 10: The relationship between group and territory sizes of the Brown Babbler in the dry season.

4.4 RELATIONSHIP BETWEEN GROUP AND CLUTCH SIZE

4.4.1 Yellow-billed Shrike

Samples of the egg of the Yellow-billed Shrike are shown in Plate 1. The clutch size ranged from 1 - 5 eggs (Table 7). The mean clutch size in the wet season was 1.71 ± 0.76 and that of

the dry season was 3.53 ± 1.06 . There was significant difference ($t\text{-value} = 5.20$; $p\text{-value} = 0.01$; $n=4$) in the clutch sizes between the wet and dry seasons, since $p < 0.05$.

There was no significant relationship between clutch size and group size, in both the wet ($r^2 = 0.06$, $p > 0.05$, $n = 7$; Fig.11) or dry ($r^2 = 0.02$, $p > 0.05$, $n = 15$; Fig. 12) seasons.



Plate 1: Eggs of the Yellow-billed Shrike in a nest

Table 7: The clutch sizes of the Yellow-billed Shrike groups in both seasons.

GROUPS	CLUTCH SIZES	
	WET SEASON	DRY SEASON
2	3	4
3	1	2
5	-	5
6	2	4
8	-	5
10	1	-
11	-	3
13	2	4
15	-	3
17	1	-
18	2	-
20	-	4
22	-	2
24	-	5
25	-	3
28	-	2
29	-	4
30	-	3
MEAN $\pm$ SD	1.71 $\pm$ 0.76	3.53 $\pm$ 1.06

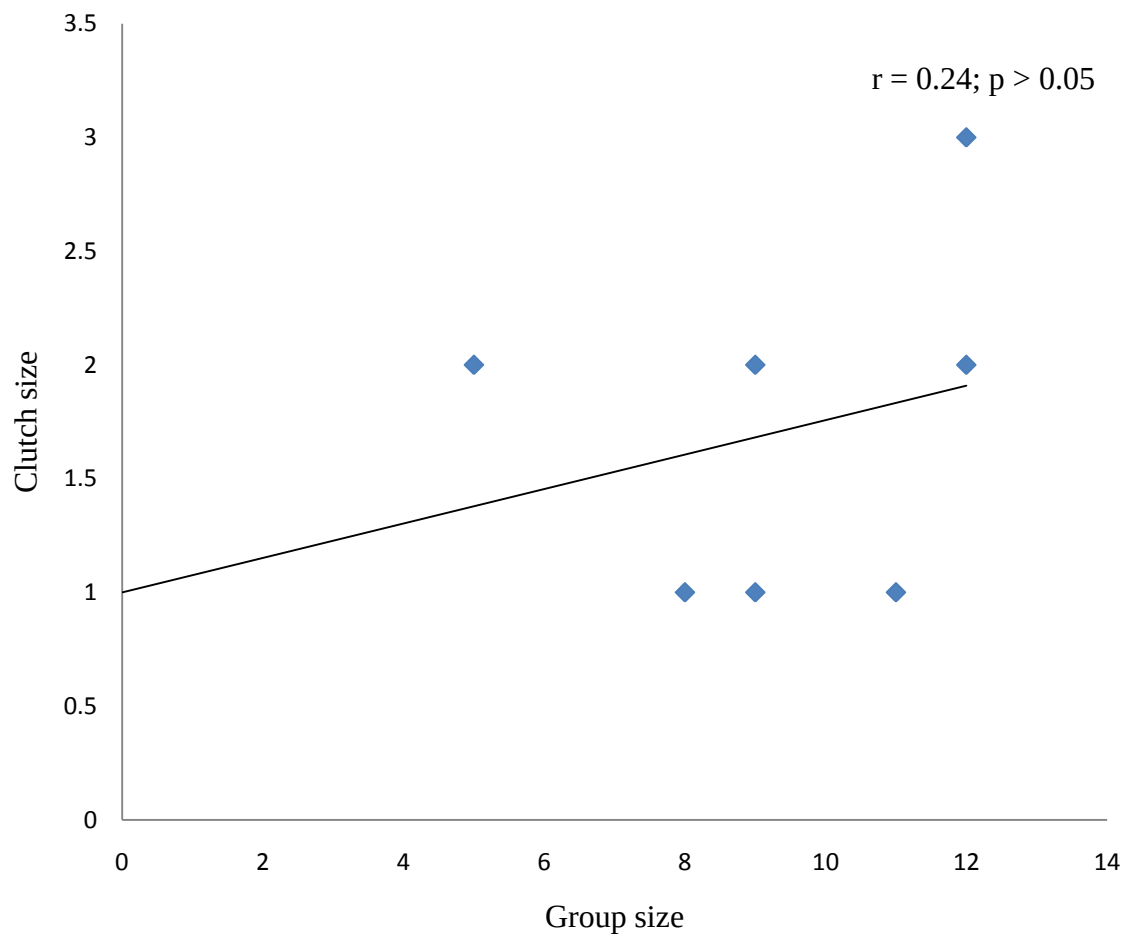


Figure 11: The relationship between group and clutch size of the Yellow-billed Shrike in the wet season.

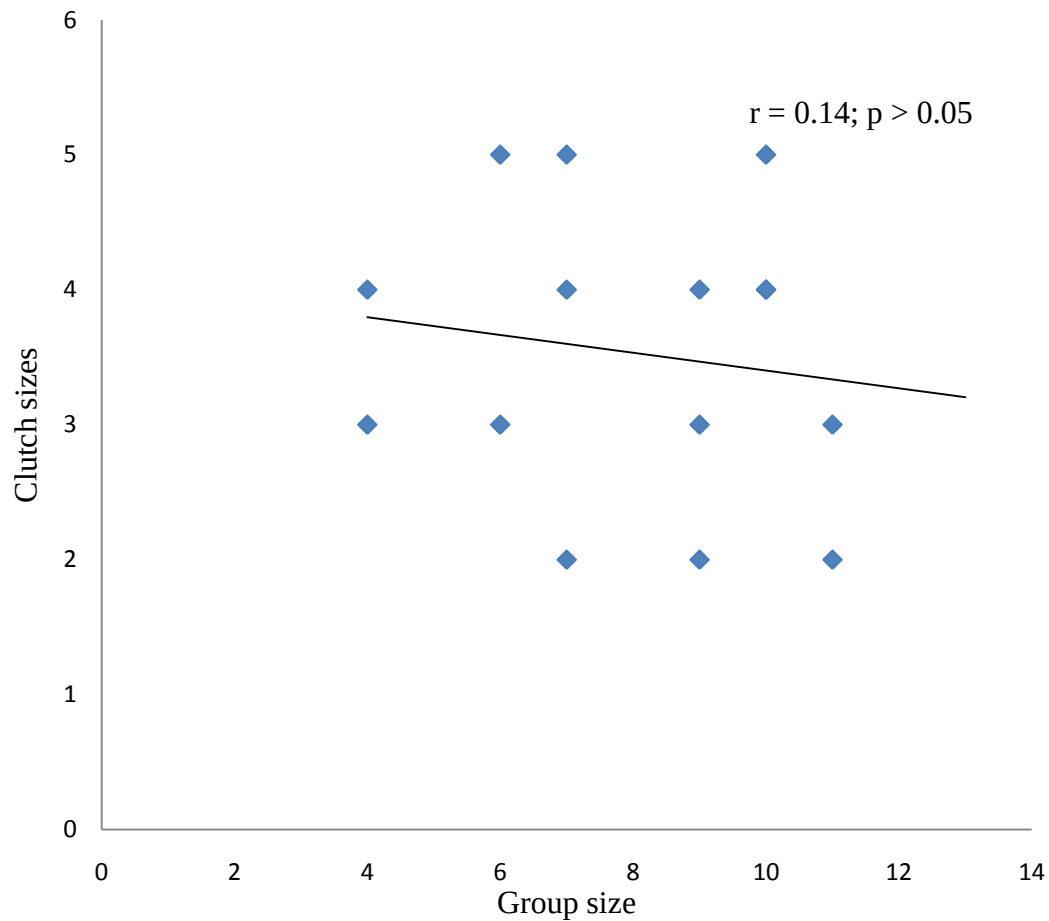


Figure 12: The relationship between group and clutch size of the Yellow-billed Shrike in the dry season.

4.4.2. Green Wood-hoopoe

The number of fledglings from a group ranged from two to four (Table 8). These birds were seen breeding in both seasons and fledgling numbers topped in both seasons. Within the two seasons, none of the groups were seen to breed more than once. Mean fledgling number in the wet season was 2.75 ± 0.96 and that of the dry season was 3.33 ± 0.58 .

There was a non-significant positive correlation (Fig.13) between group size and fledglings produced by the Green Wood-hoopoe in the wet season ($r^2 = 0.45$, $p > 0.05$, $n = 4$). Contrastingly, for the dry season there was a significant negative correlation ($r^2 = 0.75$, $p > 0.05$, $n = 3$) between group size and fledglings produced (Fig.13). A fledgling of a Green Wood-hoopoe in its nest is shown in Plate 2.



Plate 2: Fledgling of a Green Wood-hoopoe in a nest

Table 8: The number of fledglings produced by the Green Wood-hoopoe groups in both seasons.

GROUPS	FLEDGLINGS	
	WET SEASON	DRY SEASON
2	3	-
6	2	-
7	4	-
8	2	-
9	-	4
10	-	3
11	-	3
MEAN±SD	2.75±0.96	3.33±0.58

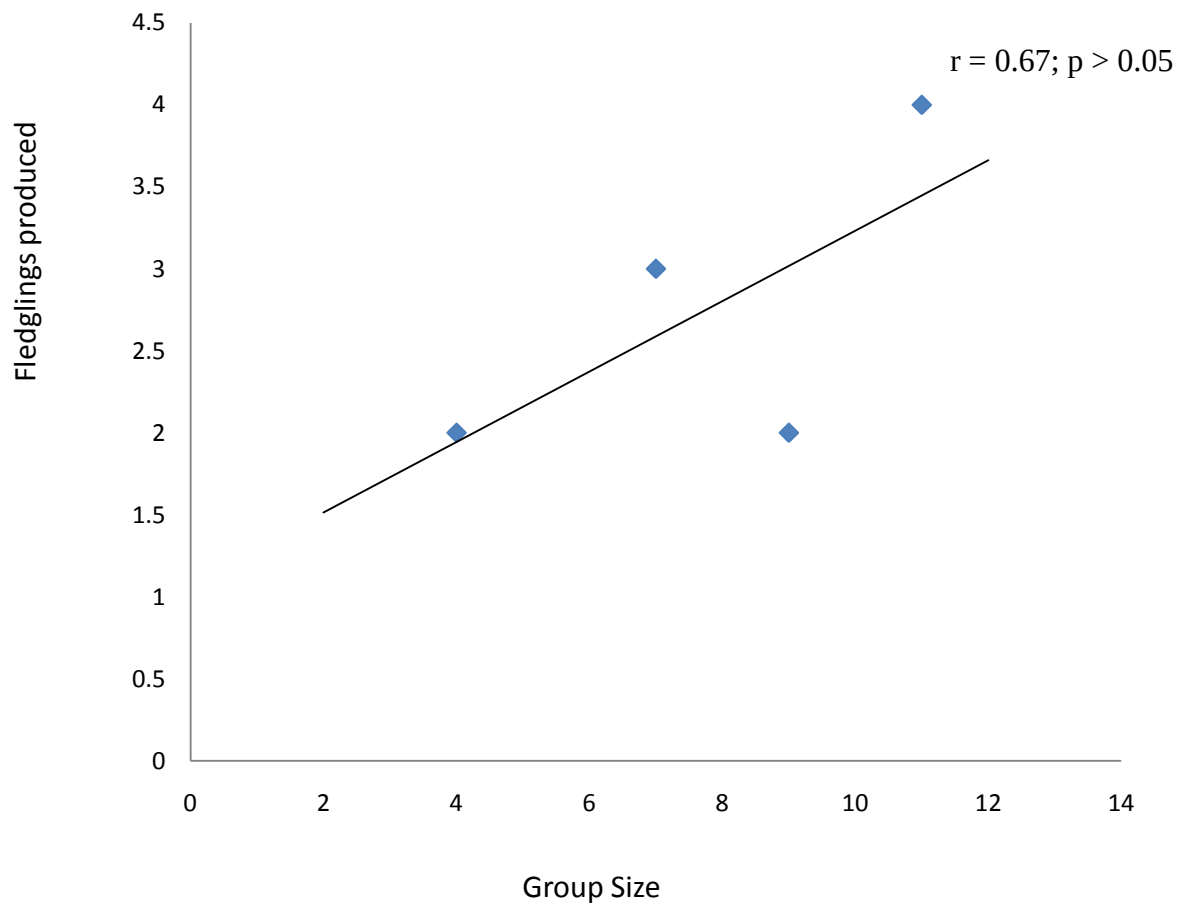


Figure 13: The relationship between group size and fledglings produced by the Green Wood-hoopoe in the wet season.

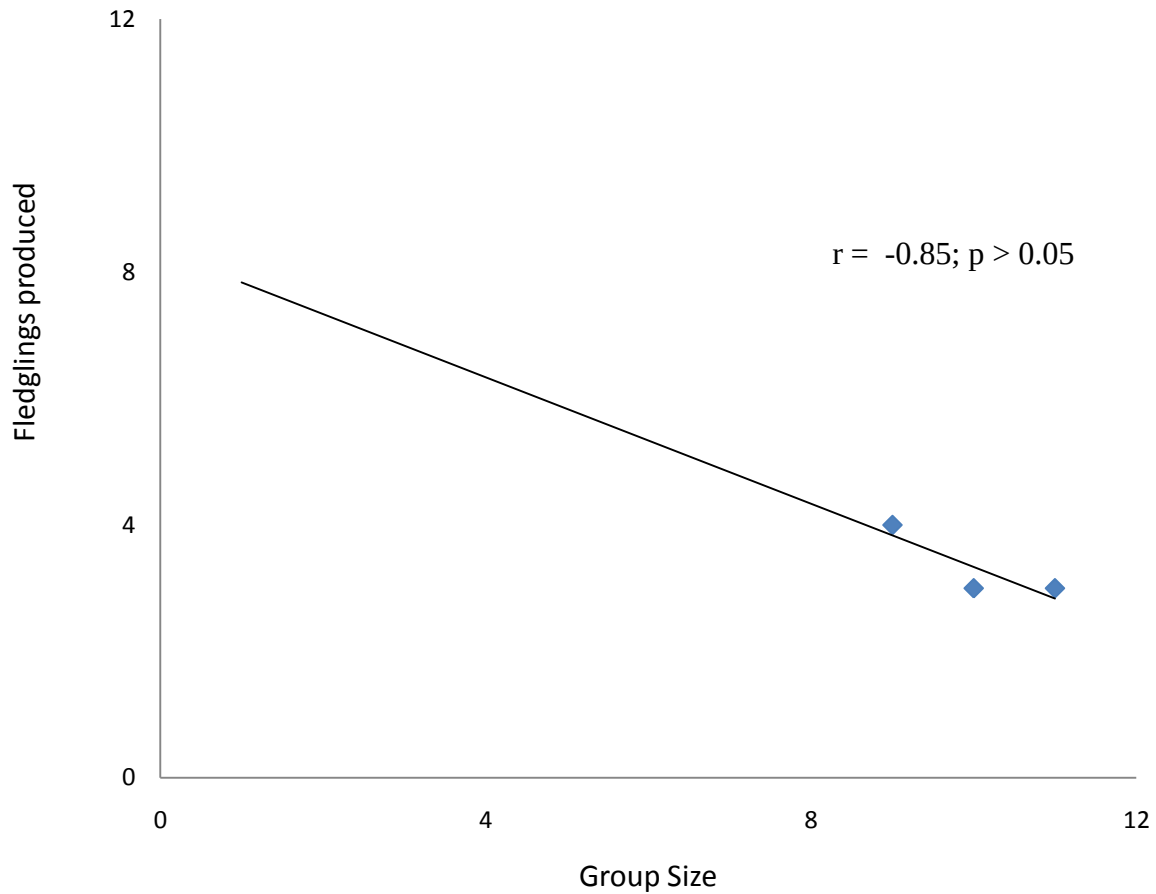


Figure 14: The relationship between group size and fledglings produced by the Green Wood-hoopoe in the dry season.

4.4.3 Brown Babbler

Clutch sizes could be recorded for only five groups of this species during the study period (Table 9). Only two and three observations were made in the wet and dry seasons respectively, hence these data is insufficient for determining true correlations. However, the general trend of relatively higher clutch sizes in the dry season observed for the two previously species was also the case for the brown babblers.

Table 9: The clutch size of the Brown Babbler groups in both seasons.

GROUPS	CLUTCH SIZE	
	WET SEASON	DRY SEASON
2	-	4
5	3	-
7	-	3
8	2	-
11	-	3
MEAN±SD	2.50±0.71	3.33±0.58

4.5. RELATIONSHIP BETWEEN GROUP SIZE AND NESTLINGS FOOD SUPPLY RATE

4.5.1 Yellow-billed Shrike

The mean food supply rate (number of deliveries per hour) of the Yellow-billed Shrike was 17.50 ± 2.20 during the study period. There was a significant positive relationship between the group size and food supply rates ($r^2 = 0.81$, $p < 0.05$, $n = 8$; Fig 14), since $p < 0.05$. Plate 3 shows an adult Yellow-billed Shrike with an earthworm, and that of Plate 4 shows a nestling of a Yellow-billed Shrike ready to be fed. These were during a breeding season, and the adult Yellow-billed Shrike was about to feed the nestling begging on the ground.



Plate 3: Adult Yellow-billed Shrikes.



Plate 4: Nestling of a Yellow-billed Shrike

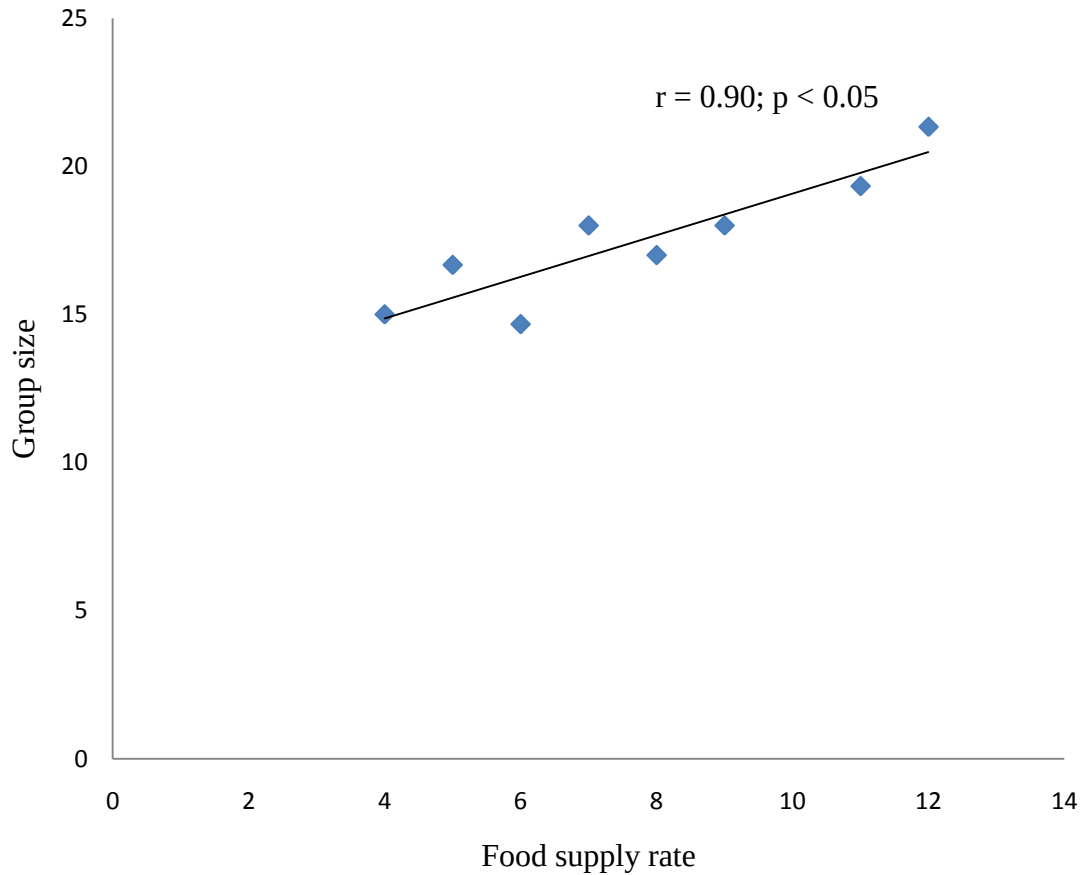


Figure 15: The relationship between group size and food supply rate (number of deliveries per hour) of the Yellow-billed Shrike.

4.6.2 Green Wood-hoopoe

Plate 5 shows an adult Green Wood-hoopoe delivering food to the fledglings. The Fledglings either come out to take the food or the food is sent inside the nests by the adults. The mean food supply rate (number of deliveries per hour) of the Green Wood-hoopoe was 26.76 ± 3.47 during the study period. There was a non-significant positive correlation ($r^2 = 0.43$, $p > 0.05$, $n = 7$; Fig.15) between the group size and the food supply rate (number of deliveries per hour) of the Green Wood-hoopoe, since $p > 0.05$.



Plate 5: Adult Green Wood-hoopoe around the nest.

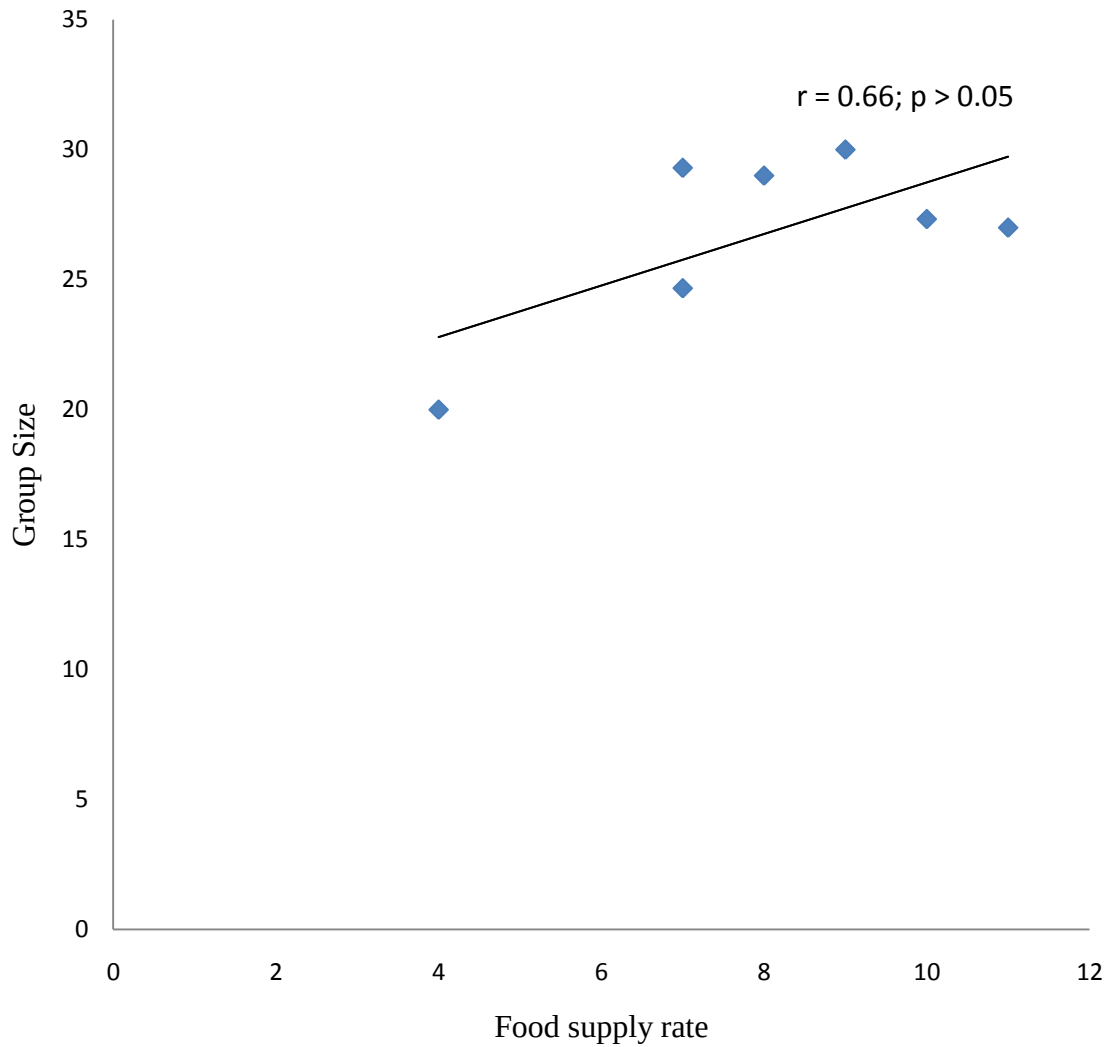


Figure 16: The relationship between group size and food supply rate (number of deliveries per hour) of the Green Wood-hoopoe.

4.6.3. Brown Babbler

The mean food supply rate (number of deliveries per hour) of the Brown Babbler was 5.76 ± 2.40 during the study period. There was a non-significant positive correlation ($r^2 = 0.77$, $p > 0.05$, $n = 5$; Fig.16) between the group size and the food supply rate (number of deliveries

per hour) of the Brown Babbler, since $p > 0.05$. Plate 6 shows an adult Brown Babbler searching for food for the nestling during a breeding period in the dry season.

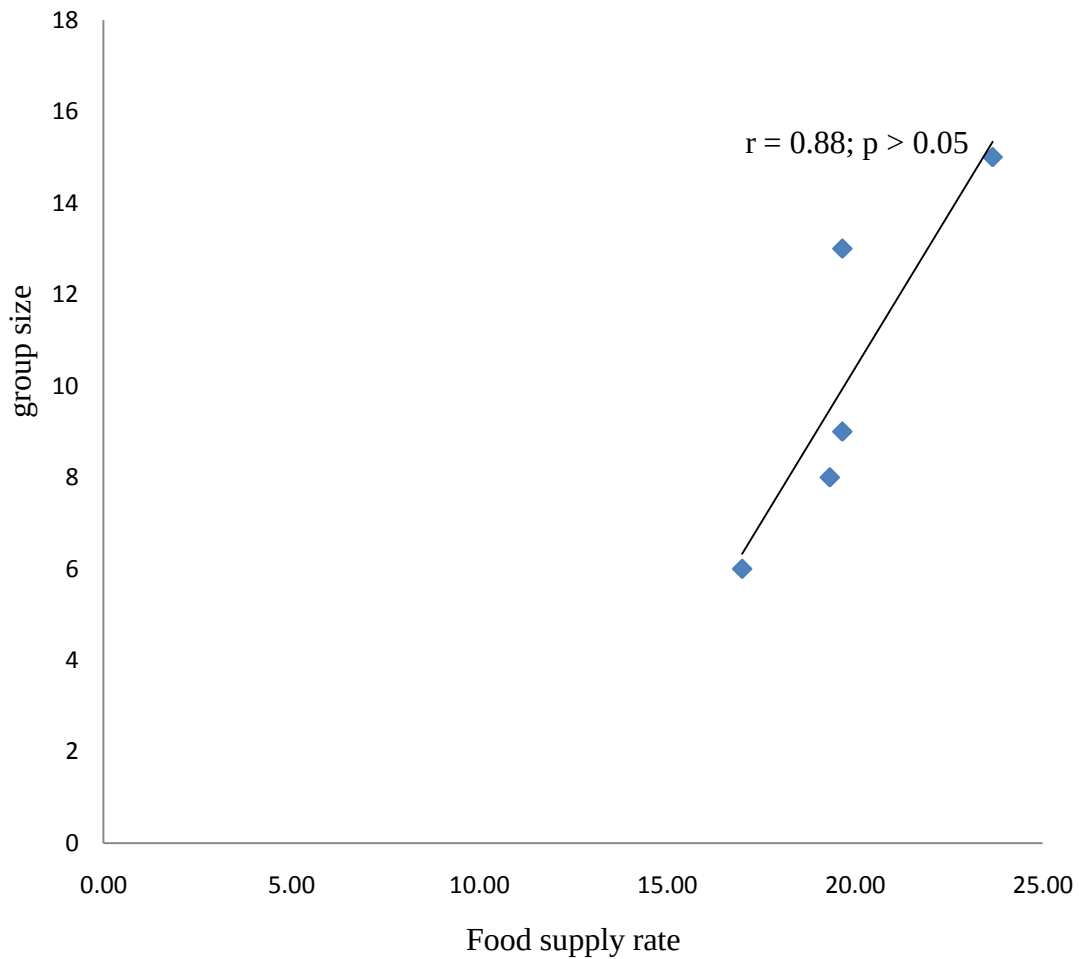


Figure 17: The relationship between group size and food supply rate (number of deliveries per hour) of the Brown Babbler.



Plate 6: Adult Brown Babbler

CHAPTER FIVE

DISCUSSION

5.1 TERRITORY DISTRIBUTION OF THE THREE COMMUNAL BREEDERS AT LEGON

As indicated by the number of territories, the Yellow-billed Shrike was the most commonly recorded communally breeding bird species on the Legon Campus followed by the Brown Babbler and the Green Wood-hoopoe (Appendices 4 & 5). The number of territories of the Yellow-billed Shrike increased during the dry season by four new territories. This could have been the fact that, during the dry season, more birds bred and in order to get the chance to breed, some birds had to occupy new territories. It might have also been that, during the dry season, there were limited resources (e.g. food) in the territories of some groups of the Yellow-billed shrike resulting in the formation of new territories by some group members. Though the birds were not ringed to establish whether or not they were members of some other territories during the wet season, Grimes (1980) reported inter-group movement and formation of new territories by Yellow-billed Shrike during breeding seasons. This thus supports the present observation.

Unlike the Yellow-billed Shrike that recorded increased number of territories during the dry season, the number of territories of the Green Wood-hoopoe decreased during the dry season by three. Two of these groups nested on rooftops and left afterwards. It might be that the availability of nesting holes was a limiting factor for them and so they just needed a place to breed. The other remaining group had its nest destroyed as a result of a road construction in the area of the nest. Continual infrastructural development on Legon campus will therefore affect the distribution of the Green Wood-hoopoe and may result in losing this species on

campus, since their nesting and roosting holes are said to be limited (Gill, 2007). The number of territories of the Brown Babbler remained stable during both seasons.

The Yellow-billed Shrike had densely packed territories with little distance in between them, though they do not overlap. They were distributed widely on the campus, with some preference for the central parts. Among the three species studied, they preferred mostly the central portions of the Legon campus than the other two species (appendices 4 & 5). This might be due to the fact that the central parts of the campus have lots of food for them to consume as a result of the leftover foods deposited on the central portions of the campus by students. The Green wood-hoopoe also had some of its territories at the central part of the campus where there was woody vegetation with many old trees and others at the extreme ends. The territories were distant and others abutting, although not overlapping. This was because the Green Wood-hoopoe mostly nested in dead parts of trees and also due to their feeding behaviour where they probe on the back of the stems of trees. The Brown Babbler had its territories widely distributed in the study area with no preference for central or peripheral portions. The territories were mostly well-spaced with no intraspecific overlap between separate groups, with only one abutting. This may also be due to the feeding behaviour of the species which feeds on varieties of insects, fruits and berries (Fry *et al.*, 1992), and so does not need any specialized environment.

5.2 CIRCANNUAL CHANGES IN TERRITORY SIZE

Grimes (1980) recorded the average territory size of the Yellow-billed Shrike in the same study area was 16.6 hectares, with some groups protecting an area as large as 27.1 hectares. In this study, territory size of 1.11 ± 0.51 hectares was obtained in the wet season and 1.22 ± 0.52 hectares in the dry season. The difference between the results of this work and that of Grimes

(1980) could be due to the difference in the number of territories identified in the study area. Thus, Grimes (1980) recorded 23 territories whilst this study recorded 31 territories. The Legon campus has seen infrastructural increase in recent times and many areas that could have been used as territories are now built up. This could have resulted in larger number of territories in the face of decreasing available space, territory sizes are bound to reduce.

The differences in the results of this study and that of Grimes (1980) could also be due to methodological differences. Whilst the Minimum Convex Polygon Method was used in this study, Grimes did not account for how his territory sizes were measured. The best method for determining territory size would have been the use of radio transmitters or marking birds with bands or patagial tags (Szymczak & Ringelman, 1986). Similar to Yellow-billed Shrike, the mean territory sizes of the Green Wood-hoopoe (4.17 ± 1.92 ha in wet season and 3.93 ± 1.35 ha in dry season) was smaller than that recorded by Radford & du Plessis (2004) in South Africa (15.5 ± 1.1 ha). Despite the differences, the territory sizes of the Yellow-billed shrike and the Green Wood-hoopoe was not significantly different in both seasons, and shows that seasonality does not affect the territory sizes of these species. For the Brown Babbler, the significant difference in the territory sizes ($t\text{-value}=2.46$, $p=0.03$, $n=14$) of both seasons implies that seasonality have effects on the territory size.

There were little changes in the location of the boundaries of the territories occupied by most groups of the Yellow-billed Shrike identified during both seasons and this was similar to that documented by Grimes (1980). Also there were changes in the locations of the boundaries of their territories occupied by the Green Wood-hoopoe during the study period. Some groups (group 2 & 8) only used the areas they occupied or defended only during their breeding periods and left afterwards. For the Brown Babbler, there was no apparent change in the

boundaries of the territories they occupied. Despite seasonality which can affect the availability of food resources to birds resulting to increase or decrease their territory sizes, other factors might have been the cause. These other factors may be group size and breeding season. This is because during the breeding seasons, the birds might have to defend the territory very well and so defends a smaller area than in the non-breeding season and also as group numbers increase, the territory sizes must also increase to accommodate the group.

The Green Wood-hoopoe protected a larger area followed by the Brown Babbler and the Yellow-billed shrike. This may be due to the fact that, body sizes have influence on the size of territories birds do occupy (Shank, 1986). With this, the Green Wood-hoopoe which was seen to have a bigger body size should occupy larger territories, followed by the Brown Babbler and the Yellow-billed Shrike. Therefore, the results of this study appear to support the observations of Shank (1986).

5.3 CIRCANNUAL CHANGE IN GROUP SIZE

Grimes (1980) recorded a variation in group sizes of the Yellow-billed Shrike of up to $\pm 24\%$ of the average group size during a period of 3 years on Legon campus, and stated that there are also intergroup movements of individuals. This study did not identify individuals by ringing and therefore the extent of intergroup movement was not studied. However, the results of this study indicated that the group sizes of the three bird species remain generally stable throughout the year. Thus, group sizes of each species in the dry season were similar to that of the wet season. This may be due to the fact that the time difference between the seasons was short and also the fact that seasonality has no effect on the group sizes of the various bird species studied.

5.4 RELATIONSHIP BETWEEN GROUP SIZE AND TERRITORY SIZE

Larger groups of birds, by requiring more resources and having better defense capabilities, can be expected to maintain larger group territories than smaller groups or pairs (Shank, 1986). For the Yellow-billed Shrike, the general pattern was that the territory size was positively correlated ($r^2=0.32$, $p < 0.05$, $n=27$) with group size, and this trend was most evident for the wet season (Fig. 5), and also followed the general trend (Shank, 1986). Grimes (1980) found that, there was no clear correlation between territory area and group size of the Yellow-billed Shrike, but this was for a census of 18 groups in March (1973), and was contrary to the results of this study. Also for the Green Wood-hoopoe, there was no correlation between the group and territory sizes in any of the two seasons. Hence, group sizes do not affect the territory size or vice versa in this species, and fewer birds seem capable of defending larger territories. In contrast to the findings of this study, Ligon & Ligon (1990) reported that the Green Wood-hoopoe in Kenya demonstrated a significant positive relationship between group size and territory size. They further reported that territories altered in size with changes in the size of the groups and its neighbours, and that the territories were not overlapping. Similarly, Radford & du Plessis (2004) showed that, the territory area utilized by Green Wood-hoopoe varied depending on both group size and the season. Similarly to the Green Wood-hoopoe, there was no obvious correlation between group and territory size of the Brown Babbler in neither the wet season nor the dry season, which indicates that smaller groups can defend and maintain large territories equally compared to larger groups. Seasons apparently also have no influence on territory and group size of this species.

5.5 RELATIONSHIP BETWEEN GROUP AND CLUTCH SIZE

There were no significant correlations established between clutch size and group size of any of the three birds, indicating that the number of individuals in a group does not influence the clutch sizes. Thus, smaller groups can foster as many nestlings as larger groups, and possibly due to the fact that group members in smaller association may increase their helping efforts according to the workload demands in feeding nestlings/ breeding females (Ligon & Ligon's, 1990).

Common to all the three species, significantly more eggs were laid in the dry season than in the wet season and this pattern was particularly true for the Yellow-billed Shrike, with a doubling of eggs in the dry season. Grimes (1980) also documented that, the Yellow-billed Shrike mainly lays its eggs in the dry season and this pattern is also corroborated by Fry *et al.* (1992) which describe the main breeding period from February to April in Ghana. In the Green Wood-hoopoe, although relatively more groups or individuals bred in the wet season, the average fledglings produced was significantly higher in the dry season compared to the wet season. Fry *et al.* (1988) reported that the Green Wood-hoopoe lays its eggs throughout the year (January-December) in Ghana, which is generally in line with the outcome of this work. Although the data was small, Green Wood-hoopoe displayed a contrasting pattern in the relationship between clutch size and group size when comparing the wet and dry season, with respective to the positive and negative correlations. In a study in Kenya, the reproductive success of Green Wood-hoopoe was not related to flock size (Ligon and Ligon's, 1990) and du Plessis (1991) suggests that, the presence of helpers do not necessarily increase the reproductive success of a Green Wood-hoopoe group. For the Brown Babbler also, more eggs were found in the dry season like the other two bird species. The data was scanty and so

correlations were not made between group and clutch sizes. Fry *et al.* (1992) recorded that eggs of the Brown Babbler are found in Ghana usually around April-May, July and November and in Nigeria from September to May. Hence, eggs recorded in this study were similar to the pattern in Nigeria.

5.6 RELATIONSHIP BETWEEN THE NESTLING FOOD SUPPLY RATE AND GROUP SIZE

The correlation probabilities of all the three birds of which nestling food supply rate was compared to group sizes revealed that, there were no significant differences between food supply rate (number of deliveries per hour) and group size for both the Green Wood-hoopoe and the Brown Babbler, but a significant difference for that of the Yellow-billed Shrike. The Average food supply rate (number of deliveries per hour) of the Yellow-billed Shrike was 17.48 ± 2.20 (Appendix 6), that of the Green Wood-hoopoe was 26.86 ± 3.47 (Appendix 7) and the Brown Babbler was 19.87 ± 2.40 (Appendix 8). The food supply rate was higher in the Green Wood-hoopoe followed by the Brown Babbler and the Yellow-billed Shrike. This showed that the body size and territory sizes may have influenced this trend. Ligon and Ligon's (1990) study of the Kenyan Wood-hoopoes showed that feeding visit frequencies increased slightly with flock size. Depending on the species and the geographical area of the species, the food supply rates may increase or remain constant as group size increases (Appendix 9). The effect of the geographical area on food supply rate is true for the Green Wood-hoopoe, where the studies in Kenya (Ligon & Ligon's, 1978) showed that group size has effect on the food supply rates, but that in South Africa (du Plessis, 1991) showed that group sizes has no effect on food supply rates.

However, an important variable omitted from almost all of these studies and that in this study is the size of the food items supplied to the nestlings. Hunter (1987) showed that the amount of food brought to chicks of Purple gallinules (*Porphyryula martinica*) increased with more helpers, although the food supply rate was not related to group size. This was as a result of the group members bringing fewer, but larger food items. So fewer food supply rate does not really determine whether the food would be insufficient for them but the quantity supplied to the nestlings is the most important factor.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

Based on the results and discussions, the following conclusions can be drawn:

All the three bird species (Yellow-billed Shrike, Green Wood-hoopoe & Brown Babbler) were widely distributed throughout the University of Ghana main campus-Legon.

They were found to live in territorial groups throughout the year, and within the groups each member helped defend the group's territory and feeding of nestlings/breeding females.

There were little changes in boundaries and sizes of the territories of all the bird species, although the Brown Babbler displayed a significant increase in territory size during the dry season.

There was no significant difference in group sizes between the two seasons for any of the three species.

Group and territory size were positively correlated in the Yellow-billed Shrike, and this trend was most evident during the wet seasons. However, group and territory size of the Green Wood-hoopoe was not related in any simple way, but group size and clutch size showed an inverse correlation in the dry season. The territory size was not related in any proportionate way to group size in the Brown Babbler, indicating that other factors may influence these parameters.

The food supply rates (number of deliveries per hour) were positively correlated to group size in all the three bird species.

The following null hypotheses were accepted;

- There were no circannual changes in the territory sizes of the Yellow-billed Shrike and the Green Wood-hoopoe.
- There were no circannual changes in group sizes of all the three bird species.

The following alternate hypotheses were accepted;

- There was a circannual change in the territory size of the Brown Babbler
- There were relationships between group sizes and; (i) territory sizes, (ii) clutch sizes and (iii) food supply rates, of all the three bird species.

6.2 RECOMMENDATIONS

- An extensive work lasting for a minimum of more than one full year should be done on these same birds to see the aspects of their ecology which is really affected by seasons.
- Markings of the birds by ringing or patagial tags, and the use of radio transmitters will be more precise in demarcating territories and determining group sizes.
- Detailed studies on food preferences and abundances of preferred foods should be carried out in both wet and dry season to test if availability of food sources induce helping according to the Habitat Saturation Hypothesis.
- Nesting availability of the Green Wood-hoopoe may be a limiting factor for its breeding ecology and providing nesting boxes could test whether helping is affected by such manipulations, and test whether the habitat saturation hypothesis prevails and operates in this way.

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APPENDICES

Appendix 1: Locations of the Group territories of the Yellow-billed Shrike

Group	Location
1	Main gate: off to bush canteen
2	Behind Akuafo hall annex C
3	Behind CEGENSA(behind agric biotech)
4	Opposite HFC, across the road(Neem tree)
5	Opposite Volta hall (beside the MTN generator)
6	Left side of the main gate of the botanical garden; near the summer hut
7	The extreme right of the main gate of the botanical gardens)
8	Behind geology department
9	Between mathematics department and ARPIS
10	Behind Legon hall annex c(after the road)
11	Akuafo hall roundabout(beside the canteen)
12	In front of central cafeteria
13	Volta hall roundabout (just beside the Legon hall spot)
14	Quadrangle in front of mathematics and stats
15	Behind the HFC bank
16	Behind the school of public health
17	Noguchi(around the canteen main gate junction)
18	Behind commonwealth hall chapel; near the generator
19	Behind the 2nd Ayido flat; around the mango tree and the maize farm
20	Opposite bungalow 7 (Ayido circle)
21	In front of bungalow 12&13(little Legon)
22	Behind the tennis court at commonwealth
23	Right side of Balme library(around the car park)
24	Opposite jean-nelson hall; across the street
25	Botany department (behind level 100&200 lab.)
26	Right upper part of bungalow 3(lower hill)
27	Behind bungalow 40 (lower hill)
28	Around bungalow 36 (lower hill)
29	Behind African studies
30	Quadrangle between zoology and botany department
31	Beside the graduate school; near nursing department.

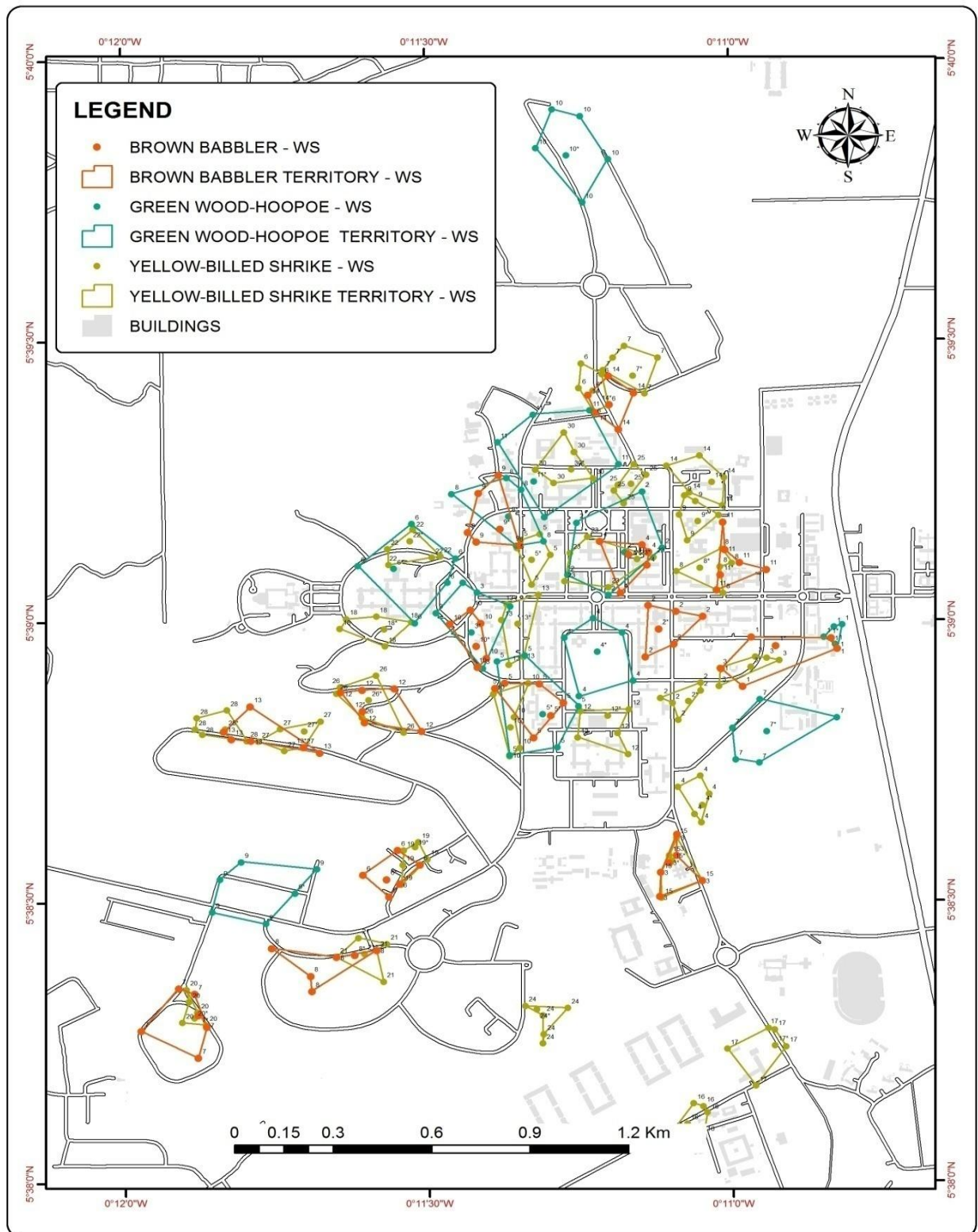
Appendix 2: Locations of the Group territories of the Green Wood-hoopoe

GROUP	LOCATION
1	Behind music & dance department
2	Rooftop of ICT building
3	In front of VBRP
4	Behind the modern languages building annex; around the athletic oval
5	In front of annex C; near the restaurant
6	On top of commonwealth hall dining room(tasty treats)
7	Behind the Nania park (near the road)
8	On top of Balme library study room
9	Around the west gate
10	Around the Vaughan dam (botanical gardens)
11	Around the food and nutrition department

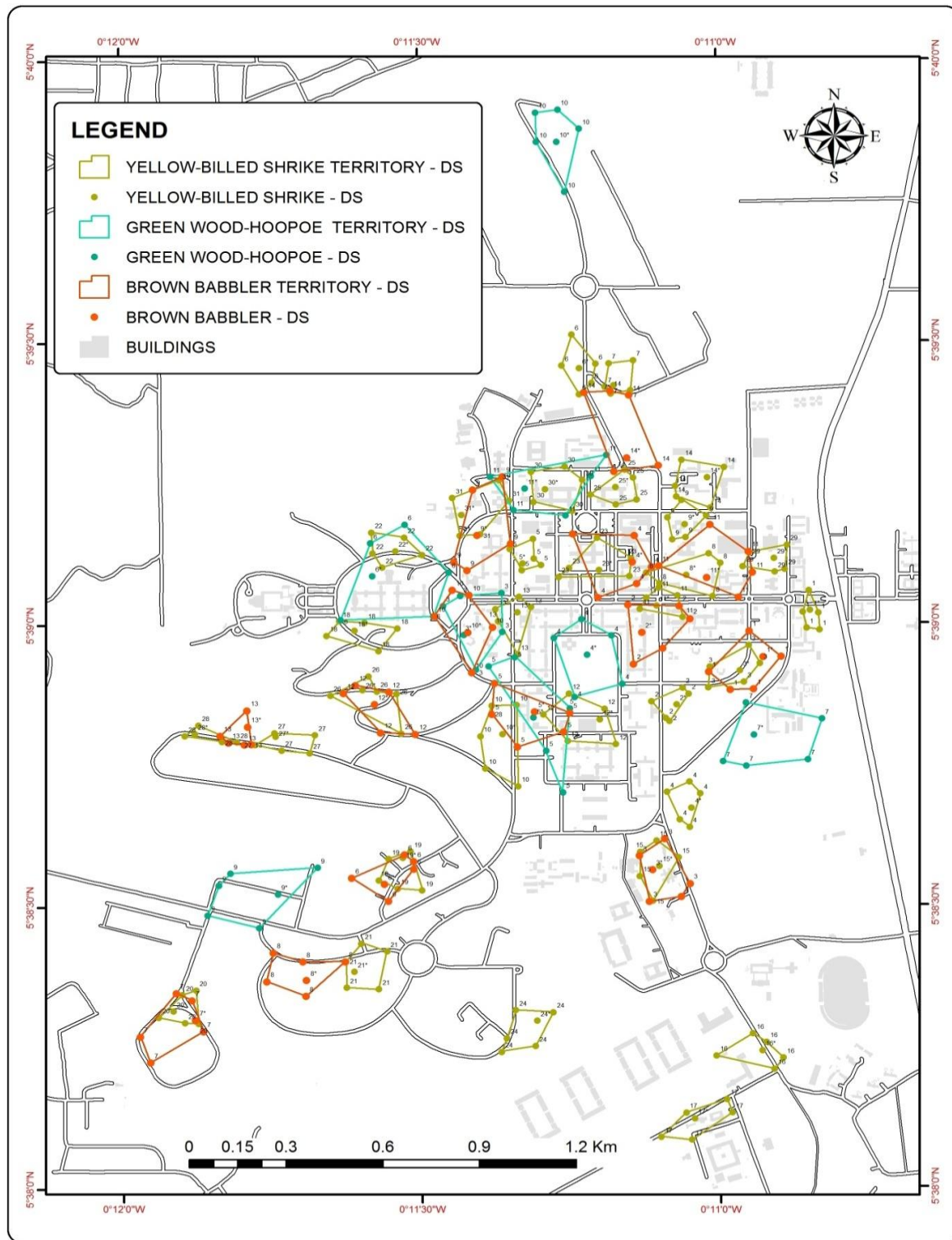
Appendix 3: Locations of the Group territories of the Brown Babbler

Group	Location
1	Around the Afua Sunderland drama studio
2	Inside Akuafo hall
3	Around the Ecobank police desk
4	Behind the physics part 1 lab
5	In front of Legon hall annex C
6	Just behind the second Ayido flat
7	Opposite bungalow 7 (Ayido flat)
8	In front of bungalow 12&13 (little Legon)
9	Behind Volta hall; opposite the nursing department
10	Around VBRP
11	Behind geology department
12	Around bungalow 3 (lower hill)
13	Opposite bungalow 6 (lower hill)
14	Behind botany department(around the green house)

APPENDIX 4: Distribution of all the three bird species in the wet season



APPENDIX 5: Distribution of all the three bird species in the dry season



Appendix 6: Food supply rate of the Yellow-billed Shrikes

Groups	Feeding rate/hr	Feeding rate/hr	Feeding rate/hr	Average
2	13	20	17	16.67
3	14	19	18	17.00
8	14	25	15	18.00
11	14	17	15	15.33
17	17	22	19	19.33
18	13	28	23	21.33
25	11	18	15	14.67
28	13	19	22	18.00

Appendix 7: Food supply rate of the Green Wood-hoopoe

Groups	Feeding rate/hr	Feeding rate/hr	Feeding rate/hr	Average
2	25	32	31	29.33
6	25	34	33	30.67
7	28	32	21	27.00
8	22	23	15	20.00
9	18	37	19	24.67
10	25	29	28	27.33
11	33	28	26	29.00

Appendix 8: Food supply rate of the Brown Babbler

Groups	Feeding rate/hr	Feeding rate/hr	Feeding rate/hr	Average
2	18	24	17	19.67
5	23	21	15	19.67
7	17	12	22	17.00
8	16	18	24	19.33
11	19	23	29	23.67

Appendix 9: Studies showing the relationship between food supply rate and the number of helpers (du Plessis, 1991)

SPECIES	REFERENCES
Helpers increase the number of feeding visits to nestlings in:	
House sparrow	<i>Passer domesticus</i> Sappington(1977)
Australian bell miner	<i>Manorina melanophrys</i> Clarke(1984)
Chestnut-bellied starling	<i>Spreo pulcher</i> Wilkinson & Brown (1984)
Greenwood hoopoe	<i>Phoeniculus purpureus</i> Ligon &Ligon (1978)
White-fronted bee-eater	<i>Merops bullockoides</i> Emlen (1984)
Pied kingfisher	<i>Ceryle rudis</i> Reyer (1980, 1984)
White-browed sparrow-weaver	<i>Plocepasser mahali</i> Earle (1983)
Acorn woodpecker	<i>Melanerpes formicivorus</i> Koenig & Mumme (1987)
Florida scrub jar	<i>Apelocoma coerulescens</i> McGowan & Woolfenden (1990)
Helpers do not increase the number of feeding visits to nestlings in:	
Kookaburra	<i>Dacelo novaeguinaea</i> Parry (1973)
Florida scrub jay	<i>Aphelocoma coerulescens</i> Stallcup & Woolfenden (1978)
Grey-crowned babbler	<i>Pomatostomus temporalis</i> Brown <i>et al.</i> (1978)
Stripe-backed wren	<i>Camphynchus nuchalis</i> Rabenold (1984)
Bicoloured wren	<i>C. Griseus</i> Austad & Rabenold (1985)
White-winged chough	<i>Corcorax melanorhamphus</i> Rowley (1977)
Arrow-marked babbler	<i>Turdoides jardinei</i> Vernon (1976)
Long-tailed tit	<i>Aegithalos caudatus</i> Gaston (1973)
Black tit	<i>Parus niger</i> Tarboton (1981)
Purple gallinule	<i>Paorphyrula martinica</i> Hunter (1987)
Pygmy nuthatch	<i>Sitta pygmaea</i> Sydeman (1989)
Splendid fairy-wren	<i>Malarus splendens</i> Russell &Rowley (1988)
Green-wood hoopoe (SA)	<i>Phoeniculus purpureus</i> du Plessis (1991)

Appendix 10: Comparisons of territories (ha), groups, population sizes, clutches, as well as food supply rates (number of visits/hour)

Species	Wet Season				Dry Season			
	Territory	Gps	Pop	C.S	Territory	Gps	Pop	C.S
YBS	1.11±0.51	27	245	12	1.22±0.52	31	281	53
GWH	4.17±1.92	11	74	11	3.93±1.35	8	59	10
BB	1.71±0.63	14	120	5	2.43±0.87	14	119	10

Gps=Groups; Pop=Population Size; C.S=Clutch Size; YBS=Yellow-billed Shrike; GWH=Green Wood-hoopoe; BB=Brown Babbler .