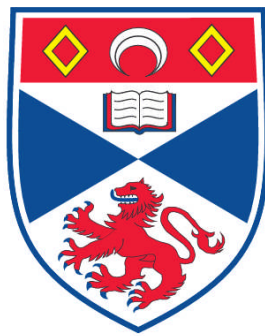


**THE DENSITY AND DIVERSITY OF BIRDS ON FARMLAND IN  
WEST AFRICA**

**Mark F. Hulme**

**A Thesis Submitted for the Degree of PhD  
at the  
University of St. Andrews**



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# **The Density and Diversity of Birds on Farmland in West Africa**



by Mark F. Hulme

Submitted for the degree of Doctor of Philosophy to the University of St Andrews

September 2007

Thesis supervisor:  
Dr Will Cresswell  
School of Biology  
University of St Andrews

**for John and Rosemary**

# Abstract

The area of land farmed in Africa is predicted to double by the year 2050 yet very few African studies have investigated the impact of different farming intensities and regimes on bird communities. This study examined avian species richness and diversity along with the densities of some common bird species on the Jos Plateau, Nigeria, in relation to habitat features on farmland over a gradient of differing farming intensities. The study area exhibited a variety of different levels of farming which differed in the habitat available for birds. Birds normally associated with savanna woodland were more associated with less intensive farming, and open-country birds were more associated with more intensive sites, with more species of birds observed where farming was less intensive. Common species of birds using cultivated land associated with different crops, with acha and millet being the most commonly used. Tree density was the most important variable predicting avian species richness and diversity, with medium tree density predicting the highest species richness and diversity. The densities of two common farmland birds were predicted best by tree density, but varied in their responses to the habitat variables, with common bulbul, a savanna generalist, associating more with less intensive, wooded areas and red-cheeked cordon-bleu, an open savanna granivore, associating with medium intensity, more open farmland. Whinchats were common in open, intensively farmed areas with few trees and good herbaceous vegetation cover. The data presented indicates the importance of retaining natural features of savanna habitat in farmland in order to maintain high avian diversity on farmland. More detailed studies are needed in order to determine the mechanisms involved in the associations observed and collaborations between ecologists and social scientists will be necessary to develop effective policies to limit the impact of the intensification of agriculture in Africa on avian biodiversity.

I, Mark F. Hulme, hereby certify that this thesis, which is approximately 50,000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

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# Chapter 1 Introduction

Tropical conservation has traditionally concentrated on natural, pristine habitats such as rainforests (Eniang & Luiselli 2002; Sampaio et al. 2003; Raman 2003), savannas (Thiollay 1998) and wetlands (MacArthur et al. 1962) due to their high levels of biodiversity, high numbers of species of conservation concern and the large numbers of threats perceived to confront them such as hunting, deforestation, draining, urban spread and land degradation (Sala et al. 2000). Human-dominated landscapes, such as agricultural land, have been all-but ignored in ecological and conservation research in the tropics as they support lower species diversities and fewer species of conservation concern (Naidoo 2004) even though it has become apparent over the last 30 years that as natural habitats decrease in area much wildlife relies on land heavily used by humans and that the type and scale of agriculture can have a marked effect on the wildlife populations found to be using it (Chamberlain et al. 2000; Benton et al. 2002).

This provides a lesson for tropical conservation. Agricultural landscapes are spreading and pristine habitats shrinking. The survival of many species may depend on their use of human-dominated landscapes and the patterns of use of different types of agricultural land by wildlife must be understood in order to incorporate these lands into conservation management plans. In addition, conservation is most effective if people can relate it to their local environment, which is likely to be an agricultural environment, so it is important that we do not concentrate solely on protected areas, which local people may not visit. This thesis will present data on surveys conducted in agricultural land on the Jos Plateau, central Nigeria, in an attempt to understand what aspects of farmland bird species are associated with and, therefore, what management prescriptions may be advised to take avian biodiversity on farmland into account.

## ***1.1. Anthropogenic Habitat Change***

Humans can alter natural habitats in a number of ways and it has been estimated that, as a result of all land-use changes, there may have been a loss of between a fifth and a quarter of pre-agricultural bird numbers (Gaston et al. 2003). Habitat must be altered to make way for habitation, which can result in extensive habitat destruction locally

and can be a major factor in habitat change when the human population increases (Catterall et al. 1998; Mortberg 2001). The harnessing of hydroelectric power through dam-building and the extraction industries, mining and logging, can lead to the complete removal of the habitat affected (Goodland et al. 1993; Lees & Peres 2006; Wickham et al. 2007). Indirect impacts on habitats include pollution, which can damage habitats through such processes as acid rain, leaching of fertilisers and climate change, which may make the climate of large areas unsuitable to sustain their current habitats or result in the flooding of low-lying areas as sea levels rise (Kappelle et al. 1999; Schroter et al. 2005). Hunting and the introduction of invasive species through human activity can have an impact on wildlife populations and thus affect the habitat by altering grazing and seed-dispersal patterns (Lodge 1993; Wright et al. 2007).

The conversion of habitat to agriculture is, however, the largest current cause of habitat change by humans, with around one third of the world's exploitable surface now dominated by agriculture (Ormerod & Watkinson 2000). In temperate zones this figure is higher still. In Britain, for example, 75% of the exploitable surface is agricultural (Ostermann 1998). This use of land results in destruction of natural habitats as well as the use and release of nitrogen, phosphorus and water and the release of pesticides (Tilman et al. 2001). Tilman *et al* (2001) estimated that about half of all potentially suitable remaining land would be converted to agriculture in developing countries by 2050. At 10<sup>9</sup> hectares this is an area larger than that of the USA, leading to unprecedented ecosystem simplification, loss of ecosystem services and species extinctions and requiring significant policy changes to control the environmental impacts of this agricultural expansion. Africa, with current high human population increases, will require agricultural changes in order to be self-sufficient for food (Imhoff et al. 2004), indeed, the area of cropland in the developing world has increased by 20% since 1961 whereas developed world cropped land has shrunk, slightly (Green et al. 2005). Therefore the effects of agriculture on biodiversity must be known in order to derive effective policies to limit the damage to current ecosystems.

## ***1.2 Disturbance and Diversity – Could Farmland Host High Biodiversity?***

Although anthropogenic use of land may result in a complete change in available habitats and ecosystem functions and services, anthropogenic effects may result in new communities of biological importance. The theoretical framework that best describes this is that of succession and disturbance within communities. Connell (1978) suggested the intermediate disturbance hypothesis, which states that species diversity will be higher with disturbances of an intermediate frequency and intensity (Connell 1978). This was backed up by observations in Uganda and Nigeria that the highest plant diversity in forest recovering from major disturbance was at a non-equilibrium intermediate stage of forest succession. At a high rate of disturbance the only species which colonise and survive will be those which reach maturity quickly. As the interval between disturbances increases more time is available for the invasion of new species so diversity increases. Under low levels of disturbance, diversity decreases as the most effective competitors for the available limited resources survive at the cost of less-efficient species, thus disturbances interrupt and set back the process of competitive elimination by removing species that are competitively excluding other organisms (Connell 1978). This suggests that high species diversity could be maintained even under a degree of anthropogenic disturbance, such as agriculture, as long as the disturbance is limited. The challenge is to reach a balance whereby disturbance does not cause significant declines in species diversity.

## ***1.3 Farmland as a Habitat for Birds***

On farmland the habitat available has been significantly altered from the natural habitat by human activity and the different species present will select for different aspects of this new habitat, depending on the requirements they have evolved for. Bird species will not have evolved entirely in the presence of agriculture on the scale seen today and will select for aspects of the land which resemble the savanna, grassland, forest or wetland they have evolved to exploit (Gill 2006). The management of farmland in different ways will yield different habitat mosaics suitable for different species.

When the natural habitat that has been changed is forest, woodland or savanna, agriculture tends to result in a more open areas with fewer trees and shrubs (Reid et al. 1997; Soderstrom et al. 2003; Marsden et al. 2006) and more perennial vegetation, with increased seasonality in the availability of seed and invertebrate food (Critchley et al. 2004). Crop fields are sown and harvested every year, during spring and summer in temperate zones and during the wet season in tropical zones, often with a second harvest of a different crop during the winter in temperate zones and the dry season in the tropics (Henderson et al. 2004). A mosaic of crop fields, arable land, fallow land, field borders and pockets of woodland may be generated with high levels of year-on-year disturbance, yet conversion to agricultural land still consistently leads to lower habitat heterogeneity (Benton et al. 2003). The crop fields vary in size, depending on the intensity of the farming practised, larger fields predominating on higher intensity farmland. The variety of crops cultivated varies, with low crop diversity described as a monoculture and viewed as indicative of high-intensity farming, whereas high crop diversity is seen as indicating lower intensity farming (Gall & Orians 1992). Agricultural land also tends to have a high input of fertilisers and pesticides which alters the soil quality and chemical make-up, which can influence vegetation and can potentially be toxic to plants and animals (Mader et al. 2002).

The typical farmland birds observed in tropical areas tend to be a mixture of woodland and savanna species and open-country, grassland species, which may not have been present before human disturbance and may have been able to expand their ranges due to agricultural habitat changes (Borrow & Demey 2001; Soderstrom et al. 2003). Forest species may also persist among relict forest patches and riparian forest along watercourses. From forest to farmland in Cameroon, for example, species richness of insectivorous birds and hole-nesting birds declined whilst the number of granivorous species, which are common in more open, scrubby and grassland habitats, increased (Waltert et al. 2005). In temperate zones this use of farmland by granivorous, open-country birds, which can make use of cereal grains, has also been noted, although insectivorous, woodland bird species can also persist in farmland by using field borders and woodland remnants (Gregory & Baillie 1998).

### **1.3.1 Biodiversity of Farmland**

Biodiversity is often used as a measure of the comparative ecological health of habitats, with more diverse communities representing a more desirable habitat from a conservation perspective (Huston 1994; Gaston 1996). Species richness is a relatively easy variable to study as it only involves the collection of data on which species were present, so it is often used as an indicator of the diversity of a community (Hopton & Mayer 2006; Thomson et al. 2007). Species richness does not, however, take into account other information relevant to diversity involving the number of individuals involved or the biomass of each species. These data can indicate whether the species are distributed equitably or whether there are a small number of common species and the rest are rare. Diversity indices take both of these factors into account, so two areas with the same number of species will have different values depending on the equitability of their distribution, with the more equitable area yielding a higher diversity index (Begon et al. 1996).

Both measures of diversity mentioned above miss another aspect of biodiversity, that of the genetic diversity between species. For example, the species data do not distinguish between species of the same or different families, which are more genetically diverse, so could be argued to constitute greater diversity (Gaston 1996). As habitat changes the number of species may remain similar but the constitution of the avian community may change at a higher taxonomic level (e.g. family). Alternatively, intraspecific variation may be lost because of intense directional selection on birds in rapidly changing habitats such as farmland, and because of bottlenecks, that may not occur in more stable, unfragmented habitats such as woodland (Fjeldsa & Lovett 1997).

Biodiversity has been found to decrease where agriculture has expanded, with an estimation, based on forecasts of biome conversions, that 27-44% of bird species could be lost to agricultural expansion from Neolithic to 2050 (Teyssedre & Couvet 2007). Increased diversity and species richness have been linked to increased non-cropped elements in an agricultural landscape in the Baltic states (Herzon & O'Hara 2007) and diversity in the agricultural landscape is often positively correlated with taxonomic richness (Bennett et al. 2006). Management strategies for conservation on

farmland have been specifically linked to a desire to increase habitat diversity and bird species richness in Europe (Gottschalk et al. 2007). With the higher species richness observed in tropical agricultural land (Mangnall & Crowe 2003; Soderstrom et al. 2003), it is likely that many species are at risk from agricultural expansion in Africa and that focussed management may have a large role to play in reducing these potential losses.

### ***1.3.2 Farmland Birds and Agricultural Intensification***

Since the 1960s the “Green Revolution” has been increasing farming yields, mainly in developed nations, by increasing the total area of cropland, using new technologies such as tractors and combine harvesters to improve efficiency, by the development of new and more effective artificial fertilisers, pesticides and herbicides and by the development of new crop varieties, including genetically-engineered crops (Tilman et al. 2001; Green et al. 2005). This has greatly reduced world hunger, with a doubling of global food-production between 1966 and 2001 (Green et al. 2005), but at an environmental price, with birds not being immune to the detrimental effects of this change from traditional farming systems to more modern, intensive forms of farming (Fuller et al. 1996; Donald et al. 2006). The conversion of greater areas of land to farming has reduced habitat heterogeneity and led to reductions in species richness and declines in bird species which were once common on European farmland (Tilman et al. 2001; Benton et al. 2003). This trend is likely to also be occurring in the tropics, and will certainly occur if previously mentioned forecasts of increases in agricultural land in developing nations are accurate (Tilman et al. 2001). It is, therefore, useful to examine the European experience in more detail to understand some of the potential issues for African farmland birds, which have been the focus of very few studies.

### ***1.3.3 How Agricultural Practices Affect Bird Abundance: A European Case Study***

Farmland birds in Europe have been well studied and provide a good case study of how the relationships between farming practices and resultant bird communities arise, and then how management measures can be applied to alter bird populations.

The Common Birds Census was started by the British Trust for Ornithology in 1962 as a standardised method for monitoring bird populations throughout the country utilising volunteer fieldworkers. It has provided constant data on the trends in occurrence of 35-50% of the commoner species in many types of habitat (Greenwood 2003) and from this it was concluded that populations of 24 of the 28 species classified as farmland birds contracted between 1970 and 1990, with 7 of these showing population declines of more than 50%. For example, corn buntings, *Emberiza calandra*, and tree sparrows, *Fringilla montanus*, both declined by over 75% throughout the whole of Britain between 1968 and 1991 (Fuller et al. 1996). Over the same period woodland species tended to increase in abundance suggesting that there was a specific relationship between farming and bird abundance over that period. Chamberlain et al (2000) examined changes in agriculture between 1962 and 1995 and used the Common Birds Census to determine indices of relative population change for 29 bird species and found that, as agriculture changed and intensified, the bird population change broadly matched, with a time-lag in the response of birds.

Once population declines were identified detailed studies were carried out in Europe investigating relationships between bird populations and agricultural practices, which can alter the habitat in different ways, influencing breeding rates, foraging rates and predation rates, and indicate mechanisms for population declines. The identification of these mechanisms is vital in order to choose the appropriate conservation measures to begin to reverse the declines in these species. In order to determine what measures have to be taken on farmed land to maximise avian diversity, data must be gathered to show what habitat factors birds are associated with. Habitat selection by wildlife in Europe has been the subject of much research and many techniques have been developed to accurately gather and analyse data, which can accurately describe species' habitat preferences at different spatial scales. With these complex multivariate data it is then possible to investigate the many different reasons why the animals occur in different habitats and the detailed habitat factors they select for (Wiens 1989).

### 1.3.3.1 Food Density

Food availability has been identified as a limiting factor for a number of species on farmland for both adult birds and chicks. Decreases in food availability could be due to decreased densities of food due to changing farming practices. Corn buntings, for example, were observed to show reduced breeding success with reduced amounts of invertebrate food for chicks, possibly due to an increased risk of predation as the adults had to travel further to find food. This decrease correlates with a decrease in invertebrate populations on intensively farmed land (Brickle et al. 2000). Measures specifically to increase invertebrate food could include the introduction of set-aside fields, crops under-sown with grass and a decrease in both herbicide and pesticide use; the introduction of these measures could then lead to an increase in corn bunting breeding success (Brickle et al. 2000). A lack of spilt grain for winter food for fully-grown birds due to more efficient harvesting practices could be a factor in the decline of the turtle dove, *Streptopelia turtur*, in Britain (Browne & Aebischer 2003) and a decrease in weed seeds due to herbicide application has reduced food availability for 26 species of granivores (Wilson et al. 1999). Wilson *et al.* (1999) also indicated, however, that a reduction in the intensification of agriculture can be shown to result in rapid recovery of food resources and that the retention of uncultivated borders and hedgerows can become important resources of seeds and invertebrate food. A shift from spring to autumn sowing of cereals has led to the loss of the best winter food source for skylark, *Alauda arvensis* (Donald et al. 2001a), and the retention of weed-rich stubbles and rotational set-aside throughout the winter is suggested as a way of improving wintering conditions for birds (Moorcroft et al. 2002).

The effect of farmland practices on food availability may be direct or indirect, with, for example, herbicides resulting in the loss of food plants for invertebrates used as chick food by the grey partridge, *Perdix perdix* (Rands 1986; Boatman et al. 2004) and an understanding of this can lead to effective measures being taken, such as the introduction of field margins where herbicide is not applied (Chiverton 1999).



### 1.3.3.2 Vegetation Structure

Food availability could also be linked to changes in the structure of the vegetation on farmland, where birds may be unable to detect food due to increased height or density of vegetation, which is the case for lapwings, *Vanellus vanellus*, and chaffinches, *Fringilla coelebs* (Butler & Gillings 2004). Vegetation structure, such as height and occurrence of leaf litter and bare ground, must be taken into account in studies of this type. Vegetation structure may also affect bird behaviour due to perceived predation risk, with some granivorous and insectivorous species preferring short sward and some longer sward due to differing anti-predation strategies (Ydenberg & Dill 1986; Whittingham & Evans 2004; Whittingham et al. 2006). Predator avoidance and starvation risk are likely to both influence habitat use by birds on farmland and trade-offs between these result in complicated patterns of habitat association which may lead to difficulty in recommending management prescriptions (Lind & Cresswell 2005). (Minderman et al. 2006). Benton *et al* (2003) argue that multivariate effects of agricultural intensification interact strongly and should be considered collectively to find general rather than specific solutions. Food availability, predator avoidance and nest-site availability have all been implicated in the importance of retaining non-cropped elements to increase habitat heterogeneity within farmland (Benton et al. 2003; Whittingham et al. 2005). Indicators of un-farmed habitat, such as woody shrubs and trees, should be included in farmland bird studies.

### 1.3.3.3 Spatial Scales

Observed habitat-selection in birds can differ depending on the scale of the study. Variables collected at three spatial scales resulted in different species-environment relationships being detected in birds in the Oregon coast range (Cushman & McGarigal 2004) and on farmland, analysis at the field-boundary scale indicated no preference for trees by yellowhammers, *Emberiza citrinella*, but this preference was observed at the territory scale (Whittingham et al. 2005). Regional variations in yellowhammer densities were then found to be more closely correlated with the boundary model. Such examples show the importance of spatial scale in testing habitat association and the importance of surveying at different scales in order to get a broader picture of habitat selection.

## **1.4 Farmland Birds in the Tropics and in Africa**

The findings described above for European farmland birds have been backed up by long-term monitoring schemes and many years of intensive research. Avian species richness in tropical areas is much higher than in Europe but there is no comparable monitoring scheme over different habitat types. As a consequence, there is a lack of baseline data on birds in farmland, even though it has been suggested that, according to Birdlife International's World Bird Database, farming is the biggest source of threat to bird species listed as threatened, and that this is substantially more important for species in developing than developed countries (Green et al. 2005). Most research on farmland in the tropics has been in the form of comparative studies between more pristine areas and adjacent farmland (Naidoo 2004), and investigating the effect of adjacent farmland and savanna on populations of birds in fragmented natural habitat (Hughes et al. 2002; Matlock et al. 2002; Marsden et al. 2006).

### **1.4.1 Tropical Habitats and Conversion to Agriculture**

Hughes *et al* (2002) surveyed agricultural land adjacent to native forest in Costa Rica and estimated that 46% of bird species native to the region were utilising agricultural land in some manner, and most used agricultural land for some foraging. They also predicted that removing tall trees and edges from the farmland mosaic would cause a decline in bird richness by approximately 40%. They concluded that tropical agriculture, if managed properly, could contribute to tropical bird conservation. Naidoo (2004), on the other hand, found that the management of agricultural land was unlikely to contribute to forest bird conservation in southern Uganda. Naidoo surveyed bird species richness in intact forest, secondary forest and smallholder agriculture and found higher diversity in the forest habitats and lower diversity in farmland; in addition species composition was significantly different in farmland and few forest species were utilising it to a significant level. It was concluded that tree densities would have to be raised to un-realistic levels on smallholdings in order to have a positive impact on forest bird populations (Naidoo 2004). Marsden *et al.* (2006) studied a forest management area in Papua New Guinea where only 13% of the land was converted for agriculture but there were still low densities of some insectivorous bird species on the converted land. Other studies have assessed the impact of slash-and-burn (Wang & Young 2003) and banana plantations (Matlock et

al. 2002) on birds of native forests, but these did not concentrate on farmland as a habitat independent of intact forest.

#### **1.4.2 Birds and Agricultural Gradients in Africa**

Wilson *et al* (1997) investigated the effect of tsetse fly control on biodiversity in Southwest Ethiopia. After control farmers were able to utilise cattle for ploughing so there was an increase in cattle-ploughed smallholdings in the area. Bird species richness and composition was sampled and it was found that riparian forest fragments contained the highest diversity, followed by smallholdings, wooded grassland and, lastly, intensive, tractor-ploughed cultivations. This suggested that conversion of wooded grassland to low-intensity agriculture had a positive effect on species richness, supporting the intermediate disturbance hypothesis that species richness enhances under low levels of disturbance. There was, however, a change in species composition that could shift the population towards one of less conservation interest.

In Burkina Faso, West Africa, Soderstrom *et al* (2003) conducted an investigation into the response of bird communities to human-use land intensification, in particular to the expansion of cultivation. They surveyed birds in areas with different soil types, fallow period lengths and grazing pressures. Vegetation structure was also measured. Avian species richness decreased from cultivation to very old fallows and the bird community was strongly affected by the amount of canopy cover and tree species richness. Nest placement was the most important factor explaining community structure, with shrub nesters benefiting from fallow periods and cavity nesters remaining in intensive farmland with large trees. They concluded that farmland may contain large populations of species of conservation interest in Africa and that more research should be carried out in tropical agricultural landscapes.

South Africa is the most developed country in sub-Saharan Africa with a high proportion of intensive agriculture and a number of avian studies there have concentrated on farmland. Higher numbers of bird species were recorded at sites with a mixture of crops compared to less diverse sites in the Aguhlas Plains, Southern South Africa (Mangnall & Crowe 2003). For Southeast South Africa, Wessels *et al* (2003) integrated land-cover, agricultural potential and species distribution data from

different taxa in order to identify potential conflict areas between land transformation and biodiversity conservation. It appeared there was substantial overlap between areas of conservation interest and transformed land, and that policies were needed to promote biodiversity on private farmland. In a parallel to the species-specific research that has taken place in Europe, the ecology and habitat-use of the helmeted guineafowl, *Numida meleagris*, has been studied on farmland in South Africa (Malan & Benn 1999; Ratcliffe & Crowe 2001). This indicated that, whilst this species has made extensive use of agricultural habitats for many years, it seems that a reduction in habitat heterogeneity for nesting and cover (Malan & Benn 1999). An increase in the use of pesticides decreasing the availability of arthropod prey and weeds for family groups of helmeted guineafowl (Ratcliffe & Crowe 2001) has led to a decline in the intensively farmed areas.

Threatened bird species which use farmland habitats have been studied in Kenya, including Hinde's Babbler, *Turdoides hindei*, which requires increased thicket cover for increased productivity (Shaw & Masina 2003) and Sharpe's Longclaw, *Macronyx sharpei*, which requires intact grassland, which is under threat by conversion of grazing land to cultivation (Muchai et al. 2002a; Muchai et al. 2002b).

### **1.5 Further research in agricultural ecosystems in Africa**

The limited studies in Africa and the wider tropics confirm that much more research needs to be carried out on tropical farmland biodiversity and that there could be great potential to contribute to maintaining the populations of common and endangered species through well-informed management of agricultural development in Africa. The study described here was conceived with the aim to address the lack of knowledge of the biodiversity retained, or even promoted, on farmland in West Africa. The study was based at the AP Leventis Ornithological Research Institute 10km east of the town Jos, Nigeria.

### 1.5.1 The Study Site

The Jos Plateau is located in Plateau State, central Nigeria at 09°52'N, 08°58'E. The Plateau is the largest landmass above 1,000 m in Nigeria and is approximately 250 km by 150 km in size. It comprises high plains with scattered rock outcrops ranging from 1220 to 1,450 m above sea level and a number of granite hill ranges that rise to 1,781 m. The average rainfall for the town of Jos is 1,411 mm per year (Payne 1998). The vegetation is scattered bush and grass, grazed by cattle, sheep and goats, with riparian forest fragments and extensive cultivation. Figure 1.1 displays the location of the study site in Nigeria.

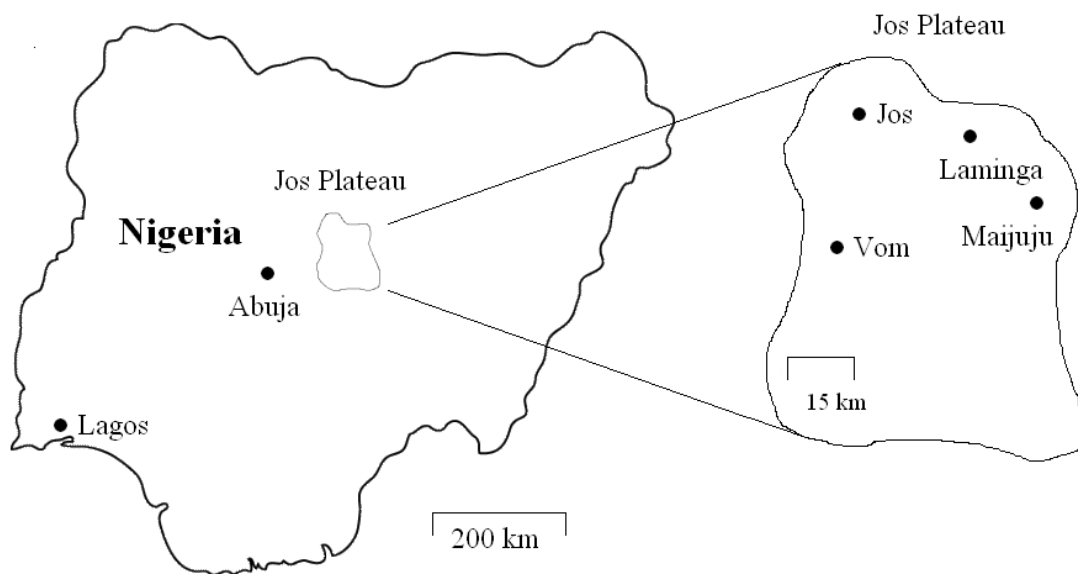


Figure 1.1 Map of Nigeria and the location of the study site around Jos, Plateau State.

The indigenously developed farming systems in West Africa include temporary intercropped fallow (mixing different crops in the same field), permanent intercropping, livestock farming and mixed farming (both arable and pastoral farming), resulting in a large diversity of management systems across West Africa. They are closely adapted to the natural environment and have minimal dependence on artificial external inputs. Population growth and migration, social change, the introduction of cash crops and policies adopted by colonial and post-colonial

governments have greatly affected the sustainability of farming systems in West Africa generally (Gyasi & Uitto 1997).

Farming activity on the Jos Plateau consists of smallholdings with both subsistence agriculture and crops grown for sale at local markets. The climatic conditions of the Plateau enables the production of a wide range of foodstuffs. Temperate fruit and vegetables in particular, which are not easily cultivated in many areas of West Africa, have become important cash crops, involving irrigation during the dry season. This was initially carried out by migrant Hausa farmers from the north of Nigeria, but more recently indigenous populations have learnt the Hausa techniques of irrigation, and mechanised water pumps have reduced in price leading to an expansion of dry season vegetable farming (Porter et al. 2003). The produce is sold locally, transported to Jos urban markets or further to other parts of Nigeria, Niger and Chad. Cereal crops are grown during the rains, and tuber crops throughout the year, mostly for subsistence but also for sale, though less profitably than for dry season crops. Cattle and sheep grazing is carried out by various communities. The pastoral Fulani people from the north of Nigeria graze extensively on the tsetse-free Plateau during the dry season, often leading to ethnic competition, which can also be a problem between Hausa farmers and market traders and the mainly indigenous land owners (Porter et al. 2003).

### ***1.5.2 Density and Diversity of Farmland birds on the Jos Plateau, Nigeria***

This thesis describes a project to collect general baseline data on bird densities and diversity on different types of farmland on the Jos Plateau and thereby suggest future directions of work studying the mechanisms underlying the patterns observed and also to provide provisional management prescriptions based on the data available.

The study was carried out in the following way: Firstly, I defined farmland as an anthropogenic habitat and described the overall bird communities as a means of establishing the relevance of the study area to farmland in Africa generally (Chapter 3). Secondly I examined the coarse scale preferences for farmland types of the common birds directly using farmed land by describing usage of dry-season stubble

fields of different crop types, acha, millet, maize and yam, controlling for the effects of different field sizes and border habitats (Chapter 4). Thirdly, I then increased the spatial scale of measurement of habitat variables and considered the effects of fallow land and non-cropped habitats as well as field characteristics in determining the species richness and diversity in farmland habitats (Chapter 5). This approach was then used to examine specific case studies of how two, representative, species use farmlands as a habitat: the common bulbul, *Pycnonotus barbatus*, a generalist, and the red-cheeked cordon-bleu, *Uraeginthus bengalus*, a granivore (Chapter 6). Finally, because Palearctic migrants using farmland habitats are of considerable interest, I then examined the factors determining the densities of one common migrant, the whinchat, *Saxicola rubetra*, on farmland, and also examine how the species utilises farmland habitats during foraging (Chapter 7). I finish the study by discussing the implications of my results for conservation and African farmland management (Chapter 8).

The specific aims of this thesis are:

1. To describe the farmland habitat of the Jos Plateau in terms of its anthropogenic use and the forms of management applied to it (Chapter 3)
2. To describe the bird community on farmland on the Jos Plateau in terms of the type of farmland present (Chapter 3)
3. To describe how bird species use crop fields and whether field edge habitats and crop type have an impact of field associations of common bird species (Chapter 4)
4. To assess whether habitat can be used to model and predict bird species richness and diversity on farmland on the Jos Plateau (Chapter 5)
5. To assess whether habitat can be used to model and predict common bulbul and red-cheeked cordon-bleu densities on farmland on the Jos Plateau (Chapter 6)
6. To assess whether habitat can be used to model and predict whinchat densities on farmland on the Jos Plateau and whether whinchat foraging behaviour depends on different farmland habitats (Chapter 7)
7. To use the analysis of the data presented to suggest areas of further research and policies for the management of farmland to take into account avian numbers and diversity (Chapter 8)

## **Chapter 2 Materials and Methods**

This chapter outlines the methods used during the study. Most data were collected using line transect methods, with stratified random locations of 100m transects. Bird occurrence, vegetation and farming data were collected for each transect. Bird density was then calculated using Distance methodology and related to habitat variables using Generalised Linear Models, after variable selection and using the Information Theoretic approach to identify key variables and models. Models were then validated using a further set of independent transect data. Data on anthropogenic influences were collected from the farmers of the study site using a questionnaire. The importance of particular crop types for birds was further examined by recording the presence of bird species within specific fields. Finally, how fields were used by whinchats was examined by focal sampling of individuals and recording their foraging behaviour.

### ***2.1 Line Transect Surveys***

#### ***2.1.1 Survey Design***

Line transects were chosen as sampling units due to the open nature of much of the area (Bibby et al. 2000; Buckland et al. 2001). Point counts were attempted but in open habitats birds left on the approach to the points and did not return during the period of the counts. The ability to detect birds ahead before they were flushed whilst walking lines led to the decision to choose line transects. The areas surveyed consisted of a mosaic of many different habitats and field types so in order to limit the habitats surveyed per line, lines were restricted to 100m in length. The program GPS Utility (GPSU 1998) was used to place the transects within each site. Initially transects were placed using random numbers, each start point being at least 200m away from the nearest neighbour in order to avoid crossing of transects. In the field a pencil was thrown at the start point to determine the direction of the transect. The transect was then walked in the direction of the pencil facing away from the direction of approach. Figure 2.1 shows an example of this placement.



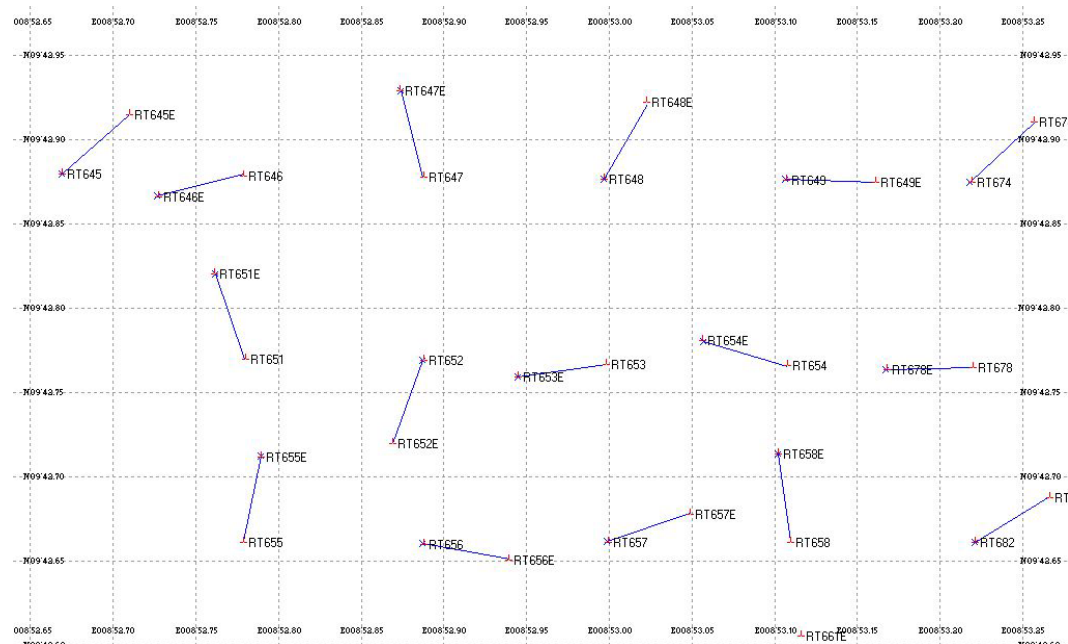


Figure 2.1. Transect placement, random system, November 2003 – April 2004.

A compass reading was taken and followed, a Garmin 12 GPS unit was used to determine the end of the transect at 100m from the start point and the end point was marked in the GPS unit. After the first field season, which ran from November 2003 until April 2004, the placement of transects was changed after it was decided that the transects need not be placed randomly and that a grid system would enable more efficient coverage and effort whilst retaining statistical robustness (Buckland et al. 2001; L. Thomas *pers comm*). The program Distance version 5 (Thomas 2006) was used to design a survey consisting of a grid of 100m long transect lines aligned north to south with 100m between each transect north to south and 200m between each line of transects east to west. Figure 2.2 shows an example of this placement.

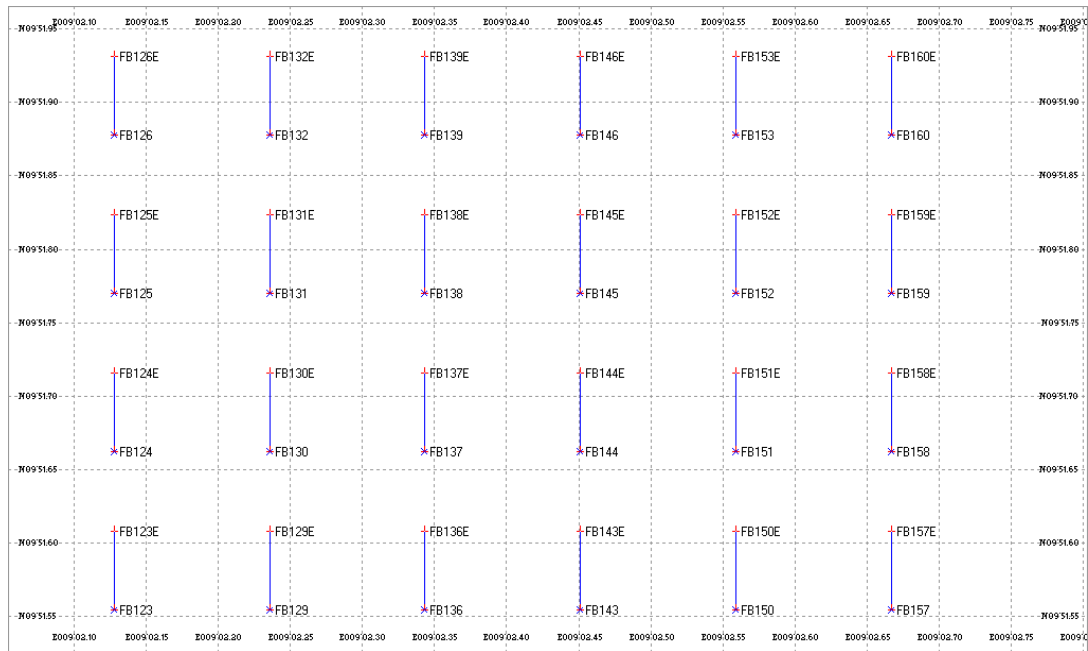


Figure 2.2. Transect placement, grid system, September 2004 – March 2006.

These transects were exported to GPSU and uploaded into the GPS unit. In the field both the start and end points of the transects were available and each transect was walked from the start point until the GPS unit indicated that the end point was reached.

### 2.1.2 Transects Conducted

Line transect surveys were carried out between 27<sup>th</sup> November 2003 and 23<sup>rd</sup> April 2004 (field season 1), between 22<sup>nd</sup> September 2004 and 11<sup>th</sup> November 2004 (field season 2), between 11<sup>th</sup> February 2005 and 27<sup>th</sup> April 2005 (field season 3) and between 9<sup>th</sup> January 2006 and 16<sup>th</sup> March 2006 (field season 4). The total number of days on which transects were conducted was 179, with a total of 1634 100m transects placed and 2524 transects surveyed, since some were repeated. Of those placed 880 transects were repeated once, making 1760 of the transects surveyed in total, and 864 were transects surveyed only once. In field season 1 80 days resulted in 1000 transects, in field season 2 29 days resulted in 421 transects, in field season 3 31 days resulted in 467 transects and in field season 4 39 days resulted in 636 transects being completed. In field season 1 475 transects were repeated with 50 transects surveyed only once. In field season 2 all transects were newly placed and 405 of these transects were repeated in field season 3. All the other 62 transects in field season 3 were new

and non-repeats. All transects in field season 4 were new and in new sites with no repeats.

### 2.2.2 Site Selection

No maps of sufficient detail were available of the area. Sites were chosen based on visual determination of the intensity of agriculture and the extent of scrubland and farmed land in order to cover as wide a range of agricultural intensities as possible. Initially, in November 2003, the area around Laminga village, including Kerker and Kerker scrub, was designated as an area of medium intensity, the area around Fobur Village was designated as an area of low intensity and the area around the villages Zarazong and the area to the west of Laminga, designated Far Laminga and Open Laminga, were designated as areas of high intensity agriculture. Later Bisichi, in February 2004, and Vom, in September 2004, were added as high intensity sites and Maijuju, in April 2004, was added as an area of medium intensity but at a lower altitude with an average altitude of 950m compared with 1250m around the other sites chosen. Local chiefs were consulted in order to gain permission to work at the sites. These sites are shown in Figure 2.3.

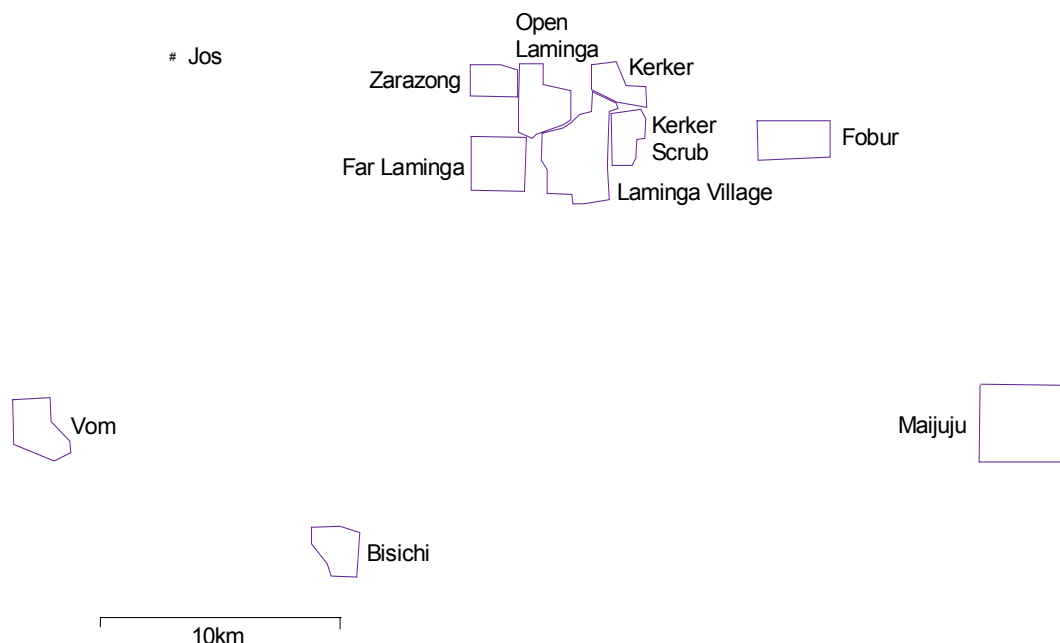


Figure 2.3. First Sites surveyed on the Jos Plateau, Nigeria.

Table 2.1 shows the number of transects placed and surveyed in each site and the field seasons they were surveyed in. Laminga village, Kerker and Kerker Scrub were considered as one site for analysis, as were Far Laminga, Open Laminga and Zarazong.

Table 2.1 Number of transects placed and surveyed by site.

Site	Total Transects Placed	Total transects surveyed	Field Season	Number of transects surveyed
Laminga Village	279	535	1	354
			2	91
			3	90
Kerker	63	109	1	96
			2	0
			3	13
Kerker Scrub	42	84	1	54
			2	15
			3	15
Far Laminga	117	221	1	100
			2	56
			3	65
Open Laminga	83	161	1	93
			2	33
			3	35
Zarazong	25	49	1	49
			2	0
			3	0
Fobur	155	293	1	156
			2	66
			3	71
Vom	84	154	1	0
			2	72
			3	82
Bisichi	41	82	1	82
			2	0
			3	0
Maijuju	112	200	1	16
			2	88
			3	96

### **2.1.3 Transect Method**

Transects were conducted between sunrise and 10am, no transects were conducted after this time in order to reduce time of day effects. Sites were chosen randomly to visit each morning. Transects were walked so as to complete each within 4 to 7 minutes, depending on the terrain and the number of birds to be recorded. All birds viewed on the ground or in vegetation were identified, sexed and aged if possible, and the number in the group recorded. Birds of the same species within 10m of each other

were counted in the same group. When the point on the transect perpendicular to the bird when first seen was reached the distance to the initial location of each bird was recorded using a Leica laser rangefinder if over 10m and estimated if below 10m. Distance estimations were checked regularly using pacing in order to maintain accuracy. The side of the transect that the bird was recorded was also noted in order to calculate the distance from the transect for groups made up of separately recorded individuals, which may have been on different sides of the transect. If birds were in a tight group, or if many recordings were to be made, the distance to the centre of the group was taken. Birds heard only were identified and recorded once for the transect. Birds first seen in the air were identified and counted and noted as flying. No distance records were taken of birds first seen in the air, even if they subsequently landed. It is assumed that during transects some birds were first recorded perched that were originally flying when the transect was started and that overall these would cancel out those birds observed landing during the transect and not included in analyses. If distance measurements were taken to all birds an inflated estimate of density would result (S. Buckland, *pers comm.*). The GPS unit was used to determine 25m sections of transects and each bird or group recorded was assigned to section 1, 2, 3 or 4, depending where they were first recorded. Groups were assigned to the section that the centre of the group lay in. Where transects were repeated these sections were retained in the same order so as to match up to habitat data also recorded in 25m sections.

#### **2.1.4 Environmental Data**

For each transect, time started and time finished were recorded. Each transect was assigned to a season defined as follows:

- 0 - August-October – Late wet season
- 1 - November-January – Early dry season
- 2 - February-April – Late dry season
- 3 - May-July – Early wet season

Wind was recorded as follows:

- 0 – no wind
- 1 – light breeze moving leaves of trees
- 2 – stronger breeze moving top branches of trees shrubs
- 3 – strong breeze moving medium branches of trees
- 4 – strong, moving larger branches of trees, surveys not conducted

Cloud cover was estimated to the nearest 10%. If there was Hamatan dust from northerly Saharan winds this was treated as cloud and cover estimated accordingly. Surveys were not carried out during rain.

### **2.1.5 Habitat Data**

At the start of each transect the habitat, field and crop type was recorded and using the GPS unit, the distance along the transect to the nearest 5m and new habitat type noted if this changed. For each habitat or crop type, a total distance covered by the transect could then be calculated. Habitat types recorded were:

- Crop type, see Table 3.1, noted if growing or harvested.
- Old farmland, to 6 years old. A local field assistant with experience of farming estimated the number of years since the land was last farmed.
- Fresh land, freshly prepared for farming but nothing planted.
- Scrub - scrubby or wooded habitat, including rocky habitat, and land not farmed in over 6 years.
- Degraded scrub - heavily eroded/cut shrubs/evidence of building or excavating.

A trained field assistant walked behind during each transect and estimated percentage cover, as viewed from above, of different vegetation and ground cover types within 20m each side of the transect and for each of the four 25m sections, resulting in four 25x40m sections. The categories estimated were:

- Short vegetation – herbaceous vegetation less than 10cm in height.
- Medium vegetation – herbaceous vegetation between 10cm and 100cm in height.
- Tall vegetation – herbaceous vegetation over 100cm in height.
- Bare ground – Bare ground visible, not including rocks over 20x20cm in size.
- Burnt vegetation – blackened vegetation and ash.
- Leaf litter – dead vegetation on the ground, not burnt.
- Rock cover – rock visible over 20x20cm in size.
- Shrub cover – woody vegetation over 50cm in height, first branching below 50cm or with branches dropping to within 50cm of the ground.
- Green vegetation – percentage of the herbaceous vegetation from categories 1, 2 and 3 that appears green.

The percentage cover of categories 1 to 7 added up to 100, shrub cover and green vegetation were independent, so areas under shrubs counted towards the totals for categories 1 to 7. Field assistants' estimations were checked regularly by myself to ensure consistency.

Transects were visited separately, in cases where tree density was high, to record tree density and landscape variables. Where tree density was low these data were collected during bird surveys. Woody plants over 3m in height were counted for each 25m section of transect within 20m of either side of the transect. Where possible they were identified to species with the aid of a field assistant. The number of species per transect section and for the whole transect was recorded.

The following was also recorded:

- Distance to nearest tree over 10m in height estimated and the species recorded.
- Distance to nearest habitation estimated.
- Distance to nearest watercourse over 5m wide, whether dry or flowing, estimated.
- Distance to nearest rock outcrop over 10m in height estimated.
- Distance to nearest gallery forest including trees over 10m in height and a stand length of over 50m estimated.

### **2.1.6 Validation Sites**

Four new sites were chosen to form the basis of a validation dataset in 2006 with which to test models based on data collected in 2004 and 2005. In order to determine whether there were spatial correlations in habitat variables within sites, which could influence the independence of new transects placed for validation purposes, Pearson correlation coefficients of variable values for transects already surveyed, at distances of 200m, 400m, 600m, 800m and 1000m from each other were calculated and univariate General Linear Models were run for each variable with the value at 0m as the dependent variable and covariates being the variable value at the other transect and the distance from the 0m transect. The interaction between the two was also tested, to see if there was a significant difference between the values and if that was dependent on the distance from the original transect.

Laminga Village, with 10 transect groups between 0m and 1000m, Far Laminga, with 8 transect groups, Open Laminga, with 3 transect groups, Vom, with 10 transect groups and Fobur, with 10 transect groups were included in the analysis. In total there were 41 transect groups and 205 values for the transects away from the original transects at 0m. Three transects were missing the number of tree species and total number of trees, hence the difference in error degrees of freedom in Table 2.2. The results of the GLMs for 8 variables are displayed in Table 2.2. Variables followed by “2” are variable values for the transects a certain distance away from the original transect.



Table 2.2. GLM results for habitat distance correlations for 41 groups of transects.

Dependent Variable	Parameter	Degrees of Freedom	F	P	R squared
Shrub cover	Shrub 2	1	26.80	<0.01**	0.46
	Distance	1	0.28	0.60	
	Distance*Shrub2	1	0.45	0.50	
	Error	196			
Number of tree Species	No. tree species 2	1	39.48	<0.01**	0.51
	Distance	1	1.57	0.21	
	Distance*No. tree Sp. 2	1	0.09	0.77	
	Error	193			
Total number of trees	Total no. trees 2	1	5.95	0.02**	0.23
	Distance	1	0.04	0.84	
	Distance*Total no. trees 2	1	1.02	0.31	
	Error	193			
Bare ground cover	Bare ground 2	1	14.41	<0.01**	0.09
	Distance	1	5.51	0.02*	
	Distance*Bare ground	1	6.74	0.01**	
	Error	196			
Short vegetation cover	Short vegetation 2	1	16.76	<0.01**	.011
	Distance	1	4.11	0.04*	
	Distance*Short veg 2	1	5.22	0.02*	
	Error	196			
Tall vegetation cover	Tall vegetation 2	1	24.47	<0.01**	0.20
	Distance	1	3.48	0.06	
	Distance*Tall veg 2	1	4.84	0.03*	
	Error	196			
Leaf Litter cover	Leaf litter 2	1	2.65	0.11	0.01
	Distance	1	1.51	0.22	
	Distance*Leaf litter 2	1	1.66	0.20	
	Error	196			
Rock Cover	Rock cover 2	1	22.43	<0.01**	0.18
	Distance	1	2.62	0.11	
	Distance*Rock cover 2	1	5.89	0.02*	
	Error	196			

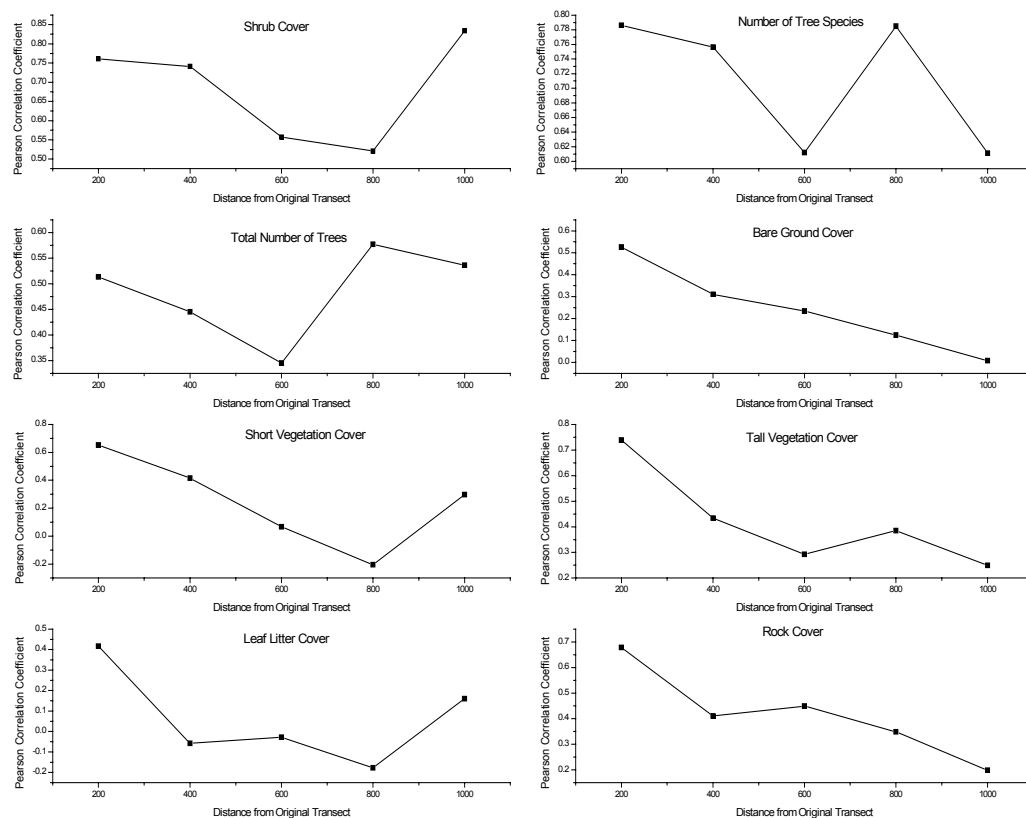


Figure 2.4. Pearson correlations coefficients for values of habitat variables at 0m with those of the same habitat variable at 200m, 400m, 600m, 800 and 1000m from an original transect.

GLMs for Shrub cover, number of tree species and total number of tree species indicated that only the value of the variable on the second transect predicted the value of the dependent variable, there was no effect of distance and no interaction, so correlations between the values of the variable on the different transects did not depend on distance. This is backed up by the charts of Pearson correlation coefficients against distance in Figure 2.4, which show no obvious trend for these three variables. GLMs for bare ground cover and short vegetation cover indicated that the value of the variable on the second transect, the distance between the transects and the interaction between the two all predicted the value of the variable on the original transect. This is also backed up by Figure 2.4, which shows the Pearson correlation coefficients decreasing with distance for bare ground cover and decreasing with distance for short vegetation cover before a rise at 1000m. A similar pattern is seen for the other variables in Figure 2.4 with correlations decreasing with distance overall. Tall

vegetation cover and rock cover also show significant effects of the variable on the second transect and for the interaction in the GLMs but leaf litter cover does not show significant effects for the covariates or the interaction. The variables which show a downwards trend in correlations away from the transect have low R squared values for the GLM, so distance may not be a major factor predicting variation seen between transects for these. There is, however, clearly some evidence of spatial correlation for some variables, so in order to reduce this, new sites were chosen between 800 and 1000m away from the nearest transects that had been surveyed in previous field seasons. The new sites are shown in Figure 2.5.

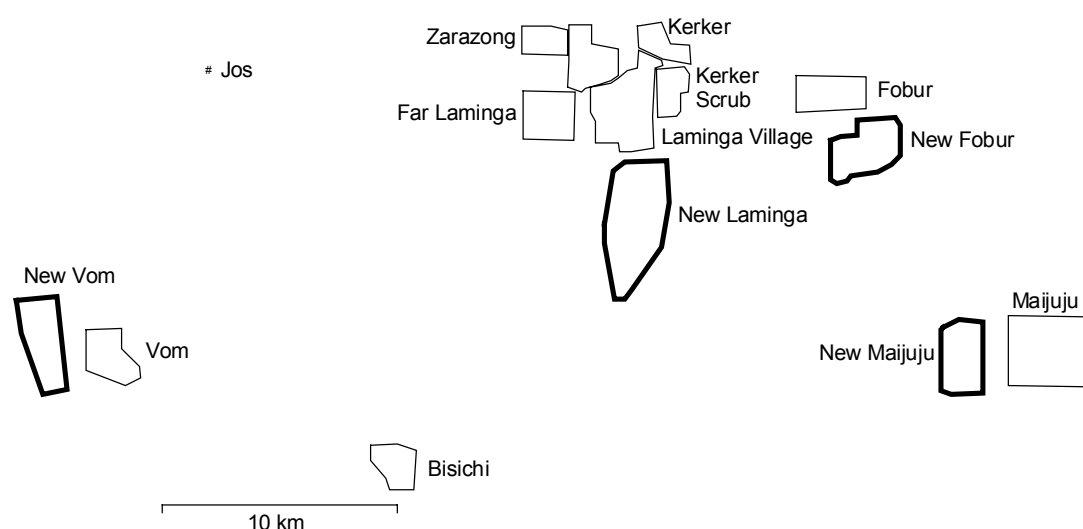


Figure 2.5. All sites surveyed including new sites for validation data outlined in bold.

## 2.1.7 Analysis of Line Transect Data

### 2.1.7.1 Canonical Correspondence Analysis

Correspondence Analysis (CA) and Canonical Correspondence Analysis (CCA) are ordination methods used to visualise patterns in complex multivariate data. Direct gradient analysis, where one set of variables, such as species data at individual sites, or indirect gradient analysis, where two sets of variables are available, such as species and environmental data at each site, are used to summarise data. Ordination methods

can be considered in two ways, either simply to summarise multivariate data in a convenient way in scatter diagrams, hence a technique for matrix approximation, or, assuming an underlying structure in the data, it aims to recover this structure (Jongman et al. 1995). Correspondence analysis constructs a theoretical variable that best explains a set of species abundance or environmental data by choosing the values of the variable for the different samples that maximise the dispersion of the species scores or differences in environmental scores. This is the first CA axis. Further axes can be constructed subject to the constraint of being uncorrelated with previous axes. The first two axes can be displayed as a scatter plot as long as these represent most of the variation in the data. The axes are calculated using a two-way weighted algorithm starting with arbitrary values for each site and conducting iterations that converge to a set of values that do not depend on the initial values (Jongman et al. 1995). Canonical ordination expresses both the pattern of variation in species composition between sites and the main relations between the species and each of the environmental variables measured, combining regular ordination with regression (Jongman et al. 1995). Rather than deriving values for each site of a theoretical variable, CCA selects the linear combination of measured environmental variables that maximises the dispersion of the species scores to give the first axis, and as with CA, subsequent axes are created that are uncorrelated with previous ones. These calculations are carried out using the software CANOCO (Jongman et al. 1995). Both CA and CCA can be subject to the arch effect, a mathematical artefact showing an, often quadratic, relation of the first axis to the second axis. This can be overcome by detrending, which ensures that, at any point along the first axis, the mean value of the site scores on the subsequent axes is about zero. CCAs are used in Chapter 3.

### 2.1.7.2 Diversity Indices

Simpson's diversity index was used to calculate diversity for each transect.

$$D = \frac{1}{\sum_{i=1}^s P_i^2}$$

S=total number of species with distance records

P<sub>i</sub>=proportion for the *i*th species of individuals

Where transects had no observations, diversity was not calculated. Simpson's index was chosen over Shannon-Weaver index as Simpson's does not include a natural logarithm, which in Shannon-Weaver results in transects with only one species having a value of zero.

### **2.1.7.3 Distance Analysis**

To derive variables accurately representing the actual abundance of birds observed on transects Distance sampling was used in order to account for the detection function, the drop-off in the proportion of birds present that are detected as distance from the observer increases (Buckland et al. 2001).

Density estimates of species by transect were calculated using Distance version 5 (Thomas 2006). All transects at all sites conducted between 2003 and 2006 were used to generate detection functions in order to estimate density for each species. Species' records were truncated at the distance to which 95% of individuals were observed. Most birds observed on the transects were treated as clusters of objects, with each group of birds seen having a mean perpendicular distance to the transect and the number of the group included in the analysis. A regression of  $\ln(\text{cluster size})$  against estimated probability of detection at distance  $x$  ( $g(x)$ ) was used to account for any group size detection bias where large clusters are more likely to be detected at greater distances than smaller clusters. Akaike's Information Criterion (AIC) values were used to decide, for each species, the key function (half normal, hazard rate or uniform) and adjustment (none, cosine, simple polynomial or hermite polynomial) for the detection function estimation and the covariates included in the analysis to take into account variation in detectability of birds in different habitats.

Density estimates were calculated for each transect, taking into account the value of the covariate on the individual transects, the distance to the birds viewed, the number of clusters and the cluster size. Effective strip width, the distance from the transect for which as many birds are detected beyond as are missed within the line, is also calculated per transect in order to use this as an offset in the GLMs when density cannot be used (Buckland et al. 2001).

#### **2.1.7.4 Generalised Linear Models**

Generalised Linear Models (GLMs) are generalizations of General Linear Models where link functions can account for non-normal distributions in the dependent variable and are run in the program SAS (SAS 2001). For normal distributions the identity link may be used:  $f(z)=z$ , the canonical, or default, link function for poisson distributions is the log link:  $f(z)=\log(z)$  and for binomial distributions it is the logit link:  $f(z)=\log(z/1-z)$ . These link functions are applied to the dependent variable values so that:

$$f(\mu y)=b_0 + b_1X_1 + b_2X_2 + \dots + b_kX_k$$

Where  $\mu y$  = the expected value of  $y$ , the dependent variable

$b_0$  = regression coefficient for the intercept

$b_i$  = regression coefficients for variables 1 to  $k$  computed from the data

$X_i$  = predictor variables 1 to  $k$

#### **2.1.7.5 Information Theoretic Approach to Model Selection**

The information theoretic approach to model selection is a likelihood-based multiple hypothesis approach to selecting the best models out of a number of possibilities rather than a single or null hypothesis approach leading to the selection of one particular model which is then assumed to represent the best possible explanation of the data under analysis (Burnham & Anderson 2002). The information theoretic approach removes much of the subjectivity inherent in traditional model selection procedures, such as stepwise backwards deletion, because it ranks all possible models, and evaluates variables as predictors within all models (Whittingham et al. 2005). The approach results in robust assessment of significant variables, although its application and description is at best lengthy. Much of the length of this thesis is the result of the use of the information theoretic approach, but as the method represents current best practice in model selection and evaluation such length is unavoidable.

### 2.1.7.6 Selection of Habitat Variables for Generalised Linear Models

Habitat variables recorded as lengths on transects were first selected if their total lengths on all transects was over 1000m. Total transect length overall was 251,375m so it was felt that any crop or habitat that rare could not realistically predict bird occurrence. Variables removed from analysis this way totalled 11765m in length, 4.68% of the total length of transect surveyed.

The 10 crops left for analysis are displayed in Table 2.3. Other variables available are:

- Old farmland aged 1 to 3 years
- Old farmland aged 4 to 6 years
- Total of old farmland aged 1 to 6 years
- Total amount of scrub
- Degraded scrub
- Freshly prepared land
- The proportion of harvested to growing crops.

Table 2.3 Length of crop types occurring on transect.

Crop	Total length of transect
Tomato	1470
Groundnut	1530
Sweet potato	3370
Cassava	4970
White beans	5705
Yam	6109
Sorghum	9705
Millet	16225
Acha	21690
Maize	24360
All crops	94384

A categorical variable “Crop Label” was created with a value determined by whether one of the 10 most common crops were present on the transect and if so which crop composed the greatest length of the transect compared to the other crops present. Any transects with a total crop length of less than 25m were classed as having no majority crop, any majority crop with a total length of less than 25m but with a total length of all crops on the transect of over 25m was classed as “other crop”. For example, if 50m

of the 100m transect passed over a maize field, 25m passed over a millet field and 25m passed over scrubland then the value of the variable would be that corresponding to maize. If 20m of the transect passed over a maize field and 80m over scrub land the value would be that for “no crop” whereas if 20m passed over maize and 25m passed over a soya field the label for “other crop” would apply. This variable was then used in models to determine whether the type of crop or presence of crop had an influence in models it was included in. The *p*-value for each class value in the model output then indicated which crops may be having most effect without the need to include each crop type as a single variable in the model, thus reducing the number of possible model permutations available for model selection.

The other variables considered for modelling were as follows:

- Site
- Year transect walked
- Season (1 to 4)
- Wind strength (0 to 3)
- Cloud cover
- Minutes after sunrise
- Distance to tree over 10m in height
- Distance to nearest habitation
- Distance to nearest watercourse
- Distance to nearest rock outcrop
- Number of tree species on transect
- Total number of trees over 3m in height on transect
- Short vegetation cover
- Medium height vegetation cover
- Tall vegetation cover
- Bare ground cover
- Burnt vegetation cover
- Leaf litter cover
- Rock cover
- Shrub cover
- Green vegetation percentage



This results in 38 variables to be considered for modelling purposes. Site was included as a factor in all models. Year, season, wind, cloud cover and minutes after sunrise are all factors that can influence bird presence independently of the habitat and management variables that this project is interested in, so should all be accounted for in the analysis in order to ensure the effects of the variables of interest in the models are not confounded by seasonal, weather and time of day effects. Figure 2.6 demonstrates the change in bird activity with increasing minutes after sunrise.

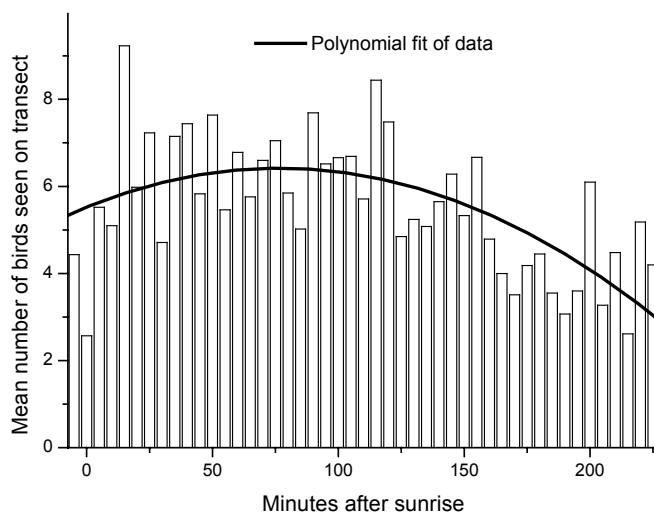


Figure 2.6 Relationship of minutes after sunrise, rounded to the nearest 5 minutes, to number of birds observed within 50m of the transect. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=5.52$ ,  $b=0.03$ ,  $c=-0.001$ ,  $R^2=0.38$ ,  $p<0.01^{**}$ ,  $N=47$  time of day bins.

When validation data are collected in a different year or in different seasons from the data used to generate the models year and season cannot be included in analyses.

There is now a choice of 32 variables to model with.

Non-parametric correlation tests were performed on these variables. There were highly significant correlation coefficients over 0.6 for Spearmans Rho tests for 5 combinations of variables, displayed in Table 2.4.

Table 2.4. Highly correlated variables, correlation coefficient over 0.6

Variable 1	Variable 2	Correlation coefficient
Total number of trees	Number of tree species	0.929**
Shrub cover	Number of tree species	0.779**
Total number of trees	Shrub cover	0.762**
Shrub cover	Scrub	0.680**
Old farmland 1-3 years	Total old farmland	0.608**

There are a number of correlated variables related to woody vegetation density, such as number of trees, number of tree species, shrub cover and scrub, indicating that any models should not contain all of these variables. The variables old farmland 1-3 years old and total old farmland would not be included together in analyses because total old farmland includes all ages of fallow land, so the fact that they are correlated is not a concern. Table 2.5 shows variables with correlation coefficients between 0.4 and 0.6.

Table 2.5. Variables with correlation coefficients between 0.4 and 0.6.

Variable 1	Variable 2	Correlation coefficient
Bare ground	Medium veg	-0.567**
Number of trees	Distance to big tree	-0.546**
Burnt veg	Medium veg	-0.521**
Number of tree species	Distance to big tree	-0.516**
Number of tree species	Scrub	0.515**
Shrub cover	Distance to watercourse	-0.490**
Scrub	Number of trees	0.485**
Number of trees	Scrub	0.485**
Rock cover	Distance to rock outcrop	-0.484**
Distance to watercourse	Scrub	-0.460**
Shrub cover	Distance to big tree	-0.452**
Shrub cover	Distance to forest	-0.440**
Number of tree species	Distance to watercourse	-0.431**
Total old farmland	Scrub	-0.425**
Shrub cover	Rock cover	0.424**
Rock cover	Number of tree species	0.412**
Tall veg	Medium veg	0.408**
Scrub	Rock cover	0.401**

Once more a number of variables relating to woody vegetation are correlated, such as distance to big tree, distance to forest, distance to watercourse, shrub cover, number of tree species and number of trees. Birds may be selecting for or against wooded scrub habitats and the correlations indicate that these variables explain this habitat in a similar way, in which case they do not need to be used in the same models. Rock cover is correlated to distance to rock outcrop, suggesting these variables should not be used in the same models. Medium vegetation is correlated with tall vegetation, bare ground and burnt vegetation, and so combinations of these should also be avoided in models.

From this information, a need to incorporate elements of both farm management and habitat structure, and a desire to limit the number of variables so as to limit the number of candidate models for selection, the following eight variables were chosen to model species richness and bird diversity. Ordination was not used due to a desire not to complicate further the interpretation of the data: although a “neat” composite score might be obtained, what correlations of bird density with this might mean in practical terms would be difficult to assess.

- Crop label
- Total number of trees over 3m in height on transect
- Total old farmland
- Bare ground cover
- Short vegetation cover
- Medium height vegetation cover
- Leaf litter cover
- Rock cover

Although bare ground cover and medium height vegetation cover were negatively correlated, they have been included together because medium vegetation was the most common vegetation height and bare ground has been mentioned as a habitat-selection factor for some species occurring on farmland (Borrow & Demey 2001).

#### **2.1.7.7 Generalised Linear Models Analysis Protocol**

Where data from the line transects were modelled against the habitat variables selected in Section 2.1.7.6 a general protocol for conducting the Generalised Linear Models was used:

In order to ensure the independence of each transect used for model selection only one set of data per transect is used. Those used in the data set were the transects from field season 1 from the 5<sup>th</sup> of March 2004 to the 23<sup>rd</sup> of April 2004, which were repeat visits to the first set of randomly-placed transects, and transects from field season 3 from the 11<sup>th</sup> of February 2005 to the 27<sup>th</sup> of April 2005, which were repeat visits to

the grid transects first placed during field season 2. This also ensures all transects are within the dry season, as are all transects for the validation dataset collected in field season 4 between the 9<sup>th</sup> of January 2006 and the 16<sup>th</sup> of March 2006.

Null models are run of GLMs using a log link function for bird species numbers using a normal distribution and a Poisson distribution. The ratio of residual deviance to residual degrees of freedom in the null model can give an idea as to whether data can be modelled as normal or Poisson, with a ratio closer to 1 being more likely to follow the distribution tested (Crawley 1993). If the Poisson distribution is used the values are rounded to the nearest whole number, as Poisson assumes discrete values, and a log link function used. If a normal distribution is used the identity (no) link function is used. When density cannot be used as the dependent variable for individual species, the count data is used with an offset of “effective area searched” is included to take into account detection variability between transects.

Models are run of all 255 possible combinations of the 8 variables selected for analysis plus minutes after sunrise, cloud cover, wind rating and site. All variables are plotted against the dependent variables and a linear or polynomial fit generated in order to determine if a quadratic term is required due to a non-linear relationship because Generalised Linear Models assume a linear relationship. All variables with quadratic terms are always modelled with the quadratic term in the same model. The ratio of the number of transects to the number of estimated parameters in the global model is  $964/35=27.5$ . Burnham and Anderson (2003) recommend the use of AICc rather than AIC when this ratio is below 40 so AICc is calculated for all models and  $\Delta AICc$  calculated, the difference between the models AICc and the lowest AICc of all models run. The model with the lowest AICc is judged to be the strongest model. Models are ordered, with the lowest  $\Delta AICc$  first, in ascending order. Akaike weights are calculated for models and individual variables and a 95% confidence set of the best models, with Akaike weights adding up to just greater than or equal to 0.95, is calculated.

In order to determine the Akaike weight for a variable below which it could be considered not to have an effect on the model, a random variable is included in the model (Whittingham et al. 2005), generated in SPSS (SPSS 2002), consisting of

values for all transects, with a normal distribution and a mean and standard deviation the same as the variable with the highest Akaike weight. The Akaike weight for this variable is calculated by running all possible models, as above, and this is repeated 20 times, with different random values being generated each time. As a conservative approach any variables with an Akaike weight below the mean plus two times the standard error of that for the random variable can be considered to be of little importance in the model.

Parameter estimates for the top-ranked model are investigated, along with standard errors and Wald chi-squared values and associated  $p$ -value, calculated using parameter estimates, indicating their effect in the overall model. If a column of the model matrix corresponding to a parameter is found to be linearly dependent, or aliased, with columns corresponding to parameters preceding it in the model, it is assigned zero degrees of freedom and displays zero for both the parameter estimate and its standard error. Type 3 chi square values are included, which uses likelihood ratios to estimate the significance of the effect of a covariate or whole factor on the overall model.

Model averaged estimates of predicted values are calculated for each transect in the validation dataset. Predicted values are calculated for each transect surveyed between the 9<sup>th</sup> of January 2006 and the 16<sup>th</sup> of March 2006 using each possible model, which were then weighted by multiplying by the Akaike weight for that model as calculated above. For each transect the sum of all these 255 values is the model averaged predicted value. These weighted values are then plotted against the observed values from the same transects and a linear regression and either Pearson's (parametric) or Spearman's rho (non-parametric) correlation coefficient calculated to determine the direction and strength of the relationship and thus the predictive power of the models.

## **2.2 Farmer Questionnaires**

Farmers were interviewed at each site that was covered in the field seasons February-May 2005 and January-March 2006. An interviewer, either myself or Mary Molokwu, was accompanied by a field assistant, Chris Nyam, who translated. In total 44 farmers

were interviewed who farmed land within the different transect sites: 5 at Fobur, 21 at Laminga, 11 at Maijuju and 7 at Vom. It was not possible to map the sites of the fields the farmers surveyed and resources did not permit a system of randomisation. The farmers who were interviewed were suggested by Chris Nyam and the chiefs of the local villages as representative of large and small-scale local farmers. Biases in the scale of the farms and farming methods used may be present due to the subjective nature of the selection of farmers and the fact that data on exactly what proportion of the study sites the farmers' land represented, but all farms were within or adjacent to the study areas described in the transect data.

The date, site, farmers name, sex and age were recorded. The following questions were asked:

- How many bags of artificial fertiliser do you buy per year?
- What is the name of the artificial fertiliser you buy?
- How many bags of manure do you buy per year?
- Do you apply manure from your own animals?
- Do you apply ash?
- What livestock do you own?
- Do you graze animals on your fields for manure?
- How much do you pay to graze animals?
- Which months do animals graze on your fields?
- What are pests on your fields?
- Do you do anything to prevent pests damaging crops?
- Do you buy pesticide?
- What is the name of the pesticide you buy?
- To which crops do you apply pesticide?
- How many bags/measures of pesticide do you buy per year?
- Do you burn all fields? How often do you burn the fields?
- How many years do you farm a field before resting it?
- How many years do you rest fields for?
- Who helps you on your farms?

For each crop planted the following was asked:

- Number of fields grown of crop
- Months of the year crop sown
- Months of the year crop harvested
- Number of measures of seed sown, number of tubers planted or length of ridges
- Number of years crop sown in same field
- Is manure applied?
- Is artificial fertiliser applied?
- Was crop sold at market last year? If so was all, most, half or only excess sold?

### ***2.3 Crop Field Observations***

The area of farmland around the village Laminga on the Jos Plateau, close to the AP Leventis Ornithological Research Institute, 09°52.7'N, 08°58.7'E, was chosen as a study site as it represents an intermediate intensity of farming with all four major crop types commonly cultivated. Four routes around the Laminga area were walked six times each between 15.00 and 18.00 from January to March 2005, with the direction walked reversed on alternate visits to control for the time of day. Each route consisted of a number of acha, maize, millet and yam fields, as seen in Figure 2.7. Each field was walked in a systematic manner, so that the entire area of the field was covered within 10m of the observer, and birds viewed in the field, either on the ground or perched on stems within the field boundaries, were identified and counted. The distance to the nearest edge habitat, defined as shrub stands greater than 5m in length, trees greater than 5m in diameter or rocks greater than 5m long at their longest point, was measured using a Leica laser range-finder.

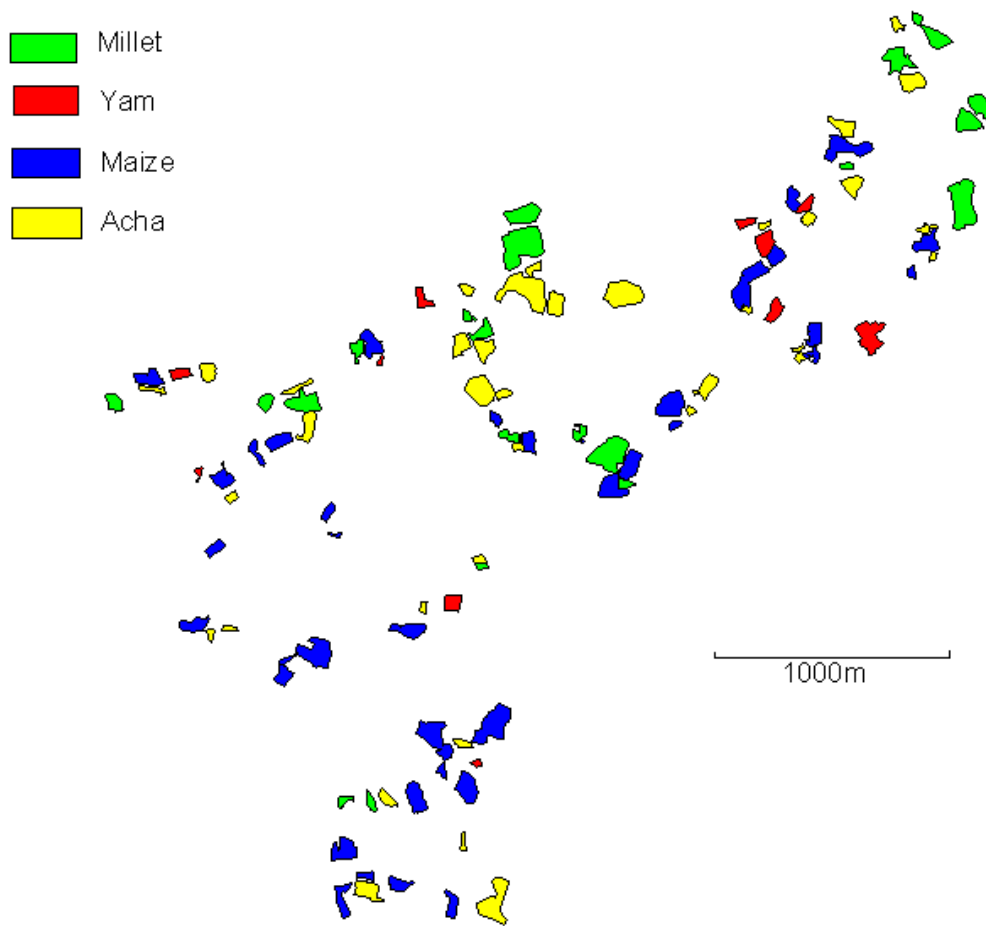


Figure 2.7 Fields included in the routes walked around Laminga, Jos Plateau. The four crop types are displayed.

For each field a GPS was used to map the border of the field and the length of the border consisting of edge habitat, as defined above, was measured. The number of trees with the trunk within the field border and the maximum width of each tree canopy were recorded. The area of the field was calculated, along with the proportion of the field border length consisting of edge habitat. Where trees were present within the field, but were not part of the field border, the longest width of the canopy of each tree was measured, the sum of the canopy widths for all trees was added to both the total field border and the total length of edge habitat and the proportion of edge habitat was calculated using these values.

The data was analysed using Generalised Linear Models and models selected using AICc values, as described in Sections 2.1.7.4 and 2.1.7.5. Due to the small size of the fields and the systematic nature of the counting methods it was assumed that all birds in the fields had been recorded: no part of a field was over 10m from the observer,



and consequently disturbance by the observer resulted in the flushing of birds, removing any possible detection bias between crop types due to differing sward heights and densities. The density of each species of bird in each field was thus calculated as the number of birds observed per hectare of field. The mean from the 6 visits to each field was calculated for the number of species per hectare and the density of each species observed per hectare. These values were used as the dependent variable with the total area of each field and the proportion of edge habitat as independent covariates, both being linearly related to the dependent variables, and crop type as a fixed factor, with all interactions. The dependent variables all contained a number of zero values, so that when field means were rounded to integers, a closer fit to the Poisson distribution than the normal distribution resulted (as measured by proximity to 1 of the ratio of residual deviance to residual degrees of freedom in the null model (Crawley 1993)). All possible 17 models were run with a Poisson distribution and log link function and AICc values weights were calculated for each model, variable and interaction. A mean random variable weight for each species, calculated from 20 runs of models including a random variable with a normal distribution and a mean and standard deviation equal to that of the continuous variable with the highest Akaike weight for that species, was also included in the model. Two standard errors were added to the weight of the random variable to provide an indication of the minimum weight each variable in the models should have to be considered as having an important influence.

## ***2.4 Whinchat Behavioural Observations***

Between February and April 2005 and January and March 2006, between sunrise and 10am, whinchats were located around Laminga and Vom on the Jos Plateau and focal observations conducted of their behaviour.

The habitat type the bird was in was recorded along with the number of perch changes, the number of times it went to the ground, the amount of time spent on the ground, the number of pecks made whilst observed on the ground and the amount of time spent in the habitat. Any prey viewed in the bill was noted and identified if possible, and any area where the bird was viewed pecking was examined after the observation for colonies of insects such as ants and termites. The observations were

limited to a minimum of 2 minutes before the bird was lost and a maximum of 10 minutes before the observation was terminated and a new bird was located. At the end of the observation the distance between the two perches the furthest distance from each other was measured. The final perch the bird was viewed on was recorded and the height of the perch in cm measured. A random direction from the perch was chosen by throwing a stick and 10m measured in that direction. The height of nearest potential perch over 20cm tall was measured.

Once an observation was completed a new whinchat was located at least 50m away from where previous observations had taken place in order to decrease the chance of recording observations from the same un-ringed individuals. Observations were not attempted if the wind rating was over 4, as defined in section 2.1.4 as wind moving the larger branches of trees.

When a bird went out of sight during a perch change or when flying up from the ground the observation was stopped at the point at which the bird was lost. Whinchats were generally widely spaced in the environment, so when an observed bird was out of sight on the ground and a bird was subsequently viewed on the ground, or flying up from the ground in the same area, this was assumed to be the bird originally observed, the observation was continued and the time spent out of sight on the ground was included in the total time spent on the ground for that observation.

The habitats were defined as crop, with crop type and whether the crop was growing or harvested specified, land farmed within the last 3 years, scrub, degraded scrub and land recently prepared for agriculture.

For each observation the habitat the bird spent the greatest amount of time in was used, as long as this was over 2 minutes, with the data for other habitats not included in the analysis. For each observation the proportion of time the bird spent on the ground, the number of sallies to the ground per minute, the number of perch changes per minute and the number of pecks per minute viewed on the ground were calculated. For each observation where the bird spent the whole time in one habitat type the furthest distance moved per minute of the observation was calculated.

Regressions of the behavioural variables against the duration of an observation period resulted in non-significant relationships for proportion of time on ground ( $F_{1,115}=0.14$ ,  $p=0.71$ ), number of sallies to ground ( $F_{1,115}=0.03$ ,  $p=0.85$ ) and number of pecks per minute viewed on ground ( $F_{1,80}=1.41$ ,  $p=0.24$ ), and so for these variables it was considered justified to use values for all the observations irrespective of their duration because there were no biases due to variation in observation duration. There was, however, a significant negative relationship for number of perch changes per minute ( $F_{1,115}=14.26$ ,  $p<0.01^{**}$ ) with observation duration due to the fact that a bird will change perch at least once in a habitat if it leaves that habitat so leading to a positive bias for perch changes where the observations are of a shorter duration so this variable was not used in the analyses. There was also a significant negative relationship for the mean furthest distance moved per minute of observation ( $F_{1,57}=46.31$ ,  $p<0.01^{**}$ ). This was probably because those whinchats which moved the most were also those which were the most difficult to follow and so were more easily lost before 10 minutes had passed. In light of this it was decided that there would be a bias towards observations of birds which did not move far if all observations under 10 minutes were removed, so the mean values of all observations over 2 minutes in length were used.

To normalise the data the proportion of time on the ground was arcsine transformed, the mean number of pecks per minute viewed in the ground had 1 added to account for zero values and the result log transformed and the mean furthest distance moved per minute were log transformed. The mean number of sallies to ground per minute was left unchanged.

## **Chapter 3 Farmland and Bird Communities on the Jos Plateau**

### ***3.1 Introduction***

The results presented in this Chapter describe an environment, on the Jos Plateau, which is highly impacted by human activities, with a gradient of farming intensities. This gradient correlates with differing avian communities, with savanna and woodland species associated with less intensive farmland with more remnant trees and shrubs, whilst more open-country, grassland species are associated with more intensively farmed, open environments. Species within these broad groups vary greatly in the specific farmland habitat types they occur on. These data provide a good basis and justification for the more detailed studies presented in subsequent chapters, as the variation observed is required for an understanding of how birds associate under different levels of agricultural activity.

Biodiversity on farmland is important for conservation. We need to understand how birds use farmland so that we can manage it to promote biodiversity, but key to this must be understanding the human requirements from the land. This might be particularly so in Africa where many people practise subsistence agriculture as well as growing cash crops for sale and where these farming systems are not very well documented in many areas. This chapter describes the farming systems in place at the different study sites where birds were surveyed.

As described in Chapter 1, population growth and migration, social change, the introduction of cash crops and policies adopted by colonial and post-colonial governments have greatly affected the sustainability of indigenously developed farming systems in West Africa (Gyasi & Uitto 1997). Farming activity on the Jos Plateau mostly consists of smallholdings with both subsistence agriculture and crops grown for sale at local markets. The climatic conditions of the Plateau enables the production of a wide range of foodstuffs. Temperate fruit and vegetables in particular, which are not easily cultivated in many areas of West Africa, have become important cash crops, involving irrigation during the dry season (Porter et al. 2003). The produce is sold locally, transported to Jos urban markets or further to other parts of

Nigeria, Niger and Chad. Cereal crops are grown during the rains, and tuber crops throughout the year, mostly for subsistence but also for sale, though less profitably than for dry season crops. Cattle and sheep grazing is carried out by various communities (Porter et al. 2003). There is little literature on the proportion of effort given over to different crops, exactly how they are managed or the products applied to them on the Jos Plateau, and no literature on the bird communities present on this agricultural land.

This chapter aims to describe, using line transect data and farmers' questionnaires, the habitat present on agricultural land on the different sites studied on the Jos Plateau and the management practices employed in the use of this land on the different sites. A general description of the bird community present on agricultural land, and which will be studied in greater detail in subsequent chapters, will also be presented. This is the first step in describing farmland as a habitat for birds and how avian diversity results from anthropogenic effects. Due to the lack of previous work describing farmland on the Jos plateau in a quantitative way with respect to bird habitats this chapter is predominantly descriptive, and acts as a baseline for future studies as well as providing a background to put later chapters into context.

### ***3.2 Materials and Methods***

Line transects were carried out with birds and habitat variables recorded as described in Section 2.1 and farmers questionnaires were conducted as described in Section 2.2.

Field season 3, transects surveyed between February and April 2005, were used as a snap-shot to summarise transect habitat data and compare between sites as it represented transects only surveyed once during that period and was also during the mid to late dry season when the majority of transects were conducted during the study. This enables comparisons between sites to be relatively unaffected by seasonal differences and changes of crops sown on the same land between years.

Detrended correspondence analysis, as described in Section 2.1.7.1, was performed on transects from field season 3, detrended to account for the arch effect. Analyses were conducted using values for 15 different habitat variables, creating a plot with all 15

variables, and on the transects from each site, creating a plot of all transects from each site. The variables included are percentage short, medium and tall herbaceous vegetation cover, percentage bare ground, leaf litter, burnt vegetation, rock and shrub cover, number of trees, number of tree species, distances to the nearest rock outcrop, habitation, gallery forest, watercourse and tree over 10m in height. Transects with similar habitat types and in similar landscape situations should cluster together in the site plots and variables with similar values on the same transects should cluster together on the variables plot.

Canonical Correspondence Analysis, with no need for detrending, was carried out on count data for all transects for the 68 most common bird species with four habitat variables; the total length of transect made up of active crop fields, old farmland and scrub habitat and the percentage cover of rock habitat on the transect.

## 3.3 Results

### 3.3.1 Farmer Questionnaires

#### 3.3.1.1 Crop types

Transects and farmer questionnaires resulted in at least 36 different crops being identified as cultivated on the study sites, which are listed in Table 3.1.

Table 3.1. Crop types recorded on transects and in farmer interviews.

Common name	Local name	Scientific name
Acha/Fonio	Acha	<i>Digitaria exilis</i> or <i>iburua</i>
Aubergine	Garden egg	<i>Solanum melongena</i>
Bambara groundnut	Bambaranut	<i>Vigna subterranea</i>
Bell pepper	Red or green pepper	<i>Capsicum annum</i>
Cabbage	Cabbage	<i>Barassica oleracea</i>
Carrot	Carrot	<i>Daucus carota</i>
Cassava	Cassava	<i>Manihot esculenta</i>
Cocoyam	Cocoyam	<i>Colocasia sp.</i>
Coffee	Coffee	<i>Coffea arabica</i>
Cucumber	Cucumber	<i>Cucumis sativus</i>
Ginger	Ginger	<i>Zingiber officinale</i>
Green bean	Green bean	<i>Phaseolus vulgaris</i>
Groundnut	Groundnut	<i>Apios americana</i>
Jute	Jute	<i>Corchorus olitrius</i>
Lemon	Lemon	<i>Citrus limon</i>
Lettuce	Lettuce	<i>Lactuca sativa</i>
Maize	Maize	<i>Zea mays</i>
Okra	Okra	<i>Abelmoschus esculentus</i>
Onion	Onion	<i>Allium cepa</i>
Pearl millet	Millet	<i>Penissetum typhoides</i>
Plantain	Plantain	<i>Plantago major</i>
Potato	Irish potato	<i>Solanum tuberosum</i>
Pumpkin	Pumpkin	<i>Cucurbita sp.</i>
Radish	Radish	<i>Raphanus sativus</i>
Rice	Rice	<i>Oryza sativa</i> or <i>glaberrima</i>
Sorghum	Guinea corn	<i>Sorghum bicolour</i>
Soya beans	Soya beans	<i>Glycine max</i>
Spinach	Spinach	<i>Spinacia oleracea</i>
Sweet potato	Sweet potato	<i>Ipomoea batatas</i>
Tomato	Tomato	<i>Lycopersicon esculentum</i>
Water yam	Water yam	<i>Dioscorea alata</i>
White beans	White beans	<i>Vigna unguiculata</i>
Yam	Yam	<i>Dioscorea rotundata</i>
	Benoi beans	Unknown
	Tamba	Unknown
	Riziga	Unknown

Figure 3.1 shows the total number of metres of transect passing through the 12 most common crop types for all transects conducted between February and April 2005 whereas Figure 3.2 displays the number of farmers, out of 45 interviewed, who farmed each crop. Acha, maize, millet, sorghum, yam, white beans, groundnut and sweet potato made up the largest proportion of the transects whilst maize, yam, bell pepper, white beans, sorghum, cocoyam, millet, tomato, cassava, acha and groundnut were cultivated by over half the farmers questioned, indicating the smaller area taken up by fields of tomato and bell pepper. Other crops played a less important role in terms of area and were not as commonly farmed. This indicates that acha, maize, millet, sorghum and yam may be the most interesting crops for this study because they both make up a large proportion of the area farmed in the sites and are also cultivated by a large proportion of farmers.

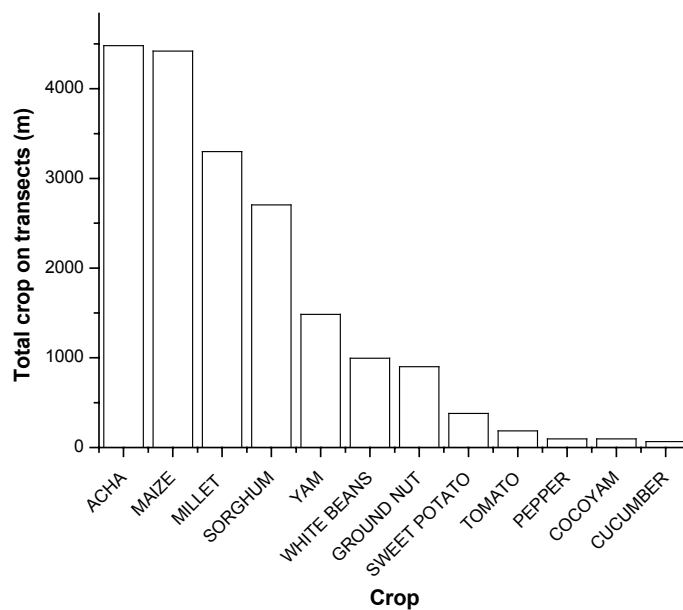


Figure 3.1. Total length of transect consisting of crops, field season 3.



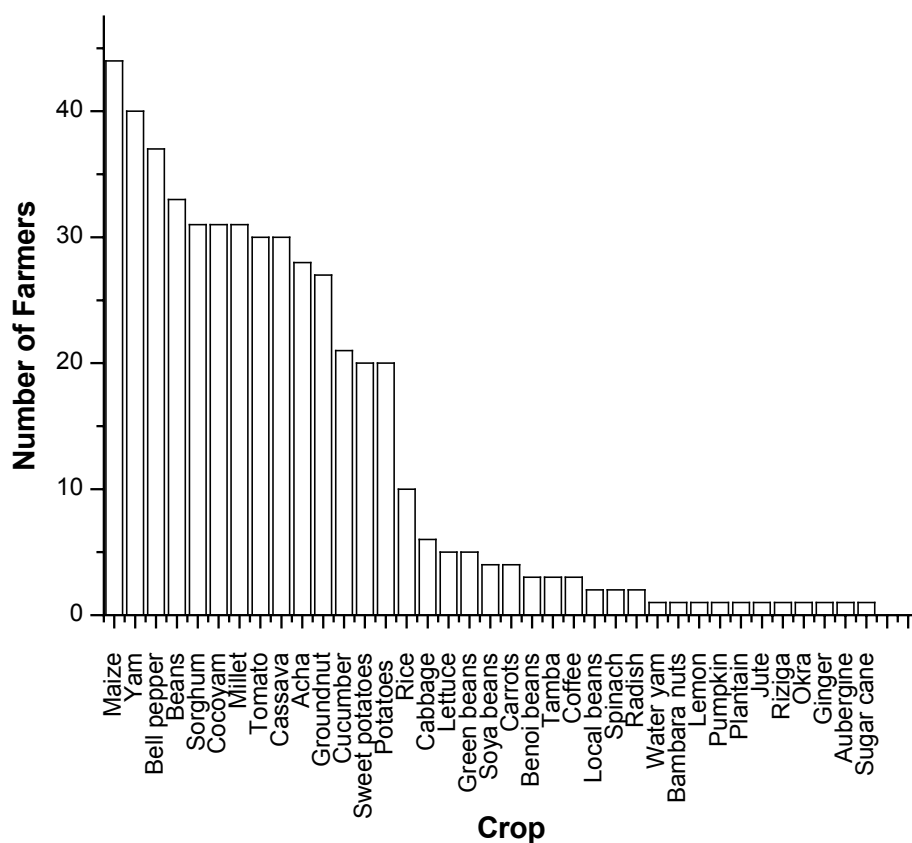


Figure 3.2. Number of farmers farming each crop, out of 45 interviewed.

Figure 3.3 and 3.4 display the months that different crops are sown and harvested by the farmers interviewed. Acha, maize, millet, sorghum and white beans are wet season crops sown between April and July and harvested between October and December, with groundnut sown between April and June and harvested between July and October. Bell pepper and tomato can be farmed throughout the year but there is a peak during the late wet season and early dry season, and are mostly irrigated by hand or pump. Cassava is planted between April and September and harvested at the same time the following year. Yam is mostly planted in January and harvested around August the same year.

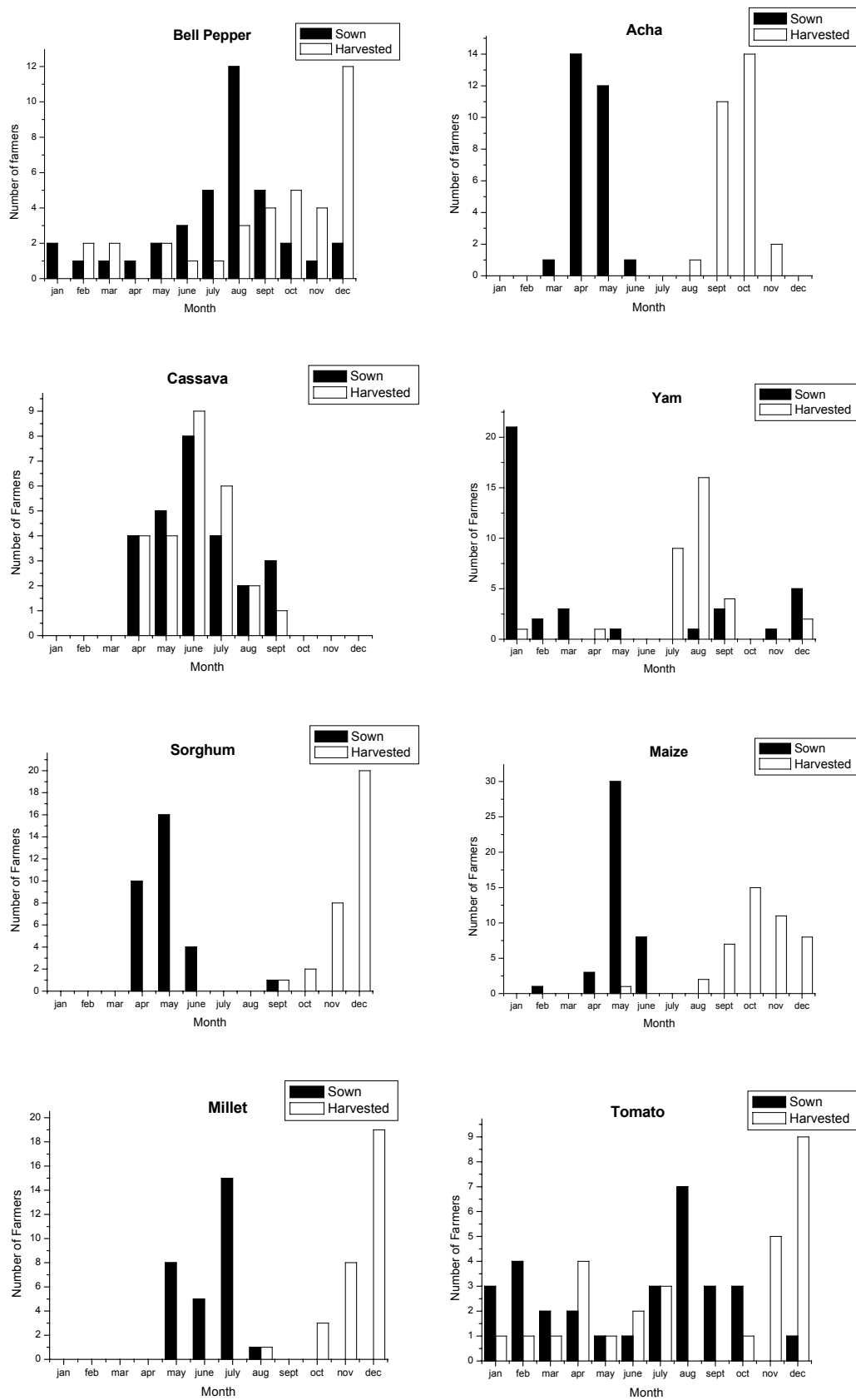


Figure 3.3. Months crops initially sown and harvested, from farmer interviews.

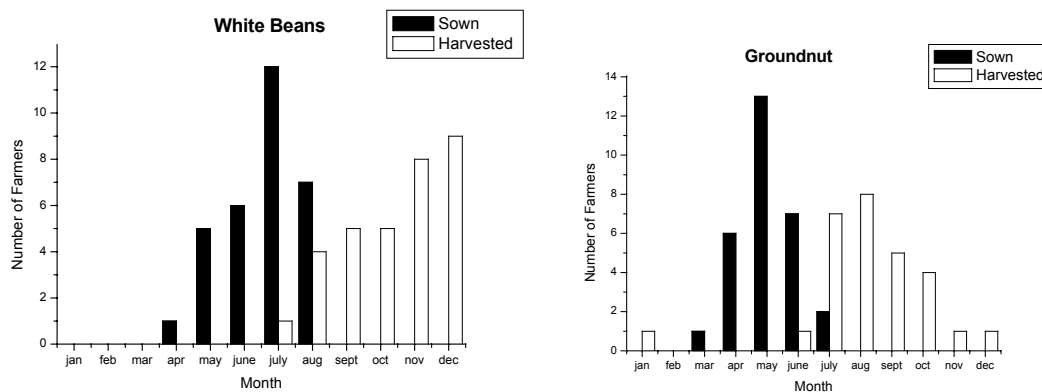


Figure 3.4. Months crops initially sown and harvested, white beans and groundnut, from farmer interviews.

### 3.3.1.2 Site differences

Figure 3.5 shows the proportion of transects conducted during field season 3 in the four main sites consisting of currently farmed land, land farmed within the last 6 years but not currently farmed, scrub land, degraded scrub land and any other habitat type. Fobur appears the least intensive site with just 44% of transects, on average, made up of farmed or recently farmed land, whereas in Vom nearly 99% of land on the transects has been farmed within the last 6 years. Laminga Village and Maijuju transects consist of 62% and 65% recent farmland, respectively, and 20% and 30% scrub land, respectively, so both appear to be of medium intensity in comparison to Fobur and Vom. This indicates that the sites chosen do represent different levels of farming intensity.

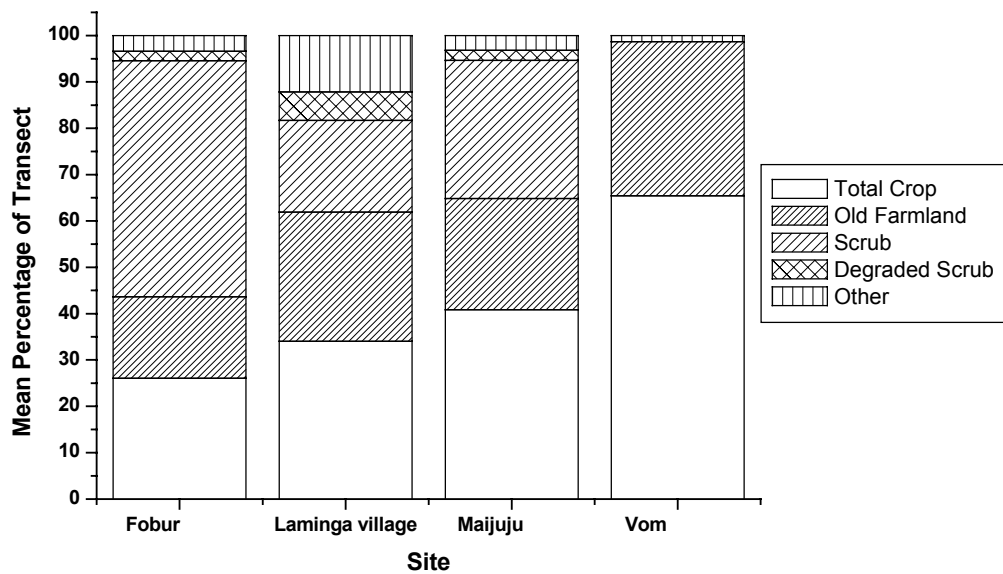


Figure 3.5. Proportion of transects farmed and not farmed by site. Field season 3, 2005.

The proportion of common crops at the four main sites are displayed in Figure 3.6. Maize and sorghum are the most common crops in Fobur, with low occurrence of millet and acha and relatively high occurrence of groundnut and sweet potato. Laminga, on the other hand, has a high occurrence of maize, acha, yam and millet and low sorghum and groundnut, Maijuju has particularly high sorghum occurrence, high yam, white bean and groundnut and low acha, maize and sweet potato. Vom has very high occurrence of acha and millet, making up, on average, 35% and 16% of each transect respectively, high occurrence of maize and low occurrence of all other crops. No yam fields were encountered on any transects in Vom. One way ANOVAs were performed for each crop displayed in Figure 3.6 for percentage of transect by site. Maize ( $F_{3,463}=1.8$ ,  $p=0.15$ , ns) and sweet potato ( $F_{3,463}=2.1$ ,  $p=0.10$ , ns) were non significant for differences between sites but acha ( $F_{3,463}=67.7$ ,  $p<0.01^{**}$ ), millet ( $F_{3,463}=16.6$ ,  $p<0.01^{**}$ ), sorghum ( $F_{3,463}=20.0$ ,  $p<0.01^{**}$ ), yam ( $F_{3,463}=5.3$ ,  $p<0.01^{**}$ ), white beans ( $F_{3,463}=4.4$ ,  $p<0.01^{**}$ ) and groundnut ( $F_{3,463}=7.9$ ,  $p<0.01^{**}$ ) were all highly significant for differences between sites. This shows that as well as differences in intensity encountered at the sites the farms also differ in crop composition.

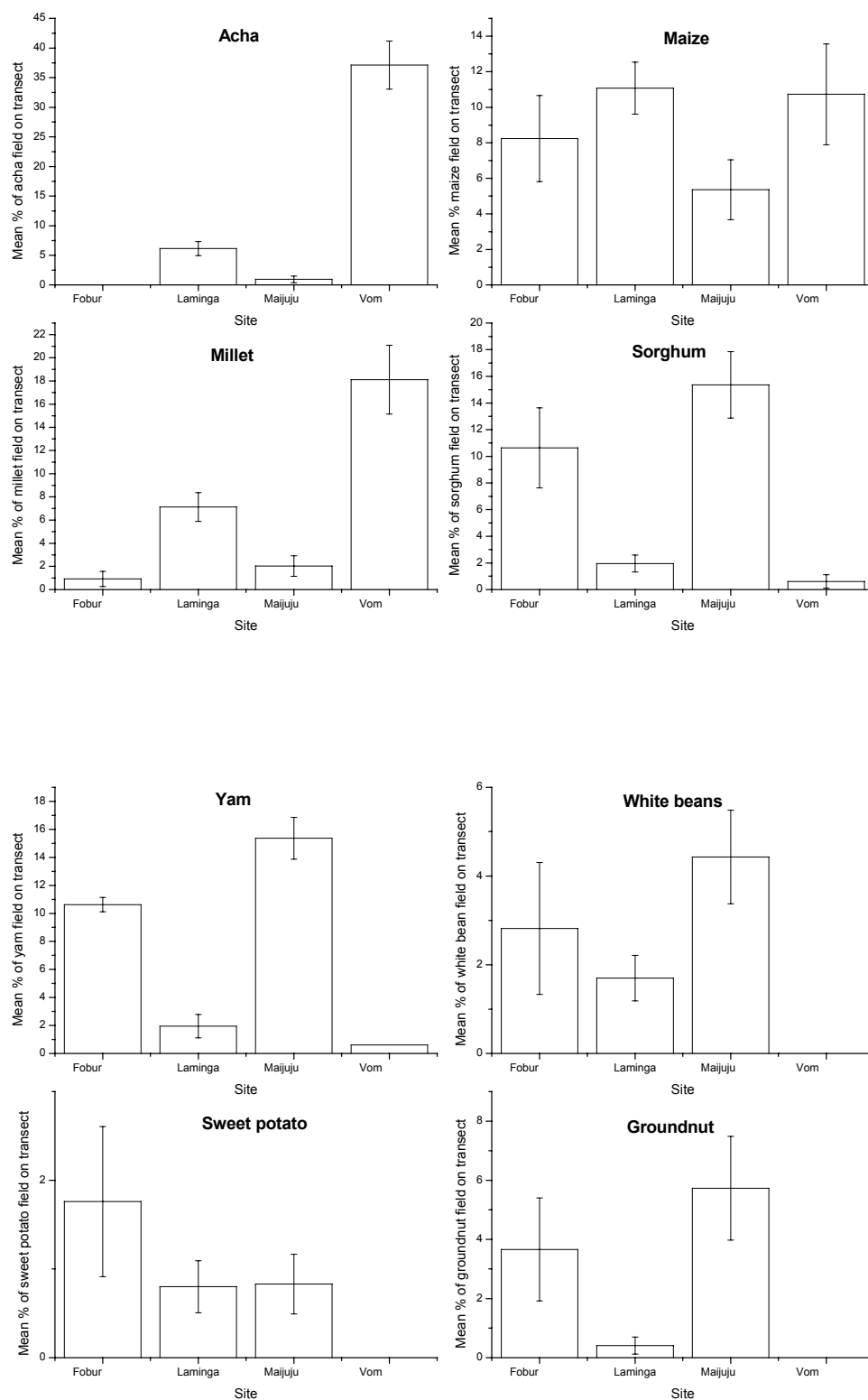


Figure 3.6. Crop occurrence per transect by site. Bars are  $\pm 1$  standard error.

Farmer questionnaires indicate that farms are larger in Vom than in the other sites, Figure 3.7 showing an average of 27 fields per farmer interviewed,  $n=7$  compared with 9 per farmer in Fobur,  $n=5$ , 18 in Laminga,  $n=20$ , and 14 in Maijuju,  $n=7$ , further indicating that farming in Vom is on a more intensive scale and in Fobur on a less intensive scale. One way ANOVA analysis supports the differences between the means,  $F_{3,35}=4.7$ ,  $p<0.01^{**}$

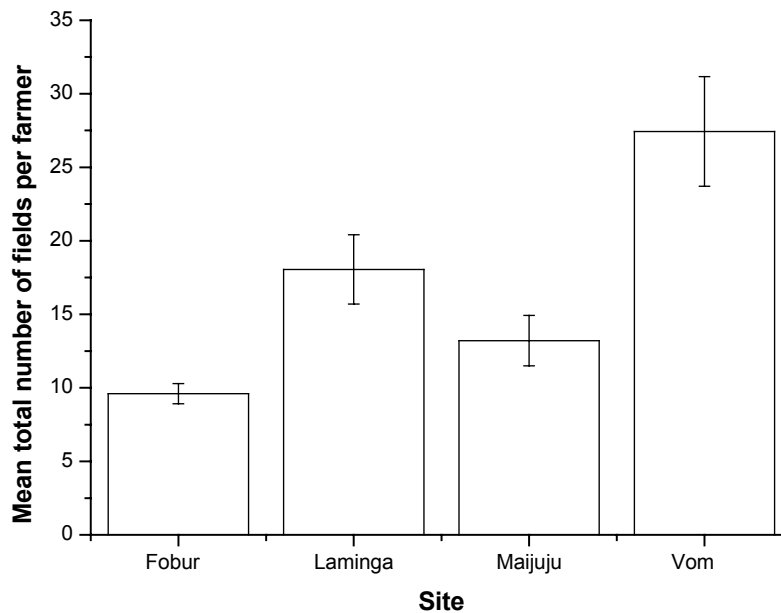


Figure 3.7. Mean number of fields cultivated per farmer by site. Bars are  $\pm 1$  standard error.

Of 45 farmers interviewed 44 used artificial fertiliser. The number of bags of fertiliser applied per field if fertiliser was applied to a field did not differ significantly between sites (One way ANOVA:  $F_{3,33}=2.1$ ,  $p=0.12$ , ns).

Of 45 farmers interviewed 41 applied manure to their fields, of these 29 used purchased chicken manure. The number of bags of manure applied per field if manure was applied did not differ by site (One way ANOVA:  $F_{3,29}=0.5$ ,  $p=0.69$ , ns).

The mean number of years fields were left fallow did not vary significantly between sites (One way ANOVA  $F_{3,39}=1.2$ ,  $p=0.32$ , ns).

Farmers were asked in the questionnaire, for each crop type, if they sold none, and they and their family consumed all that was grown, if they sold just the excess that

was not consumed, if they sold most of what was grown or if they sold all of what was grown. Figures 3.8, 3.9 and 3.10 display the results of the farmers' answers overall by crop and overall by site. Figures 3.8 and 3.9 shows results for the most commonly grown crops over all sites. Bell peppers, tomatoes, groundnut and cassava were mostly sold at markets rather than grown for consumption. Acha, maize, millet, sorghum and sweet potato were mostly grown for home consumption, normally only the excess was sold. White beans and cocoyam were grown for home consumption but were also commonly sold at the market, whereas yam was rarely sold, most farmers consuming all the harvest.

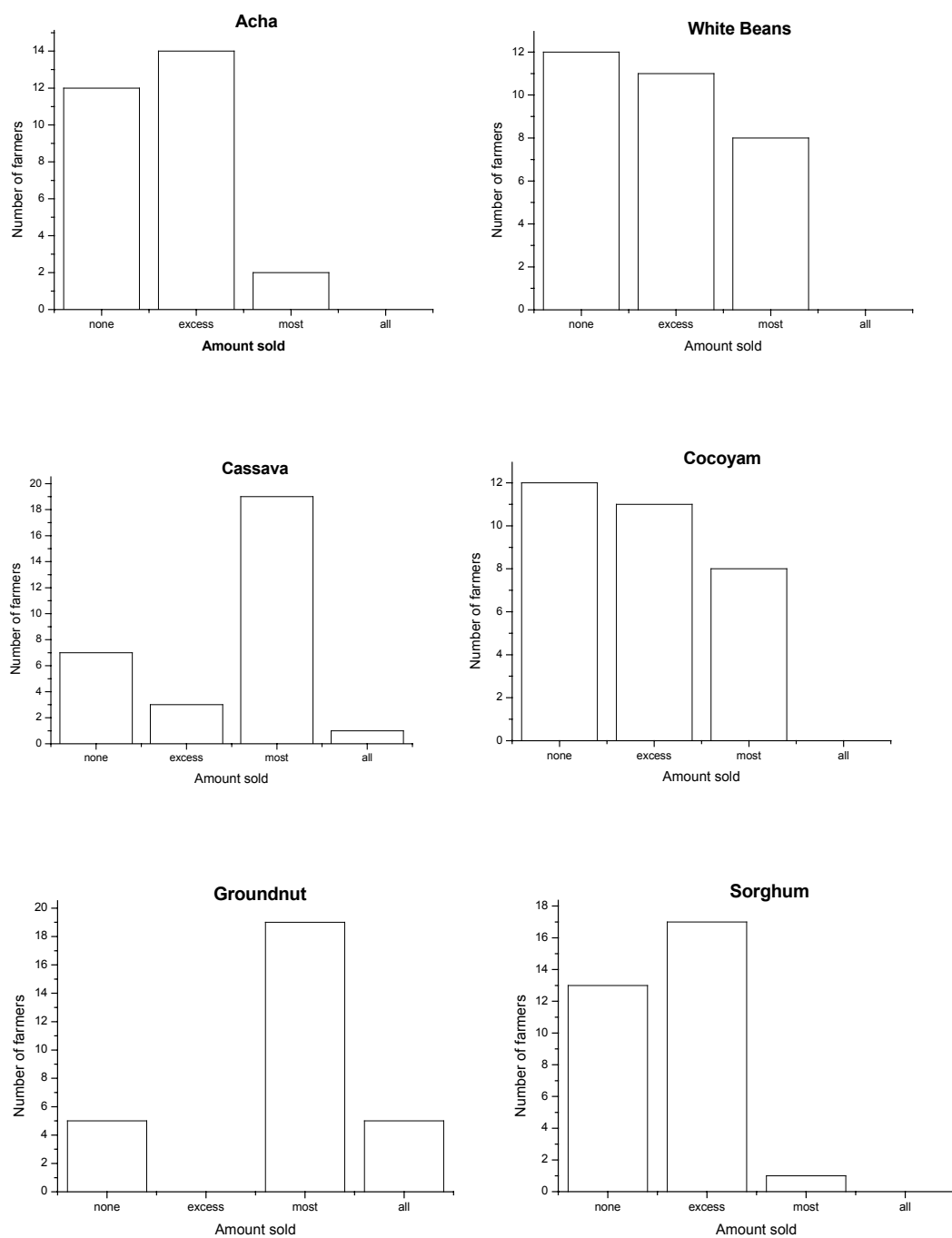


Figure 3.8. Amount of crop sold by farmers, across sites.



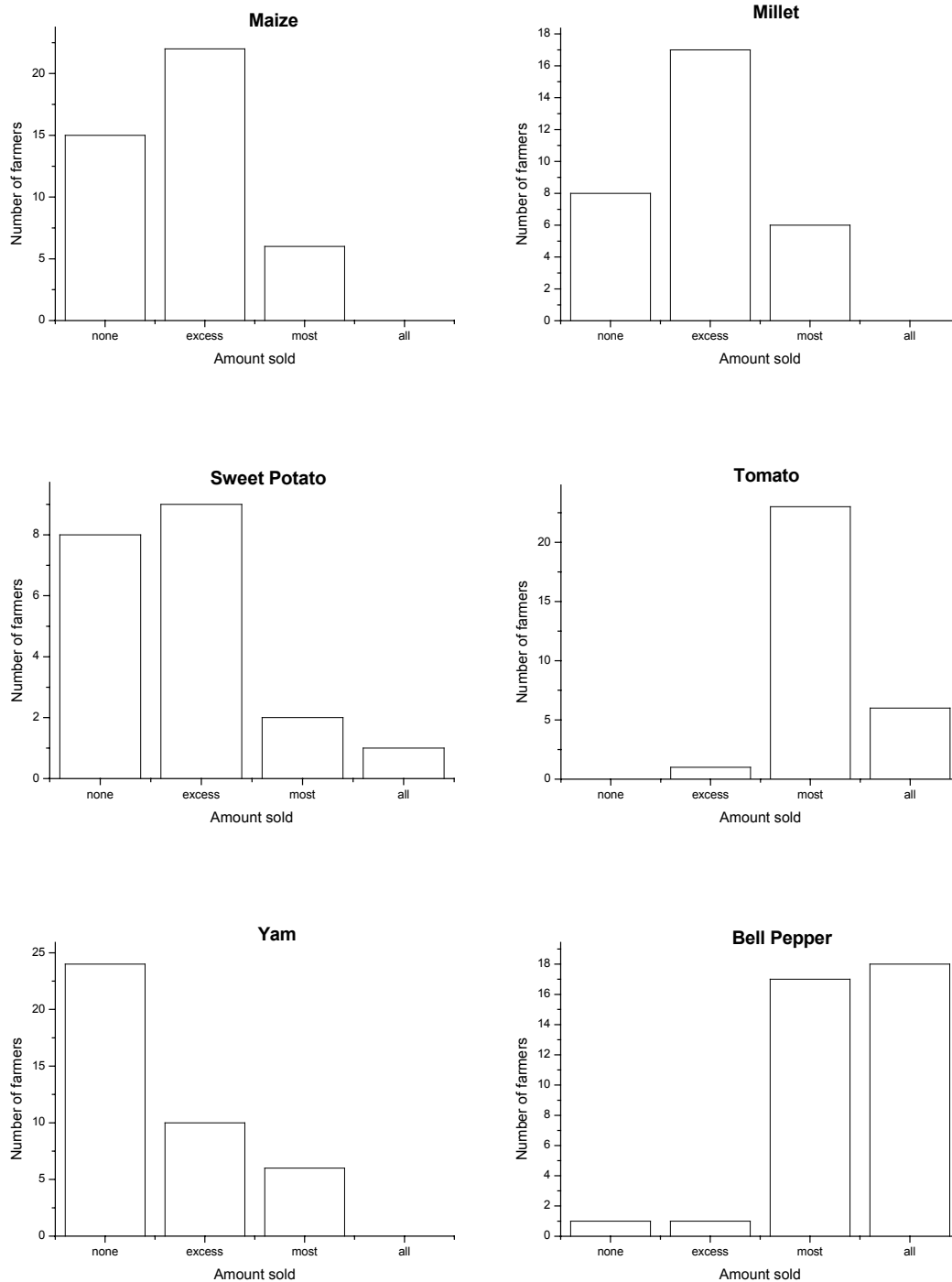


Figure 3.9. Amount of crop sold by farmers, across sites.

Figure 3.10 shows the proportion of crops sold in differing amounts by farmers at the different sites. There is a marked difference between sites in the proportion of crops not sold at all and the proportion where only the excess is sold, with relatively less not sold, one way ANOVA  $F_{3,495}=7.1$ ,  $p<0.01^{**}$ , and more excess sold, one way ANOVA  $F_{3,495}=6.9$ ,  $p<0.01^{**}$  at Fobur and Vom than at Laminga and Maijuju. There is no

significant difference between sites for proportion of crops where most are sold, one way ANOVA  $F_{3,495}=0.2$ ,  $p=0.90$ , ns, or proportion of crops which are all sold at the market, one way ANOVA  $F_{3,495}=1.9$ ,  $p=0.14$ , ns. This indicates that Laminga and Maijuju are similar in terms of the proportions of crops sold at markets, which may be expected if they have similar farming intensities, as has been suggested in Figure 3.5, but Vom and Fobur also show similar patterns of crops sold, which differs from that of Laminga and Maijuju, which may be surprising considering the differences in farming intensities indicated above.

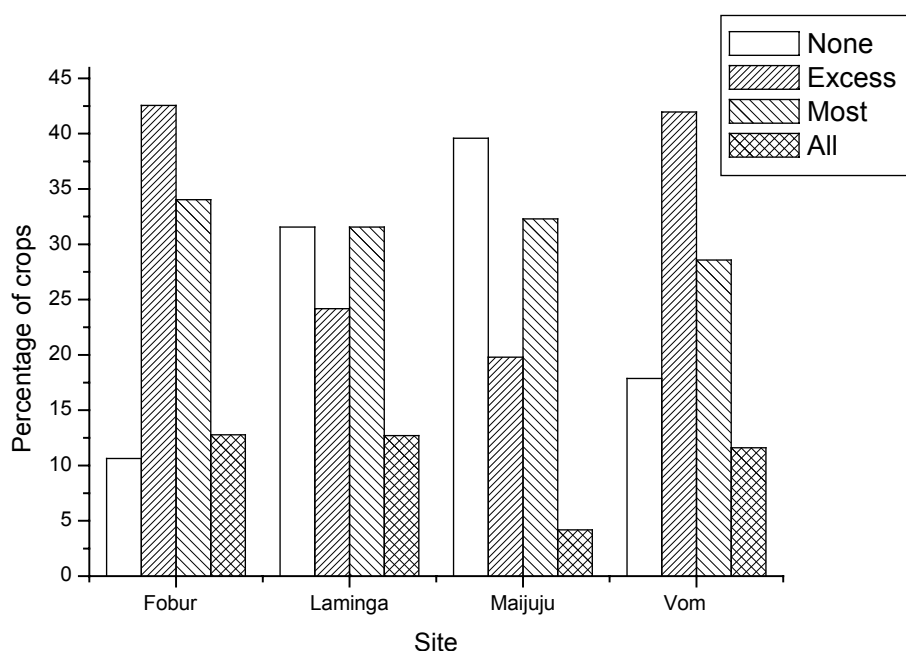


Figure 3.10. Proportion of crops sold at market, by site.

Of the 44 farmers using artificial fertiliser 43 used NPK, compound fertilisers containing nitrogen, phosphorous and potassium, the second most common was urea,  $\text{CON}_2\text{H}_4$ , followed by single superphosphate (SSP), created by the action of sulphuric acid on phosphate rock resulting in  $\text{Ca}(\text{H}_2\text{PO}_4)_2$  and  $\text{CaSO}_4$ . Some farmers did not distinguish between fertilisers sold by the Golden Fertiliser Company. Table 3.2 shows a summary of these results.

Table 3.2. Fertiliser used by farmers.

<b>Fertiliser</b>	<b>Number of farmers using fertiliser</b>
NPK	43
Urea	33
SSP	20
Golden	6

Pesticides were widely used, Table 3.3 provides a list of those mentioned by farmers. The most commonly used pesticide was known as Gamalin 20, used by 28 of 45 farmers interviewed. The accepted common name for Gamalin 20 is HCH, it is an insecticide and rodenticide (Technical Committee 81 2000) and is not described as an avicide, but on the Jos Plateau some farmers said that they used it as an avicide. It is applied to seeds in liquid form and farmers are told by chemical salesmen that birds eat the seeds and die, which then scares other birds away. Pestox was also widely used; this is a powder applied to seeds before sowing to prevent damage, thought by farmers to be caused by fungus or insects. It is listed as an acaricide (mites and ticks) and insecticide which had its registration cancelled in the United States of America in 1987, though many different products have carried the name (U.S.EPA 2006). The other pesticides mentioned were less widely used and included Ampro, listed in the United States as a disinfectant and virucide, also known as Betco Pull (U.S.EPA 2006), Karate cso and Decis, both acaricides and insecticides and Apron, a fungicide (U.S.EPA 2006).

Table 3.3. Pesticide used by farmers.

<b>Pesticide</b>	<b>Number of farmers using pesticide</b>
Gamalin 20	28
Pestox	20
Karate	4
Ampro plus	2
Apron	2
Decis	2

Farmers used a number of techniques to avoid crop pest problems, these are listed in Table 3.4. The most common was applying pesticide, some actively chased birds off fields, scare crows were erected by some to scare off birds, cassette tape was placed around some fields to scare birds as the sun reflected off it, some used smoke to drive birds and insects away, applied ash to smother insects or placed nets over vegetable

crops to prevent birds from reaching them. Some employed hunters to shoot or trap birds and squirrels and one farmer only planted crops that were unaffected by pests.

Table 3.4. Pest prevention method used by farmers.

Pest prevention method	Number of farmers using method
Pesticide	30
Pests chased	14
Scarecrows	12
Cassette tape	10
Smoke	2
Hunters used	2
Apply ash	1
Nets	1
Restricted planting to those crops not affected	1

The crops receiving pesticide treatment most regularly were maize, millet and sorghum, more than 50% of fields of these crops received pesticide treatment as seen in Figure 3.11. Of the other common crops acha, yam, white beans and groundnut received pesticide treatment on less than 20% of fields.

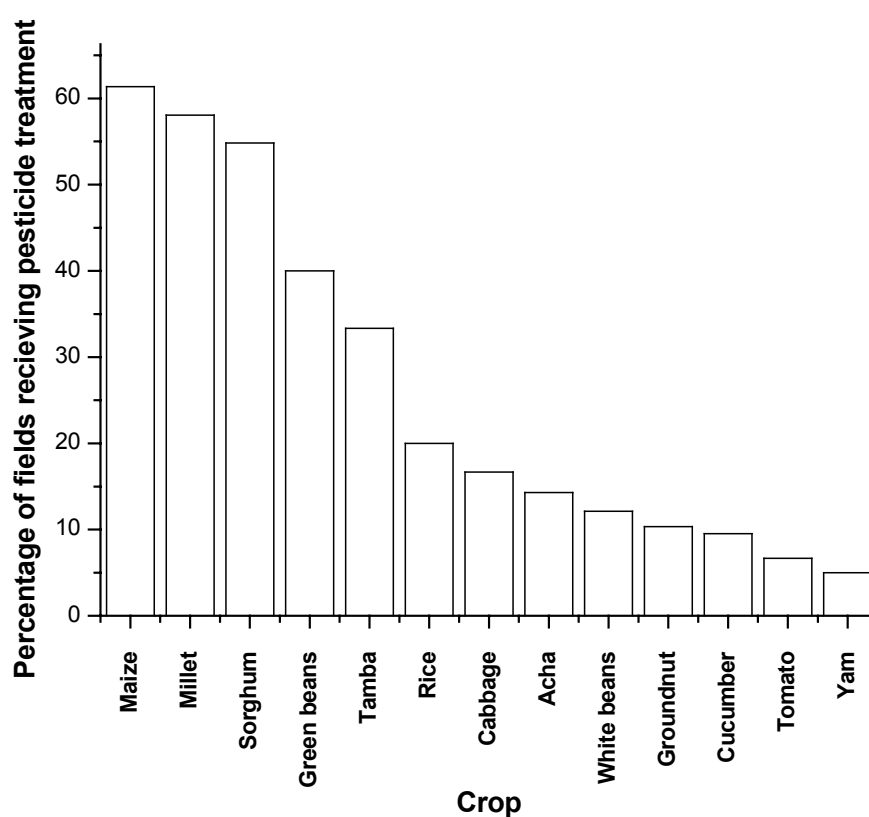


Figure 3.11. Proportion of crops treated with pesticide.

### 3.3.2 Correspondence Analysis of Environmental Variables by Site

Detrended correspondence analysis, performed on transects from field season 3 with values for 15 different habitat variables, is presented in Figure 3.12. The plots in Figures 3.13 and 3.14 show some separations by site indicating that these sites are distinct with respect to habitat features. Comparing, for example, plots of transects in Fobur, towards the left hand side of the plot, Maijuju, towards the centre of the plot, and transects in Vom, towards the right hand side of the plot, when plotted on the same scale, indicates different values for the habitat variables in these three different sites. Laminga is a large and varied site, and when transects are separated into different areas, the plots differ, with Far Laminga, Open Laminga and Kerker concentrated towards the right hand side of the plot, close to plots from the open area of Vom, and Laminga Village and Kerker Scrub more towards the centre and left hand side of the plot, closer to the more closed, scrubby areas of Fobur and Maijuju. This indicates that the separation of transects into sites for analysis would work to an extent but there is also substantial overlap and variation in habitat types on sites, particularly within the site of Laminga. Therefore it was considered better to consider habitat variables in models when looking for detailed trends in the data rather than simply separating transects by site and looking for trends that way.

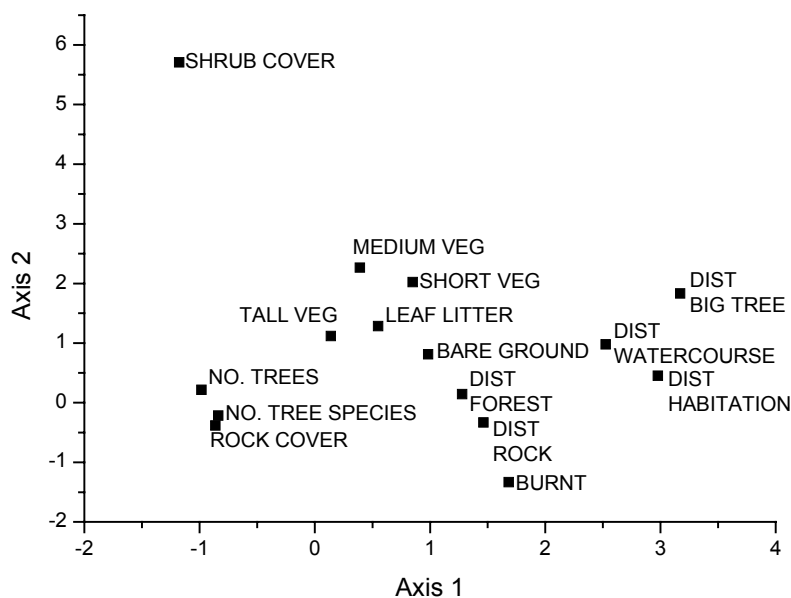


Figure 3.12. Detrended Correspondence Analysis plotted for 15 habitat variables. All variables were rescaled to maximum 100 to avoid positive weighting bias for variables with large values.

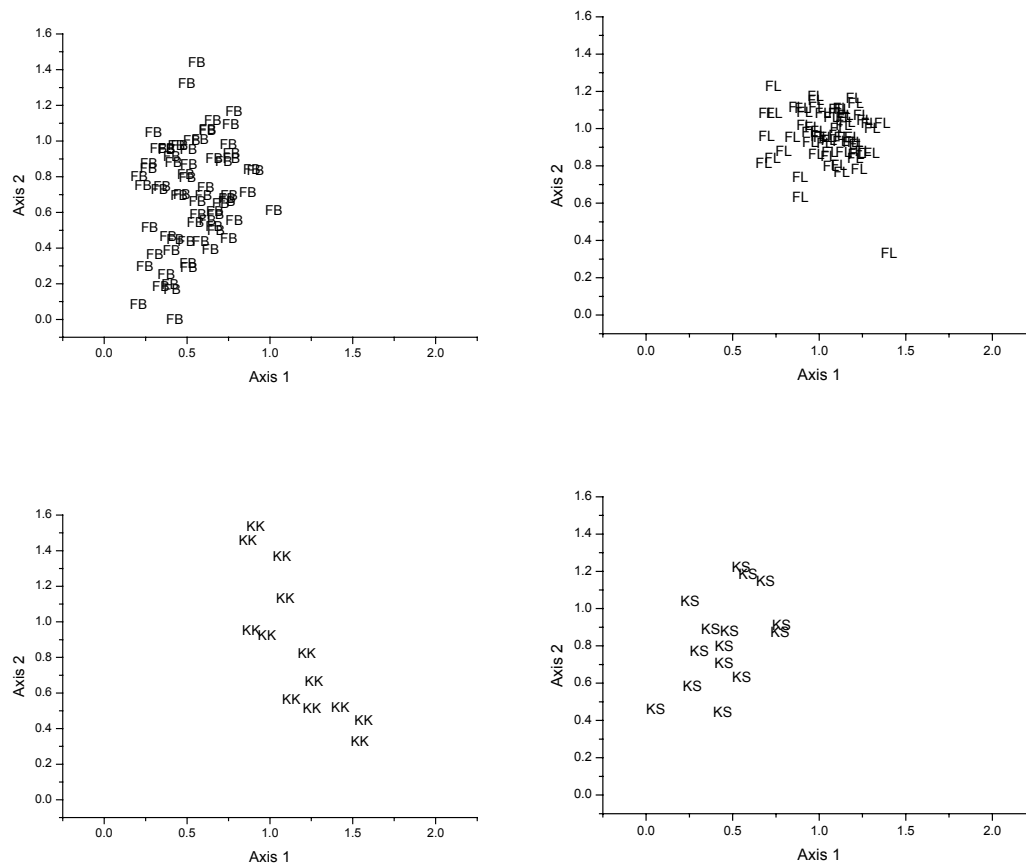


Figure 3.13. Detrended Correspondence Analysis, transects plotted for sites. FB=Fobur, FL=Far Laminga, KK=Kerker, KS=Kerker Scrub.

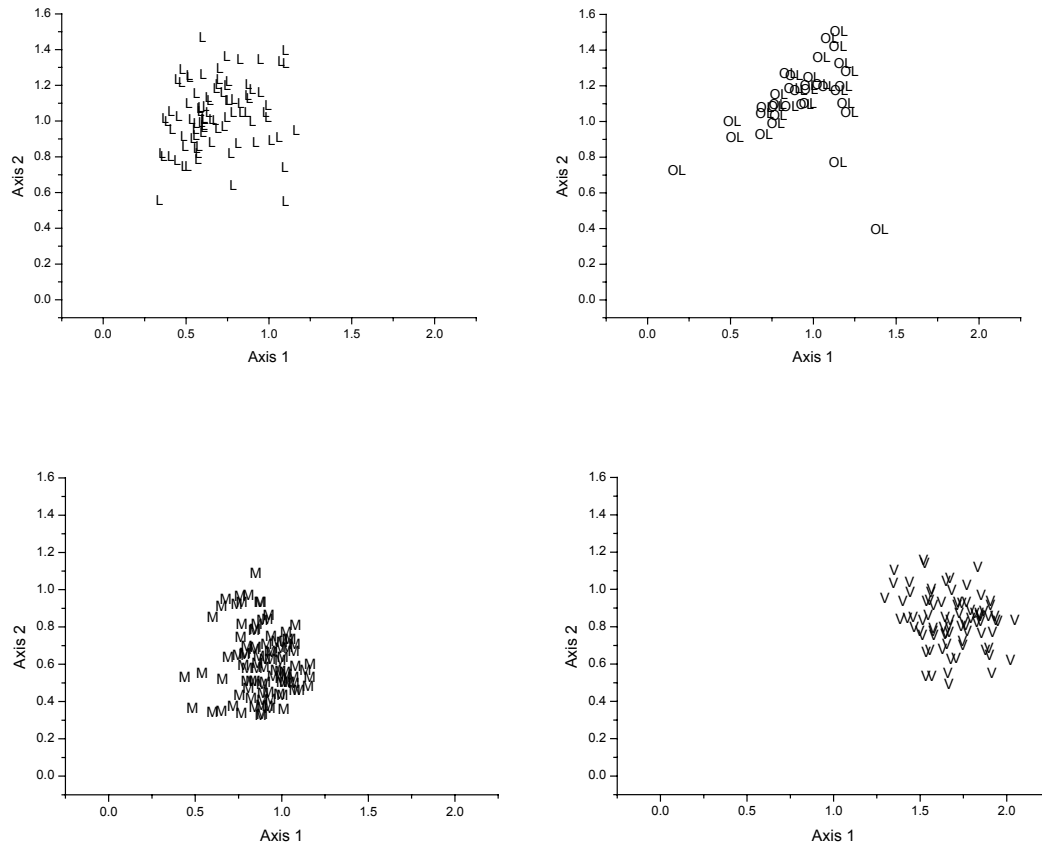


Figure 3.14. Detrended Correspondence Analysis, transects plotted for sites. L=Laminga Village, OL=Open Laminga, M=Maijuju, V=Vom. Laminga consists of five different areas, Laminga Village, Far Laminga, Kerker and Kerker Scrub.

### 3.3.3 Bird Communities on Farmland

The total number of species of birds observed on the transects was 237, with 202 of these recorded with distance to transect, the others only observed flying. The Appendix lists all species encountered along with the number of distance records for each species.

The 30 most common birds detected on transects are listed in Figure 3.15.

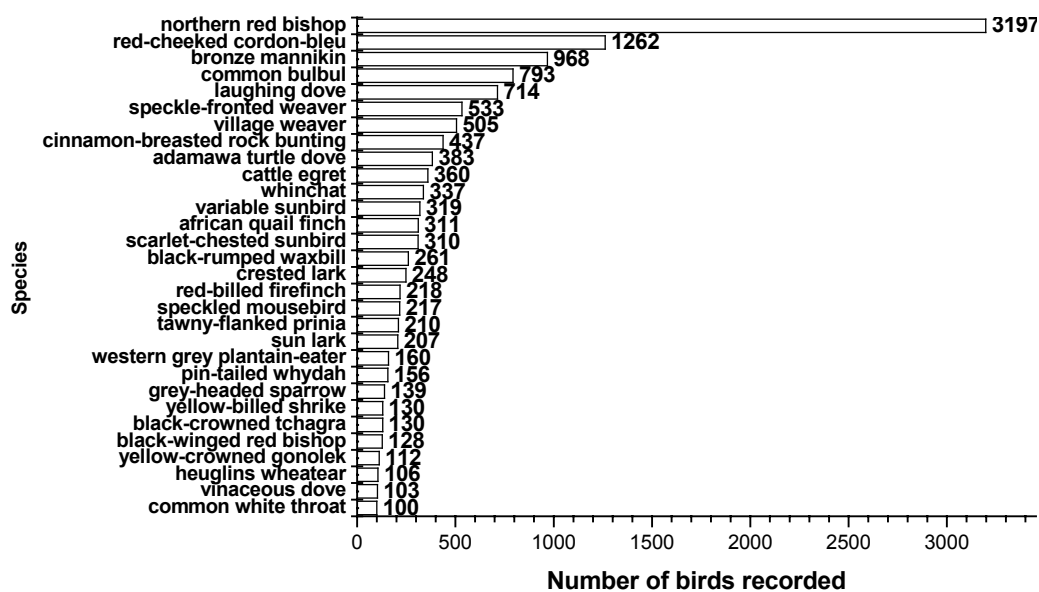


Fig 3.15. Common birds species recorded on transects, total from 2571 transects. The 30 most common of 202 species.

Figure 3.16 displays the scatter plot for the Canonical Correspondence Analysis on the 68 most common bird species on the transects, with four habitat variables. The plot is of the first two CCA axes, the Biplot scores from the CANOCO output, with each species marked and the direction of influence of each habitat variable indicated with an arrow, the length of each arrow represents the relative influence of each variable on the separation of the species in the plot.



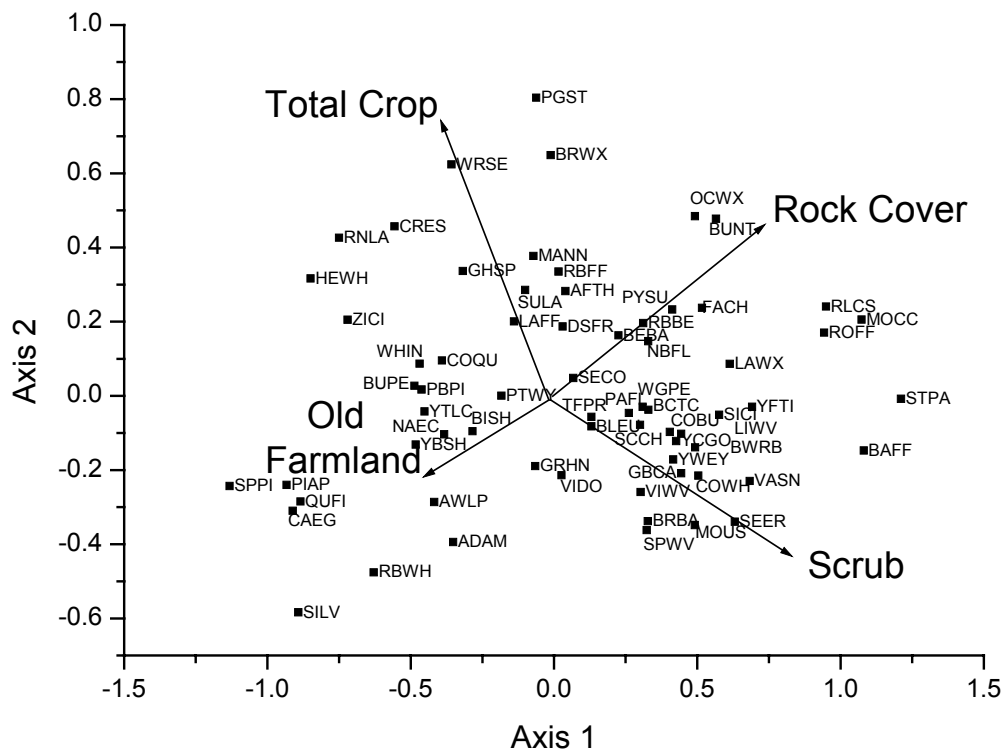


Figure 3.16. Canonical correspondence analysis, 68 bird species with four habitat variables. Species abbreviations are listed in the Appendix.

Bird species do appear to have preferences for different habitats within the agricultural landscape. A number of species such as senegal eremomela (SEER), speckled mousebird (MOUS), common whitethroat (COWH), variable sunbird (VASN), grey-backed cameroptera (GBCA), speckle-fronted weaver (SPWV) and brown babbler (BRBA) appear to have a preference for scrub habitat, or land that has not been farmed for over 6 years, as they fall in the lower right hand side of the scatter plot, in the direction of the scrub habitat influence. Cinnamon-breasted rock bunting (BUNT), rock firefinch (ROFF), familiar chat (FACH), rock loving cisticola (RLCS) and mocking cliff chat (MOCC) are among those species that are found in the upper right hand corner so appear to select for high percentages of rock cover. Birds that appear to select for crop field habitats, upper left hand side of the scatter plot, include white-rumped seedeater (WRSE), crested lark (CRLA), rufous-naped lark (RNLA), Heuglin's wheatear (HEWH), black-rumped waxbill (BRWX) and purple glossy starling (PGST) whilst old farmland less than 6 years old, on the lower left hand side

of the scatter plot, is seemingly preferred by, among others, African quail finch (QUFI), adamawa turtle dove (ADAM), cattle egret (CAEG), speckled pigeon (SPPI) and African silverbill (SILV). Species towards the centre of the scatter plot, and so without an obvious habitat preference, include Senegal coucal (SECO), double spurred francolin (DSFR), northern red bishop (BISH) and laughing dove (LAFF).

### **3.4 Discussion**

#### **3.4.1 Farmland**

Farmland on the Jos Plateau does vary in terms of habitat, management practices and bird communities. The different sites chosen for study separate out under correspondence analysis for measured habitat and landscape variables, confirming that the sites differ by habitat. Vom was identified as more open and with less shrub, Fobur more shrub and woodland, and Laminga and Maijuju in-between. Sites also differ in the amount of land currently farmed with more in Vom than anywhere else, less in Fobur than anywhere else and, again, Laminga and Maijuju in-between. It appears that there is a direct correlation between the intensity of agriculture, as measured by the amount of farmland, and the structural habitat observed, with more open habitats where farming is more intense and more shrubs and trees where farming is less intense on a spatial scale. This provides a basis for interpreting bird survey data in terms of both habitat structure and farming effects.

With 36 different types of crops being identified, agriculture on the Jos Plateau appears diverse, though there is great variation in the extent of different crops being farmed and a small number of crops make up a large proportion of land farmed. These common crops, acha, maize, millet, sorghum and yam, are wet season crops, whilst predominantly dry season crops, such as tomato and bell pepper, make up a relatively small area of farmed land, yet tomato and bell pepper are grown by many farmers interviewed and make up an economically important resource for the Plateau (Porter et al. 2003). When considering the influence of farmed land on the occurrence of bird species the crops making up the greatest proportion of land should be considered for their individual effects, yet seasonal influence, displayed in the sowing and harvesting calendars for the different crops, and food availability may mean that dry season crops

should be considered, despite the low area taken up by actively farmed land during the dry season.

The use of artificial fertilisers was very common, with 98% of farmers interviewed applying some to their fields and all sites studied showing similar levels of use. There was one farmer in Maijuju who applied especially large amounts, which raised the levels of use for Maijuju. Porter et al (2003) suggest that the use of fertiliser has increased on the Jos Plateau over recent years as land has come under more farming pressure with population growth, and that this will have negative impacts on soil fertility. Manure was also widely used, 91% applied manure from at least one source and 64% of farmers bought manure to apply to fields. The cost of fertiliser and manure was often mentioned by farmers as a problem and a limiting factor in their ability to achieve the desired yields for their crops. There are limits to the conclusions that will be able to be reached in this study as to the impact of fertiliser and manure use on bird populations as it is not known which fields on the study sites were subject to applications.

Pesticides were also widely used with 67% of farmers interviewed using at least one form of chemical to combat pests. The level of understanding of the actions and even the names of the substances they were using appeared to be low in many cases. Often the pests damaging the crops were unknown, simply being referred to as insects, and advice was taken from the chemical traders at the market as to which substances to use. Actions taken to avoid pests and diseases did not appear to include any that took into account factors such as water-logging of the soil on irrigated fields or the presence of affected plants nearby which can have an effect on infestations. At least one substance used, Pestox, appears to be one that has been removed from use in the USA. This, combined with the possibility of misuse of chemicals due to the lack of knowledge displayed, suggests, not only poor effectiveness in dealing with pests, but also potential damage to human health and unknown effects on domestic and wild animals, the study of which are beyond the scope of this project. Porter et al (2003) suggested that pests and diseases were a growing problem for farmers on the Plateau, possibly due to a reduction in intercropping and an increase in continuous cropping of dry season crops, however, this study suggests that the dry season crops tomatoes and bell peppers require less use of pesticide by the farmers interviewed than wet season

crops such as maize and millet. If it is the case that crop pests and diseases are increasing then farmers must spend more on pesticides and expend more time and labour on the other forms of pest prevention mentioned in interviews than previously, reducing economic benefits and increasing health risks. Such problems could also be partly alleviated through changes in crop management.

Despite the pressures placed on land, most farmers still regularly left land fallow in order for it to regenerate, and that this was consistent across all sites, although continuous farming was common for dry-season irrigated crops. This suggests that farming in the areas studied has not reached the high levels of intensity witnessed in many more developed, temperate areas.

The proportions of crops sold at market show how crops tend to divide by those mostly farmed for subsistence or only sold when in excess, such as millet, maize, acha, yam and sorghum, and those mostly farmed for sale such as tomatoes, bell peppers, cassava and groundnut. Subsistence crops dominate in terms of area farmed. More excess crops appear to be sold at Vom and Fobur than at Laminga and Maijuju, suggesting that the importance of crops as cash crops does not depend solely on the area farmed. It was suggested by some farmers that Fobur is a fertile area and that it is the terrain that limits the proportion of land in active agriculture, whereas Vom is a flat area with few rocks so it is easy to cultivate on a large scale. The fact that the proportions of farmers who sell most of their produce is not significantly different between sites suggests intensity does not differ, but Vom also has more area under cultivation and farmers cultivate more fields than at other sites indicating that the amounts sold, which was a difficult measure to quantify through interviews with farmers, may be greater overall than at other sites.

The picture generated of farming on these study sites on the Jos Plateau is of small-scale farmers with most land given over to subsistence agriculture but with a number of economically important crops, often grown in areas where water is readily available for irrigation. Application of artificial substances as fertilizers and pesticides is common, suggesting problems with soil fertility, crop pests and disease infestation. Farming intensity is low, with no areas covered under large-scale business ownership,

but intensities do vary between sites surveyed in terms of the amount of land farmed and produce sold at market.

### **3.4.2 Bird Communities**

Viewing Figure 3.16 it is not surprising that species with a known preference for rocky habitats (Borrow & Demey 2001), such as cinnamon breasted rock bunting, mocking cliff chat, stone partridge, rock-loving cisticola and rock firefinch, are clustered towards the direction of influence of rock cover. Many species listed as being present in savanna and other woodland habitats in Borrow and Demy (2001) such as variable sunbird, yellow white-eye, yellow-fronted tinkerbird, speckled mousebird, brown babbler, scarlet-chested sunbird, Senegal eremomela and speckle-fronted weaver are clustered towards the direction of influence of scrub habitat, whereas birds of open grassland habitats were clustered towards the influence of crop land and fallow land. These included crested lark, rufous-naped lark, Heuglins wheatear, zitting cisticola and bronze manikin. Fallow land was favoured by whinchat, plain-backed pipit, northern ant-eating chat, northern red bishop and African quail finch. Fallow land is listed in Borrow and Demey (2001) as being a favoured habitat for rufous-naped lark, which was present on transects with more crop fields, and black-winged red bishop, which was more a bird of scrubby habitats in this study. Many bird species are listed in Borrow and Demey (2001) as being found on farmland, 'farmbush', cultivation or the edges of cultivation, including those found on more extensive farmland such as crested lark, plain-backed pipit, whinchat and Heuglin's wheatear, but also many that were found in more scrubby, wooded areas, such as variable sunbird, brown babbler, black-winger red bishop, pale flycatcher and western grey plantain eater and those in between such as laughing dove, double-spurred francolin, sun lark, African thrush and pin-tailed wydah.

Although there are many species that use farmland as a habitat, and are known to do so, there is a great deal of variation in the range of farmland habitat used by different species and there appears to be little quantitative data as to what type of farmland species prefer and what precisely the different species select for in choosing the habitat required when this habitat is within a farmland landscape. This will be explored in the following chapters.

## **Chapter 4 The Use of Crop Fields by Birds on the Jos Plateau**

### ***4.1 Introduction***

Data for common bird species at the crop field level, presented in this chapter, indicate that there is variation between species in their associations with specific crop types. Species vary also in their associations with field size and the presence of non-crop border habitat which are consistent with the species literature, with savanna birds staying close to edge habitat (Borrow & Demey 2001; Fry & Keith 2004). The crop preferences observed are consistent with theories of foraging efficiency and predator avoidance.

Intensified agriculture has been implicated in the decline of many farmland bird species in Europe (Fuller et al. 1996; Chamberlain et al. 2000; Butler et al. 2007) and many different mechanisms have been suggested and studied as possible causes of this decline for various different species. In Europe some species of birds have specifically been found to prefer particular crops, such as reed buntings in England preferring oil seed rape to other crop types in summer (Gruar et al. 2006), reed, sedge and marsh warblers preferring oil seed rape to cereal crops as foraging habitat in Poland (Surmacki 2005), yellowhammers preferring winter barley to wheat and other habitats in England (Morris et al. 2001) and crops with low vegetation height and cover preferred to oilseed rape by skylarks in France (Butler & Gillings 2004). In Africa and the tropics studies have been more limited, with the highest number of species of birds recorded at sites with a mixture of crops compared to less diverse sites in the Aguhlas Plains, South Africa (Mangnall & Crowe 2003) but there is no published information on specific crop preferences.

Stubble fields have long been known to provide important winter resources for seed-eating passerines in Europe (Tucker 1992; Wilson et al. 1996; Mason & Macdonald 1999). Stubble fields have been found to vary in seed abundance by crop, with barley having a higher seed abundance than wheat, and certain bird species only foraged on fields with a minimum seed density (Moorcroft et al. 2002). It is possible that similar patterns of bird field use may be present during the dry season in Africa.

The aims of this chapter are to determine whether the bird species which use stubble crop fields have a preference for certain crop types and whether certain crop types host higher species richness, or whether crop type is not a significant factor when the size of the field and the presence of edge habitat is taken into account. Edge habitat must be included as edge effects have been documented to be an important factor in the choice of foraging habitat for birds (Butler et al. 2005). Some species may prefer to keep close to cover for escape from predators, whilst others stay away from cover, which may be used by predators (Ydenberg & Dill 1986). Larger fields contain more open space further from cover than smaller fields so the area of the field may also interact with the edge habitat and crop type variables.

This Chapter describes a complementary study, at the field level, to the transect surveys described in subsequent chapters at a larger spatial scale. Studies at different spatial scales can test different functional responses to variables and thus can produce different results (Cushman & McGarigal 2004; Whittingham et al. 2005). Differences in the patterns in the presence of birds in the fields with respect to crop type could also lead to clear management proposals if any crop appears to be preferred at this time of year. This chapter uses counts of birds using harvested fields during the middle of the dry season to determine whether the type of the four most common crops has an impact on the species richness of birds directly observed in fields and the density of certain species commonly observed in crop fields. The distance from cover the birds are observed at will be recorded and crop type, proportion of edge habitat in the field boundary along with field area will be modelled in order to determine the patterns in the presence of birds in the fields.

## **4.2 Methods**

Crop fields around Laminga village were surveyed as described in Section 2.3 with four routes walked six times, each field systematically searched for birds on the ground or in the stubble. The data was analysed using Generalised Linear Models and the Information Theoretic approach (Burnham & Anderson 2002) selecting models based on AICc values as described in Sections 2.1 and 2.3.

### **4.3 Results**

118 fields were surveyed over the 4 routes walked, with 41 being maize fields, 39 acha, 26 millet and 12 yam. A total of 1332 birds were observed from 49 different species. Species chosen for General Linear Models were those which were observed on more than 15 fields over the course of the study, including red-cheeked cordon-bleu, laughing dove, sun lark, cinnamon-breasted rock-bunting, crested lark and red-billed firefinch. Figure 4.1 shows the mean distance to cover of the 15 most common species observed. There are significant differences between species, one way ANOVA,  $F=19.9$ ,  $df=13$ ,  $p<0.01^{**}$ , with species such as northern red bishop, sun lark, crested lark and cinnamon-breasted rock-bunting using areas further from cover than double-spurred francolin and all the common waxbills. Whinchat, common bulbul, laughing dove and speckle-fronted weaver are found at intermediate distances from cover.



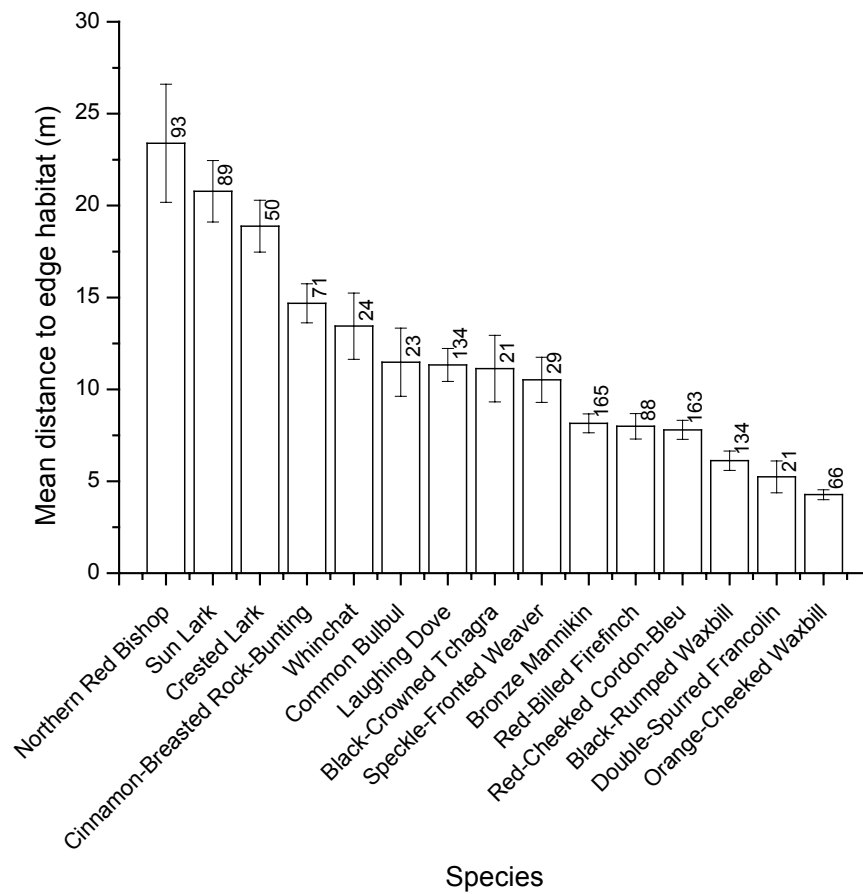


Figure 4.1 Observed distances to edge habitat for bird species observed in fields. Error bars are +/- one standard error.

The results of the models run for species richness and species density are displayed in Table 4.1, showing the top model, its Akaike weight and the number of models in the 95% confidence set of models, and in Table 4.2, showing the Akaike weights for each variable and interactions. Although crop type is not an important predictor for species richness, with field area and edge habitat being much more useful predictors, it does appear in the top model, by AICc, for all the species density model groups and has a high Akaike weight, relative to the random variable, for all species. The same applies for edge habitat for all species except for red-billed firefinch. Field area has a high Akaike weight for laughing dove, cinnamon-breasted rock-bunting and crested lark. The only interaction with a high Akaike weight was field area with crop type for cinnamon-breasted rock-bunting, although 5 out of 7 of the top models include an interaction term.

Table 4.1 Top models, Akaike weight of top models and number of models in 95% confidence set of models for each dependent variables using Generalised Linear Models with a poisson distribution and log link function.

Dependent Variable	Total no. birds/species observed	No. fields birds observed (of 118)	Top Model	Akaike Weight of Top Model	No. Models in 95% confidence group
Species richness	49	96	Field Area, Prop Edge, Field Area X Prop Edge	0.48	5
Red-Cheeked Cordon-Bleu	163	39	Proportion Edge, Crop Type	0.56	5
Laughing Dove	134	48	Field Area, Proportion Edge, Crop Type, Prop Edge X Crop Type	0.29	9
Sun Lark	89	29	Prop Edge, Crop Type, Prop Edge X Crop Type	0.18	14
Cinnamon-Breasted Rock-Bunting	71	28	Field Area, Proportion Edge, Crop Type, Field Area X Crop Type	0.68	4
Crested Lark	50	25	Crop Type	0.23	8
Red-Billed Firefinch	88	17	Field Area, Crop Type, Field Area X Crop Type	0.33	7

Table 4.2 Akaike variable weights for the species richness and species density models. An asterix (\*) indicates a weight higher than the random variable weight plus two standard errors.

Variable	Species richness	Red-Cheeked Cordon-Bleu	Laughing Dove	Sun Lark	Cinnamon-Breasted Rock-Bunting	Crested Lark	Red-Billed Firefinch
Area of field (Ha)	0.98*	0.35	1.00*	0.60	0.99*	0.59*	0.60
Crop Type	0.12	1.00*	1.00*	0.90*	1.00*	0.54*	1.00*
Proportion of Edge Habitat	0.97*	1.00*	0.92*	0.78*	0.99*	0.42*	0.29
Area X Prop Edge	0.54	0.11	0.39	0.16	0.21	0.06	0.08
Prop Edge X Crop Type	0.01	0.15	0.66	0.30	0.1	0.01	0.02
Area X Crop Type	0.01	0.02	0.31	0.25	0.97*	0.01	0.48
Random Variable	0.60	0.65	0.68	0.61	0.47	0.33	0.63
Random Variable + 2S.E.	0.72	0.79	0.82	0.77	0.59	0.37	0.79

As an example of the trends between the dependent variables and the covariates in the models, Figures 4.2 and 4.3 show the negative linear relationship of species richness to field area and positive linear relationship to proportion of edge habitat.

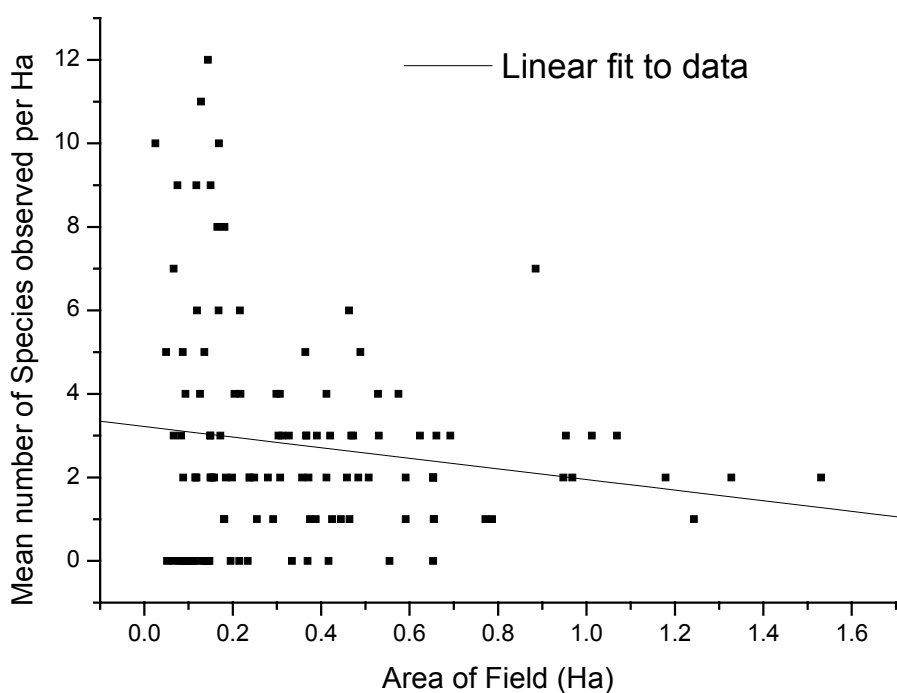


Figure 4.2 Relationship of field area to species richness per hectare. The line represents a linear fit to the data, intercept=3.22, gradient=-1.27,  $R=-0.15$ ,  $p=0.11$ , ns,  $N=118$ . A Polynomial fit accounted for a smaller amount of variance so a linear function was chosen.

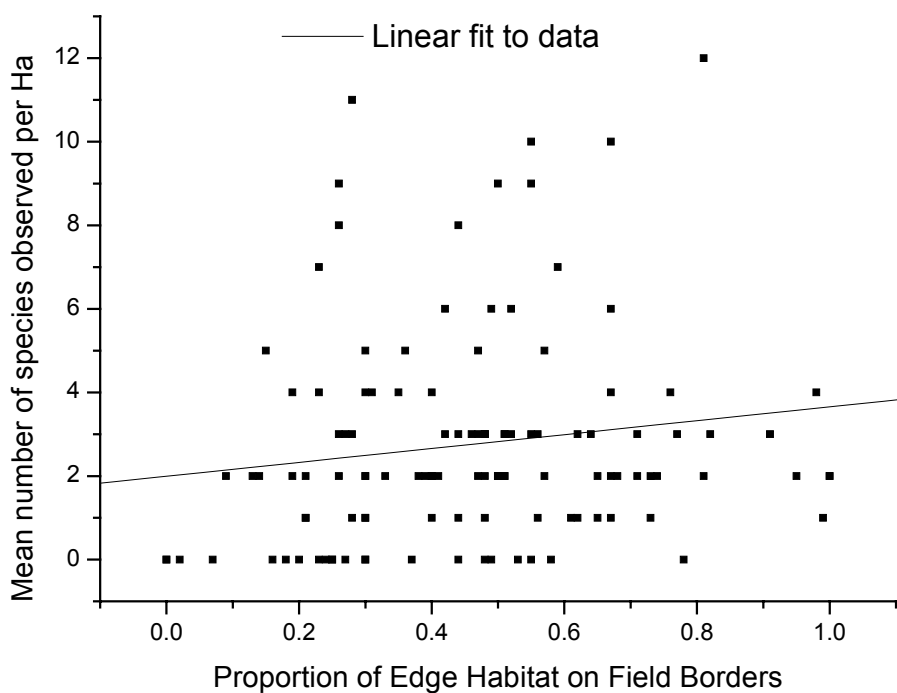


Figure 4.3 Relationship of proportion of edge habitat to species richness per hectare. The line represents a linear fit to the data, intercept=1.99, gradient=1.66,  $R=0.14$ ,  $p=0.12$ , ns,  $N=118$ . A Polynomial fit accounted for a smaller amount of variance so a linear function was chosen.

Table 4.3 shows, by species, the parameter estimates in the top density models, as selected for by AICc, for crop type. Acha fields had high densities of red-cheeked cordon-bleu; densities in maize fields were high for crested lark and red-billed firefinch; densities in millet fields were high for red-cheeked cordon-bleu, laughing dove, cinnamon-breasted rock-bunting and crested lark; and densities in yam fields were high for sun lark.

Table 4.3 Parameter estimates from top models, by AICc, for crop types by species, with standard errors of the estimates and Wald Chi Squared *p*-values

Species	Crop Type	Parameter Estimate	Standard Error	Chi Squared value	<i>p</i> -value
Red-Cheeked Cordon-Bleu	Acha	2.03	0.72	7.95	<0.01**
	Maize	0.92	0.74	1.55	0.21
	Millet	1.45	0.74	3.87	<0.05*
	Yam	0	0	.	.
Laughing Dove	Acha	0.44	0.97	0.21	0.65
	Maize	0.36	0.98	0.14	0.71
	Millet	1.85	0.96	3.72	0.05*
	Yam	0	0	.	.
Sun Lark	Acha	-1.35	0.62	4.69	0.03*
	Maize	-2.33	0.73	10.28	<0.01**
	Millet	-2.66	0.86	9.58	<0.01**
	Yam	0	0	.	.
Cinnamon-Breasted Rock Bunting	Acha	1.23	0.99	1.53	0.22
	Maize	-0.72	1.13	0.4	0.53
	Millet	2.68	0.95	7.91	<0.01**
	Yam	0	0	.	.
Crested Lark	Acha	-0.67	0.73	0.84	0.36
	Maize	0.56	0.62	0.82	0.37
	Millet	0.33	0.67	0.24	0.63
	Yam	0	0	.	.
Red-Billed Firefinch	Acha	0.51	1.22	0.18	0.67
	Maize	1.80	1.22	2.19	0.14
	Millet	0.43	1.64	0.07	0.79
	Yam	0	0	.	.

The directions of the relationships between the dependent variables and the field area and proportion of edge habitat variables are shown in Table 4.4. Density and species richness decreased with increasing field area, except for crested lark, which displayed an increase. Density and species richness increased with increasing proportion of edge

habitat on field borders, taking tree presence into account, except for sun lark and crested lark densities, which decreased .

Table 4.4 Gradients of relationships between dependent variables and covariates in models when plotted independently.

Dependent Variable	Area of Field Gradient	Proportion of Edge Habitat Gradient
Species Richness	-1.27	1.99
Red-Cheeked Cordon-Bleu	-0.03	1.91
Laughing Dove	-1.18	0.92
Sun Lark	-0.44	-0.77
Cinnamon-Breasted Rock-Bunting	-0.20	0.90
Crested Lark	0.28	-0.15
Red-Billed Firefinch	-0.003	0.15

Figure 4.4 shows the interaction plot for the only interaction with a high Akaike weight, that between crop type and field area for cinnamon-breasted rock-bunting density. Millet fields had a very high density of buntings in smaller fields of 0.2 hectares or less (n=23) compared to other crops (n=27), which display more constant density up to fields of 0.6 hectares. There is further variation for larger fields but the increase in density for yam fields at 0.8 hectares, and the increase for millet at 1.4 and 1.6 hectares is based on just one field respectively so this may not be a biologically significant interaction at higher field areas.

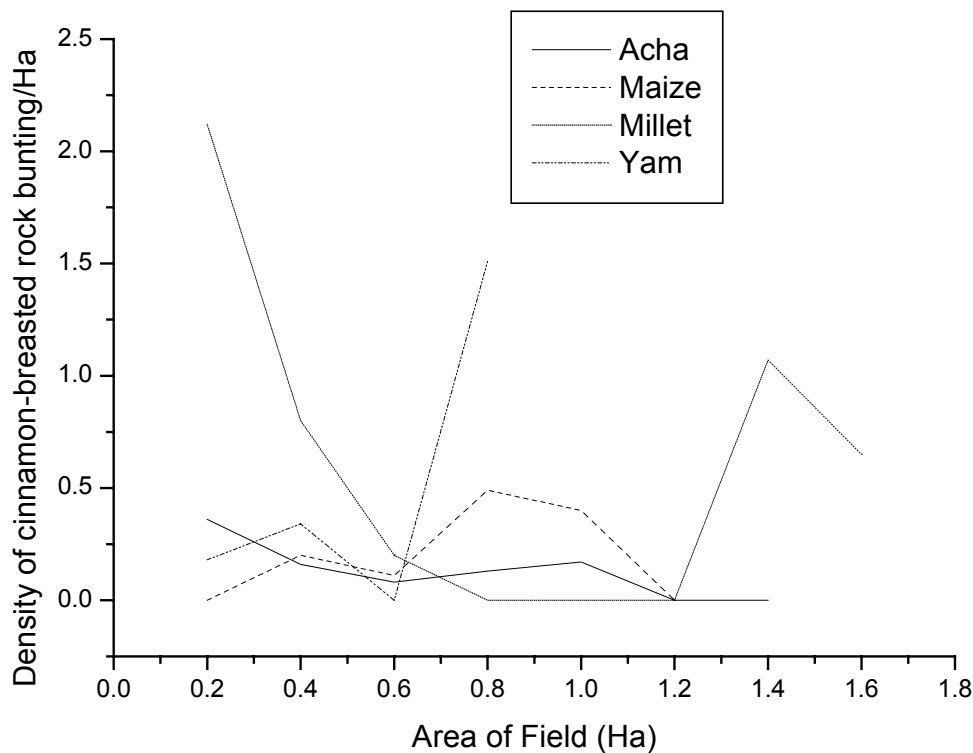


Figure 4.4 Interaction between crop type and field area for cinnamon-breasted rock-bunting density (see Table 4.2).

## 4.4 Discussion

Field area and proportion of edge habitat had a significant role to play for many species, with Table 4.4 showing that all birds, except for crested lark, tend to prefer smaller fields and all, except for crested and sun larks, prefer higher proportions of edge habitat. The results for crested lark and sun lark are unsurprising considering they are species of open habitats and the other species studied are more commonly associated with scrub and savanna habitats (Borrow & Demey 2001). Savanna birds will be more likely to keep close to edge habitat in order to escape from predators whilst open-country birds will be more likely to avoid edge habitat, where predators may be concealed (Ydenberg & Dill, 1986). Smaller fields will have fewer open areas and shorter distances to the edge habitats that occur on the field borders, and Figure 4.1 shows that sun lark and crested lark use areas of crop fields further away from edge habitat than the other species. Interactions are present in some of the top models, with Figure 4.4 displaying the only one with a high Akaike weight, where small millet fields display higher densities of cinnamon-breasted rock-buntings than small fields of

other crop types. This is, perhaps, the reason why cinnamon-breasted rock-buntings are observed at greater distances from edge habitat than most other species, when all observations are taken together in Figure 4.1, but shows a negative trend for area of field and a positive trend for proportion of edge habitat in Table 4.4. The reasons why millet fields may result in a different pattern of density is not clear, there may be a foraging advantage in small millet fields that is not present in other small fields, predator-avoidance could be more effective in smaller millet fields compared to in other crop types or small millet fields may be present closer to rock outcrops, favoured by cinnamon-breasted rock-buntings, than other small crop fields. Even when all these factors were taken into account, crop type was an important factor in the species' models strengthening the argument that the trends viewed for crop types are genuine.

Although species richness does not appear to be affected by the type of crop, the results from the models suggest that a number of species are selecting field habitat partly by crop type during the middle of the dry season. Table 4.3 indicates that acha was the preferred crop for red-cheeked cordon-bleu, followed by millet, with parameter estimates of 2.03 and 1.45 respectively. Acha also provided a habitat used by red-billed firefinches, along with maize, with parameter estimates of 0.51 and 1.80 respectively, although neither chi squared values were significant. Acha is a small grain, which is known to be used as food by waxbills (*pers obs.*) and is similar to the naturally occurring grass seeds on which these granivores feed (Borrow & Demey 2001). Data is lacking on the amount of grain available during the middle part of the dry season but acha grains have been observed in soil samples at this time of year, amongst other seeds (*pers obs.*). Laughing doves and cinnamon-breasted rock-buntings appeared to select for millet fields over other crop types; parameter estimates for the top models were 1.85 for laughing dove (close to significance), and 2.68 for cinnamon-breasted rock-bunting (highly significant). Again, there is no data for seed densities for millet fields but millet grains have been observed in soil samples from millet fields at this time of year (*pers obs.*) and although there is no evidence to suggest that this is what birds are feeding on there is a possibility that larger seed-eating birds such as laughing doves and buntings may be in a better position than waxbills to exploit the larger millet grains than acha grains. As well as for red-billed firefinch, maize was a preferred crop for crested lark, but the parameter estimate is



only 0.56 and the chi-squared value is not significant. No maize grains were observed in soil samples from maize fields but other, unidentified, seeds were observed (*pers obs.*). Yam fields were preferred by sun larks but not selected for by other species.

The differences in vegetation structure between the different crop types is likely to play a role in determining which species select which crops (Butler & Gillings 2004), with yam fields with large furrows and in the middle of the dry season having very little vegetation, acha with small furrows and low, dense groups of stems, and millet and maize with medium-size furrows and high, well-spaced stems, with maize stems being thicker and retaining more leaves (*pers obs.*). The open space of yam fields, for example, are likely to favour a bird such as the sun lark, which, as Figure 4.2 shows, is found a long way from cover, and which probably needs open areas to aid it in foraging for invertebrates, which would be more exposed (Butler & Gillings 2004). The vegetation similarity argument does not, however, appear to explain the great preference of cinnamon-breasted rock-bunting for millet over maize, which has similar vegetation structure. The differing vegetation structures may represent differing foraging risks for different species, depending on their vigilance behaviour. It has been shown that chaffinches, in different patches with different stubble heights, will forage at different rates depending on the ability to detect predators, with more foraging possible with short stubbles where predator detection is easiest (Butler et al. 2005). Acha may represent such a “safe” patch for red-cheeked cordon-bleu and red-billed firefinch whereas the higher stubble in millet and maize fields are less safe, as well as including lower troughs between the ridges where seed may fall and which may provide a narrower angle of vision for predator detection. Millet and maize, on the other hand, have less dense sward than acha and this may be an advantage over acha for predator detection. It is likely that a combination of predator avoidance and food availability is driving the selection of different crop types by some species. Sward height in stubble fields has been demonstrated to be a factor influencing the selection of agricultural land by passerines in the United Kingdom, with the literature indicating that, for 15 of the 20 species comprising the UK Government’s ‘Farmland Bird Index’, shorter vegetation is likely to enhance foraging efficiency and reduce predation risk when ground foraging, although longer vegetation enhances food supply (Whittingham & Evans 2004) and experiments have resulted in an indication that granivorous and insectivorous passerines select for short stubble height with

skylarks and meadow pipits selecting for longer stubble (Whittingham et al. 2006). This could be reflected in the choice of red-cheeked cordon-bleu for short-sward acha and of crested larks for high-sward maize in this study.

The crop preferences of various species observed in this study require further, detailed study in order to determine the mechanisms driving the habitat selection, whether these are based on increased food supplies, increased availability of food, avoidance of predation or some other factor. As noted in section 4.1, this survey is a relevant parallel study to the line-transects, the results of which are presented in subsequent chapters, as it indicates, more specifically than the line-transect survey, how birds are selecting habitat which is directly affected by human management in the form of the choice of crop type farmed. Any management recommendations should take these results into account along with the results from the line transect survey. The indications are that the choice of recommended crop type will depend on the priority species for conservation but that crop type will not affect overall avian species richness at the scale of agriculture observed in Laminga.

## **Chapter 5 Diversity and Species Richness of Birds on Farmland**

### ***5.1 Introduction***

The data presented in this chapter shows that, of the habitat features modelled, tree density is the most important variable determining avian species richness and diversity on the Jos Plateau. Low tree density predicts lower avian diversity with diversity rising with tree density before dropping off at very high densities. This is consistent with the presence of many species of savanna birds on farmland and suggests that the retention of natural habitats is important to retain diversity on farmland.

Biodiversity is often used as a measure of the comparative ecological health of habitats, with more diverse communities representing a more desirable habitat from a conservation perspective (Huston 1994). Biodiversity has been found to decrease where agriculture has expanded, with an estimation, based on forecasts of biome conversions, that 27-44% of bird species could be lost to agricultural expansion from Neolithic to 2050 (Teyssedre & Couvet 2007). Management strategies for conservation on farmland have been specifically linked to a desire to increase habitat diversity and bird species richness in Europe (Gottschalk et al. 2007), and, with the higher species richness observed in tropical agricultural land (Mangnall & Crowe 2003; Soderstrom et al. 2003), it is likely that many species are at risk from agricultural expansion in Africa and that focussed management may have a large role to play in reducing these potential losses.

The aims of this chapter are to determine the habitat and farmland variables which predict the diversity and species richness of bird communities on the Jos Plateau and whether the resulting models can accurately predict diversity and species richness in an independent dataset from similar habitats. Data from line transects on the Jos Plateau, Nigeria, are modelled with habitat variables representing different farmland habitats and management types and those which best describe the avian species richness and diversity are determined using the Information Theoretic approach and

comparisons with an independent validation dataset. Implications for farmland management are then discussed.

## **5.2 Materials and Methods**

Transects were placed and conducted as described in section 2.1. Simpson's diversity indices were calculated as described in Section 2.1.7.2 for each transect with birds seen within 50m of the transect. Transects with no birds with distance measurements within 50m were not included in the analysis. Species richness and Simpson's diversity indices were modelled separately as dependent variables. The eight habitat variables were chosen for modelling as described in section 2.1.7.6. Generalised Linear Models were used with the Information Theoretic approach (Burnham & Anderson 2002) described in Section 2.1.7.7. This includes determining the linearity of the relationship between independent and dependent variables, the calculation of AICc values and Akaike weights for models and variables, including a random variable (Whittingham et al. 2005), and the validation of the models using the validation dataset.

In order to determine if site had a significant effect on species richness due to differences in the detectability of birds on the transects the following analysis was undertaken: Perpendicular distances of birds from the transect were split into five 10m bands up to 50m from the transect. Mean number of species recorded per band was calculated by site and the proportionate change in the number of species in relation to the previous, closer band was calculated, for example, the proportion seen in band 20-30m compared to the band 10-20m from the transect. The effect of site on the proportionate change in the number of bird species observed between bands was modelled in a univariate ANOVA,  $F_{13,42}=1.0$ ,  $p=0.51$ , ns. There appears to be no significant difference in the drop-off in detectability of species as a whole between sites, despite the differences in habitat between sites (see Chapter 3) and the differences between sites in absolute species numbers. This provides justification for using unadjusted number of species observed across all transects in the models. The mean proportionate change in the number of species observed in bands away from the transect was 0.65, standard error=0.03, i.e. for each 10m band away from the transect 0.65 times of the number of bird species were observed relative to the adjacent band

closer to the transect. To take into account this decline in detectability of birds away from the transect, the number of species observed only within 50m of each transect was used as the dependent variable for species richness models.

Figure 5.1 shows the frequency of bird species numbers for the transects used to model species richness. The normal distribution null model resulted in a ratio of residual deviance to residual degrees of freedom of 4.39 and the Poisson model gave a ratio of 1.99 indicating that the data is overdispersed for both models, but that the data fit a Poisson distribution better than a normal distribution. On the basis of this the GLMs were performed using the Poisson distribution with a log link function.

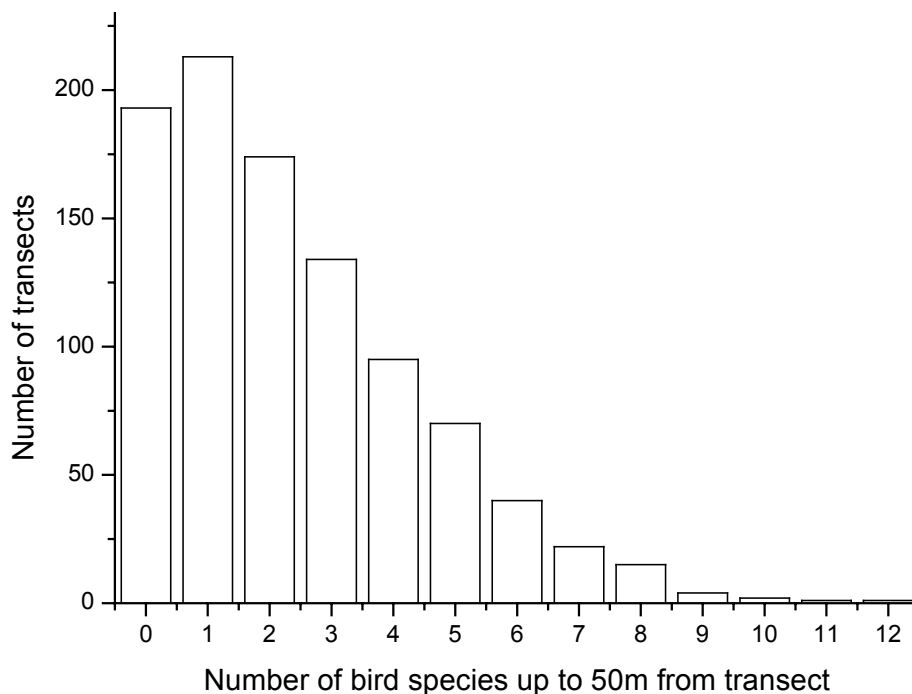


Figure 5.1. Frequency of number of bird species on transects for model-fitting dataset.

## 5.3 Results

### 5.3.1 Species Richness

The relationships between species richness and the predictive variables are displayed in Figures 5.2 to 5.13, along with either linear or polynomial regression lines and parameters. Some variables showed significant linear relationships with number of

bird species. Rock cover showed a significant linear rise in species richness with increased percentage cover. There was a significant linear drop in species richness with increased minutes after sunrise as bird activity drops off, but there was no significant relationship with cloud cover. An increased wind rating, Figure 5.4, resulted in significantly decreased species richness, justifying the decision to include this in all models. Wind may have affected detectability of birds as well as activity (Buckland et al. 2001).

All other variables tested showed significant polynomial relationships with an initial rise in species richness as the variable increased in value, to a peak, where a range of values of the variable corresponded with high species richness, and then a decrease in species richness beyond a certain value of the variable. This pattern was more marked for some variables than others, with the variables number of trees and percentage bare ground showing the strongest effects. It appears that the number of trees is correlated with an increase in species richness up to a peak between 20 to 30 trees within 20m of the transect when species richness decreases. A similar pattern for bare ground results in a peak between 35% and 45% cover followed by a decline in species richness, for short vegetation the peak is between 25% and 35% cover, for medium vegetation it is between 20% and 30% cover and for old farmland there is a peak between 40% and 60% cover. Those variables displaying polynomial relationships were modelled along with their quadratic term. These were short vegetation, medium height vegetation, bare ground cover, total percentage of old farmland on the transect and the total number of trees over 3m in height on the transect.

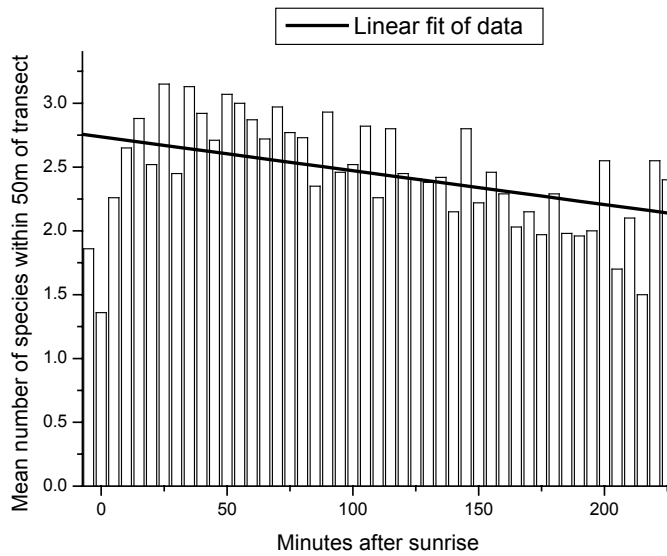


Figure 5.2 Relationship of minutes after sunrise, rounded to the nearest 5 minutes, to number of bird species. The line represents a linear fit to the interval data, the fit to the raw data gave intercept=2.74, gradient=-0.002,  $R=-0.43$ ,  $p<0.01^{**}$ ,  $N=47$  time of day bins.

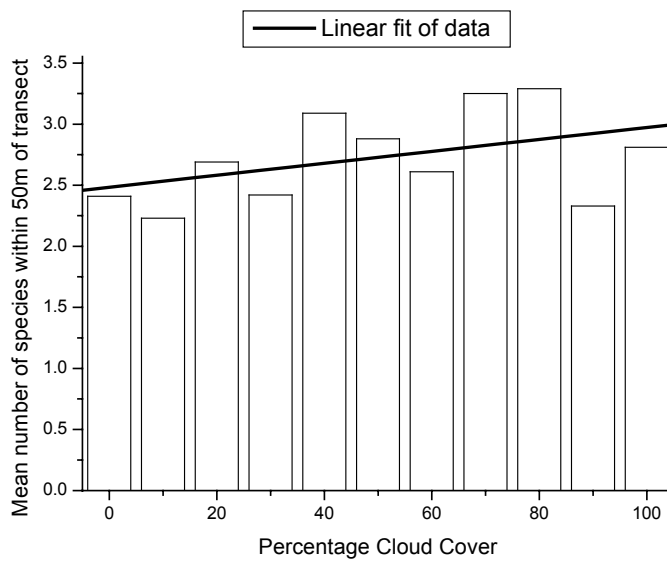


Figure 5.3 Relationship of percentage cloud cover to number of bird species. The line represents a linear fit to the data, intercept=2.48, gradient=0.005,  $R=0.44$ ,  $p=0.18$ ,  $N=11$ .

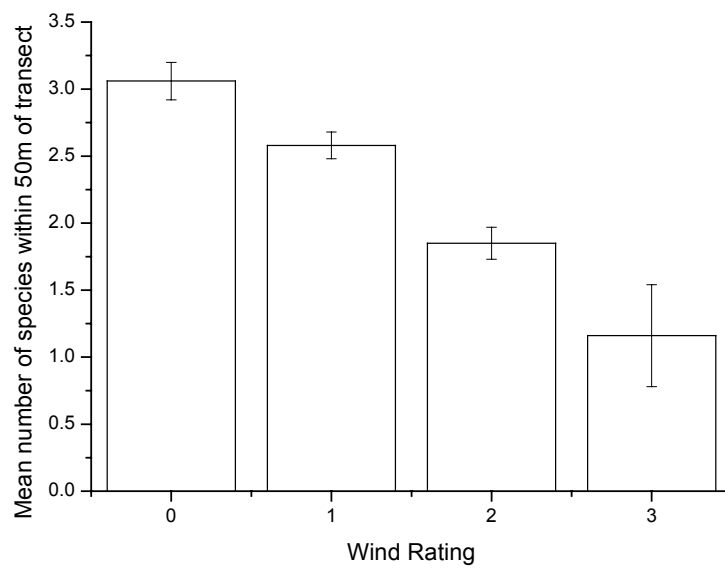


Figure 5.4 Relationship of wind rating to number of species. The scale of the ratings is ordinal, with 0 representing no wind and 3 representing the strongest wind in which a transects would be surveyed , error bars are +/- one standard error. Species richness decreases with wind strength, one way ANOVA  $F_{3,959}=10.5$ ,  $p<0.01^{**}$

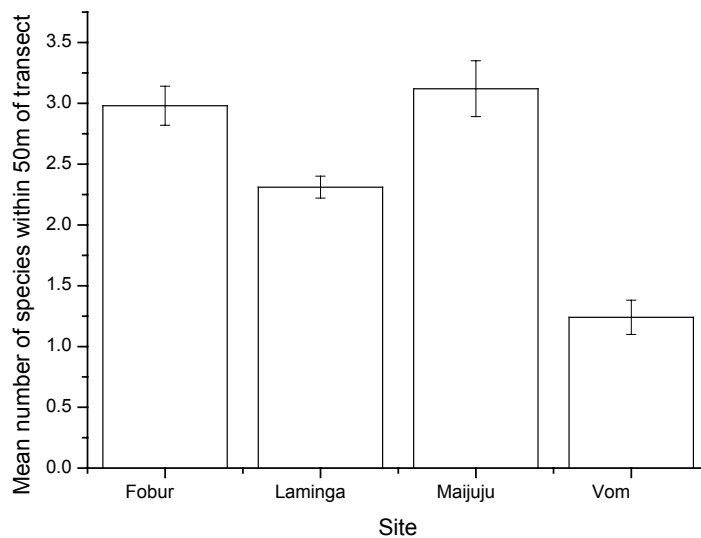


Figure 5.5 Number of species by site, error bars are +/- one standard error. There is a significant difference between sites, one way ANOVA  $F_{3,959}=22.5$ ,  $p<0.01^{**}$



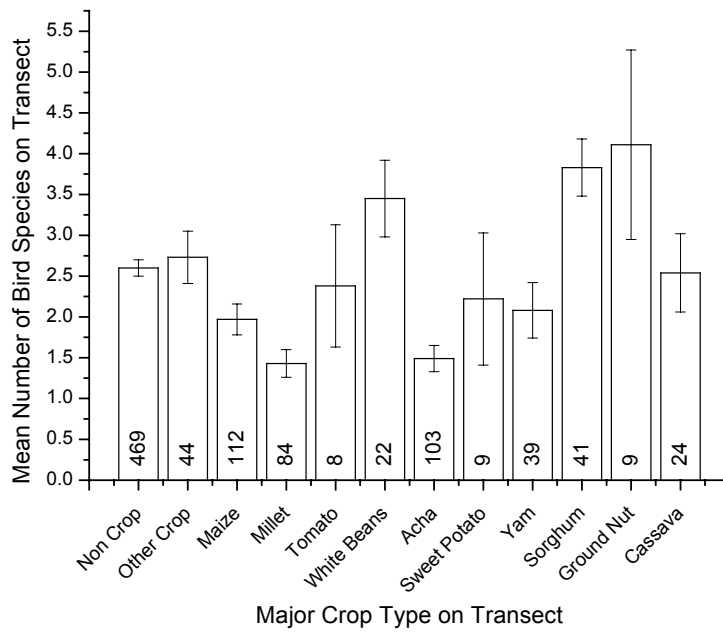


Figure 5.6 Crop type against mean species richness. Numbers in columns are number of transects with crop as major crop type on transect, error bars are  $\pm$  one standard error. There is a significant difference between the factors, one way ANOVA  $F_{3,963}=7.7$ ,  $p<0.01^{**}$

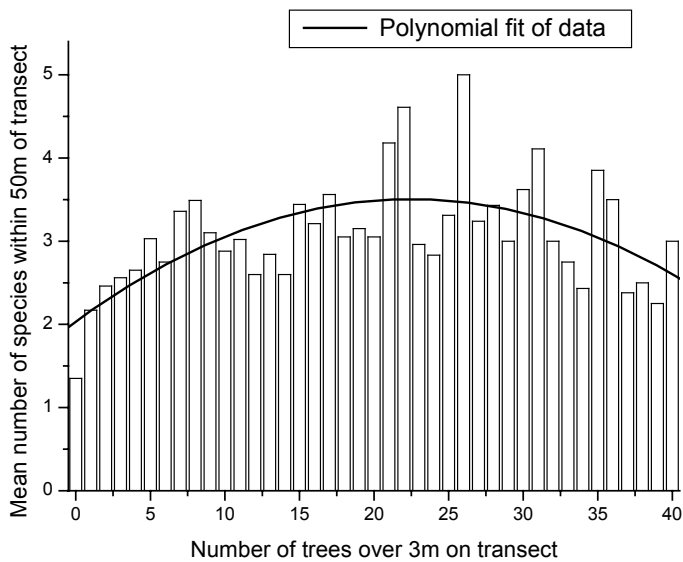


Figure 5.7 Relationship of number of trees on a transect to number of bird species. The line represents a polynomial fit to the data,  $y=a+bx+cx^2$ ;  $a=2.03$ ,  $b=0.13$ ,  $c=-0.003$ ,  $R^2=0.38$ ,  $p<0.01^{**}$ ,  $N=41$ .

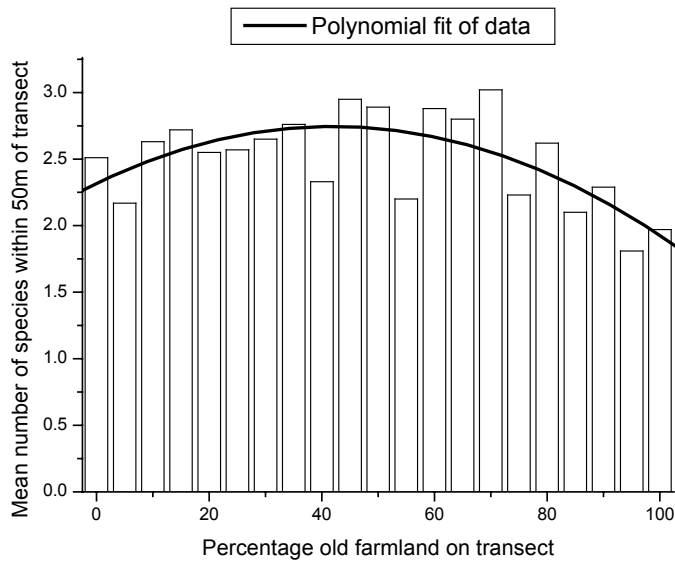


Figure 5.8 Relationship of percentage old farmland to bird species. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.321$ ,  $b=0.02$ ,  $c=-0.001$ ,  $R^2=0.49$ ,  $p<0.01^{**}$ ,  $N=21$ .

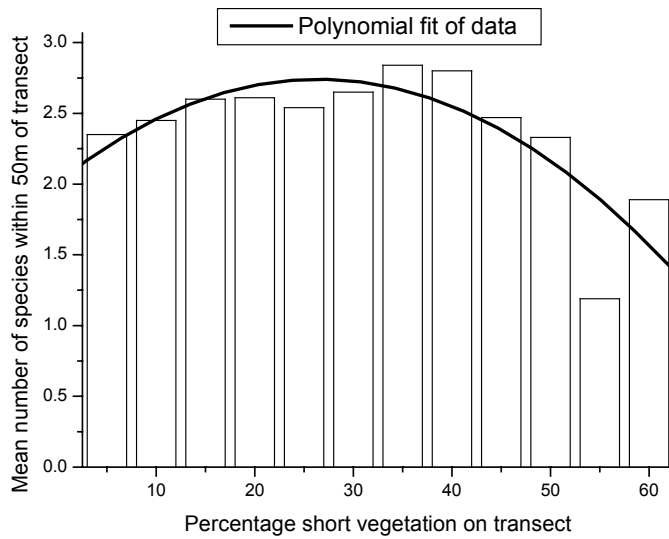


Figure 5.9 Relationship of short vegetation cover to number of bird species. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.01$ ,  $b=0.06$ ,  $c=-0.001$ ,  $R^2=0.65$ ,  $p<0.01^{**}$ ,  $N=12$ .

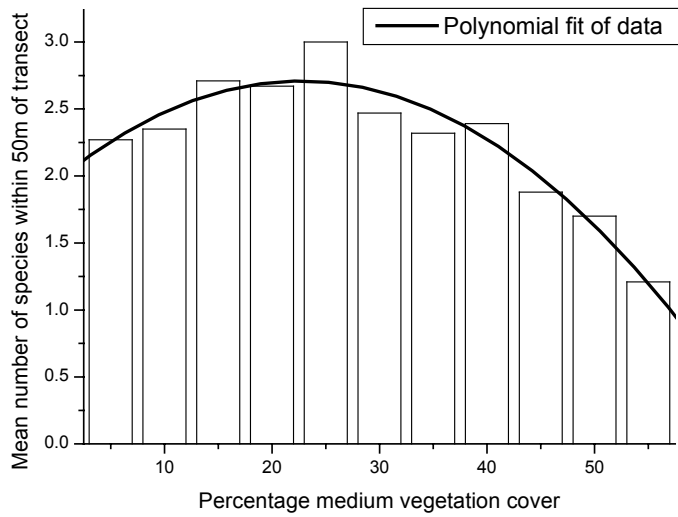


Figure 5.10 Relationship of medium vegetation cover to number of bird species. The line represents a polynomial fit to the data,  $y=a+bx+cx^2$ ;  $a=1.97$ ,  $b=0.07$ ,  $c=-0.001$ ,  $R^2=0.38$ ,  $p<0.01^{**}$ ,  $N=41$ .

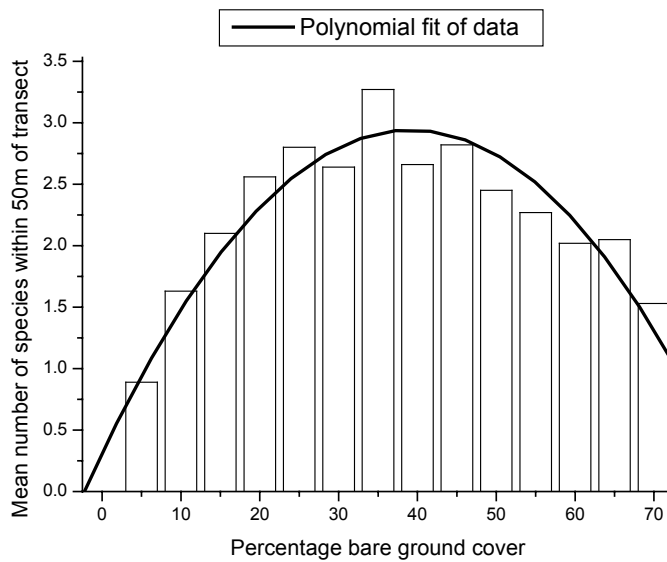


Figure 5.11 Relationship of percentage bare ground cover to bird species. The line represents a polynomial fit to the data,  $y=a+bx+cx^2$ ;  $a=0.31$ ,  $b=0.13$ ,  $c=-0.002$ ,  $R^2=0.92$ ,  $p<0.01^{**}$ ,  $N=15$ .

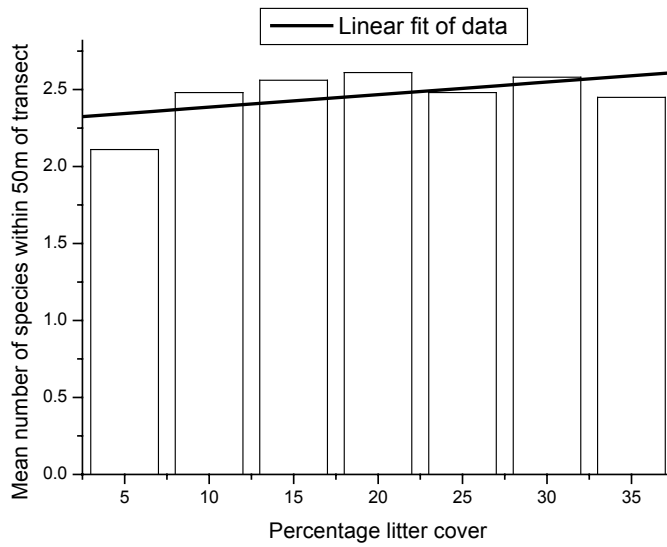


Figure 5.12 Relationship of percentage leaf litter to bird species. The line represents a linear fit to the data, intercept=2.30, gradient=0.008,  $R=0.52$ ,  $p=0.22$ ,  $N=7$ .

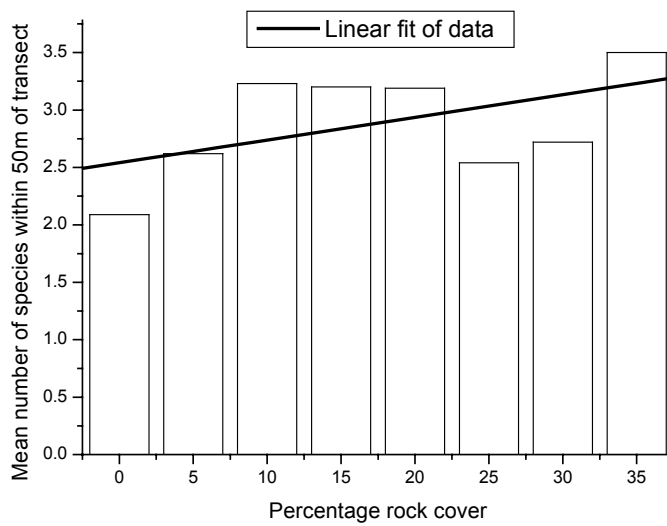


Figure 5.13 Relationship of percentage rock cover to number of bird species. The line represents a linear fit to the data, intercept=2.54, gradient=0.02,  $R=0.52$ ,  $p<0.01^{**}$ ,  $N=8$ .

The 95% confidence set of models contained 12 models, with the top 3 ranked models having Akaike weights of 0.16, 0.11 and 0.10 respectively. The models in the confidence set are displayed in Table 5.1 and the variable Akaike weights are in Table 5.2.

Table 5.1. 95% confidence set of models, dependent variable number of bird species within 50m of transect. Transects conducted between March and April 2004 and between February and April 2005. All models include minutes after sunrise, wind and cloud cover. “Q” indicates a quadratic term of the variable preceding it included in the model.

Rank	Model Number	Model	AICc	$\Delta$ AICc	Akaike weight
1	232	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Medium veg + Q, Rock cover	1537.5	0.00	0.16
2	252	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Medium veg + Q, Bare ground + Q, Rock cover	1538.2	0.67	0.11
3	177	Crop Type, Total Trees + Q, Short veg + Q, Medium veg + Q, Rock cover	1538.4	0.88	0.10
4	249	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Medium veg + Q, Leaf Litter, Rock cover	1538.6	1.03	0.09
5	255	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Medium veg + Q, Bare ground + Q, Leaf Litter, Rock cover	1538.8	1.25	0.08
6	220	Crop Type, Total Trees + Q, Short veg + Q, Medium veg + Q, Leaf Litter, Rock cover	1539	1.49	0.07
7	247	Crop Type, Total Trees + Q, Short veg + Q, Medium veg + Q, Bare ground + Q, Leaf Litter, Rock cover	1539.2	1.64	0.07
8	248	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Bare ground + Q, Leaf Litter, Rock cover	1539.2	1.69	0.07
9	231	Crop Type, Total Trees + Q, Short veg + Q, Medium veg + Q, Bare ground + Q, Rock cover	1539.2	1.71	0.07
10	230	Crop Type, Total Trees + Q, Old farmland + Q, Short veg + Q, Bare ground + Q, Rock cover	1539.6	2.06	0.06
11	219	Crop Type, Total Trees + Q, Short veg + Q, Bare ground + Q, Leaf Litter, Rock cover	1539.8	2.25	0.05
12	175	Crop Type, Total Trees + Q, Short veg + Q, Bare ground + Q, Rock cover	1540.8	3.31	0.03

Tables 5.2. Variable Akaike weights for all 255 models run, dependent variable number of bird species within 50m of transect.

Variable	Akaike weight
Total Trees	1.00
Crop Type	1.00
Rock Cover	0.99
Short Vegetation	0.96
Medium Vegetation	0.78
Old Farmland	0.60
Bare Ground	0.56
Leaf Litter	0.45

The random variable included in the model consisted of values for all transects with a normal distribution and a mean and standard deviation the same as the variable with the highest Akaike weight, Total Trees, which has a mean of 9.88 and standard deviation of 13.71. The mean Akaike weight for the random variable was 0.37 with a standard error of 0.03 after 20 runs with different values. As a conservative approach any variables with an Akaike weight below the mean plus two times the standard error of that for the random variable, in this case 0.43, can be considered to be of little importance in the model.

The top-ranked model, model number 232, included all variables except bare ground and leaf litter, which were also the variables with the lowest Akaike weights, 0.56 and 0.45 respectively. Of the other variables total number of trees and the crop type factor had the highest weights of 1.00, meaning the combined weights of those models, not including these two variables, was below 0.01, indicating the strong influence they had on species richness. All variables had Akaike weights above 0.43 so seemed to also have a large influence on species richness. Table 5.3 displays the parameter estimates for each covariate and factor, along with standard errors and Wald chi-squared values and associated *p*-value, and Type 3 chi square values with significance indicated by one or two asterix.

Tables 5.3. Parameter estimates for top ranked model, model number 232 in Tables 5.4. Q indicates quadratic term. The top ranked model parameters indicate the direction in which the different variables are influencing species richness within the context of the model and chi squared tests indicate the influence each variable is having on that particular model.

Parameter		Parameter estimate	Standard error	Chi-Square	p-value	Type 3 Chi-Square
Intercept		-0.30	0.27	1.26	0.26	
Minutes after sunrise		-0.001	$4 \times 10^{-4}$	10.78	<0.01**	10.79**
Site	Fobur	0.26	0.11	5.35	0.02*	23.55**
Site	Laminga	0.37	0.09	15.78	<0.01**	
Site	Maijuju	0.46	0.11	16.71	<0.01**	
Site	Vom	0	0	.	.	
Wind	0	0.17	0.16	1.11	0.29	13.30 **
Wind	1	0.12	0.15	0.63	0.43	
Wind	2	-0.06	0.16	0.13	0.71	
Wind	3	0	0	.	.	
Cloud cover		$-4 \times 10^{-4}$	$8 \times 10^{-4}$	0.02	0.89	0.02
Crop type	Non-crop	0.14	0.14	1.03	0.31	49.27**
Crop type	Other crop	0.28	0.16	2.96	0.09	
Crop type	Maize	0.04	0.15	0.08	0.78	
Crop type	Millet	-0.25	0.16	2.29	0.13	
Crop type	Tomato	0.14	0.27	0.29	0.59	
Crop type	White beans	0.43	0.18	5.82	0.02*	
Crop type	Acha	-0.16	0.16	1.04	0.31	
Crop type	Sweet potato	0.06	0.26	0.05	0.82	
Crop type	Yam	-0.03	0.17	0.04	0.85	
Crop type	Sorghum	0.41	0.16	7.07	<0.01**	
Crop type	Groundnut	0.51	0.21	5.70	0.02*	
Crop type	Cassava	0.00	0.00	.	.	
Total trees		0.02	0.003	42.07	<0.01**	49.78**
Old farmland		0.004	0.002	2.18	0.14	2.17
Short vegetation		0.03	0.01	10.97	<0.01**	11.37**
Medium vegetation		0.03	0.01	5.57	0.02*	5.80*
Rock cover		0.01	0.004	17.07	<0.01**	16.31**
Total trees Q		-0.04	0.00	16.63	<0.01**	26.22**
Short vegetation Q		$-4 \times 10^{-5}$	$2 \times 10^{-4}$	8.28	<0.01**	8.83**
Medium vegetation Q		$-9 \times 10^{-9}$	$3 \times 10^{-4}$	8.10	<0.01**	8.86**
Old farmland Q		-0.4	0.00	3.81	0.05	3.82

As suggested by the individual plots displayed in Figures 5.2 to 5.5, minutes after sunrise has a significant negative parameter so species richness decreases as minutes after sun increases. Cloud cover, as the plot suggests, has a positive impact on species richness, although this is not significant, wind has a significant negative impact

overall. Sites vary significantly in species richness and this is reflected in the parameter estimates and chi squared values. The fact that these trends are controlled for in the model means the trends for the other variables should be free of the influence of time of day, wind and cloud cover.

Crop type had a significant influence on the models. Chi squared values for the individual parameters show negative effects on species richness of some common crops, such as maize, millet, acha and yam, whereas positive effects are seen for tomato, white beans, sweet potato, sorghum and groundnut. These effects were significant for maize, millet, sorghum and yam. Figure 5.6 shows mean species richness for transects with major crop types which shows lower values for maize and millet compared with transects with no major crop type and higher values for groundnut, sorghum and white beans, as would be expected from the model results. All other variables had significant chi squared results in Table 5.3 and positive parameter estimates, (except for the quadratic terms which then have negative parameter estimates), except for old farmland, which was not significant.

Figure 5.14 shows the relationship between the recorded data for the validation dataset, between the 9<sup>th</sup> of January 2006 and the 16<sup>th</sup> of March 2006, and the weighted predicted values. Due to the non-normal nature of the dependent variable, the non-parametric Spearman's correlation coefficient was calculated comparing the number of bird species observed within 50m of the transect and the predicted values for the model.



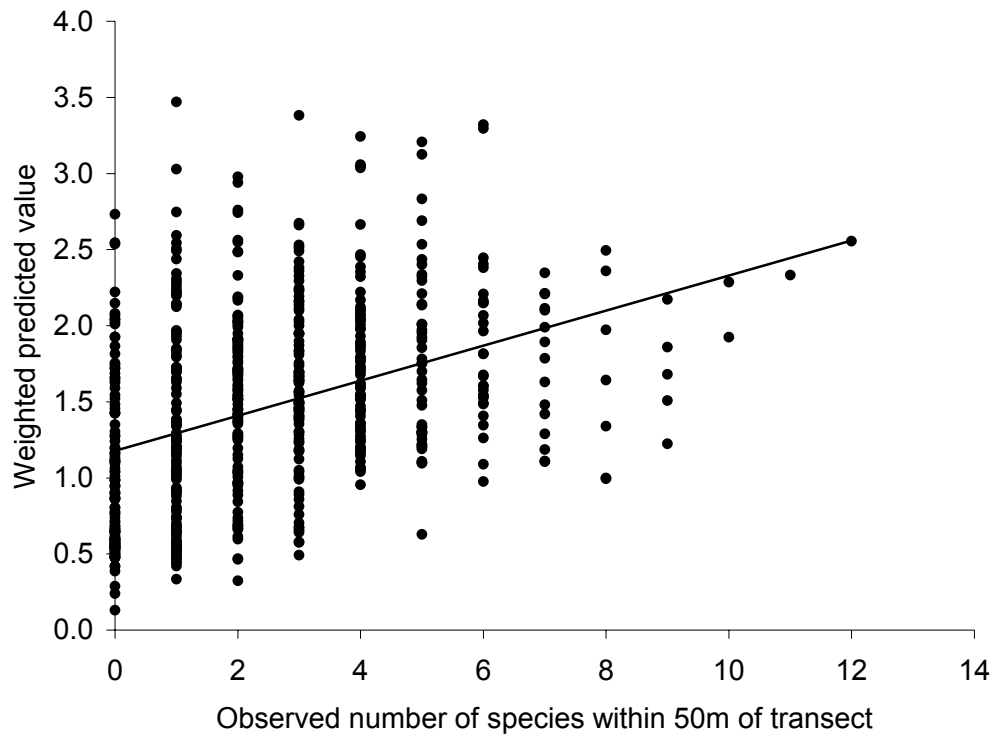


Figure 5.14 Species richness against weighted predicted values for all models. Linear regression line  $F_{1,634}=114$ ,  $p<0.01^{**}$ , intercept=1.18, sd=0.04 gradient= 0.12, sd=0.01,  $R^2=0.15$ . Spearman's rho correlation coefficient = 0.425,  $p<0.01^{**}$ , N=636.

### 5.3.2 Simpson's Diversity Indices

The relationships between Simpson's diversity index and the predictive variables are displayed in Figures 5.15 to 5.26, along with either linear or polynomial regression lines and parameters. The relationships are similar to those for species richness, except that many patterns are less marked, particularly for crop type, old farmland, short vegetation and bare ground. The variables with a non-linear relationship with the response variable were the same as for species richness, total trees, short vegetation, medium vegetation, bare ground and old farmland.

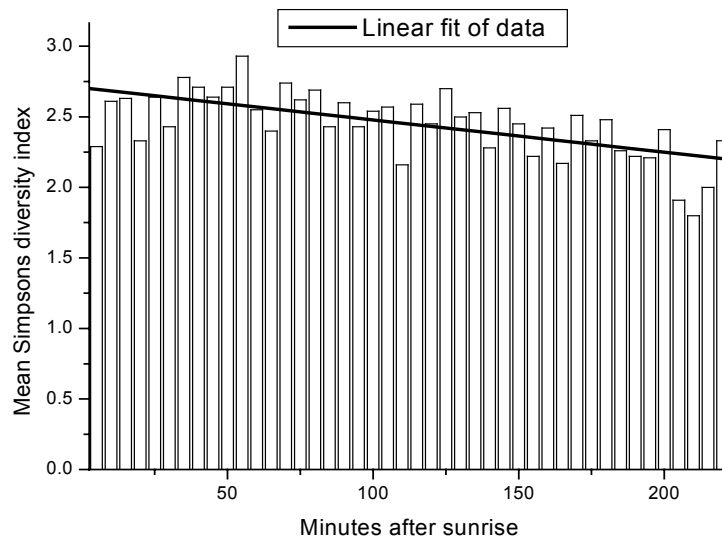


Figure 5.15 Relationship of minutes after sunrise to Simpson's diversity index. The line represents a linear fit to the interval data, the fit to the raw data gave an intercept=2.71, gradient=0.002,  $R=0.63$ ,  $p<0.01^{**}$ ,  $N=44$ .

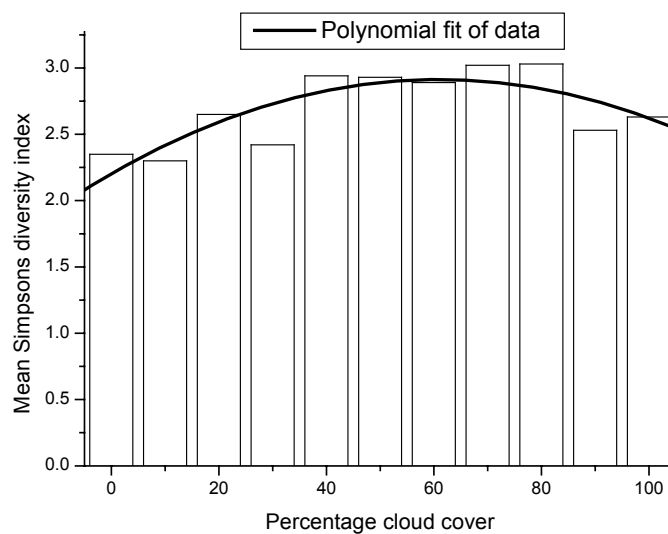


Figure 5.16 Relationship of percentage cloud cover to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.20$ ,  $b=0.02$ ,  $c=-0.001$ ,  $R^2=0.67$ ,  $p=0.01^{**}$ ,  $N=11$ .

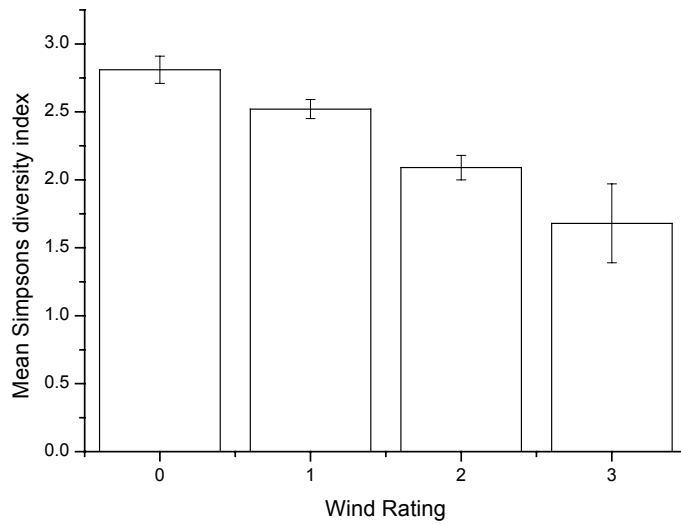


Figure 5.17 Relationship of wind rating to Simpson's diversity index. The scale of the ratings is ordinal, with 0 representing no wind and 3 representing the strongest wind transects were surveyed in, error bars are +/- one standard error. Simpson's diversity index decreases with wind strength, one way ANOVA  $F_{3,766}=8.5$ ,  $p<0.01^{**}$

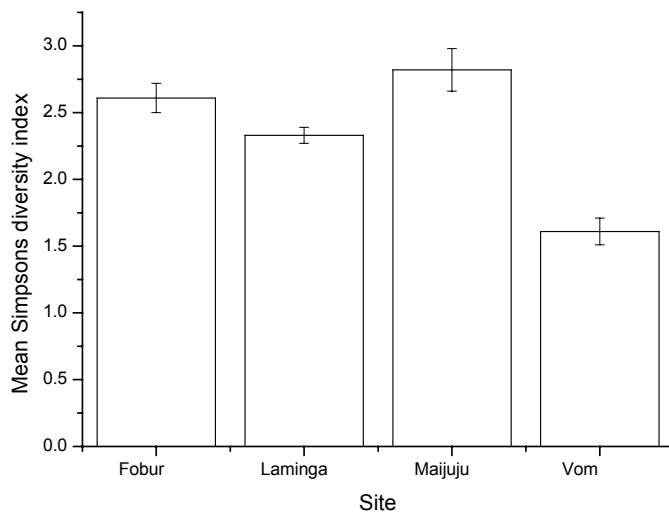


Figure 5.18 Simpson's diversity index by site, error bars are +/- one standard error. There is a significant difference between sites, one way ANOVA  $F_{3,770}=12.9$ ,  $p<0.01^{**}$

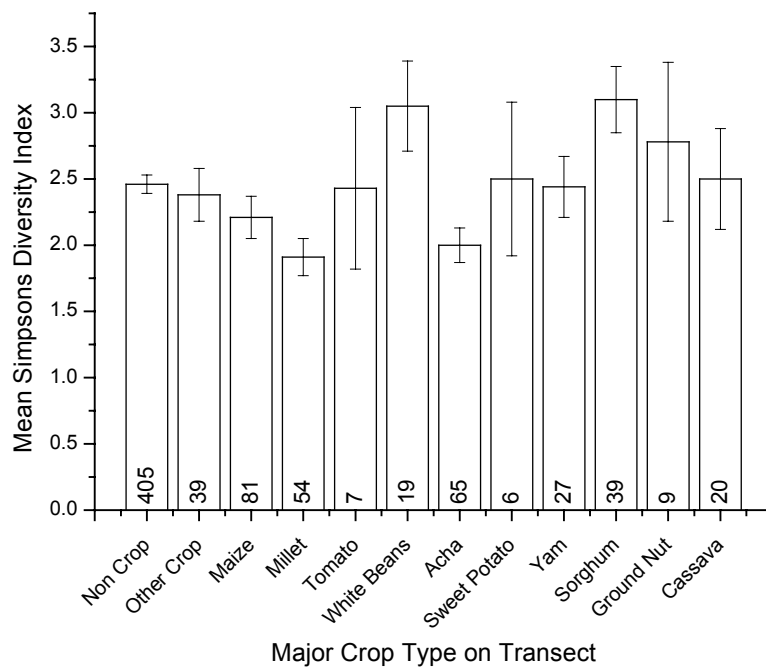


Figure 5.19 Crop type against Simpson's diversity index. Numbers in columns are number of transects with crop as major crop type on transect, error bars are +/- one standard error. There is a significant difference between the crop types, one way ANOVA  $F_{3,770}=2.9$ ,  $p<0.01^{**}$

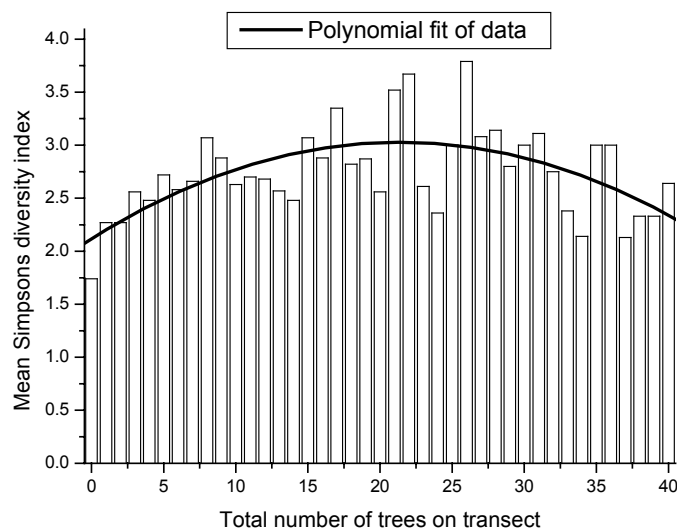


Figure 5.20 Relationship of total number of trees to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.12$ ,  $b=0.08$ ,  $c=-0.002$ ,  $R^2=0.39$ ,  $p<0.01^{**}$ ,  $N=41$ .

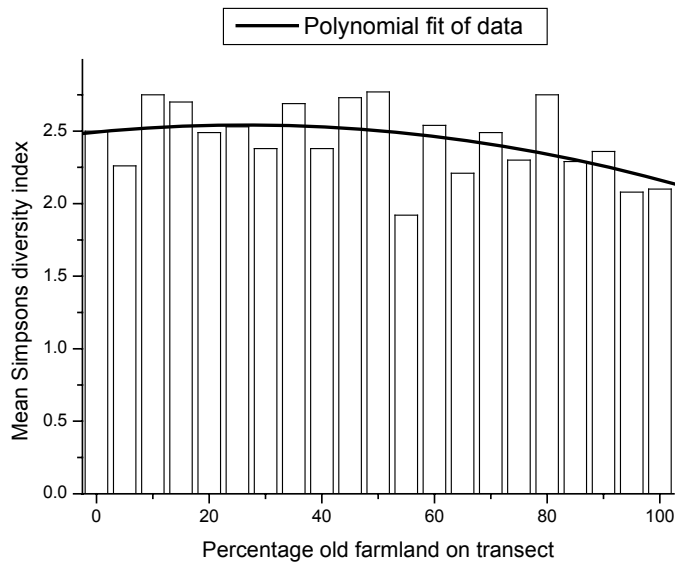


Figure 5.21 Relationship of percentage old farmland to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.49$ ,  $b=0.003$ ,  $c=-0.001$ ,  $R^2=0.23$ ,  $p=0.09$ ,  $N=21$ .

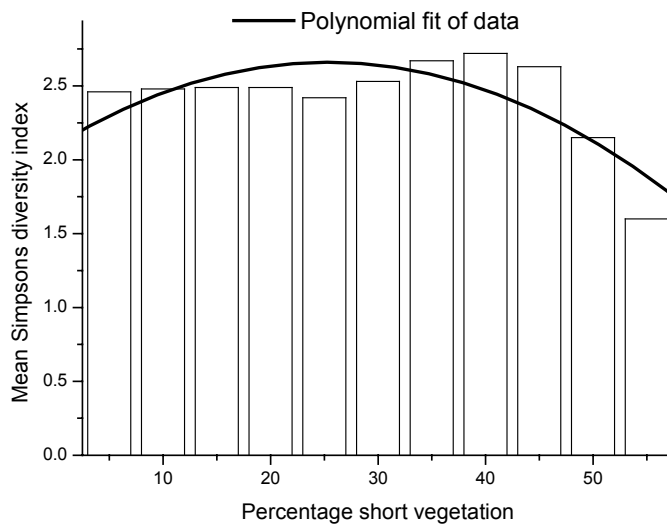


Figure 5.22 Relationship of percentage short vegetation to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.10$ ,  $b=0.044$ ,  $c=-0.001$ ,  $R^2=0.61$ ,  $p=0.02^*$ ,  $N=11$ .

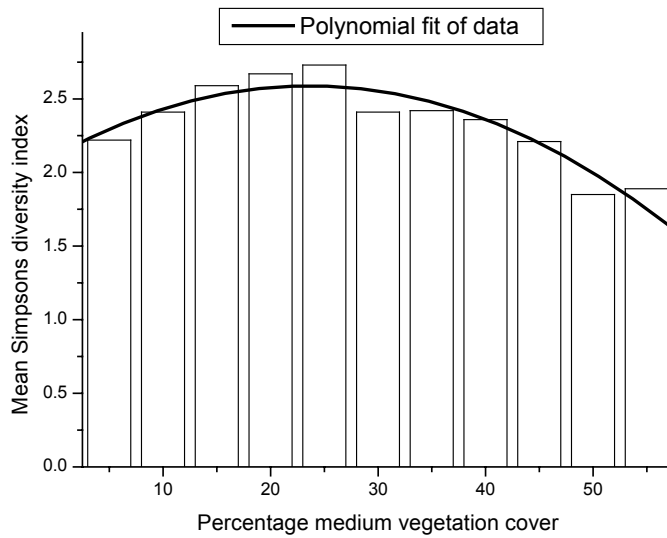


Figure 5.23 Relationship of percentage medium vegetation cover to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=2.11$ ,  $b=0.04$ ,  $c=-0.001$ ,  $R^2=0.87$ ,  $p<0.01^{**}$ ,  $N=11$ .

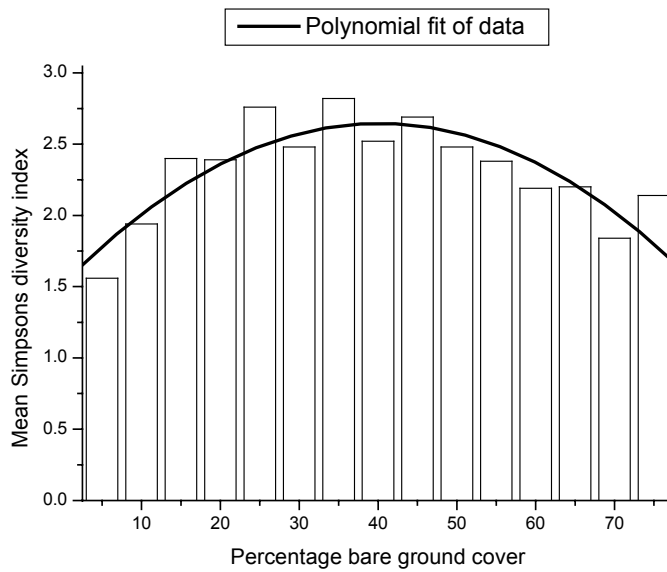


Figure 5.24 Relationship of percentage bare ground cover to Simpson's diversity index. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=1.52$ ,  $b=0.06$ ,  $c=-0.001$ ,  $R^2=0.74$ ,  $p<0.01^{**}$ ,  $N=15$ .

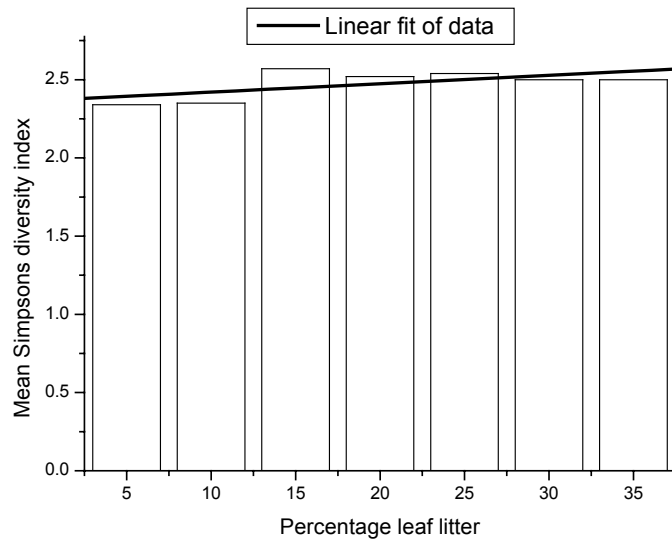


Figure 5.25 Relationship of percentage leaf litter to Simpson's diversity index. The line represents a linear fit to the data, intercept=2.38, gradient=0.005,  $R=0.63$ ,  $p=0.13$ ,  $N=7$ .

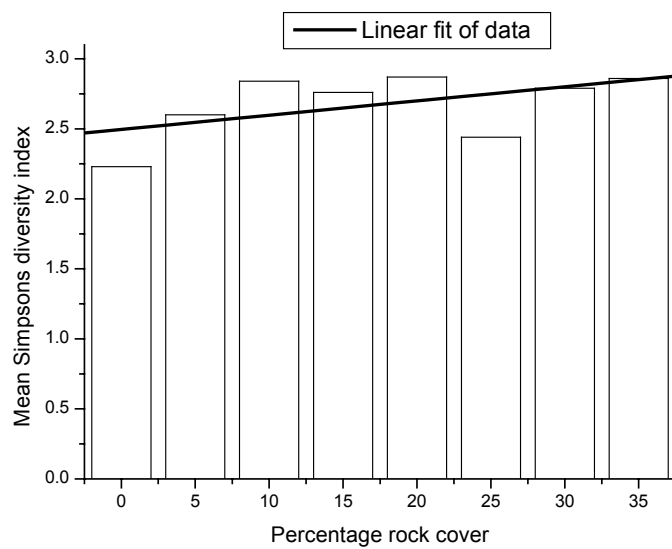


Figure 5.26 Relationship of percentage rock cover to Simpson's diversity index. The line represents a linear fit to the data, intercept=2.50, gradient=0.01,  $R=0.54$ ,  $p=0.17$ ,  $N=8$ .

The 95% confidence set of models consisted of 42 models with the top 3 ranked models having Akaike weights of 0.14, 0.08 and 0.07 respectively. The top 10 models are listed in Table 5.4, variable weights are listed in Table 5.5 and the top-rated model parameters are listed in Tables 5.6. The mean Akaike weight for 20 generated values of a random variable was 0.33, standard error 0.02, therefore, any variables with Akaike weights below 0.37 could be considered to have little effect on the models. This includes leaf litter, bare ground, old farmland and crop type. Total trees, at 1.00, had the highest Akaike weight, with rock cover also high, at 0.86, medium and short vegetation were higher than the random variable, at 0.61 and 0.53 respectively.

Tables 5.4. 95% confidence set of models, dependent variable Simpson's diversity index by transect. Transects conducted between March and April 2004 and between February and April 2005. "Q" indicates a quadratic term of the variable preceding it included in the model.

Rank	Model Number	Model	AICc	$\Delta$ AICc	Akaike weight
1	106	Total trees + Q, Short veg +Q, Medium veg +Q, Rock cover	500.68	0.00	0.14
2	42	Total trees + Q, Medium veg +Q, Rock cover	501.82	1.13	0.08
3	40	Total trees + Q, Short veg +Q, Rock cover	502.18	1.49	0.07
4	165	Total trees + Q, Short veg +Q, Medium veg +Q, Leaf litter, Rock cover	502.27	1.58	0.06
5	100	Total trees + Q, Medium veg +Q, Bare ground + Q, Rock cover	502.90	2.22	0.05
6	39	Total trees + Q, Bare ground + Q, Rock cover	503.11	2.43	0.04
7	95	Total trees + Q, Medium veg +Q, Leaf Litter, Rock cover	503.12	2.44	0.04
8	9	Total trees + Q, Rock cover	503.34	2.66	0.04
9	93	Total trees + Q, Short veg + Q, Leaf Litter, Rock cover	503.51	2.83	0.03
10	181	Total trees + Q, Old farmland + Q, Short veg + Q, Medium veg + Q, Rock cover	503.85	3.17	0.03



Tables 5.5. Variable Akaike weights for all 255 models run, dependent variable Simpson's diversity index by transect.

Variable	Akaike Weights
Total Trees	1.00
Rock Cover	0.86
Medium Vegetation	0.61
Short Vegetation	0.53
Leaf Litter	0.33
Bare Ground	0.31
Old Farmland	0.19
Crop Type	0.00

Tables 5.6. Parameter estimates for top ranked model, model number 106 Tables 5.8. Q indicates quadratic term.

Parameter		Parameter estimate	Standard error	Chi-Square	p-value	Type 3 Chi-Square
Intercept		0.04	0.25	0.02	0.88	
Min. after sunrise		$-6 \times 10^{-4}$	$5 \times 10^{-4}$	1.91	0.17	1.92
Wind	0	0.16	0.18	0.73	0.39	8.80*
Wind	1	0.11	0.18	0.36	0.55	
Wind	2	-0.05	0.18	0.07	0.79	
Wind	3	0	0	.	.	
Cloud cover		$9 \times 10^{-4}$	$8 \times 10^{-4}$	1.1	0.29	1.09
Site	Fobur	0.28	0.12	5.42	0.02	14.65**
Site	Laminga	0.27	0.10	7.05	0.01	
Site	Maijuju	0.44	0.12	13.96	$2 \times 10^{-4}$	
Site	Vom	0	0	.	.	
Total no. trees		0.01	$3.2 \times 10^{-5}$	4.18	0.04	4.33*
Total no. trees Q		$-1 \times 10^{-4}$	$-1 \times 10^{-4}$	1.12	0.29	1.25
Short veg		0.02	$9.4 \times 10^{-3}$	3.35	0.07	3.44
Short veg Q		$-4 \times 10^{-4}$	$2 \times 10^{-4}$	4.45	0.03	4.73*
Medium veg		0.03	0.01	5.05	0.02	5.26*
Medium veg Q		$-7 \times 10^{-4}$	$3 \times 10^{-4}$	5.12	0.02	5.54*
Rock Cover		0.01	$3.8 \times 10^{-3}$	6.57	0.01	6.33*

Total trees, medium vegetation and rock cover have significant chi squared values and positive parameter estimations for model 106. Site and wind are also significant.

Figure 5.27 shows the relationship between the model averaged Simpson's diversity index values and the observed values for the validation dataset. Due to the non-normal

nature of the dependent variable the non-parametric Spearman's correlation coefficient was calculated.

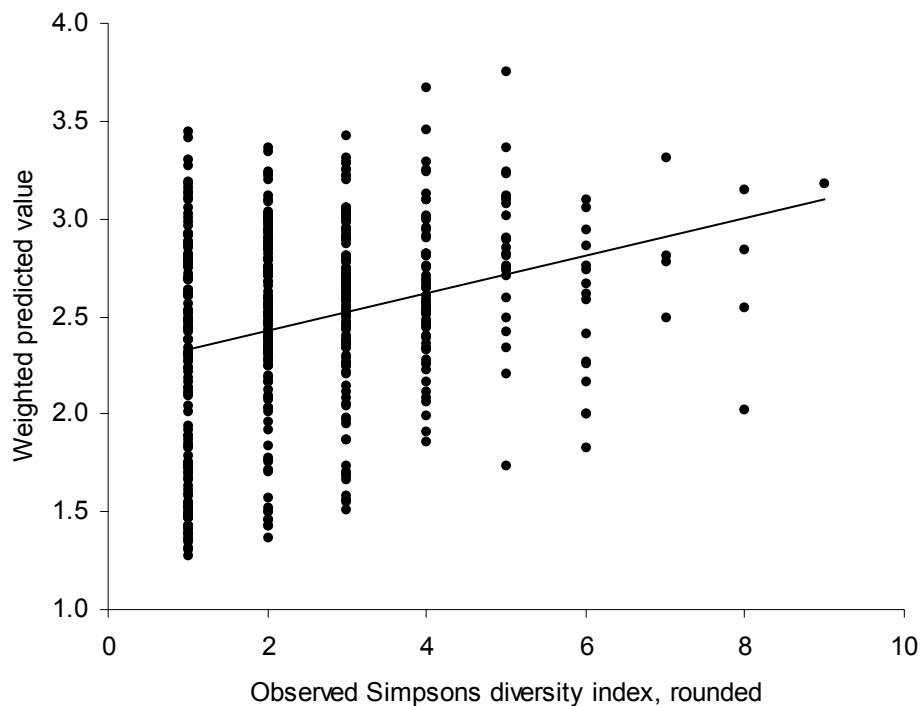


Figure 5.27, Simpson's diversity index against weighted predicted values. Linear regression line  $F_{1,512}=43.2$ ,  $p<0.01^{**}$ , intercept=2.25, sd 0.04, gradient= 0.10, sd=0.02,  $R^2=0.08$ . Spearman's rho correlation coefficient = 0.268\*\*,  $p<0.01$ ,  $N=513$ .

## 5.4 Discussion

### 5.4.1 Species Richness

The polynomial relationships observed for some variables are in line with patterns observed for habitat variables in many ecosystem studies (Jongman et al. 1995) and suggest that a varied habitat may be best for high species richness. There appear to be ideal ranges for these variables but whether the patterns in species richness observed are a direct result of the independent influence of each variable is not apparent solely from these figures: models that account for the confounding effects of variables need to be considered. The Information Theoretic approach to model selection has highlighted the fact that no one model for species richness incorporating the selected variables is a strong competitor to be the preferred model, with the highest Akaike weight only 0.16. This means interpretation of the model results is best done using a

multi-model approach. Of the 8 variables all 8 had Akaike weights over 0.43, so have strong effects in the models run. Of the 12 models in the 95% confidence set, one included all 8 variables, 4 included 7 variables, 6 included 6 variables and one included 5 variables, further demonstrating that several variables had strong influences on species richness.

Judging by parameter estimates in the top model for the crop type factor it appears that the presence of agriculture itself does not have a fundamental effect. In total there were 388 transects with no active crops along their length and 207 transects with no land farmed within 6 years, if there were a very significant negative effect of agriculture it might be expected to be observed in these data. No major crop type dominated in terms of both occurrence and effects on number of species, and overall different crop types had different effects. The lack of significance for some crop types in the top-ranked model may however reflect low sample sizes and so a lack of statistical power. That crop type factor itself has an Akaike weight of 1.0 appears to be due to the effect of different crops rather than the presence of crops.

The reasons for the differences between the crops are unclear. Whether maize, millet and acha tend to be planted in areas of low species richness whilst sorghum is planted in areas of high species richness is one possibility. This is backed up by Figure 5.5, which shows high species richness for Maijuju and Fobur, where Figure 3.6 shows more sorghum was cultivated than other sites, and lower species richness for Vom, where more acha and millet was cultivated than other sites, so it is possible that other differences between sites may be responsible for the differences observed between crops. Differences between crop types within sites, however, were consistent, suggesting that unless a significant variable has been omitted from the modelling process the differences between crops are likely to be genuine. This could have interesting implications when managing farmland for biodiversity.

No studies have linked specific crops in the tropics with increased or decreased bird species richness, although, it has been noted in the temperate Western Cape of South Africa, where there are many species and families in common with West Africa, sites

including a mixture of different crops and some natural habitat resulted in higher bird species richness than on sites with one major crop (Mangnall & Crowe 2003). The data presented here indicates that some crops are better for species richness than others. In studies on temperate farmland outside of Africa, the emphasis has been on the effect of crop variety and rotation on bird populations rather than the type of crop (McLaughlin & Mineau 1995; Benton et al. 2003) although the effect of different types of winter crop specifically planted with avian seed-eaters in mind has been investigated, with some crops being more beneficial than others (Henderson et al. 2004). The results of these models in relation to crops presents the possibility of an alternative approach to simply suggesting frequent crop rotation to farmers in order to maximise the number of species using farmland: the type of crop used in the rotation can be emphasised as important also. For example, it would appear that sorghum could be encouraged over and above maize and acha as it hosts a larger number of bird species. These results contrast with those observed at the field level in Chapter 4, where crop type was not found to be an important predictor of species richness, although the lack of data for sorghum, due to few sorghum fields being present in Laminga, could be a factor in this as well as differences due to the different spatial scales.

The continuous variable with the highest Akaike weight is total number of trees, which is present in all the models in the 95% confidence set. The parameter estimate for model 232 is positive at 0.021. The quadratic variable has a negative parameter estimate of  $-0.001$ , which is consistent with the polynomial shape of the plot in Figure 5.7, as the number of trees increases and positively affects the number of species observed the negative influence of the quadratic term results in the drop-off in species richness beyond a certain value. This pattern could be due to an optimum level of tree density being reached, beyond which the number of species observed in the agricultural savanna mosaic decreases. The possibility of a drop off in detectability at the highest tree densities cannot be completely ruled out as having an effect on these results, although this has probably been accounted for in limiting the distance at which a bird is counted as observed for the analysis to 50m from the transect, and, other variables that are unlikely to affect detectability also display a similar polynomial pattern.

Changes in vegetation structure in savanna habitats have been implicated in changes in bird community composition before (Skowno & Bond 2003), with marked changes observed from grassland to woodland areas related to changes in the vegetation density and vertical complexity of the vegetation. The measure of number of trees in the models probably represents an increase in woody vegetation density because only trees over 3m in height were counted for this variable, and vertical complexity is likely to be higher with a higher number of trees on the transect. Studies have also suggested that in temperate farmland the presence of woody vegetation can encourage the presence of woodland bird species (Fuller et al. 2001). The added presence of savanna woodland bird species, such as scarlet-chested sunbird and speckle-fronted weaver, alongside the open habitat and grassland species in the fields, such as whinchat, crested lark and plain-backed pipit, could increase the species richness in areas where there is a greater presence of woody vegetation. Tropical studies that have investigated bird diversity and species richness on farmland have also suggested that tree density and the presence of woody vegetation can have a positive effect (Wilson et al. 1997; Soderstrom et al. 2003).

This study, which has been conducted over a longer time-period and at a more intensive level than other African studies, appears to be in general agreement with the idea that trees in farmlands are good for birds, although the effect of tree density is more complex than simple positive linear trend. It is possible that, considering the paucity of pristine habitat on the Jos Plateau, there may be a limit to the number of savanna species available to populate farmland in certain areas once the open area species have dropped off, or that high tree density in itself does not necessarily lead to an increase in the number of species able to use the habitat. High tree densities in this study could represent areas that have been recently cleared and where woodland is returning, with many young trees over 3m in height, as opposed to areas of dense riparian forest, which were not well covered in the surveys due to problems of access. Forests, as complex, climax habitats, have higher species richness than light woodland (Gill 2006; Lindenmayer et al. 2006), whereas younger, less complex, dense woodland may not provide the habitat heterogeneity required to support as many species. Comparisons between lightly wooded farmland and a more pristine savanna-forest mosaic may indicate whether species richness would continue to rise with increased tree density in these situations. In any case, it appears that any farmland

management strategy should include the retention of a certain amount of woody vegetation in order to maximise the number of bird species occurring.

Rock cover also has a large Akaike weight and a positive parameter estimate for model 232, again consistent with the plot in Figure 5.13, which shows a positive linear trend in species richness with increasing rock cover. Rock cover is also present in all the 12 models in the 95% confidence set. Transects were limited on and around rock outcrops by accessibility so the higher percentages of rock cover are poorly represented in the dataset, which may have influenced the results and the shape of the trend, but up to 35% rock cover there is a positive effect on species richness. Rock cover provides habitat for a number of specialist species (Borrow & Demey 2001), which offset the loss of farmland species on transects with high rock cover and less cropped land which may account for the increase in species richness with an increase in rock cover. Species such as cinnamon breasted rock bunting and stone partridge are more common in rocky areas. The presence of rocks will also affect the persistence of vegetation which would otherwise have been cleared if the land were more suitable for farming, resulting in scrub and savanna birds being also found around rocky areas. If transects on areas with even greater rock cover were more practical there may have been a drop-off in species numbers towards the upper end of the scale as the number of species able to use very rocky habitats is likely to be limited. The utility of this information for the management of farmland for avian diversity could be in concentrating efforts around areas of high rock cover in order to be sure of preserving areas with higher species richness whilst also having less of a negative effect on farmers' perceptions as they represent areas of low agricultural productivity.

Short vegetation has a high Akaike weight and is present in 11 of 12 models in the 95% confidence set, and has an optimal value of between 20% and 40% cover. Medium vegetation also has a high Akaike weight and appears in 9 of 12 models in the 95% confidence set, and has an optimal value of between 20% and 30% cover. These variables represent very general information: vegetation could be a planted crop or part of the natural vegetation, such as grass or other herbaceous plants. There is also a structural element missing from the data, that of vegetation density. Despite these uncertainties there is strong evidence that the presence of vegetation itself

influences the number of bird species observed on the transects. Herbaceous vegetation can provide food, in the form of seeds or invertebrates using it as habitat, cover for shelter or predator avoidance and breeding advantages, in the form of nesting sites and materials (Wiens 1989; Gill 2006). Different species have different requirements, some, such as larks and pipits, preferring open areas with high, less dense sward, others, such as bronze manikins and bishops, preferring high, dense sward. Management for a mixture of crops with varying vegetation densities may be effective in retaining the maximum number of species in an area of farmland (Benton et al. 2003). This has been found to be the case in European farmland where varied sward densities and heights can provide food for different species and provide habitats with reduced perceived predation risk for others (Whittingham & Evans 2004). Experiments involving shortening stubble have resulted in increased numbers of granivorous passerines and invertebrate feeders. Skylarks and meadow pipits preferred areas with higher sward (Whittingham et al. 2006).

Old farmland has an Akaike weight of 0.60, which is higher than the random variable Akaike weight plus two standard errors, and is in 7 of 12 models in the 95% confidence set. It has a polynomial relationship with species richness, although the relationship as viewed in Figure 5.8 is less marked than other variables and there are likely to be many factors at work considering the fact that fallow land can vary depending on the previous crops, the number of years the land has been fallow for, the amount the land has been grazed and differences between transects in water availability, soil type and other abiotic factors. There does seem to be an effect, nonetheless, of including the fact that land was recently farmed in the model with an optimum proportion of fallow land of between 30% and 50% to maximise species richness.

Studies in temperate zones have pointed to the benefits of fallow land for avian diversity (Henderson et al. 2000; Wolff et al. 2001) but it has also been suggested that fallow land in a farmland savanna habitat in Burkina Faso, West Africa, contained fewer bird species as the number of years since planting has finished, or the germination of new plants once the crops are not planted (Soderstrom et al. 2003). The increased complexity of the new vegetation structure rather than the single crop, or mixed crop, previously on the land may encourage a greater variety of species to

visit fallow land. The benefits of both the large food source and beneficial habitat provided by certain crops and the increased vegetation and habitat variety of land unfarmed for a longer period may limit the number of species that can effectively use more recent fallow land thus resulting in its lesser effect in the models and the complex relationship observed.

Leaf litter and bare ground have some effect. Although they have the lowest Akaike weights, they are, however, in 6 and 8 of 12 models in the 95% confidence set respectively and are above the Akaike weight plus two standard errors of the random variable. Any conclusions reached about these variables would be less reliable than for other variables.

The results of the model-averaged predictions against the observed values for the validation dataset, Figure 5.14, were not quite as expected, with an intercept of 1.18 (sd=0.04), a gradient of 0.12 (sd=0.01) and only an  $R^2$  of 0.15. Had the predictions exactly matched the observed values, the intercept would have been close to zero, gradient 1.00 and  $R^2$  1.00. This would suggest that these models should not be used to predict exactly the number of species to be observed in an independent site but can still give an idea as to the trend to be expected given the habitat and type of farmland. This effect has been demonstrated for other models, for example, skylark abundance was modelled using regression based on counts in one region of the United Kingdom and was a poor absolute predictor of abundance using data from other regions, but predicted relative abundance consistently (Whittingham et al. 2003). The trend in the predicted results in this study on the Jos Plateau, though weaker than observed, was in the right direction, so knowledge of the habitat variables could give an idea as to whether to expect higher or lower species richness, if not the exact values. Even so, extra caution should probably be used if extrapolating to regions and seasons beyond the study sites and season described here which may display variability in the habitat variables beyond the range modelled, particularly when birds may display regional rather than national patterns of habitat association (Whittingham et al. 2007). But this study has demonstrated the ability of the models to predict species richness in general terms and provides some support to conclusions derived from the model data and some confidence in any management decisions made on the basis of these model results.



### **5.4.2 Simpson's Diversity Indices**

Models based on Simpson's diversity indices had less predictive power than those based on species richness, with 42 models in the 95% confidence set compared with 12 for species richness. The variable Akaike weights also differed from those for the species richness models. Crop type, in particular, had an Akaike weight of just less than 1 for species richness and just over zero for Simpson's diversity index models. Old farmland was 0.41 lower and short vegetation 0.43 lower in the diversity models, although the random variable weight plus the standard deviation of 0.43 indicates that, in this group of models, a lower Akaike weight should indicate important predictive variables than those for the species richness models.

Diversity indices take into account both the number of species present and the number of individuals of each species present. The more species there are and the more evenly the species are distributed in terms of individuals the higher the index. The difference in effects of the different variables when equitability is taken into account indicates that the farmland habitat is affecting equitability in a different way to species richness. Figures 5.6 and 5.19 indicate that the differences between the crop type factors are greater for species richness than for Simpson's diversity indices, although one way ANOVAs were both highly significant. It is unclear why the crop type variable has so much less predictive power in the Simpson's diversity indices models than those in the species richness models. There seems to be less difference in the equitability of species between crop types than there is difference in overall number of species. This indicates there are certain common species which are present on crops and the addition of more species on different crops raises the species richness, but not enough individuals are added to greatly raise equitability and so Simpson's diversity index. These data suggest that the choice of crop may have a stronger effect on the diversity of birds on farmland than on abundances per se.

The fact that the total number of trees is a good predictor of Simpson's diversity index shows that tree density is important for diversity as well as species richness, presumably by having a large effect on equitability. Within the optimum range of tree density the distribution of the extra species is equitable enough for the diversity index to increase along with the number of species, in other words, the extra species are

present in sufficient numbers to greatly affect the diversity index. The optimum range, of between 20 and 30 trees on the transect, is the same as that for species richness. This emphasises the importance of the presence of woody vegetation when taking avian diversity into account in farmland management.

Rock cover was a good predictive variable, although slightly less so than for species richness, which suggests that equitability and species richness rise with rock cover. This may be due to the increase in woody vegetation observed at higher levels of rock cover, as discussed earlier. Short and medium herbaceous vegetation also show predictive powers in the models, although to a lesser degree than tree numbers and rock cover, as also observed in the species richness models. It appears that the species that benefit from these types of vegetation, as discussed above, also occur in sufficient numbers to affect the Simpson's diversity index.

The reduction in old farmland predictive power compared to that in the species richness models is another indication that the type of farmland may not have as great an affect on diversity as it does on species richness and that management efforts for diversity should concentrate on maintaining woody vegetation and other structural elements of the habitat within existing farmland. In particular, land which has been farmed within the last 6 years will not have seen a large change in the amount of slow-growing woody vegetation, which seems to be the most important predictor of diversity and may partly explain the lack of predictive power of old farmland.

The comparisons of the model-averaged predicted results against observed values for the validation dataset, Figure 5.27, demonstrate that the predictive power of the diversity models is not as accurate as that for the species richness models. The intercept is well over zero at 2.25, sd 0.04, the gradient is in the correct direction but only 0.10, s.d. = 0.02,  $R^2$  is only 0.08 and Spearman's rho only 0.268. But it should be noted that the models were originally generated using only transects where birds were observed so when these are used to predict data where there is a possibility of observing no birds there is likely be a positive bias in the resulting values. Overall, predicting diversity indices in this way appears, therefore, limited in value, but no other study is known to have attempted to validate data in this way.

In summary, tree density is the most important habitat variable recorded, influencing both species richness and diversity, and areas with trees must be retained on farmland in order to ensure that many species persist in the habitat. The habitat around rock outcrops should be retained with farming concentrated elsewhere. The results indicate that white beans, sorghum and groundnut are beneficial for species richness but diversity is unaffected by crop type, showing that a choice must be made between equitability and species richness when planning management for avian diversity. The results from a validation study indicate that the models presented correctly predict the trend in the observed data. Even if we cannot accurately predict the absolute species numbers, we can identify the important habitat variables that maximise species richness.

## Chapter 6 Density of Common Bulbul and Red-Cheeked Cordon-Bleu on Farmland

### 6.1 Introduction

This chapter describes how two common species of bird on farmland on the Jos Plateau differ in their habitat associations and how different types of farmland may benefit them and birds with similar habitat requirements. The common bulbul, *Pycnonotus barbatus*, associates with areas with more retained trees, being a savanna generalist, and the red-cheeked cordon-bleu, *Uraeginthus bengalus*, associates with medium tree density and can use crop fields for foraging as a granivorous bird of open woodland. The retention of scrub and woodland is recommended to aid both guilds, which could be helped by focussing attention on rocky sites as conservation areas, which are less ideal for farming and lead to the retention of the habitats surrounding them.

The density of individual species of birds is dependent on a number of factors which, taken together, will be unique to that particular species. A species will have evolved different morphology and behaviour to other species in order to use different habitats and resources and avoid competition, which would otherwise lead to the eventual exclusion of all but the species that exploits the resources available most effectively (Connell 1978). On farmland the habitat available has been significantly altered from the natural habitat by human activity and the different species present will select for different aspects of this new habitat depending on the requirements they have evolved for. Bird species will not have evolved entirely in the presence of agriculture on the scale seen today and will select for aspects of the land which resemble the savanna, grassland, forest or wetland they have evolved to exploit (Gill 2006). The management of farmland in different ways will yield different habitat mosaics suitable for different species and it is important to understand which aspects of the habitat distinct species are selecting for and, therefore, what management practices may be beneficial for these and other, similar, species.

The power of the models available is limited by the number of registrations of the species in question on the transects used for the model. In this chapter the habitat

preferences of two suitably common species, representing two different guilds of birds present on farmland on the Jos Plateau, will be studied in detail.

The common bulbul is an omnivore, in the family Pycnonotidae, which eats significant quantities of several different types of fruit and invertebrates, as well as the occasional small vertebrate (Keith et al. 1992; Milla et al. 2005), as a generalist it is one of the most widespread and abundant birds in Africa occurring from Morocco to South Africa (Borrow & Demey 2001). It is found in wooded and bushy habitat and is only absent from large tracts of unbroken forest, open grassland with no bushes and treeless desert (Keith et al. 1992). There were 793 registrations of common bulbuls on the transects conducted (see Figure 3.15), which made it the most abundant of all the omnivores and frugivores recorded. Although the common bulbul is one of the most abundant birds in Africa, and appears to have little need for conservation efforts to be directed at it, it has sufficient records on the transects for modelling and is used here as a model for all omnivorous birds which use agricultural land.

The red-cheeked cordon-bleu is a granivorous waxbill, family Estrildidae, which feeds mainly off small annual grass seeds and is widely distributed in West Africa where there is light woodland and bushy grassland (Keith et al. 1992; Borrow & Demey 2001). It is described as being particularly abundant in areas where a large amount of millet and sorghum is cultivated (Keith et al. 1992). With 1262 registrations it is the second most abundant granivore recorded on the transects after the northern red bishop but does not display the prominent flocking behaviour and intra-African migration of that species so was chosen as an example of a typical resident granivore.

In this study I examine which variables predict the densities of common bulbul and red-cheeked cordon-bleu on farmland on the Jos Plateau, Nigeria using Generalised Linear Models and the Information Theoretic approach to model selection, and then validate these models using an independent dataset. Implications for management of agricultural land for these and similar species are discussed.

## 6.2 Methods

### 6.2.2 Distance Analysis

Transects were placed and conducted as described in Section 2.1. Density estimates per transect for each species were calculated as described in Section 2.1.7.3 (Buckland et al. 2001) using Distance version 5 (Thomas 2006). Species were truncated at the distance to which 95% of individuals were observed, which was 50m for common bulbuls and 35m for red-cheeked cordon-bleus. For common bulbuls a half normal detection function with a cosine adjustment was chosen using AIC values. Figure 6.1 shows the relationship between the actual detections of birds and the fitted function.

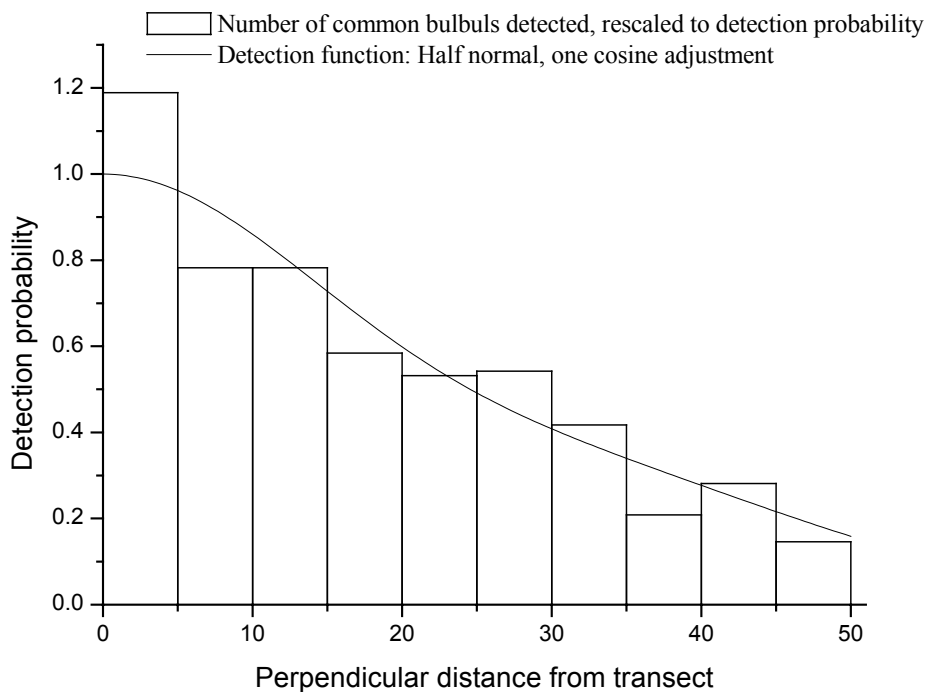


Figure 6.1 Detection function fitted over actual detections of common bulbuls for all transects. Function is half normal with one cosine adjustment, detection drops off with distance from transect. Model fit is good: Kolmogorov-Smirnov test -  $D=0.4$ ,  $p=0.37$ , ns. Chi squared test, 10m intervals - Chi squared=1.90,  $p=0.17$ , ns.

Detectability was affected by vegetation. When percentage shrub cover, with all transects missing the shrub variable removed from the dataset, was included as a covariate the model had a greater AIC value than when total number of trees on the

transect was a covariate,  $\Delta AIC=178$ , but when all transects missing the tree number variable were removed, number of trees had a greater AIC value,  $\Delta AIC=117$ . Other combinations of variables tried as covariates had higher AIC values. Despite the higher AIC value in comparison to that when number of trees was included, percentage shrub cover was chosen as the covariate to use to control for detectability effects as there were fewer missing values. Any missing values were all in the first field season when methods were still being developed and the variable was not to be used in subsequent GLMs with the data generated. Figure 6.2 shows the relationship between shrub cover and the estimated detection function.

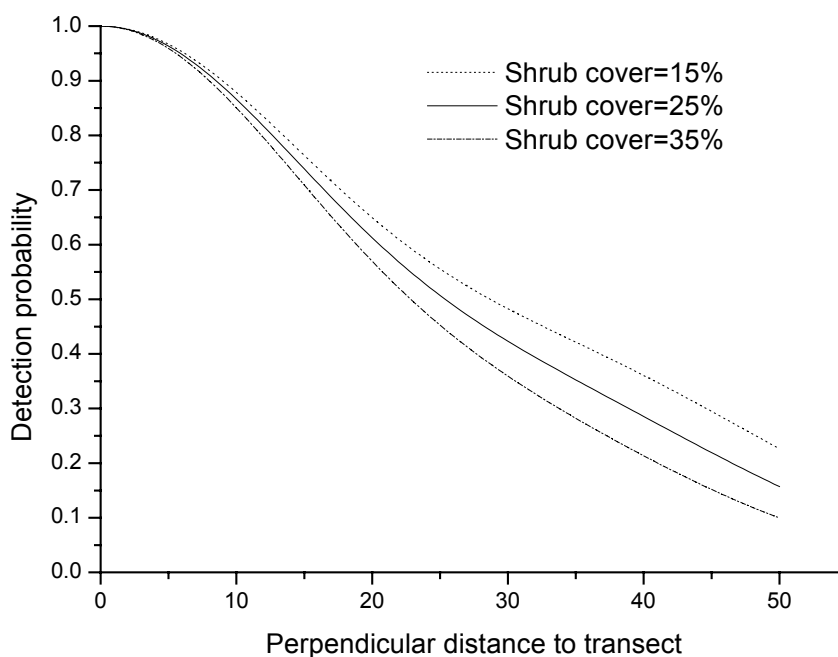


Figure 6.2 Detection probability for common bulbul at lower, middle and upper quartiles of shrub cover values. Detection is more likely away from the transect with lower shrub cover.

For red-cheeked cordon-bleu a half normal function with a cosine adjustment was chosen using AIC values. Figure 6.3 shows the relationship between the actual detections of birds and the fitted function.

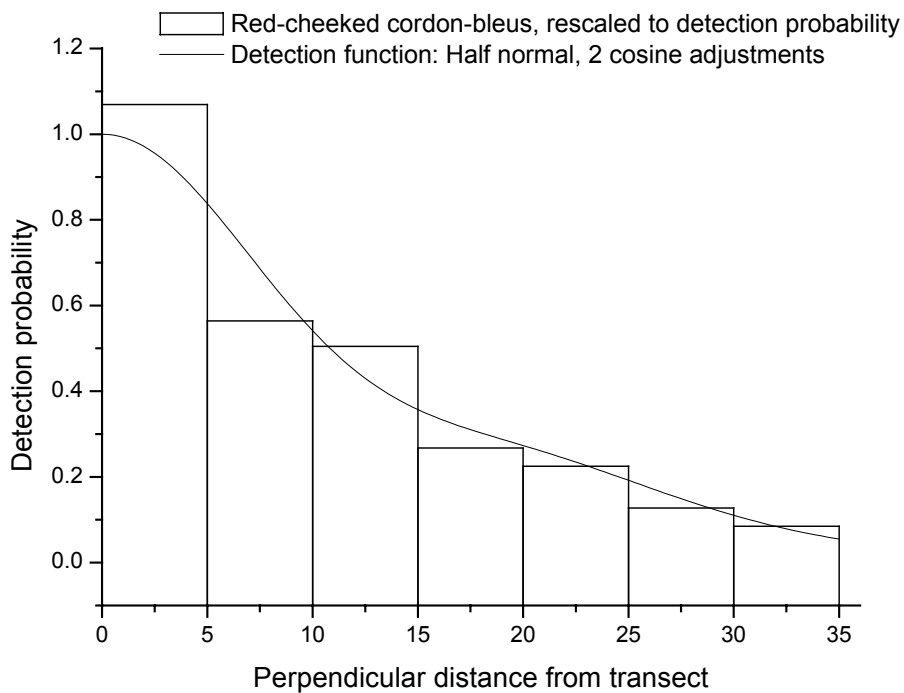


Figure 6.3 Detection function fitted over actual detections of red-cheeked cordon-bleus for all transects. Function is half normal with two cosine adjustments, detection drops off with distance from transect. Model fit: Kolmogorov-Smirnov test -  $D=0.05$ ,  $p=0.04^*$ . The fit is not very good, but better than for other options.

Detectability was affected by vegetation. When percentage shrub cover, with all transects missing the shrub variable removed from the dataset, was included as a covariate the model had a greater AIC value than when total number of trees on the transect was a covariate,  $\Delta AIC=154$ , but the when all transects missing the tree number variable were removed, number of trees had a greater AIC value,  $\Delta AIC=149$ . Other combinations of variables tried as covariates had higher AIC values than these. As with common bulbuls, percentage shrub cover was chosen as the covariate to use to control for detectability effects because there were fewer missing values, the transects with missing values were all in the first field season when methods were still being developed and the variable was not to be used in subsequent GLMs with the data generated. Figure 6.4 shows the relationship between shrub cover and the estimated detection function.



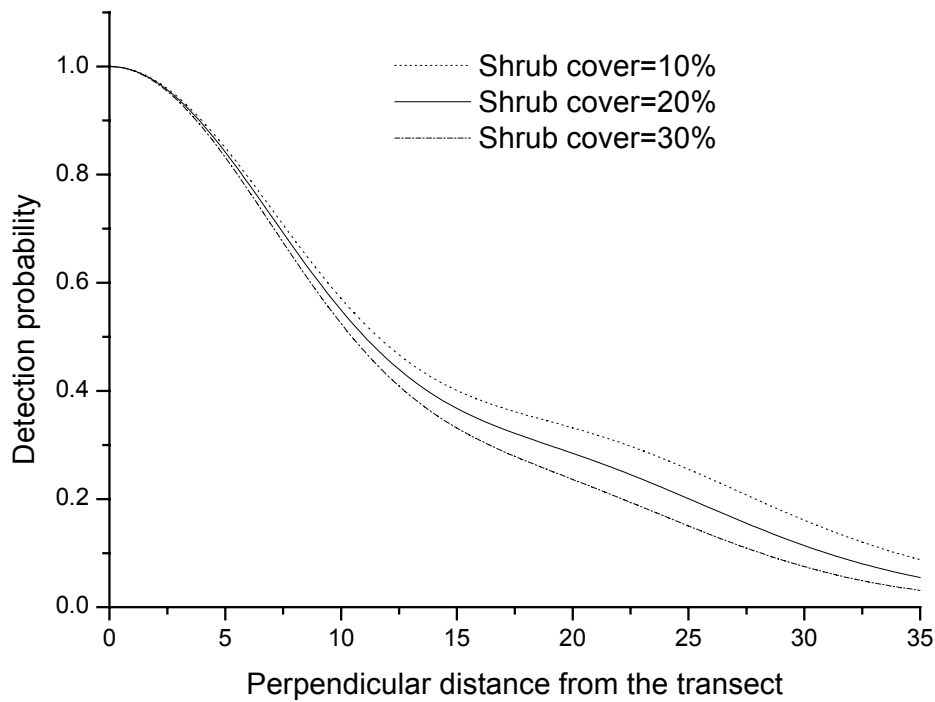


Figure 6.4 Detection probability for red-cheeked cordon-bleu at lower, middle and upper quartiles of shrub cover values. Detection is more likely away from the transect when shrub cover is lower.

Density estimates were by transect, taking into account the value of the shrub cover covariate on the individual transects, the distance to the birds viewed, the number of clusters and the cluster size. Effective strip width, the distance from the transect for which as many birds are detected beyond as are missed within the line, is also calculated per transect in order to use this as an offset in the GLMs when density cannot be used (Buckland et al. 2001).

### 6.2.3 Generalised Linear Models

The eight habitat variables were selected for analysis as described in Section 2.1.7.6 and analysis was performed using Generalised Linear Models and the Information Theoretic approach (Burnham & Anderson 2002) described in Section 2.1.7.7. This includes determining the linearity of the relationship between independent and dependent variables, the calculation of AICc values and Akaike weights for models and variables, including a random variable (Whittingham et al. 2005), and the validation of the models using the validation dataset.

For common bulbul densities the normal distribution null model resulted in a ratio of residual deviance to residual degrees of freedom of 1.86 and the Poisson model gave a ratio of 2.06 indicating that the data is over dispersed for both models, but, with a ratio closer to 1, the data fit a normal distribution better than poisson (Crawley 1993), therefore, the models were run using density as a response with a normal distribution, an identity link function and no offset. For red-cheeked cordon-bleu the normal distribution null model resulted in a ratio of residual deviance to residual degrees of freedom of 51.5 and the Poisson model gave a ratio of 8.5, highly over dispersed, whereas for counts the ratios were 2.3 and 2.7 for normal and poisson distributions, also over dispersed but closer to 1. The normal distribution with number of birds had the ratio closest to 1 (Crawley 1993). Number of birds was therefore chosen as the response variable and a normal distribution for the models with an identity link function and with effective area searched as an offset.

All 255 combinations of the eight habitat variables, plus quadratics for variables with non-linear relationships to the dependent variables, minutes after sunrise, wind rating, cloud cover and site were run. Akaike weights were calculated for each model based on AICc values (Burnham & Anderson 2002).

## **6.3 Results**

### **6.3.1 Common Bulbul**

#### **6.3.1.1 Generalised Linear Models**

Figures 6.5 to 6.16 show plots of density of common bulbuls against the habitat variables used in the Generalised Linear Models, along with linear or polynomial fits to the data. Rock cover is the only variable with an obviously non-linear relationship to density so is the only variable where a quadratic term is included in the models in which it occurs. Total trees, medium vegetation and leaf litter show a linear positive trend against density, and old farmland, short vegetation, bare ground, minutes after sunrise, cloud cover and wind rating show a negative trend. Fobur recorded greater common bulbul density than other sites, with Laminga and Maijuju recording medium levels of density and Vom having the lowest density. Maize, millet, acha and yam

have lower densities than transects with no major crop type whilst white beans, sweet potato and sorghum have higher densities but high standard errors.

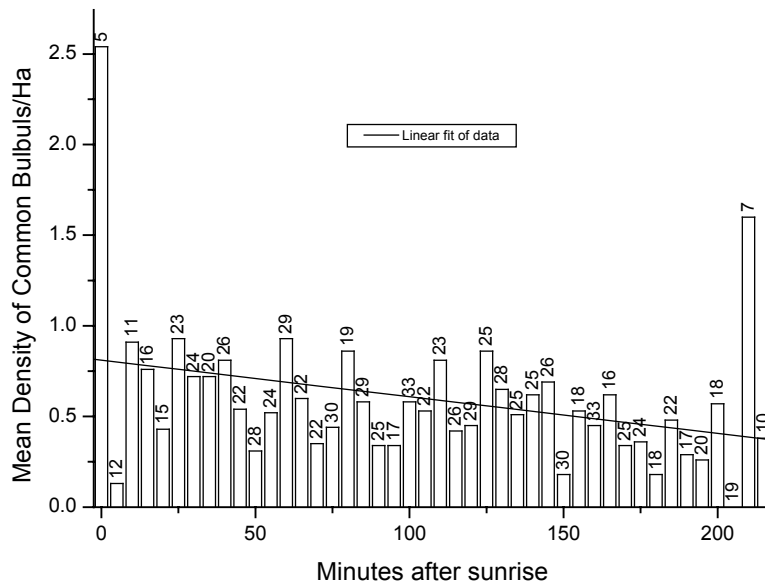


Figure 6.5 Relationship of minutes after sunrise, rounded to the nearest 5 minutes, to density of common bulbuls. The line represents a linear fit to the interval data, a fit to the raw data gave intercept=0.89, gradient=-0.003,  $R=-0.18$ ,  $p<0.01^{**}$ ,  $N=222$  time interval bins. A Polynomial fit accounted for a similar amount of variance so a linear function was chosen.

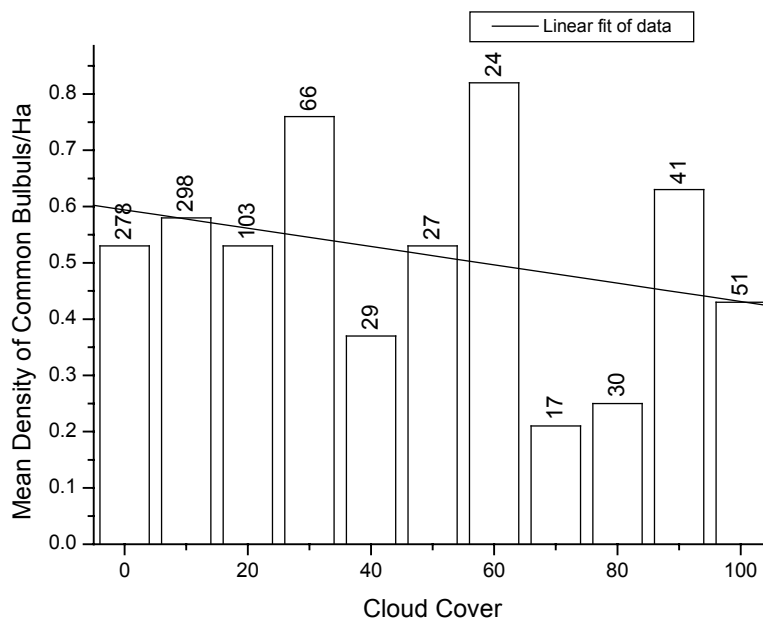


Figure 6.6 Relationship of percentage cloud cover to density of common bulbuls. The line represents a linear fit to the data, intercept=0.59, gradient=-0.002,  $R=-0.28$ ,  $p=0.40$ ,  $N=11$ .

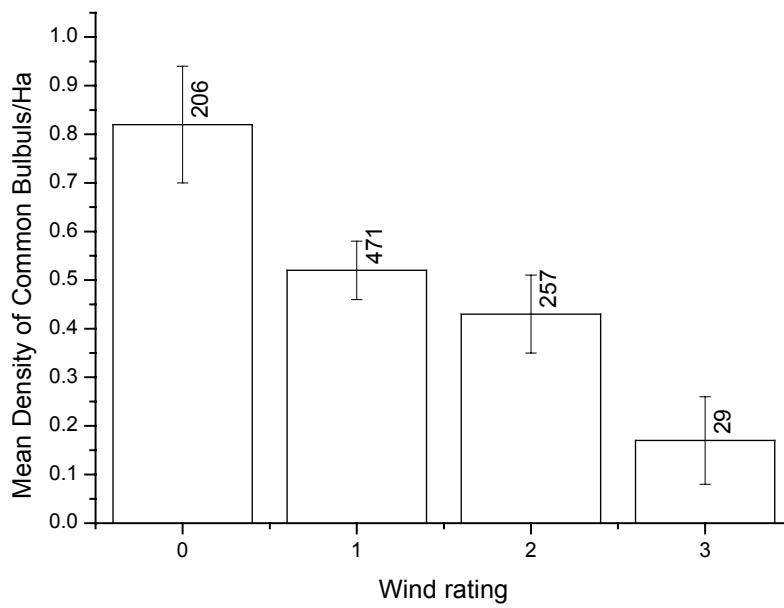


Figure 6.7 Relationship of wind rating to density of common bulbuls. The scale of the ratings is ordinal, with 0 representing no wind and 3 representing the strongest wind transects were surveyed in, error bars are +/- one standard error. Species richness decreases with wind strength, one way ANOVA  $F_{3,959}=4.3$ ,  $p<0.01^{**}$

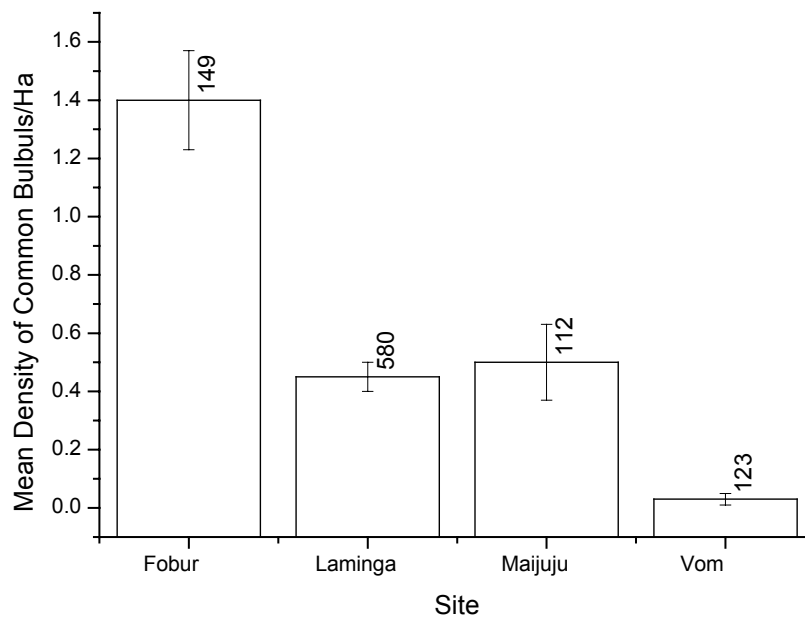


Figure 6.8 Density of common bulbuls by site, error bars are +/- one standard error. There is a significant difference between sites, one way ANOVA  $F_{3,959}=28.6$ ,  $p<0.01^{**}$

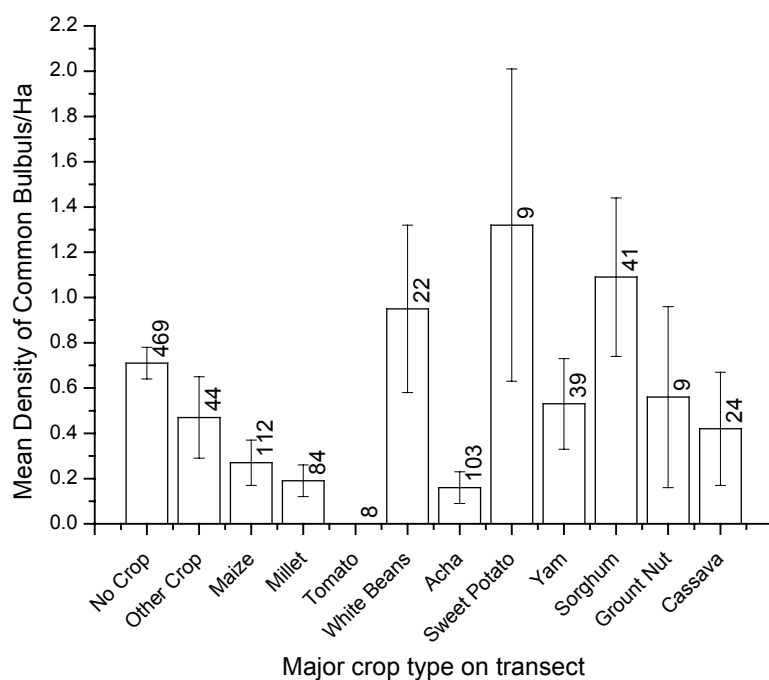


Figure 6.9 Crop type against density of common bulbuls. Numbers in columns are number of transects with crop as major crop type on transect, error bars are  $\pm$  one standard error. There is a significant difference between the crop types, one way ANOVA  $F_{11,963}=3.6$ ,  $p<0.01^{**}$

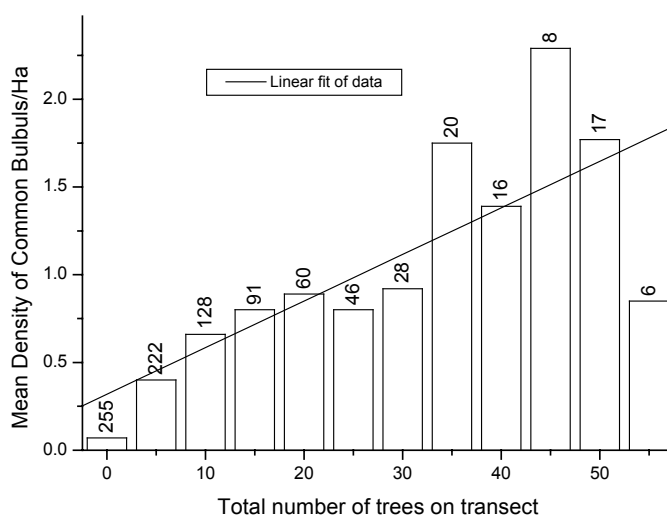


Figure 6.10 Relationship of number of trees on transect, in intervals of 5, to density of common bulbuls. The line represents a linear fit to the interval data, a fit to the raw data gave intercept=0.28, gradient=0.03,  $R=0.63$ ,  $p<0.01^{**}$ ,  $N=51$ .

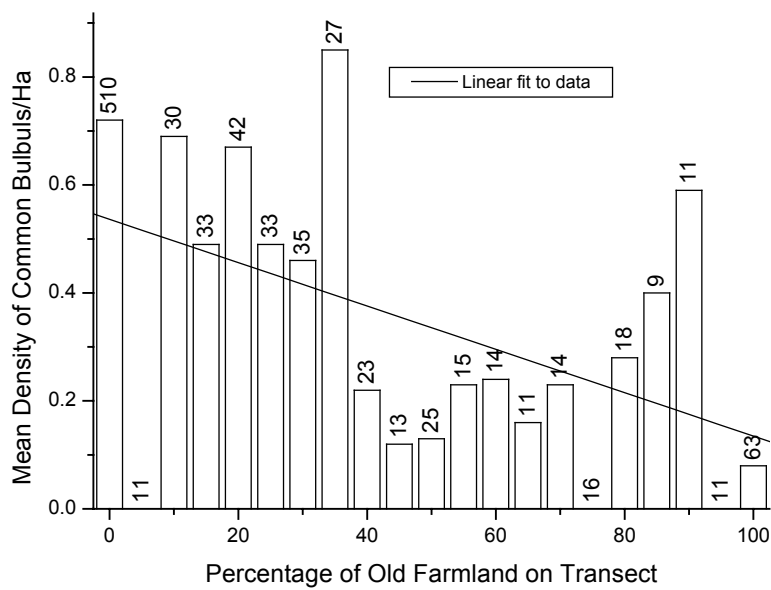


Figure 6.11 Relationship of percentage old farmland to density of common bulbuls. The line represents a linear fit to the data, intercept=0.54, gradient=-0.004,  $R=-0.48$ ,  $p=0.03^*$ ,  $N=21$ .

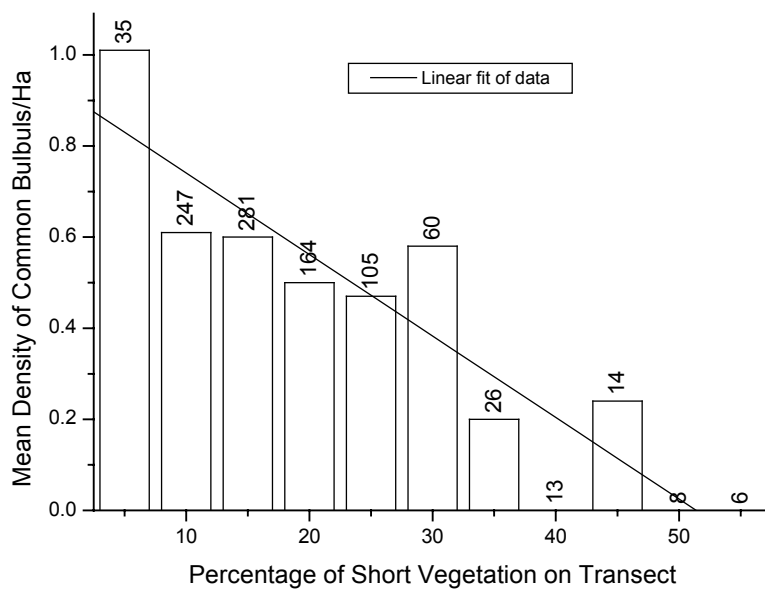


Figure 6.12 Relationship of short vegetation cover to density of common bulbuls. The line represents a linear fit to the data, intercept=0.92, gradient=-0.02,  $R=-0.92$ ,  $p<0.01^{**}$ ,  $N=11$ .

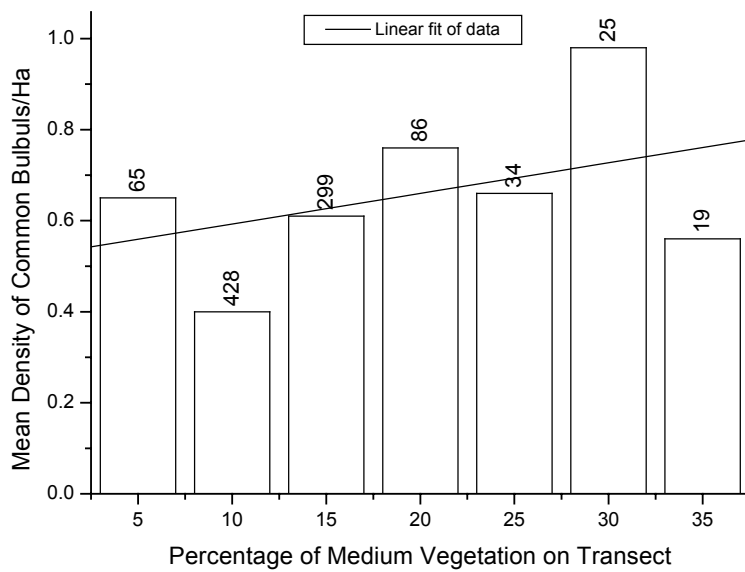


Figure 6.13 Relationship of medium vegetation cover to density of common bulbuls. The line represents a linear fit to the data, intercept=0.53, gradient=0.01,  $R=0.40$ ,  $p=0.37$ ,  $N=7$ . A Polynomial fit accounted for a similar amount of variance so a linear function was chosen.

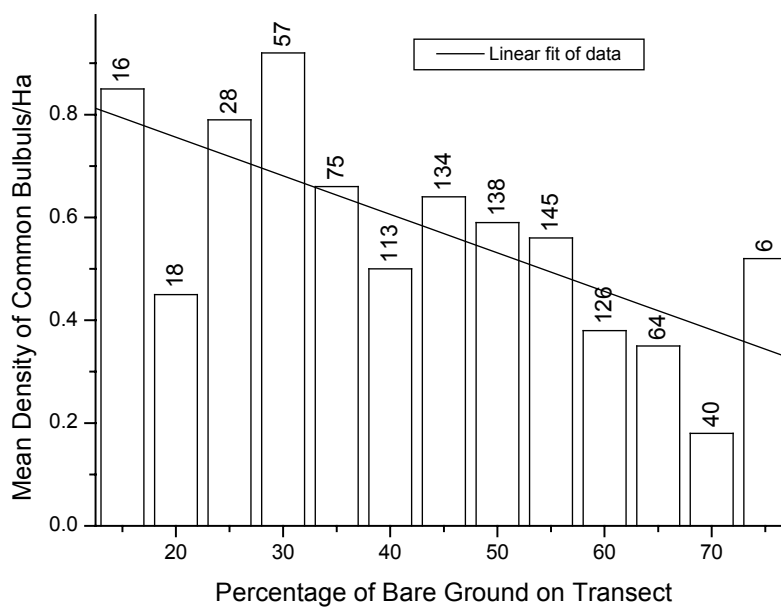


Figure 6.14 Relationship of percentage bare ground cover to density of common bulbuls. The line represents a linear fit to the data, intercept=0.91, gradient=-0.01,  $R=-0.70$ ,  $p<0.01^{**}$ ,  $N=13$ .

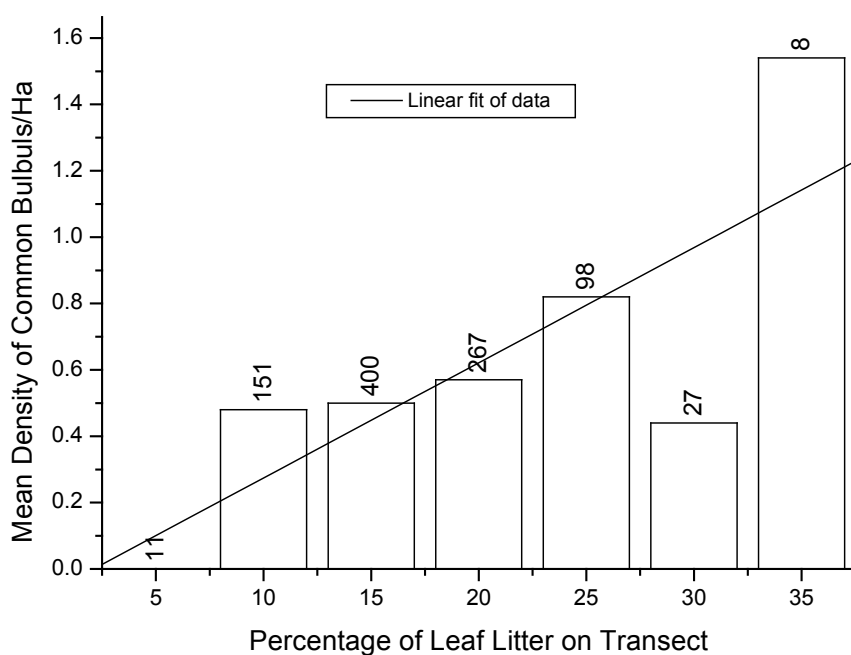


Figure 6.15 Relationship of percentage leaf litter to density of common bulbuls. The line represents a linear fit to the data, intercept=-0.07, gradient=0.03,  $R=0.79$ ,  $p=0.03^*$ ,  $N=7$ .

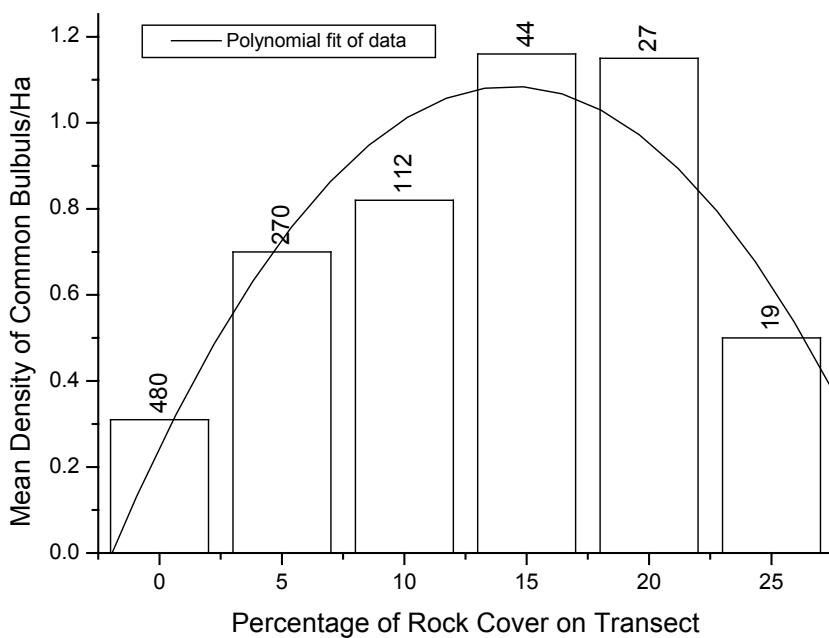


Figure 6.16 Relationship of percentage rock cover to density of common bulbuls. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=0.24$ ,  $b=0.12$ ,  $c=-0.004$ ,  $R^2=0.83$ ,  $p=0.07$ ,  $N=6$ .



The results for the top 10 models are presented in Table 6.1. There were 29 models in the 95% confidence set of models.

Table 6.1 Top 10 models for common bulbul density models based on Akaike weights. Transects conducted between March and April 2004 and between February and April 2005. All models include minutes after sunrise, wind and cloud cover. “Q” indicates a quadratic term for the previous variable included in the model.

Rank	Model Number	Model	AICc	$\Delta$ AICc	Akaike weight
1	54	Crop Type, Total Trees, Old farmland	3045.4	0.00	0.15
2	121	Crop Type, Total Trees, Old farmland, Leaf Litter	3045.4	0.02	0.15
3	125	Crop Type, Total Trees, Old farmland, Medium veg	3047.1	1.71	0.06
4	119	Crop Type, Total Trees, Old farmland, Bare ground	3047.3	1.95	0.06
5	192	Crop Type, Total Trees, Old farmland, Medium veg, Leaf Litter	3047.4	1.96	0.06
6	126	Crop Type, Total Trees, Old farmland, Short veg	3047.4	1.97	0.06
7	196	Crop Type, Total Trees, Old farmland, Short veg, Leaf Litter	3047.4	1.99	0.06
8	189	Crop Type, Total Trees, Old farmland, Bare ground, Leaf Litter	3047.5	2.13	0.05
9	104	Crop Type, Total Trees, Old farmland, Rock cover + Q	3048.7	3.33	0.03
10	195	Crop Type, Total Trees, Old farmland, Short veg, Bare ground	3049.1	3.66	0.02

Variable Akaike weights are presented in Table 6.2. Total trees, old farmland and crop type have the highest weights, and these are the variables in the top-ranked model, number 54, and are present in all the top 10 models in Table 6.1. The random variable included in the model consisted of values for all transects with a normal distribution and a mean and standard deviation the same as the variable with the highest Akaike weight, Total Trees, which has a mean of 9.88 and standard deviation of 13.71. The mean Akaike weight for the random variable was 0.40 with a standard error of 0.04 after 20 runs with different values. As a conservative approach any variables with an Akaike weight below the mean plus two times the standard error of that for the random variable, in this case 0.48, can be considered to be of little importance in the model.

Table 6.2 Variable Akaike weights for common bulbul density models.

Variable	Akaike weight
Total Trees	1.00
Old Farmland	1.00
Crop Type	0.94
Leaf Litter	0.47
Medium Vegetation	0.29
Bare Ground	0.28
Short Vegetation	0.28
Rock Cover	0.15

The top two models, numbers 54 and 121, have the same Akaike weight, 0.15.

Parameter estimates for model 121, chosen as it includes an extra variable, leaf litter, are shown in Table 6.3. As indicated by figures 6.5 to 6.16 the parameter estimates indicate positive trends for total trees and leaf litter and negative trends for minutes after sun, cloud cover, wind and old farmland. Negative trends are also indicated for maize, millet and acha, as also suggested by Figure 6.9. All variables in the model have significant chi squared results except for wind, cloud and, for type 3 Chi-squared analysis, leaf litter, although this was marginal.

Table 6.3 Parameter estimates for second ranked model for common bulbul density, number 121, Akaike weight 0.15, the same as the top ranked model. The model parameters indicate the direction in which the different variables are influencing common bulbul density within the context of the model and chi squared tests indicate the influence each variable is having on that particular model.

Parameter		Parameter estimate	Standard error	Chi-Square	<i>p</i> -value	Type 3 Chi-Square
Intercept		-3.86	1.03	14.09	<0.01**	
Minutes after sunrise		-0.01	<0.01	7.34	<0.01**	7.42**
Wind	0	-0.04	0.61	0.01	0.94	0.34
	1	-0.06	0.59	0.01	0.92	
	2	-0.14	0.60	0.05	0.82	
	3	0	0	.	.	
Cloud cover		<0.01	<0.01	1.39	0.23	1.43
Site	Fobur	3.02	0.73	17.16	<0.01**	49.99**
	Laminga	2.47	0.72	11.74	<0.01**	
	Maijuju	2.26	0.75	9.14	<0.01**	
	Vom	0.00	0.00	0.00	0.00	
Crop type	Non-crop	0.47	0.42	1.22	0.27	46.57**
	Other crop	0.40	0.50	0.64	0.43	
	Maize	-0.76	0.50	2.27	0.13	
	Millet	-0.28	0.52	0.29	0.59	
	Tomato	-22.13	49118.81	0	0.99	
	White beans	0.88	0.49	3.22	0.07	
	Acha	-0.31	0.52	0.36	0.55	
	Sweet potato	1.20	0.56	4.56	0.03	
	Yam	0.40	0.50	0.65	0.42	
	Sorghum	0.74	0.46	2.55	0.11	
	Groundnut	0.04	0.72	0	0.96	
	Cassava	0.00	0.00	0.00	0.00	
Total trees		0.01	<0.01	13.55	<0.01**	11.48**
Old farmland		-0.01	<0.01	27.52	<0.01**	33.49**
Leaf Litter		0.02	0.01	3.95	0.05*	3.83

### 6.3.1.2 Validation

Figure 6.17 shows the relationship between the recorded data for the validation dataset, between the 9<sup>th</sup> of January 2006 and the 16<sup>th</sup> of March 2006, and the weighted predicted values. Pearson's correlation coefficient was calculated comparing the density of common bulbuls observed on the transect and the predicted values for the model. Although the  $R^2$  value is low at 0.04 and the slope gradient only 0.04 the positive slope of the highly significant regression line shows that predicted values increase as observed density increases.

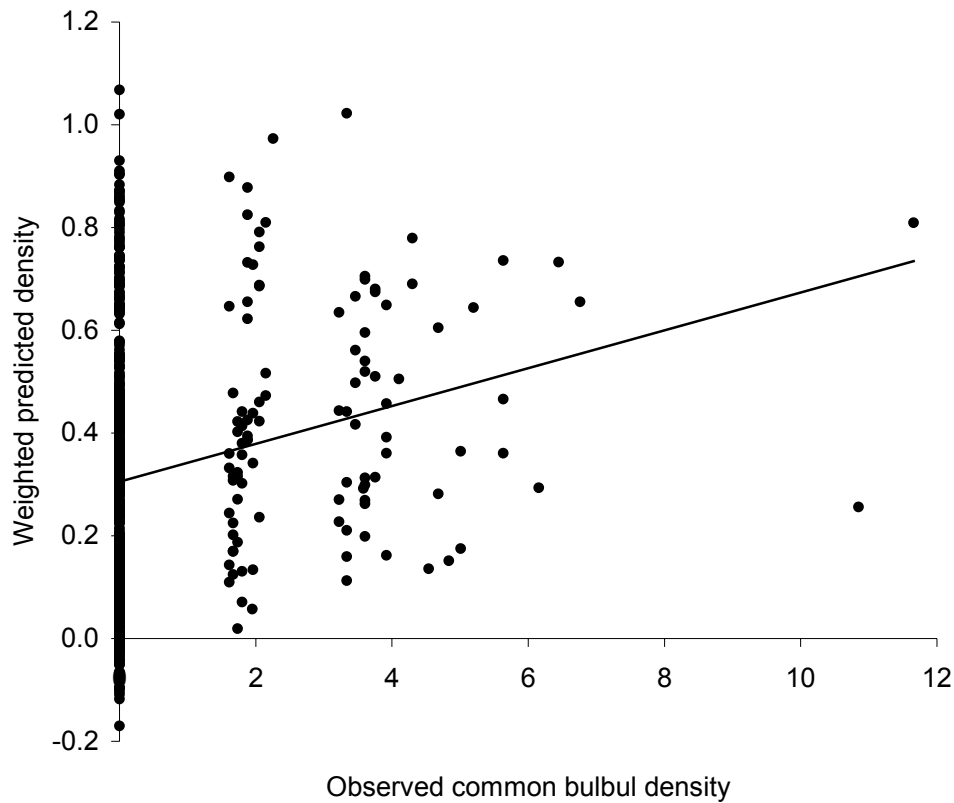


Figure 6.17 Weighted predicted values for common bulbul density on validation transects against observed values on visits to transects in 2006. Linear regression line  $F_{1,634}=26.0$ ,  $p<0.01^{**}$ , intercept=0.31,  $sd=0.01$  gradient= 0.04,  $sd=0.01$ ,  $R^2=0.04$ . Pearson correlation coefficient = 0.20,  $p<0.01^{**}$ ,  $N=636$ .

### 6.3.2 Red-Cheeked Cordon-Bleu

#### 6.3.2.1 Generalised Linear Models

Figures 6.18 to 6.29 show plots of numbers of red-cheeked cordon-bleu against the habitat variables used in the Generalised Linear Models, along with linear or polynomial fits to the data. Minutes after sunrise, which drops before a slight rise in bird numbers later in the day, total number of trees, short vegetation and bare ground, which all rise to an optimum value for bird numbers before dropping off at higher values, all had polynomial relationships, which fitted better than linear functions, and so quadratic terms of these variables were included in the models that they occurred

in. Cloud cover, old farmland, leaf litter and rock cover show a linear positive trend against mean number, while medium vegetation shows a negative trend. Numbers drop with higher wind ratings, except for rating 3, where they rise, though variation for the mean is high due to small sample size for wind rating 4. Fobur, Laminga and Maijuju had greater numbers of birds recorded there than Vom. Maize, millet, tomato, acha, sweet potato, yam and cassava had lower numbers of birds than transects with no major crop type whilst white beans and groundnut had higher numbers but with high standard errors.

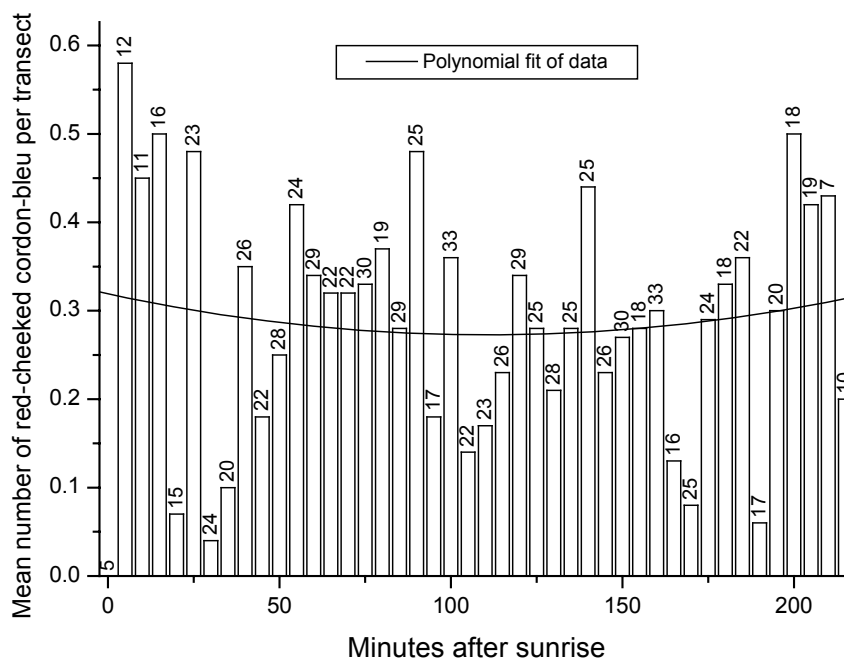


Figure 6.18 Relationship of minutes after sunrise, rounded to the nearest 5 minutes for clarity with the number of transects in each bin above the columns, to number of red-cheeked cordon-bleu recorded. The line represents a polynomial fit to the interval data, a fit to the raw data,  $y=a + bx + cx^2$ , gave parameters of  $a=0.82$ ,  $b=-0.008$ ,  $c<0.001$ ,  $R^2=0.02$ ,  $p=0.12$ , ns,  $N=222$  time interval bins. A linear fit accounted for a smaller amount of variance so a polynomial function was chosen.

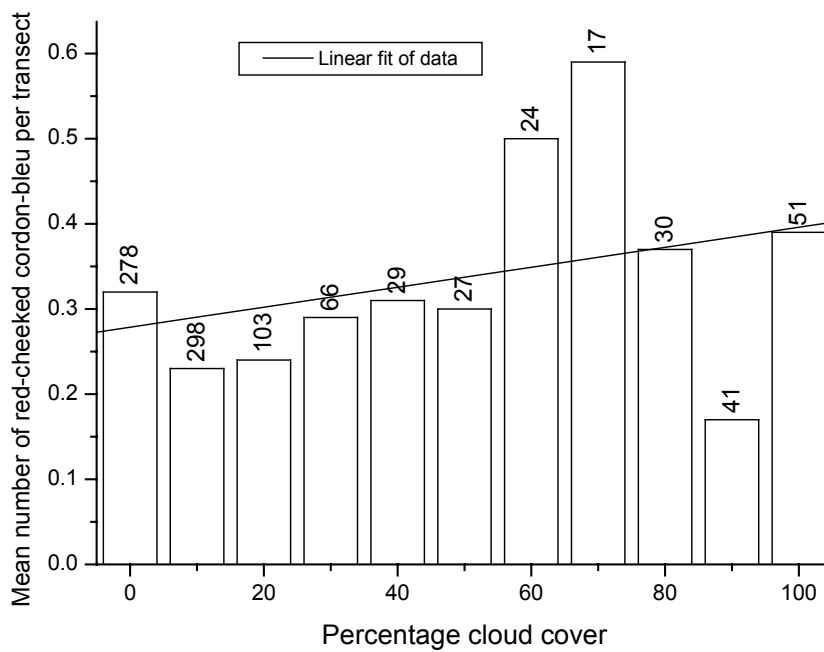


Figure 6.19 Relationship of percentage cloud cover to number of red-cheeked cordon-bleu. The line represents a linear fit to the data, intercept=0.59, gradient=-0.002,  $R=-0.28$ ,  $p=0.40$ ,  $N=11$ .

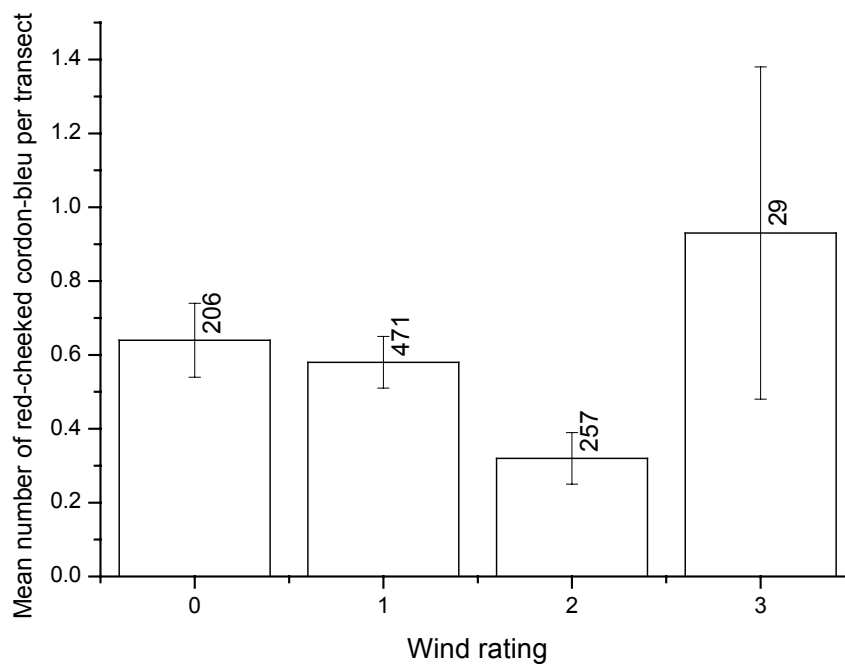


Figure 6.20 Relationship of wind rating to number of red-cheeked cordon-bleu. The scale of the ratings is ordinal, with 0 representing no wind and 3 representing the strongest wind transects were surveyed in, error bars are  $\pm$  one standard error. Mean number differs with wind strength, one way ANOVA  $F_{3,959}=3.7$ ,  $p=0.01^{**}$ .

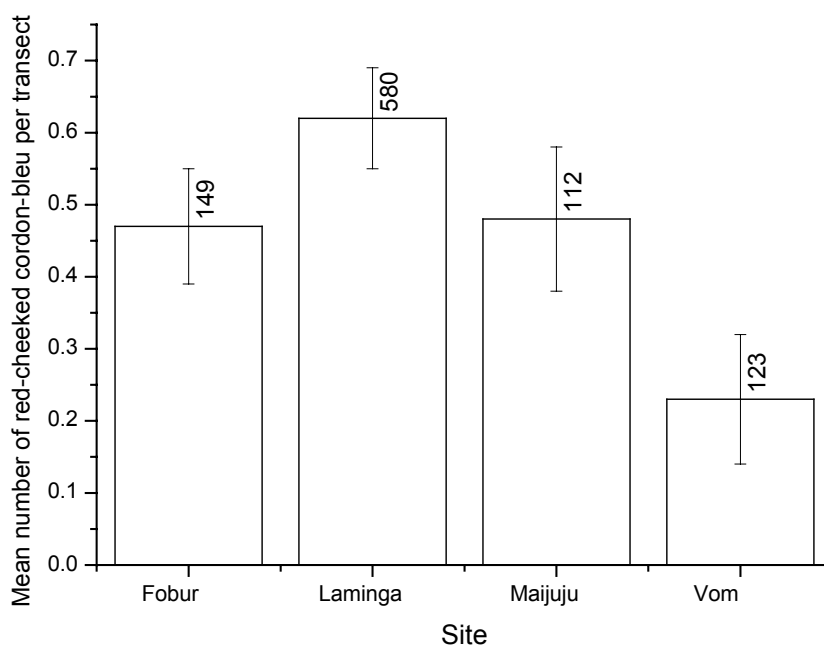


Figure 6.21 Number of red-cheeked cordon-bleu by site, error bars are +/- one standard error. There is a significant difference between sites, one way ANOVA  $F_{3,959}=2.9$ ,  $p=0.03^*$ .

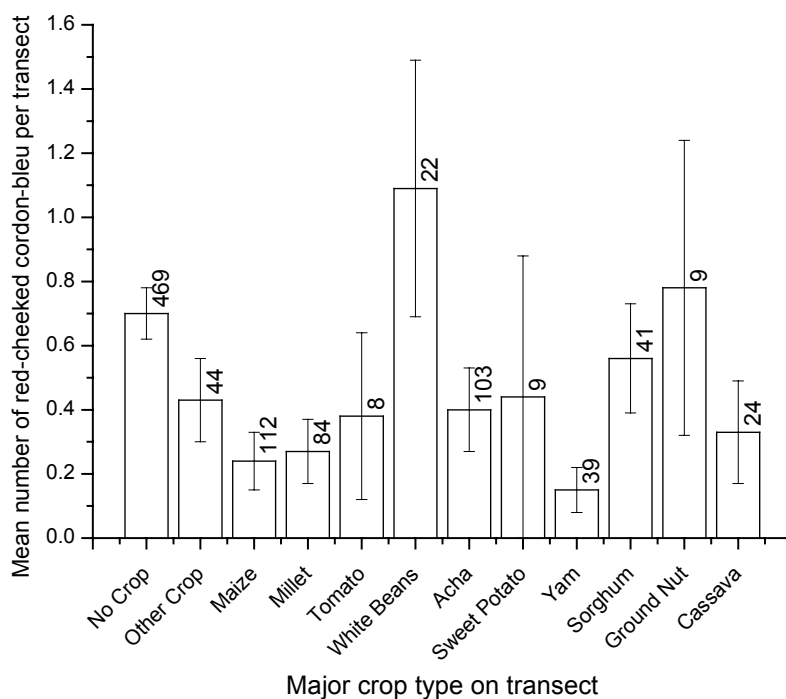


Figure 6.22 Crop type against number of red-cheeked cordon-bleu. Numbers in columns are number of transects with crop as major crop type on transect, error bars are +/- one standard error. There is a significant difference between the crop types, one way ANOVA  $F_{11,963}=2.1$ ,  $p=0.02^*$ .

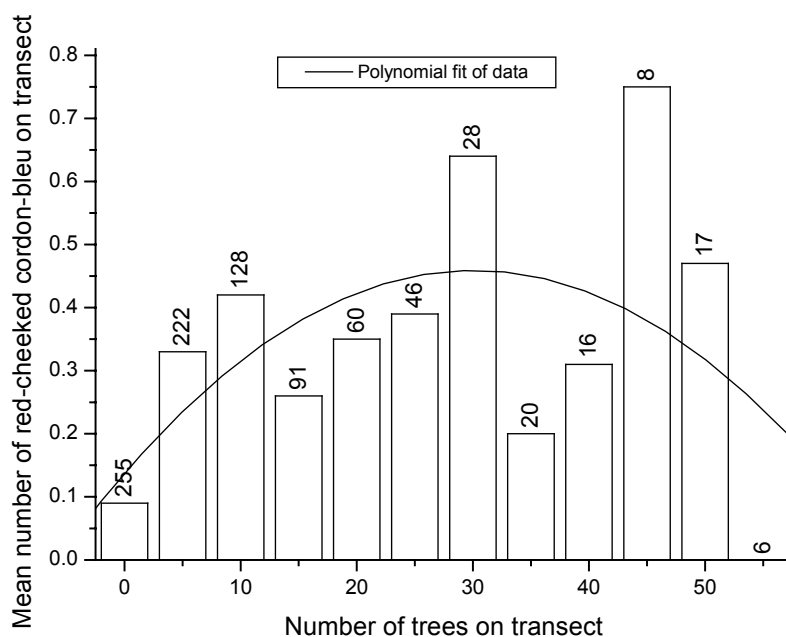


Figure 6.23 Relationship of number of trees on transect, in intervals of 5 for clarity, to number of red-cheeked cordon-bleu. The line represents a polynomial fit to the interval data, a fit to the raw data,  $y=a + bx + cx^2$ , gave parameters of  $a=0.21$ ,  $b=0.03$ ,  $c<-0.001$ ,  $R^2=0.05$ ,  $p=0.18$ , ns,  $N=69$ . A Linear fit accounted for a smaller amount of variance so a polynomial function was chosen.

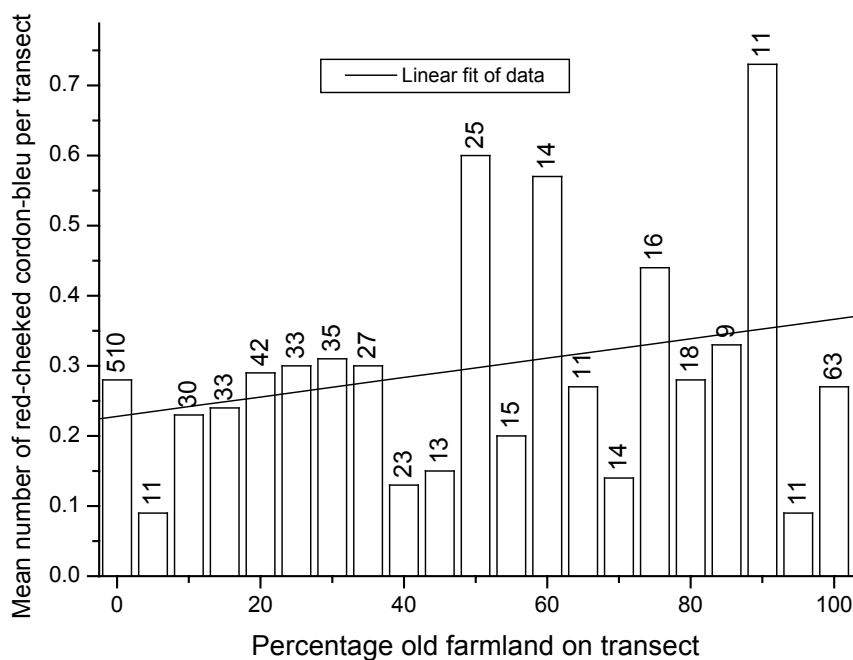


Figure 6.24 Relationship of percentage old farmland to number of red-cheeked cordon-bleu. The line represents a linear fit to the data, intercept=0.22, gradient=0.001,  $R=0.26$ ,  $p=0.26$ , ns,  $N=21$ .



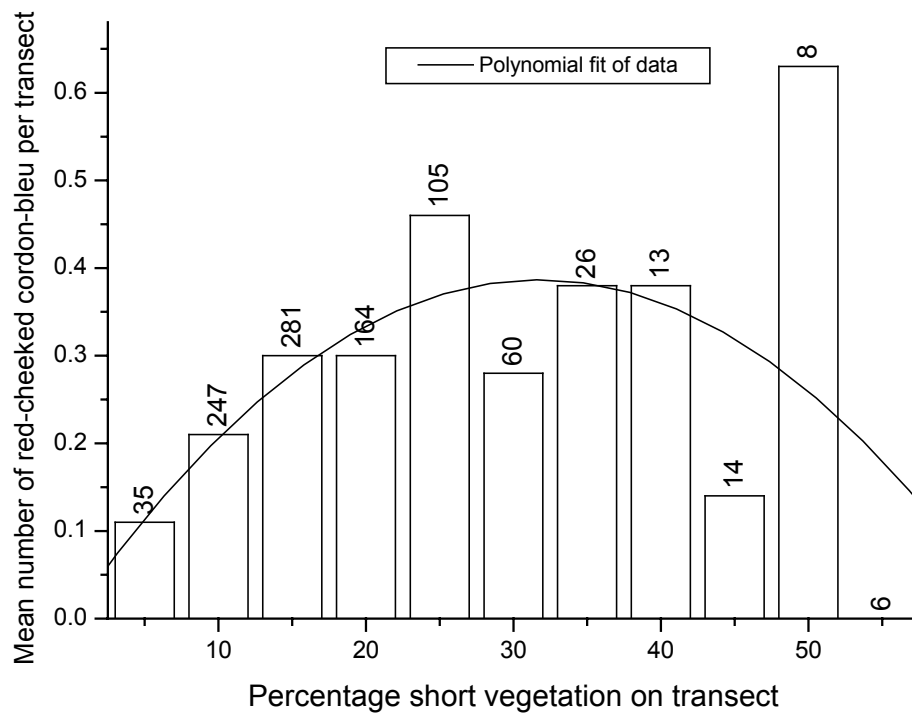


Figure 6.25 Relationship of short vegetation cover to number of red-cheeked cordon-bleu. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=0.002$ ,  $b=0.02$ ,  $c<0.001$ ,  $R^2=0.27$ ,  $p=0.28$ , ns,  $N=11$ .

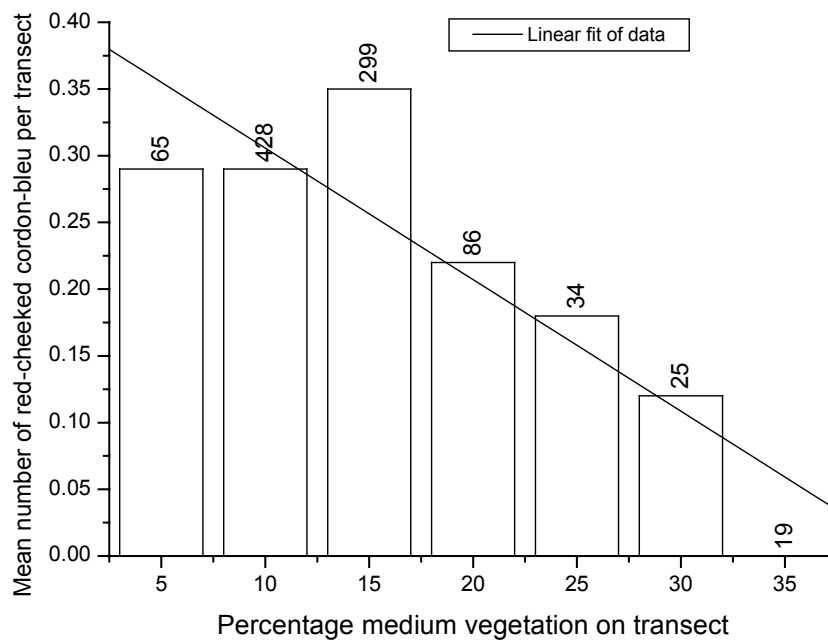


Figure 6.26 Relationship of medium vegetation cover to number of red-cheeked cordon-bleu. The line represents a linear fit to the data, intercept=0.40, gradient=-0.01,  $R=-0.89$ ,  $p<0.01^{**}$ ,  $N=7$ .

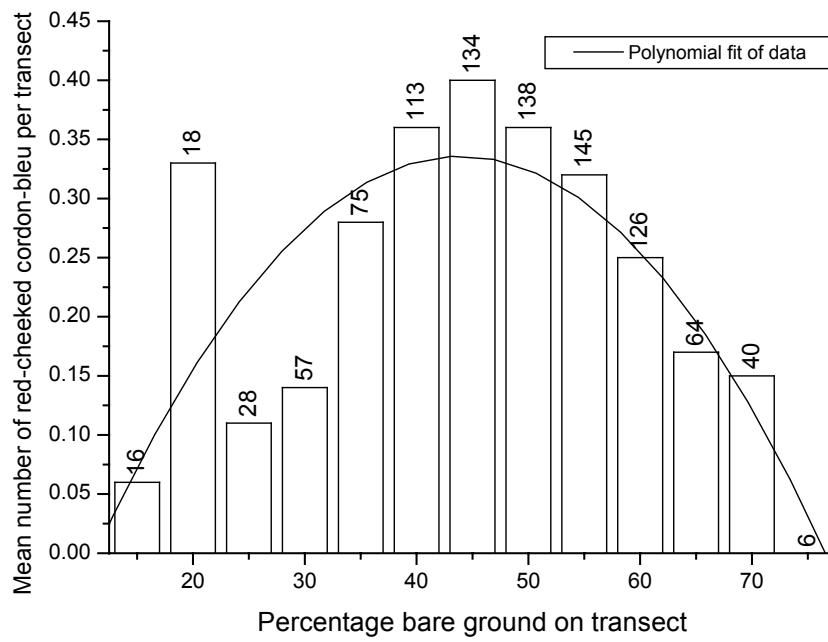


Figure 6.27 Relationship of percentage bare ground cover to number of red-cheeked cordon-bleu. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=-0.27$ ,  $b=0.03$ ,  $c<0.001$ ,  $R^2=0.64$ ,  $p<0.001^{**}$ ,  $N=13$ .

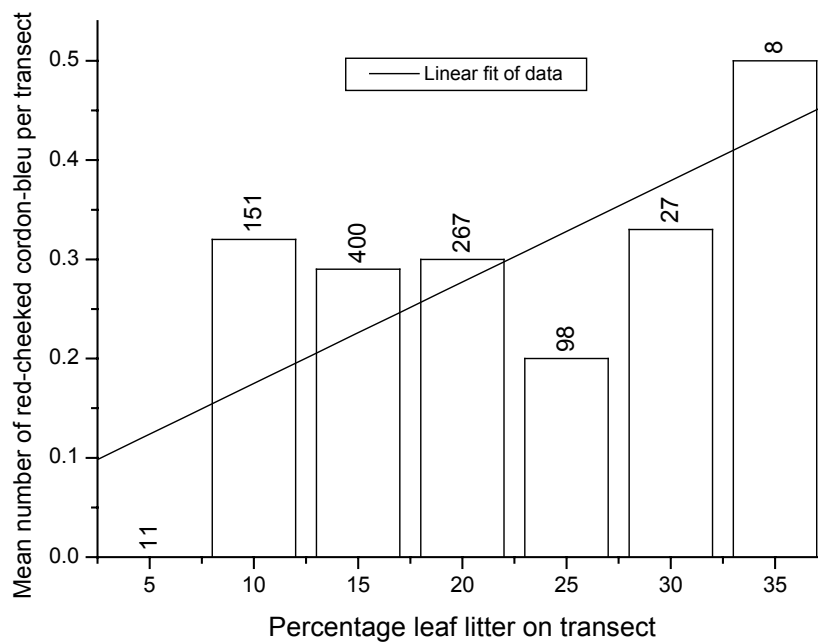


Figure 6.28 Relationship of percentage leaf litter to number of red-cheeked cordon-bleu. The line represents a linear fit to the data, intercept=0.07, gradient=0.01,  $R=0.73$ ,  $p=0.06$ , ns,  $N=7$ .

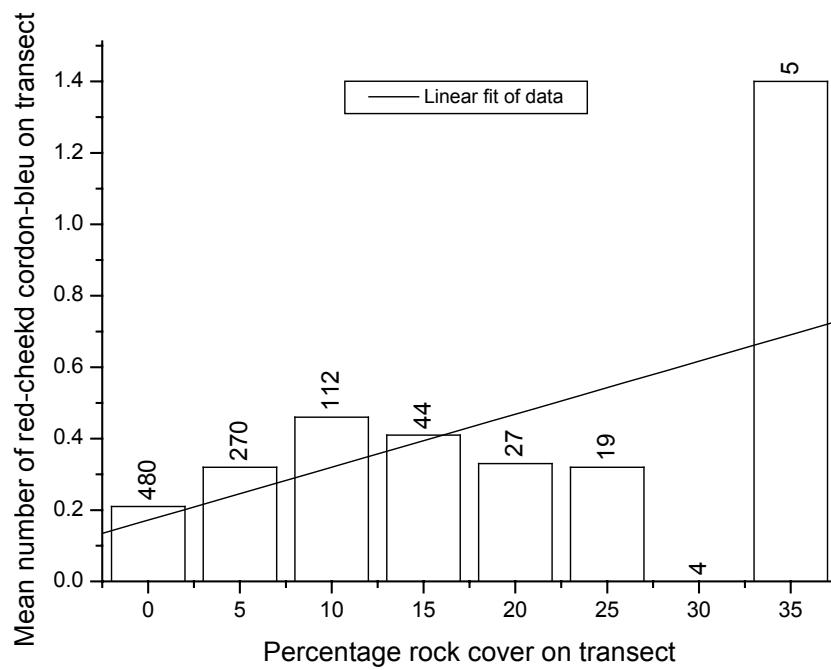


Figure 6.29 Relationship of percentage rock cover to number of red-cheeked cordon-bleu. The line represents a linear fit to the data, intercept=0.17, gradient=0.01,  $R=0.44$ ,  $p=0.27$ , ns,  $N=8$ .

The results for the top 10 models are presented in Table 6.4. There were 16 models in the 95% confidence set of models.

Table 6.4 Top 10 models for red-cheeked cordon bleu count models based on Akaike weights. Transects conducted between March and April 2004 and between February and April 2005. All models include minutes after sunrise, wind and cloud cover. “Q” indicates a quadratic term for the previous variable included in the model.

Rank	Model Number	Model	AICc	$\Delta$ AICc	Akaike weight
1	179	Total Trees + Q, Old farmland, Short veg + Q, Bare ground + Q, Rock cover	3317.24	0.00	0.23
2	233	Total Trees + Q, Old farmland, Short veg + Q, Medium veg, Bare ground + Q, Rock cover	3318.22	0.99	0.14
3	105	Total Trees + Q, Short veg + Q, Bare ground + Q, Rock cover	3318.31	1.08	0.13
4	180	Total Trees + Q, Short veg + Q, Medium veg, Bare ground + Q, Rock cover	3319.00	1.76	0.10
5	222	Total Trees + Q, Old farmland, Short veg + Q, Bare ground + Q, Leaf litter, Rock cover	3319.31	2.07	0.08
6	250	Total Trees + Q, Old farmland, Short veg + Q, Medium veg, Bare ground + Q, Leaf litter, Rock cover	3320.10	2.87	0.05
7	164	Total Trees + Q, Short veg + Q, Bare ground + Q, Leaf litter, Rock cover	3320.22	2.99	0.05
8	223	Total Trees + Q, Short veg + Q, Medium veg, Bare ground + Q, Leaf litter, Rock cover	3320.50	3.26	0.05
9	181	Total Trees + Q, Old farmland, Short veg + Q, Medium veg, Rock cover	3321.83	4.59	0.02
10	185	Total Trees + Q, Short veg + Q, Medium veg, Bare ground + Q, Leaf litter	3322.07	4.83	0.02

Variable Akaike weights are presented in Table 6.5. Total trees has the highest weight at 1.00 followed by short vegetation at 0.99, bare ground at 0.91, rock cover at 0.90, old farmland at 0.59 and medium vegetation at 0.49. The top 5 variables are in the top-ranked model, number 179 in Table 6.4, and the top 6 variables are in the second-ranked model, number 233. The top three variables are in all the top 8 models, with

total trees and short vegetation in all the 95% confidence group models. Leaf litter has a weight of 0.32 and crop type has a particularly low weight. The random variable included in the model consisted of values for all transects with a normal distribution and a mean and standard deviation the same as the variable with the highest Akaike weight, Total Trees, which has a mean of 9.88 and standard deviation of 13.71. The mean Akaike weight for the random variable was 0.34 with a standard error of 0.02 after 20 runs with different values. As a conservative approach any variables with an Akaike weight below the mean plus two times the standard error of that for the random variable, in this case 0.38, can be considered to be of little importance in the model. Leaf litter and crop type have lower Akaike weights than this, so can be considered less important in the models than the six top variables.

Table 6.5 Variable Akaike weights for red-cheeked cordon-bleu count models.

Variable	Akaike weight
Total Trees	1.00
Short Vegetation	0.99
Bare Ground	0.91
Rock Cover	0.90
Old Farmland	0.59
Medium Vegetation	0.49
Leaf Litter	0.32
Crop Type	<0.01

Parameter estimates for the top model, number 179, Akaike weight 0.23, are shown in Table 6.6. As indicated by Figure 6.24, the parameter estimate indicates a positive trend for old farmland. Total trees, short vegetation and bare ground show positive trends with negative trends for the quadratics whilst minutes after sunrise shows a negative trend with a positive trend for its quadratic, which is to be expected considering the polynomial fit in Figure 6.18 shows a different shape to those in Figures 6.23, 6.25 and 6.27. Wind shows a significant effect, as does site, but minutes after sunrise and cloud cover have no significant effect. As expected from the results of the variable weights all the selected habitat variables have significant effects apart from old farmland, which has a marginally non-significant Chi square result and also has the lowest Akaike weight.

Table 6.6 Parameter estimates for top ranked model for red-cheeked cordon-bleu counts, number 179 in Table 6.4, Akaike weight 0.23. The model parameters indicate the direction in which the different variables are influencing species richness within the context of the model and chi squared tests indicate the influence each variable is having on that particular model.

Parameter		Parameter estimate	Standard error	Chi-Square	<i>p</i> -value	Type 3 Chi-Square
Intercept		-3.15	0.68	21.56	<0.01**	
Minutes after sunrise		<-0.01	<0.01	0.70	0.40	0.7
Minutes after sunrise + Q		<0.01	0	0.79	0.37	0.79
Wind	0	-0.27	0.31	0.75	0.39	8.32*
	1	-0.25	0.29	0.70	0.40	
	2	-0.55	0.30	3.44	0.06	
	3	.	.	.	.	
Cloud cover		<-0.01	<0.01	3.46	0.06	3.45
Site	Fobur	-0.11	0.21	0.27	0.60	11.41**
	Laminga	0.33	0.15	4.66	0.03*	
	Maijuju	0.23	0.21	1.24	0.26	
	Vom	.	.	.	.	
Total trees		0.04	<0.01	24.77	<0.01**	24.44**
Total trees + Q		<-0.01	<0.01	10.08	<0.01**	10.03**
Old farmland		<0.01	<0.01	3.17	0.08	3.16
Short veg		0.06	0.02	10.40	<0.01**	10.34**
Short veg + Q		<-0.01	<0.01	3.58	0.06	3.57
Bare ground		0.08	0.02	10.38	<0.01**	10.32**
Bare ground + Q		<-0.01	<0.01	6.86	0.01**	6.83**
Rock cover		0.03	0.01	12.63	<0.01**	12.55**

### 6.3.2.3 Validation

Model averaged estimates of predicted values were calculated for each transect in the validation dataset, as in section 6.3.1.2 for common bulbuls. Figure 6.30 shows the relationship between the observed number of red-cheeked cordon-bleu within 50m of the transect and the weighted predicted values and Figure 6.31 shows the relationship between the observed densities per hectare of red-cheeked cordon-bleu and the weighted predicted densities based on models generated using density data with a Poisson distribution and no offset. The regression line in Figure 6.30 shows a negative slope, but the fact that effective area was used as an offset in the models and that the observed number of red-cheeked cordon-bleu does not take into account differences in detectability created problems in comparing predicted values directly with observed values. The regression line in Figure 6.31 shows a positive slope, although there are

problems with the models generated using density data as the available distribution functions do not fit the data well.

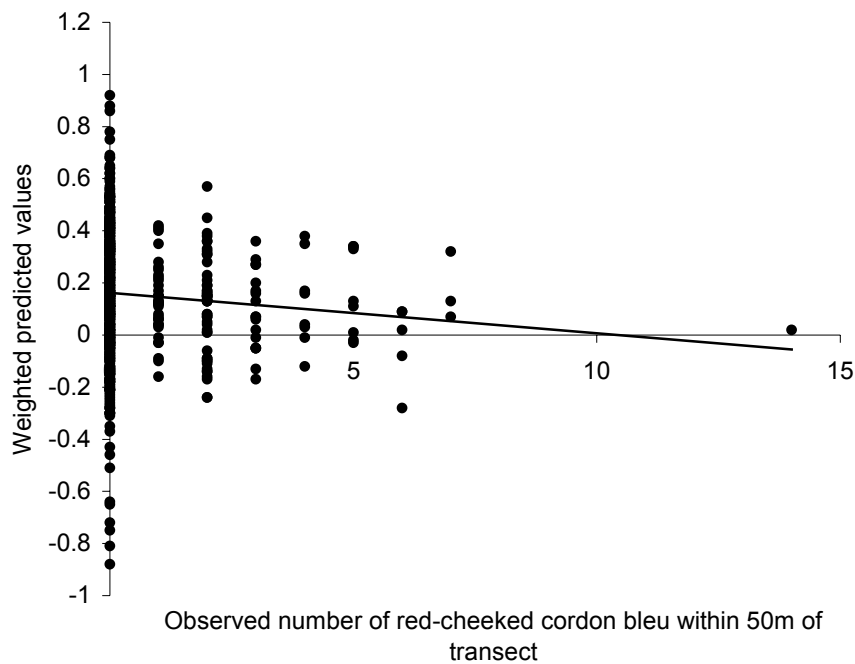


Figure 6.30 Weighted predicted values for number of red-cheeked cordon-bleu on validation transects against observed values on visits to transects in 2006. Linear regression line  $F_{1,634}=4.7$ ,  $p=0.03^*$ , intercept=0.16,  $sd=0.01$  gradient= -0.02,  $sd=0.01$ ,  $R^2=0.01$ . Pearson correlation coefficient = -0.09,  $p=0.03^*$ ,  $N=636$ .

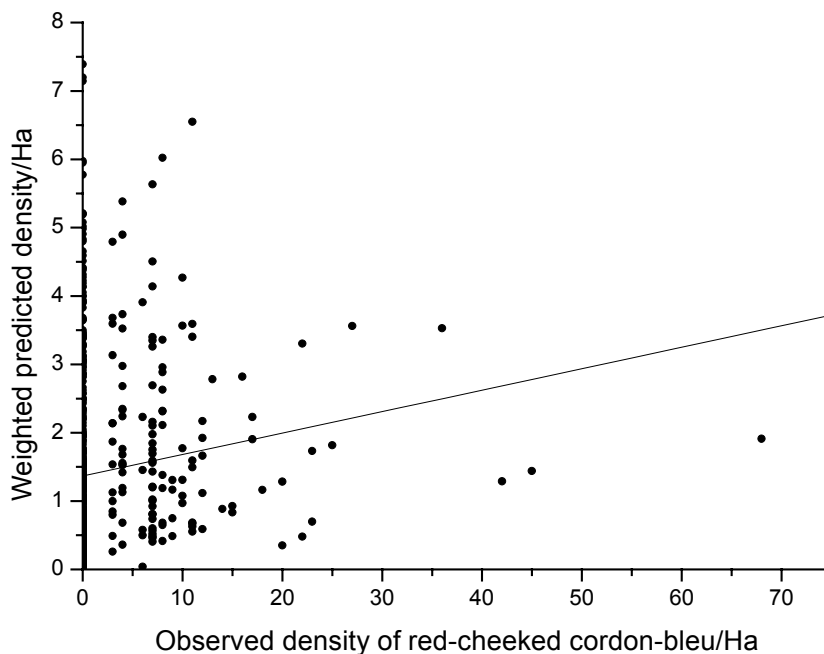


Figure 6.31 Weighted predicted values for density of red-cheeked cordon-bleu per hectare on validation transects against observed values on visits to transects in 2006. Linear regression line  $F_{1,634}=6.6$ ,  $p=0.01^{**}$ , intercept=1.4,  $sd=0.07$  gradient= 0.03,  $sd=0.01$ ,  $R^2=0.01$ . Pearson correlation coefficient = 0.10,  $p=0.01^{**}$ ,  $N=636$ .

## **6.4 Discussion**

### **6.4.1 Common Bulbul**

The top variables in the common bulbul models, total number of trees and old farmland, both have linear relationships with density, so that an increase in tree density is correlated with an increase in common bulbul density and an increase in fallow land on the transect is correlated with a decrease in common bulbul density. The fact that land farmed less than 6 years ago is unlikely to have developed significant tree and shrub cover indicates that these areas may still be too open to host high densities of a species which, according to the literature and the data presented here, selects for trees and shrubs (Keith et al. 1992; Borrow & Demey 2001).

Crop type is a major factor in the models, with an Akaike weight of 0.94 and Figure 6.9 demonstrates how there is a preference for areas with no major crops, which are also more likely to be in less open and more scrubby and wooded sites, whilst there are lower densities in maize, millet and acha fields than on other crop types. This is not borne out by the chi squared values for the top model in Table 6.3 where each level of the factor is compared to the previous in the chi squared test, but overall the crop type factor has a highly significant Type 3 chi squared value in the model.

Common bulbuls are omnivorous, feeding on fruits, nectar, insects and some seeds (Keith et al. 1992; Borrow & Demey 2001; Milla et al. 2005) so are able to adapt to many environments but it is likely that they encounter an abundance of these different types of food in more varied habitats. Although they may be able to exploit invertebrate food in cultivated fields, they will be limited in their access to fruits, and because seeds make up only a small part of their diet (Keith et al. 1992) they would be unable to make great use of the grain present. It would be interesting to study whether or not gardens of fruit and vegetables grown for sale at the market represent a significant food resource for frugivorous and omnivorous species such as common bulbuls, as was suggested during the farmer questionnaires in Chapter 3, where birds figured highly as perceived pests. The limited area these represented on the transects, as the sample size of 8 in Figure 6.9 for tomatoes as a major crop demonstrate, restricted the conclusions this study could make regarding these crops.



All other variables fell below the level of significance established by the Akaike weight limit of the random variable plus two standard errors. The apparent increase in common bulbul density with increased leaf litter could be correlated with the selection for trees and shrubs, which occur in areas with high leaf litter. High leaf litter, however, also occurs in stubble fields where the remains of harvested crops may lie on the ground, which may have led to the low Akaike weight observed, because these two habitats, with high and low common bulbul densities respectively, cancel each other out. Short vegetation and bare ground show a negative linear trend for common bulbul density, bare ground being particularly prevalent in crop fields, but these trends are unimportant in the models, as is the polynomial effect of rock cover. Medium vegetation shows a negative linear trend, perhaps indicating a preference away from grassland and crop fields but, again, in the models this appears to be unimportant when the top three variables are also included.

The results from the validation dataset indicate that the models do predict the correct trend in the data but the trend is very slight. This perhaps indicates the difficulties faced with the large numbers of zeros in the dataset as most transects did not produce a common bulbul sighting within 50m of the transect. The zeros in the data result in a less than ideal fit to the distribution functions available for the SAS procedure and there were insufficient non-zero records to use an inflated zero distribution, which may have affected the predicted values produced for the models when the normal distribution was used. But the results from the variable weights appear to relate well with the literature so the models used here can probably be treated with confidence at least with respect to identifying key variables and the direction of their effect on common bulbul densities.

Although the common bulbul is one of the most abundant birds in Africa, and appears to have little need for conservation efforts to be directed at it, it has sufficient records on the transects for modelling and is used here as a model for all omnivorous birds which use agricultural land. Managing farmland to take into account the presence of omnivorous birds would appear to require a retention of scrub and wooded habitat and an avoidance of large fields, which provide habitat which appears little used by these birds.

#### **6.4.2 Red-Cheeked Cordon-Bleu**

The variable with the highest Akaike weight, total trees, has a polynomial relationship with number of birds on the transect, which fits with the description of red-cheeked cordon-bleu as preferring bushy grassland, sahelian and northern guinea savanna and being absent from treeless areas (Fry & Keith 2004). The optimum number of trees within 20m of the transect of around 30, followed by a drop off, is to be expected if the birds are selecting for open woodland savanna and not for heavily wooded or unwooded areas. Of the other variables with high Akaike weights, short vegetation has a polynomial relationship with an optimum of around 30% short vegetation cover, bare ground has an optimum of around 45% cover and rock cover shows a positive relationship. Red-cheeked cordon-bleu forage in loose soil on bare ground (Fry & Keith 2004; *pers obs*), which would explain the preference for a high percentage of bare ground, but the preference for a higher than the mean percentage of short vegetation could indicate the use of this vegetation either for shelter or food. Given that short vegetation here is described as lower than 10cm from the ground, its use as a food source appears the most likely, especially as the small seeds of annual grasses provide a large part of their diet (Fry & Keith 2004).

A preference for high rock cover could be the result of a selection for the scrub habitat that persists around rock outcrops, as it is unlikely that food sources would be abundant on the rocks themselves considering the foraging behaviour described above. Nests are located in trees and bushes, which may be more abundant around rock outcrops, but most nesting is thought to occur in the wet season, outside the season in which these transects were conducted. The local practise of drying grain on rocks could provide food for many species of seed-eating birds (*pers obs*).

Old farmland and medium vegetation, both with negative linear trends, have medium Akaike weights, but above the random variable plus two standard errors threshold. The preference for old farmland could be due to the increased growth of short vegetation once the land is not actively cultivated, and there may be residual grain left from previous years of cultivation. An increase in medium vegetation could lead to a decrease in foraging habitat as it replaces short vegetation and bare ground. It is likely that seeds on higher grasses may be unavailable to red-cheeked cordon-bleus due to

their ground-foraging behaviour. Leaf litter is unimportant in the models and crop type has a very low Akaike weight. Considering the fact that red-cheeked cordon-bleu eat small grass seeds, a preference for crop fields with small seeds available, such as acha, might be expected. Acha fields, however, show a low density of birds in Figure 6.22 compared with transects with no major crop type, and in the models the crop type factor is not important, so birds in the mid to late dry season must be selecting for other habitat features. The relative lack of data in the models on the late wet and early dry season during the growing and harvesting period of the wet-season crops could be a reason for this but more data would have to be collected during these months to reach any conclusions.

The validation data indicated that these models do not correctly predict the number of red-cheeked cordon bleu, with a negative trend observed in the data in Figure 6.30, but there are difficulties in predicting numbers of birds when effective area searched has been used as an offset in the models, and the habitat on the transect affecting the detection function in the validation transects has been considered for the predicted values, but not the observed number of birds. When density was used as the response variable, with no offset, (as presented in Figure 6.31) a positive trend was shown when predicted density was compared with observed density on the validation transects, confirming that the problem probably lies with the use of an offset rather than observed densities.

As an example of a granivorous bird that uses an agricultural landscape the results from the models suggest, again, that the retention of shrubs and trees is very important when considering management for these types of species. The choice of crop does not seem to be important but casual observations of birds feeding in acha fields and the lack of extensive data for the whole year means this conclusion could be modified with more data. The retention of habitat around rock outcrops also seems to be important for this species.

#### **6.4.3 Implications for Species Conservation on Farmland**

The data presented here indicates that different species and guilds of birds on farmland in West Africa require different habitats and different potential agricultural

management considerations. This is in line with findings in studies in temperate and tropical regions, where different species have been found to be limited by different features of the farmland habitat, which has led to different management prescriptions being put into place. For example, yellowhammers in Europe forage on seeds and invertebrates in field margins during the summer (Stoate et al. 1998; Wilson et al. 1999) so would benefit from increasing food supplies by leaving grass margins (Vickery et al. 2002), whereas skylarks avoid field boundaries so would benefit more from whole-field management approaches such as set-aside, overwinter stubbles and undersown cereals (Vickery et al. 2002). Experiments have found that leaving central patches in fields can increase skylark territory densities whilst the presence of fields without these patches but with un-cropped field margins led to decreased skylark productivity despite an increase in invertebrate food densities in the margins, which were exploited by other bird species (Clarke et al. 2007). In Kenya, Sharpe's longclaw has been found to select for short grassland, which is threatened by agricultural expansion, but which may be compatible with dairy farming which maintains short sward (Muchai et al. 2002b) and group densities of Hinde's babbler have been found to increase with increased cover in an agricultural habitat, leading to the conclusion that management of farmland to increase thicket cover may significantly raise the bird's density and productivity (Shaw & Masina 2003).

The preference of both bird species studied here for higher tree density suggests, as in the Hinde's babbler, that retention and increase of scrub and woodland in agricultural areas in West Africa could be beneficial. The experience from Europe indicates that management prescriptions such as this, which can be derived from modelling birds' densities with habitat variables as presented here, can have a beneficial effect on bird populations. The important relationship of short vegetation to red-cheeked cordon-bleu densities could, as has been seen to be the case for Sharpe's longclaw, suggest management practices, such as grazing of fallow land, which maintain a percentage of short sward which optimises birds' densities. The experience of the decline in previously common farmland birds in Europe over the last decades (Fuller et al. 1996; Chamberlain et al. 2000; Butler et al. 2007) teaches that in Africa the common birds may be the ones to experience declines with increased agricultural expansion and intensity, so studies such as this one are vital now in order to understand the potential mechanisms of decline and plan for management prescriptions to avoid it.

## Chapter 7 Density and Behaviour of Whinchats on Farmland

### 7.1 Introduction

This chapter describes data showing that the whinchat, *Saxicola rubetra*, is common in open areas of the Jos Plateau with few trees and plenty of herbaceous vegetation. Altitude determines the local distribution of the whinchat. Whinchats are absent from the lower-lying site but on the high plateau whinchats are common and appear to have plentiful habitat. Whinchat densities may increase alongside the intensification of agriculture. Foraging behaviour does not vary significantly between the habitats whinchats occur on.

The whinchat is a palearctic migrant of the family Turdidae which breeds from western Europe east to Siberia and winters in two distinct areas, in West Africa, South of the Sahel and in Eastern Central Africa (Keith et al. 1992). It arrives in West Africa in September-October and leaves April-May, frequenting guinea savanna and savanna/forest mosaic where it forages, mainly on the ground, for insects, millipedes, centipedes, spiders, snails, earthworms and some seeds (Keith et al. 1992).

The whinchat is a common bird on its breeding grounds but there has been a gradual decrease in population over the last 20 years (Gibbons et al. 1993; Baillie et al. 2006) which has been linked to changes in management practices on pasture, with early mowing damaging nests and affecting prey abundance (Britschgi et al. 2006). Populations fluctuations of some palearctic migrants, such as the whitethroat, *Sylvia communis*, and the sedge warbler, *Acrocephalus schoenobaenus*, have been linked to habitat conditions on wintering grounds such as rainfall variation and habitat loss, although data is in short supply (Winstanley et al. 1974; Baillie & Peach 1992; Kelsey 1992; Kelsey 1992; Vickery et al. 1999) and it is possible that more species may encounter population limitations in their wintering grounds which may be linked to human management of the habitat they use. As whinchats are in decline and use farmland habitat extensively in their wintering grounds (Keith et al. 1992) it is important that any potential mechanisms limiting their population are studied both in Europe and Africa.

Modelling whinchat habitat associations, whilst necessary, provides no explanations as to why birds may be associated with particular aspects of the agricultural landscape. Focal observations of how whinchats allocate their time can give information as to how efficiently the birds are foraging in the different habitats and sites and thus indicate whether sites vary in suitability for over-wintering birds (Sutherland 1996; Norris 2004). Focal observations have been used in the past to determine how species can tolerate environmental constraints (Soroka & Morrison 2005) and how behaviour varies in different sized flocks (Warkentin & Morton 2000) and the same principles can apply here to analyse differences in the behaviour of individual birds on different farmland habitats in order to determine the characteristics of farmland habitats which make them suitable for whinchats.

The Aims of this chapter are, firstly, to determine which habitat features whinchats associate with on the Jos Plateau, whether these are consistent with the preferences reported in the literature and whether these can be related to farmland management practices, and, secondly, whether whinchats vary in foraging effort on the different farmland habitats in which they occur. Distance analysis and Generalised Linear Models will be applied to line transect data to determine habitat selection and focal observations will be used to measure foraging effort in different habitats.

## **7.2 Methods**

### **7.2.1 Transects and General Linear Models**

#### **7.2.1.2 Distance Analysis**

Transects were performed as described in section 2.1. Density estimates per transect for whinchats were calculated as described in Section 2.1.7.3 (Buckland et al. 2001) using Distance version 5 (Thomas 2006). Registrations were truncated at the distance to which 95% of individuals were observed, which was 60m for whinchats. The birds observed on the transects were treated as individual objects, rather than clusters of objects.

A half normal function with no adjustments was chosen using AIC values. Figure 7.1 shows the relationship between the actual detections of birds and the fitted function.

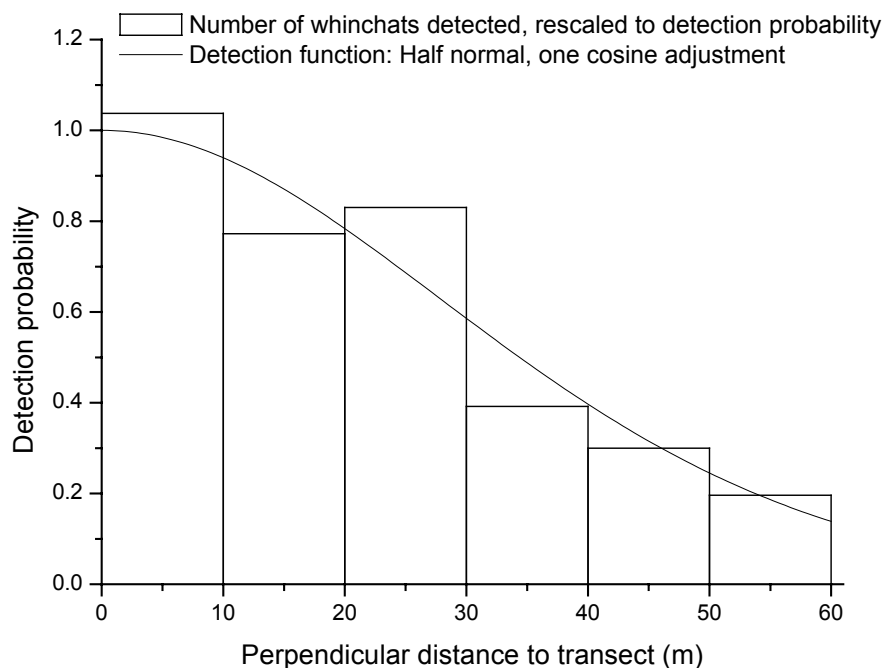


Figure 7.1 Detection function fitted over actual detections of whinchats for all transects. Function is half normal with no adjustments, detection drops off with distance from transect. Model fit is good: Kolmogorov-Smirnov test -  $D=0.05$ ,  $p=0.35$ , ns. Chi squared test, 10m intervals - Chi squared=5.62,  $p=0.13$ , ns.

Detectability was affected by vegetation. When percentage shrub cover, with all transects missing the shrub variable removed from the dataset, was included as a covariate the model had a greater AIC value than when total number of trees on the transect was a covariate,  $\Delta AIC=172$ , but the when all transects missing the tree number variable were removed, the model using number of trees as a covariate had a greater AIC value than when shrub cover was used,  $\Delta AIC=43$ . Other combinations of variables tried as covariates had higher AIC values. Despite the higher AIC value in comparison to when number of trees was included, percentage shrub cover was chosen as the covariate to use to control for the effects of vegetation on detectability as there were fewer missing values, they were all in the first field season when methods were still being developed and the variable was not to be used in subsequent GLMs with the data generated. Figure 7.2 shows the relationship between shrub cover and the estimated detection function.

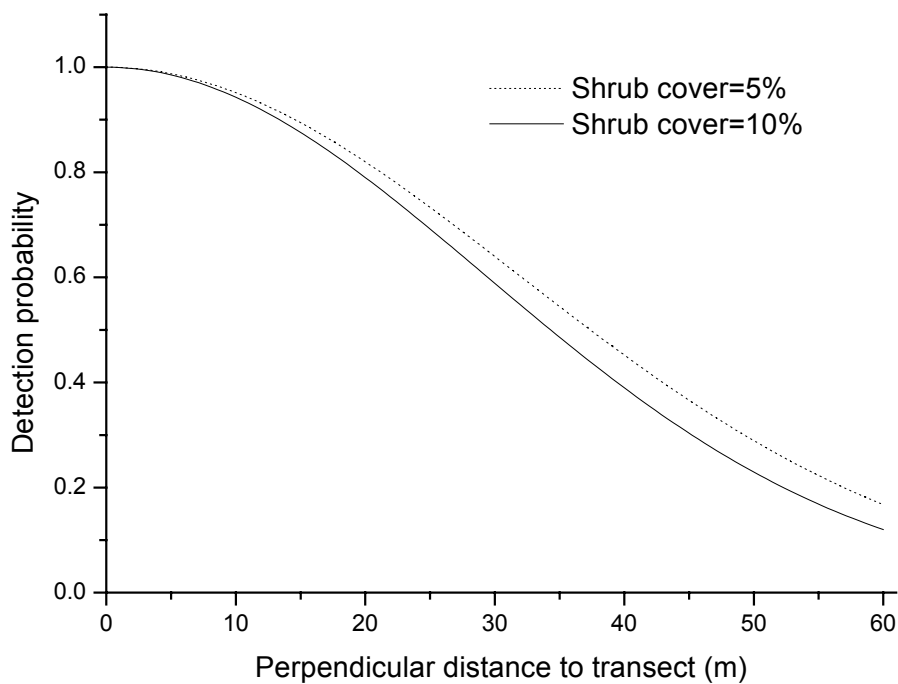


Figure 7.2 Detection probability for whinchat at lower and upper quartiles of shrub cover values. Detection is more likely away from the transect with lower shrub cover.

### 7.2.1.3 Generalised Linear Models

The eight habitat variables were selected for analysis as described in Section 2.1.7.6 and analysis was performed using Generalised Linear Models and the Information Theoretic approach (Burnham & Anderson 2002) described in Section 2.1.7.7. This includes determining the linearity of the relationship between independent and dependent variables, the calculation of AICc values and Akaike weights for models and variables, including a random variable (Whittingham et al. 2005), and the validation of the models using an independent dataset.

When models were run using only the single runs of transects to avoid pseudoreplication issues with the data, i.e. transects conducted between March and April 2004 and between February and April 2005, as in Chapters 5 and 6, the models did not converge due to the smaller sample size for whinchats compared with common bulbuls and red-cheeked cordon-bleu. For this reason all transects with values for the necessary variables were used for the models, except for the validation



transects conducted in 2006. This resulted in 1582 transects being used for modelling as opposed to 920 when repeat transects were not included, therefore 42% of the transects used were repeats but no transect was repeated more than once.

For whinchat density, the normal distribution null model resulted in a ratio of residual deviance to residual degrees of freedom of 0.36 and the Poisson model gave a ratio of 0.86, whereas for counts, the ratios were 0.33 and 0.77 for normal and poisson distributions. The Poisson distribution with rounded density values had the ratio closest to 1 (Crawley 1993) so was chosen as the response and distribution for the models with a log link function and no offset.

### **7.2.2 Behavioural Observations**

Whinchats were located and focal observations conducted of their behaviour between February and April 2005 and January and March 2006, between sunrise and 10am, around Laminga and Vom on the Jos Plateau as described in Section 2.4. This included noting the habitat type, the number of perch changes, the number and duration of sallies to the ground, the maximum distance moved, the number of pecks, any food items observed and a comparison between the height of its last perch and nearby vegetation. ANOVAs were used to analyse the data with the behavioural variable as the dependent variable: any non-normal data was transformed.

## **7.3 Results**

### **7.3.1 Density Models**

Figures 7.3 to 7.14 show plots of density of whinchats against the habitat variables used in the Generalised Linear Models, along with linear or polynomial fits to the data. Minutes after sunrise, which rises before a drop in bird numbers later in the day, old farmland and rock cover, which both drop before rising at higher values, all had polynomial relationships, which fitted better than linear fits, so quadratic terms of these variables were included in the models they occurred in. Short vegetation and medium vegetation show a linear positive trend against density, whereas cloud cover, total number of trees, bare ground and leaf litter show a negative linear trend. When

wind is present numbers drop with higher wind ratings. Vom and Laminga recorded greater numbers of birds than Fobur and no birds were recorded in Maijuju. Maize, millet, acha and sweet potato have higher densities than transects with no major crop type, whilst white beans and sorghum have lower numbers.

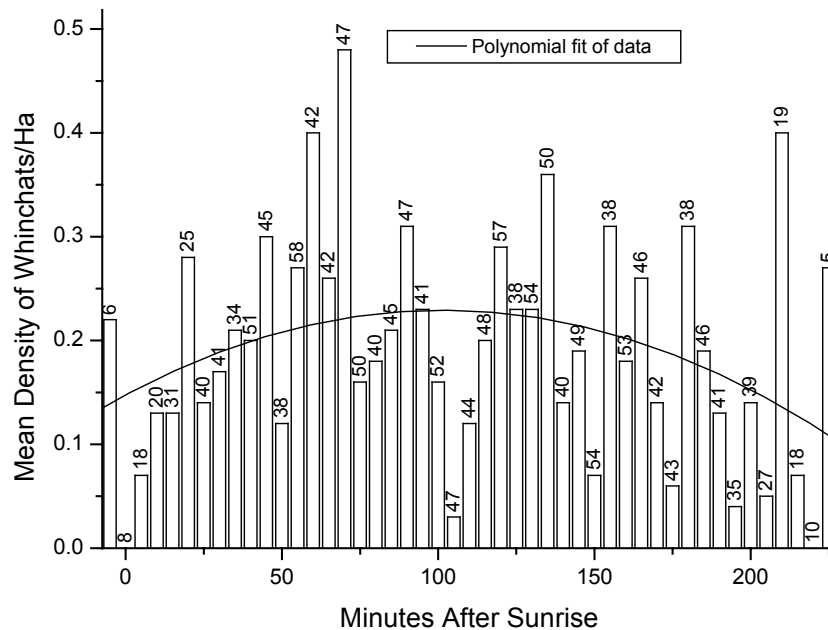


Figure 7.3 Relationship of minutes after sunrise, rounded to the nearest 5 minutes, to density of whinchats. The line represents a polynomial fit to the interval data, a fit to the raw data gave the following parameters:  $y=a+bx+cx^2$ ;  $a=0.15$ ,  $b=0.002$ ,  $c<-0.001$ ,  $R^2=0.04$ ,  $p=0.02^*$ ,  $N=230$  time interval bins.

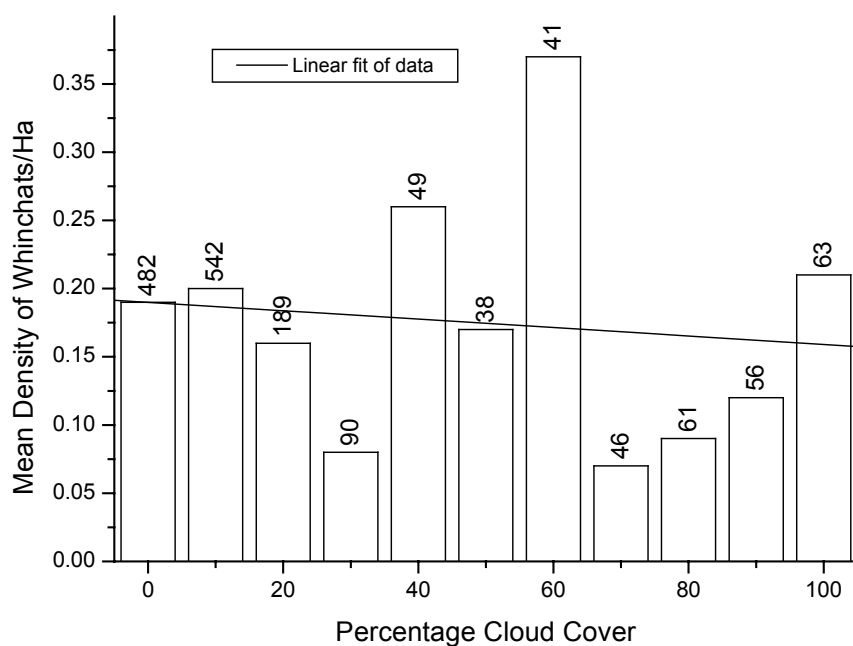


Figure 7.4 Relationship of percentage cloud cover to density of whinchats. The line represents a linear fit to the data, intercept=0.19, gradient<-0.001, R=-0.12, p=0.73, N=11.

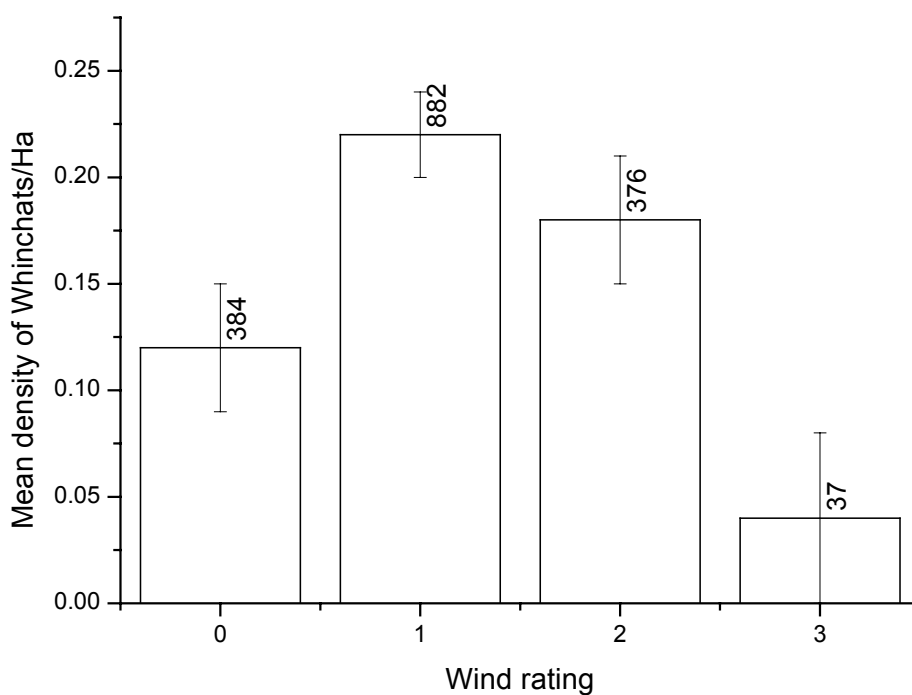


Figure 7.5 Relationship of wind rating to density of whinchats. The scale of the ratings is ordinal, with 0 representing no wind and 3 representing the strongest wind transects were surveyed in, error bars are +/- one standard error. Species richness decreases with wind strength, one way ANOVA  $F_{3,959}=3.6$ ,  $p=0.01^{**}$

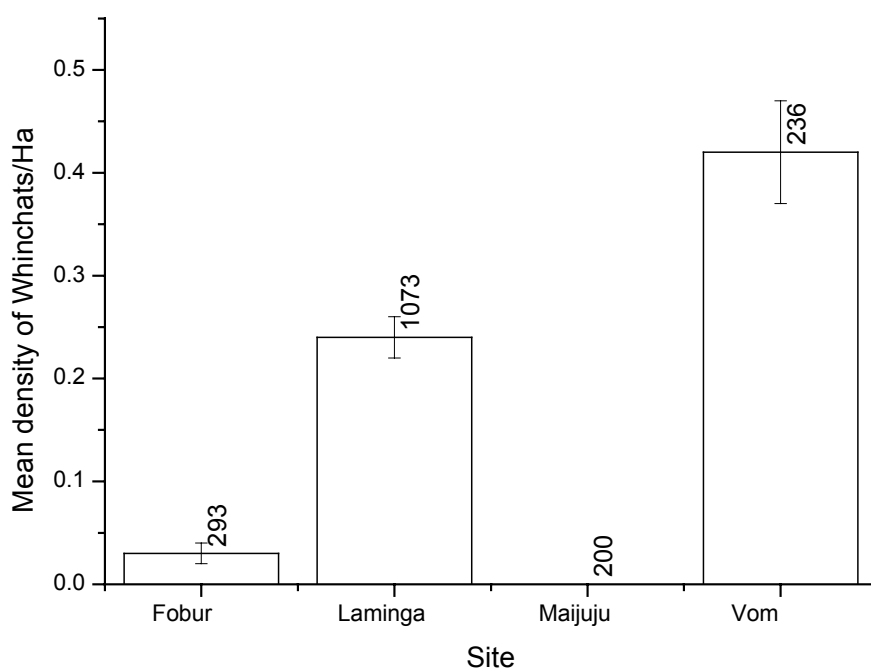


Figure 7.6 Density of whinchats by site, error bars are +/- one standard error. There is a significant difference between sites, one way ANOVA  $F_{3,959}=29.5$ ,  $p<0.01^{**}$

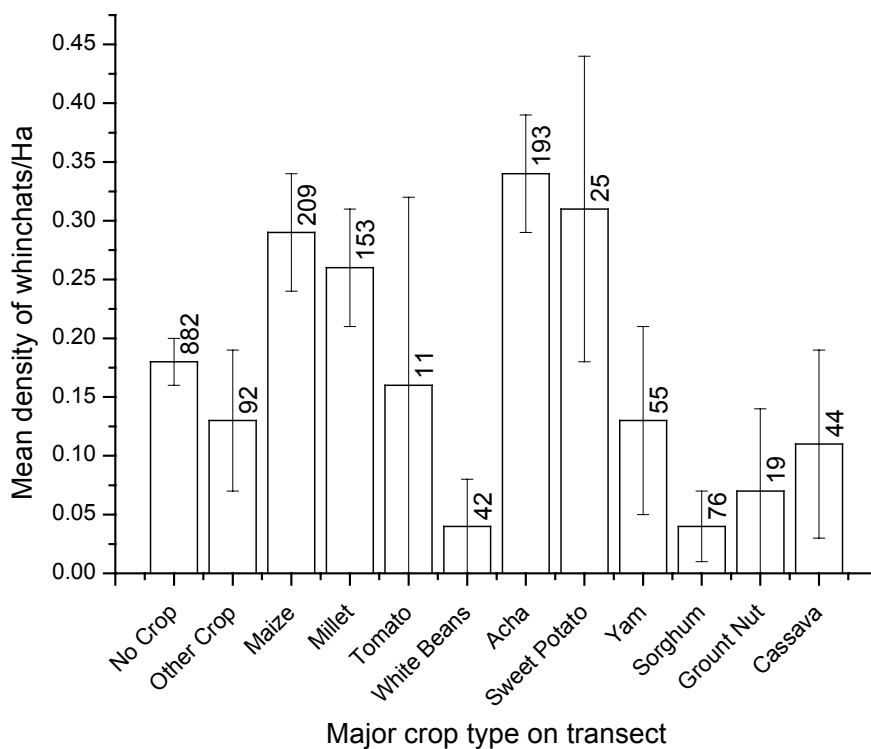


Figure 7.7 Crop type against density of whinchats. Numbers in columns are number of transects with crop as major crop type on transect, error bars are +/- one standard error. There is a significant difference between the factors, one way ANOVA  $F_{11,963}=2.9$ ,  $p<0.01^{**}$

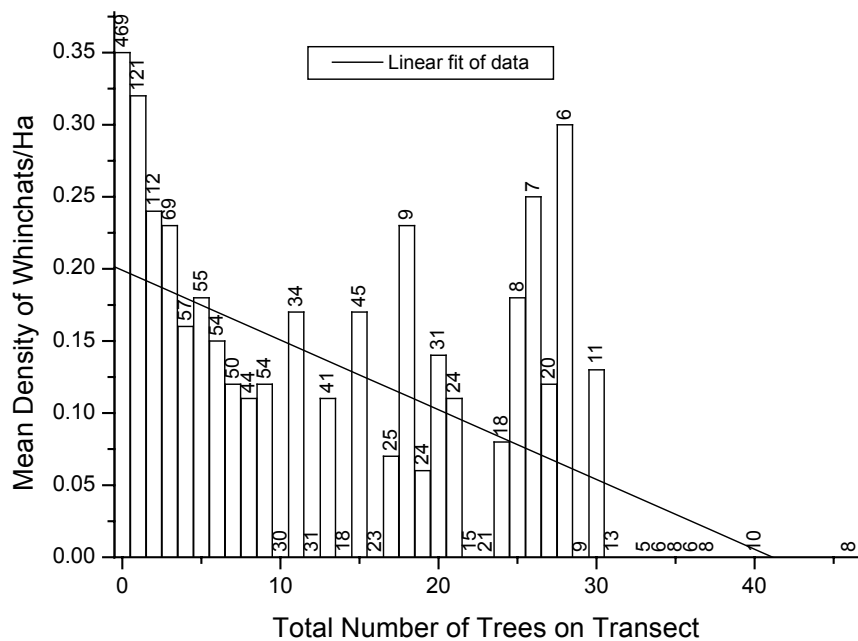


Figure 7.8 Relationship of number of trees on transect, in intervals of 5, to density of whinchats. The line represents a linear fit to the interval data, a fit to the raw data gave intercept=0.20, gradient=-0.005,  $R=-0.64$ ,  $p<0.01^{**}$ ,  $N=46$ .

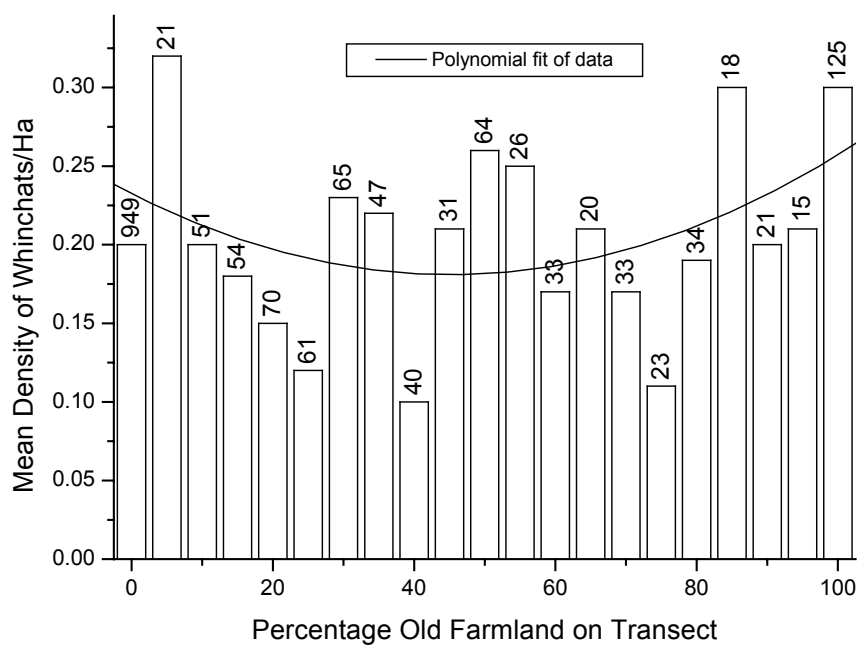


Figure 7.9 Relationship of percentage old farmland to density of whinchats. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=0.23$ ,  $b=-0.002$ ,  $c<0.001$ ,  $R^2=0.14$ ,  $p=0.25$ ,  $N=21$ . The linear fit explained less of the variance so the polynomial was chosen.

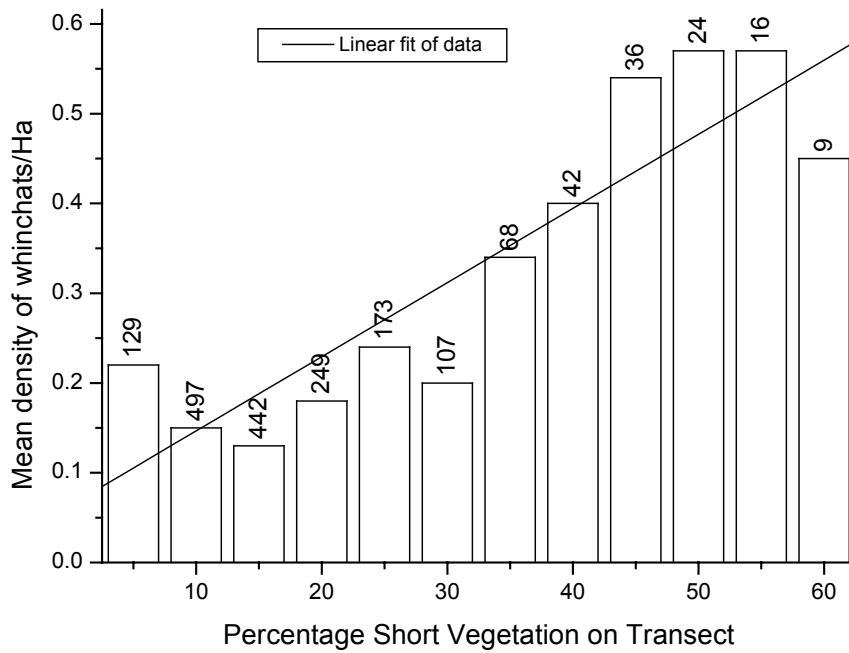


Figure 7.10 Relationship of short vegetation cover to density of whinchats. The line represents a linear fit to the data, intercept=0.06, gradient=0.008,  $R=-0.89$ ,  $p<0.01^{**}$ ,  $N=12$ .

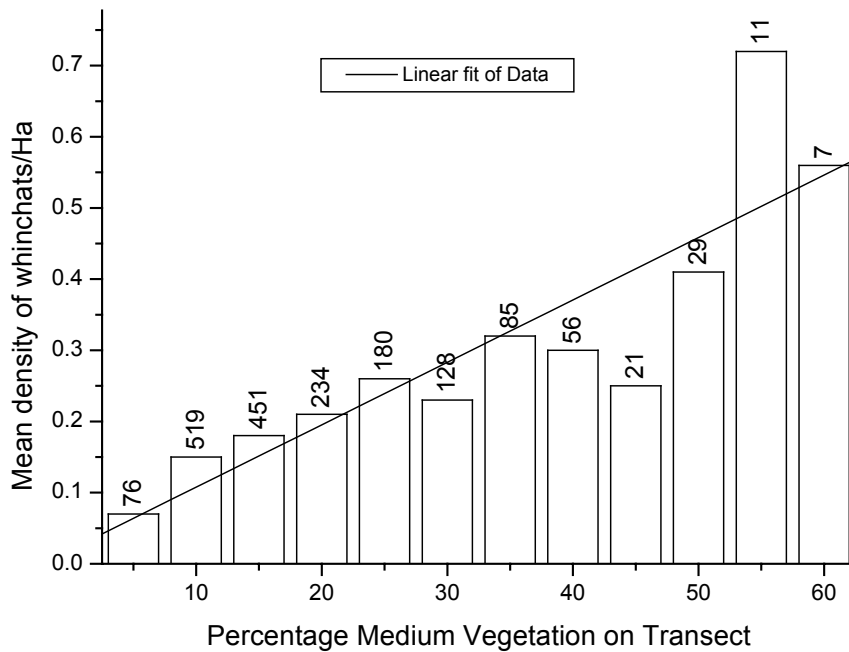


Figure 7.11 Relationship of medium vegetation cover to density of whinchats. The line represents a linear fit to the data, intercept=0.02, gradient=0.009,  $R=0.87$ ,  $p<0.01^{**}$ ,  $N=12$ .

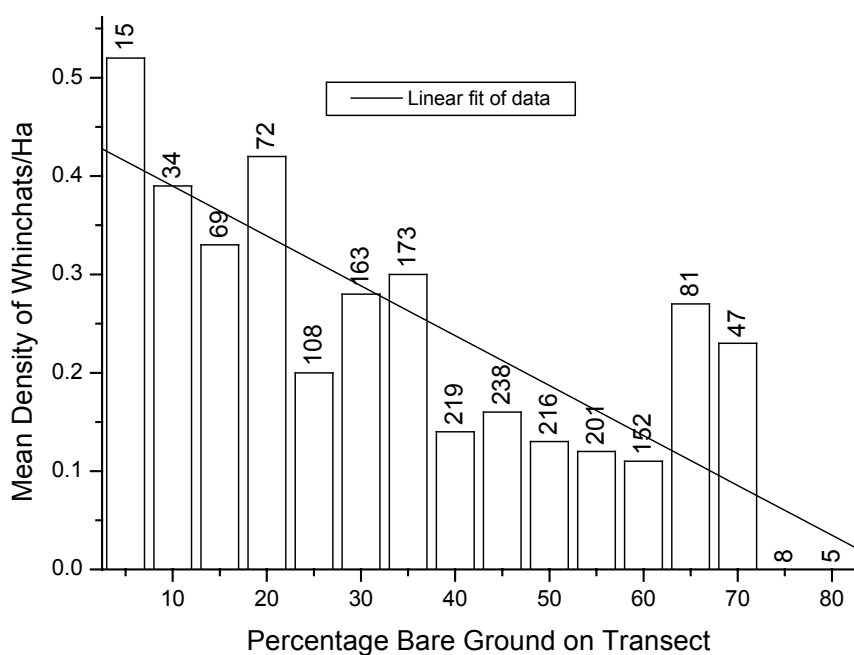


Figure 7.12 Relationship of percentage bare ground cover to density of whinchats. The line represents a linear fit to the data, intercept=0.44, gradient=-0.005,  $R=-0.83$ ,  $p<0.01^{**}$ ,  $N=16$ .

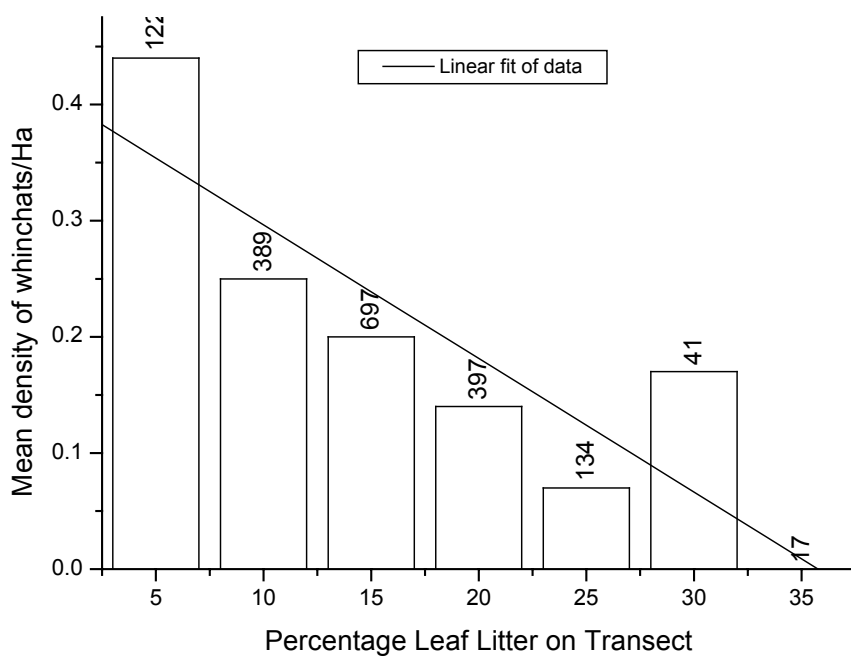


Figure 7.13 Relationship of percentage leaf litter to density of whinchats. The line represents a linear fit to the data, intercept=0.41, gradient=-0.012,  $R=-0.88$ ,  $p<0.01^{**}$ ,  $N=7$ .

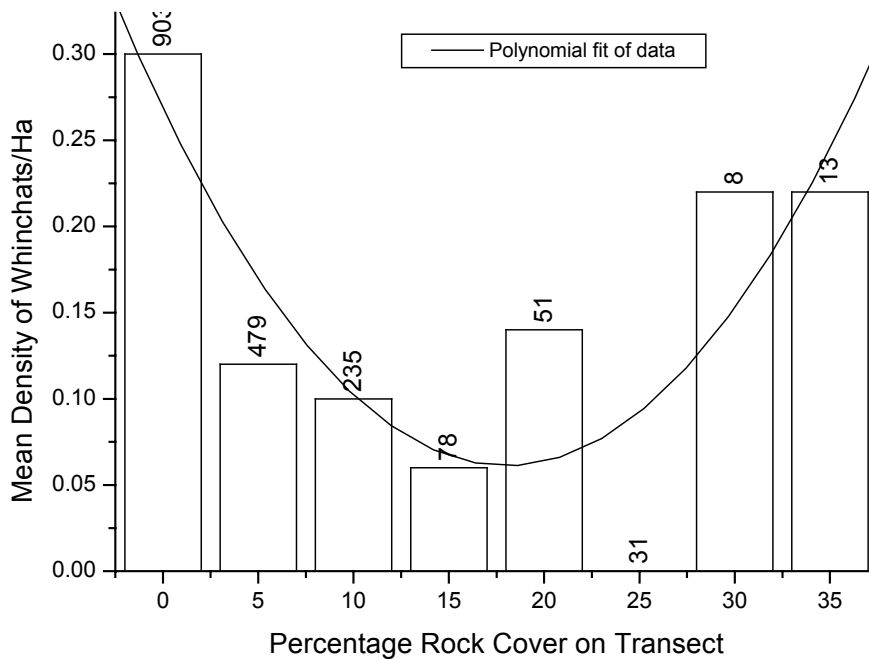


Figure 7.14 Relationship of percentage rock cover to density of whinchats. The line represents a polynomial fit to the data,  $y=a + bx + cx^2$ ;  $a=0.19$ ,  $b=-0.016$ ,  $c<0.001$ ,  $R^2=0.67$ ,  $p=0.06$ ,  $N=8$ . The linear fit explained less of the variance so the polynomial was chosen.

The results for the top 10 models are presented in Table 7.1. There were 20 models in the 95% confidence set of models. Variable Akaike weights are presented in Table 7.2. Total trees, bare ground and leaf litter have the highest weights with rock cover and old farmland the next highest and these are the variables in the top-ranked model, number 172. Total trees and bare ground are present in all the top 10 models in Table 7.1 and leaf litter is in the top 9 models. The random variable included in the model consisted of values for all transects with a normal distribution and a mean and standard deviation the same as the variable with the highest Akaike weight, Total Trees, which has a mean of 9.88 and standard deviation of 13.71. The mean Akaike weight for the random variable was 0.47 with a standard error of 0.06 after 20 runs with different values. As a conservative approach any variables with an Akaike weight below the mean plus two times the standard error of that for the random variable, in this case 0.59, can be considered to be of little importance in the model.



Table 7.1 Top 10 models for rounded whinchat density models based on Akaike weights. Transects conducted between November 2003 and April 2005. All models include minutes after sunrise with quadratic, wind and cloud cover. “Q” indicates a quadratic term for the prior variable included in the model.

Rank	Model Number	Model	AICc	$\Delta$ AICc	Akaike weight
1	172	Total Trees, Old farmland + Q, Bare ground, Leaf Litter, Rock cover + Q	1021.33	0.00	0.21
2	228	Total Trees, Old farmland + Q, Medium veg, Bare ground, Leaf Litter, Rock cover + Q	1022.04	0.71	0.14
3	222	Total Trees, Old farmland + Q, Short veg, Bare ground, Leaf Litter, Rock cover + Q	1022.08	0.76	0.14
4	96	Total Trees, Bare ground, Leaf Litter, Rock cover + Q	1022.99	1.67	0.09
5	250	Total Trees, Old farmland + Q, Short veg, Medium veg, Bare ground, Leaf Litter, Rock cover + Q	1024.02	2.70	0.05
6	45	Total Trees, Bare ground, Leaf Litter	1024.16	2.84	0.05
7	190	Total Trees, Old farmland + Q, Short veg, Bare ground, Leaf Litter	1024.32	3.00	0.05
8	111	Total Trees, Old farmland + Q, Bare ground, Leaf Litter	1025.01	3.68	0.03
9	171	Total Trees, Medium veg, Bare ground, Leaf Litter, Rock cover + Q	1025.06	3.73	0.03
10	164	Total Trees, Short veg, Bare ground, Leaf Litter, Rock cover + Q	1025.17	3.85	0.03

Table 7.2 Variable Akaike weights for whinchat density models.

Variable	Akaike weight
Total Trees	1.00
Bare Ground	1.00
Leaf Litter	0.91
Rock Cover	0.75
Old Farmland	0.70
Short Vegetation	0.38
Medium Vegetation	0.33
Crop Type	<0.01

Parameter estimates for the top model, number 172, are shown in Table 7.3. As indicated by figures 7.3 to 7.14 the parameter estimates indicate negative trends for total trees, bare ground, cloud cover and leaf litter and positive trends for old farmland and its quadratic, rock cover and its quadratic and minutes after sun and its quadratic. The differences between sites are highly significant according to the chi squared

values and the differences between wind ratings are significant. Total trees, bare ground and leaf litter all have highly significant chi squared values.

Table 7.3 Parameter estimates for top ranked model for whinchat density, number 172 in Table 7.1, Akaike weight 0.21. The model parameters indicate the direction in which the different variables are influencing species richness within the context of the model and chi squared tests indicate the influence each variable is having on that particular model.

Parameter		Parameter estimate	Standard error	Chi-Square	p-value	Type 3 Chi-Square
Intercept		-0.99	1.09	0.83	0.36	
Minutes after sunrise		<0.01	<0.01	0.47	0.50	0.47
Minutes after sunrise Q		<-0.01	<0.01	1.47	0.22	1.52
Wind	0	1.43	1.02	1.95	0.16	9.68*
	1	1.81	1.01	3.20	0.07	
	2	1.54	1.01	2.30	0.13	
	3	0	0	.	.	
Cloud cover		<-0.01	<0.01	1.07	0.30	1.11
Site	Fobur	-2.14	0.51	18.00	<0.01	71.17**
	Laminga	-0.45	0.16	7.72	<0.01	
	Maijuju	-25.13	43664.95	0	0.99	
	Vom	0	0	.	.	
Total trees		-0.03	0.01	9.34	<0.01	13.83**
Old farmland		<0.01	<0.01	0.55	0.46	0.54
Old farmland Q		<-0.01	<0.01	1.63	0.20	1.61
Bare ground		-0.02	<0.01	39.09	<0.01	38.94**
Leaf Litter		-0.03	0.01	6.64	0.01	6.95**
Rock Cover		-0.04	0.03	1.72	0.19	1.72
Rock Cover Q		<0.01	<0.01	0.25	0.62	0.24

### 7.3.2 Validation

Figure 7.15 shows the relationship between the recorded data for the validation dataset, between the 9<sup>th</sup> of January 2006 and the 16<sup>th</sup> of March 2006, and the weighted predicted values. Spearman's rho correlation coefficient was calculated comparing the number of bird species observed within 50m of the transect and the predicted values for the model. Although the  $R^2$  value is low at 0.01 and the slope gradient only 0.02 the positive slope of the highly significant regression line shows that predicted values increase as observed density increases.

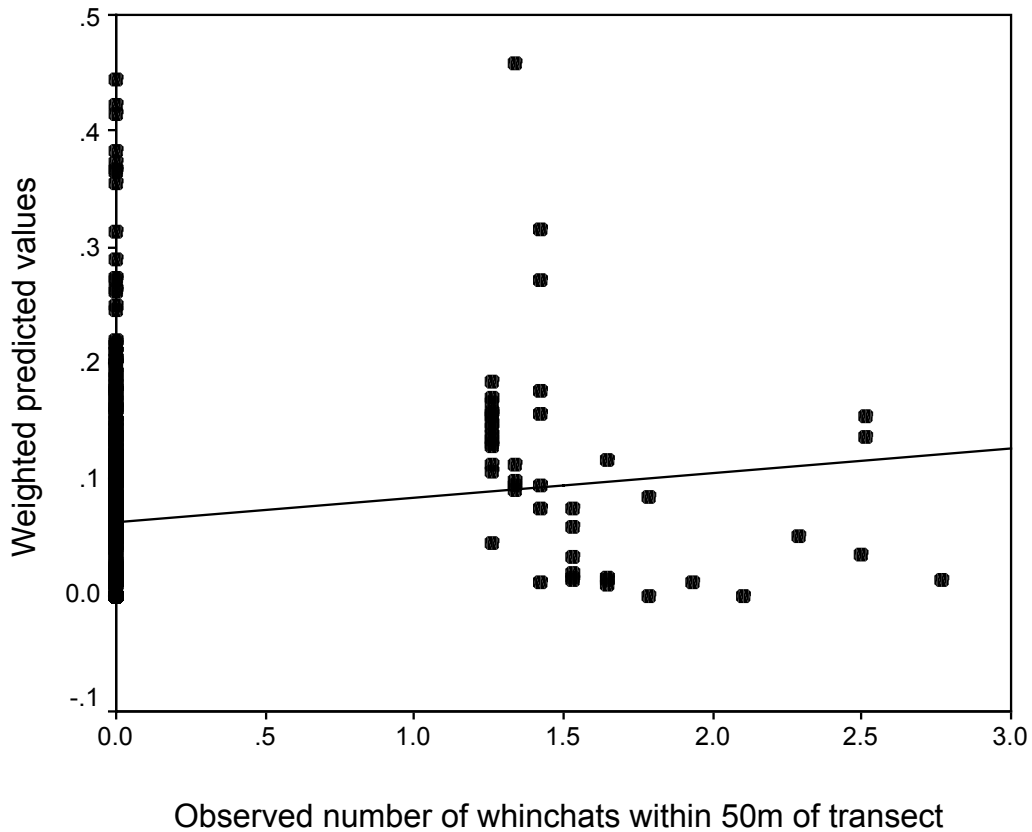


Figure 7.15 Weighted predicted values for density of whinchats on validation transects against observed values on visits to transects in 2006. Linear regression line  $F_{1,634}=8.9$ ,  $p=0.03^*$ , intercept=0.06,  $sd<0.01$  gradient= 0.02,  $sd<0.01$ ,  $R^2=0.01$ . Spearman's rho correlation coefficient = -0.15,  $p<0.01^{**}$ ,  $N=636$ .

### 7.3.3 Whinchat Behaviour

The frequencies of the habitats the whinchats were observed in are displayed in Table 7.4. Due to the low sample sizes for a number of habitat and crop types the habitats were pooled into three classes: crop, non-crop and old farmland.

Table 7.4 Frequencies of habitats whichat observations occurred in and the subsequent general habitat definition.

Habitat	Frequency	General Habitat	Frequency
Harvested Maize	23	Crop	64
Harvested Millet	22		
Harvested Acha	11		
Harvested Maize/Sorghum	4		
Harvested Sorghum	1		
Harvested White Beans	1		
Tomato	1		
Yam	1		
Scrub	35	Non-Crop	37
Prepared Land	2		
Old Farmland	15	Old Farmland	15
Total	116	Total	116

There were a total of 116 observations of over 2 minutes in length of which 86 were in the Laminga area and 30 in the Vom area and a total of 81 observations where birds were observed on the ground of which 56 were in the Laminga area and 25 were in the Vom area. There were 59 observations where the furthest distance moved and the general habitat type were both recorded, of which 41 were in the Laminga area and 18 were in the Vom area. The means of the behavioural variables were compared between sites using t-tests. The results for all variables were not significant: proportion of time on the ground ( $t_{3,114} = 0.58$   $p=0.56$ ), number of sallies to ground per minute ( $t_{3,114} = 0.58$   $p=0.56$ ), number of pecks per minute observed on the ground ( $t_{3,79} = -0.78$   $p=0.44$ ) and furthest distance moved per minute ( $t_{3,57} = -0.90$ ,  $p=0.37$ ). Observations from the different sites were, therefore, pooled for the analyses.

ANOVAs were run with the behaviour variables as the dependent variable and general habitat as a fixed factor (Table 7.5): none of the models were significant, indicating that whinchats were not altering their foraging behaviour depending on the type of farmland habitat being used.

Table 7.5. Results of ANOVAs comparing means of whinchat behavioural variables in different farmland habitats.

Dependent Variable	General Habitat Type	Mean	SD	Degrees of Freedom	F	<i>p</i> -value
Proportion of time on ground (arcsin transformed)	Crop	0.30	0.21	2	0.53	0.59
	Non-Crop	0.31	0.32			
	Old Farmland	0.38	0.34			
Number of Sallies to ground per minute	Crop	0.50	0.33	2	1.83	0.16
	Non-Crop	0.40	0.39			
	Old Farmland	0.60	0.43			
Number of pecks per minute observed on ground (log transformed)	Crop	0.83	13.5	2	1.32	0.27
	Non-Crop	0.99	12.6			
	Old Farmland	1.05	0.49			
Mean furthest distance moved per min (log transformed)	Crop	6.57	8.91	2	0.64	0.53
	Non-Crop	7.01	9.38			
	Old Farmland	7.71	7.16			

In order to include all fields with harvested maize in the analysis mixed fields of harvested maize and sorghum were pooled with harvested maize fields. The means for the behaviour variables for the three most common crops were compared using ANOVAs (Table 7.6): none of the models were significant, indicating that whinchats were not altering their foraging behaviour depending on the type of crop being used.

Table 7.6 Results of ANOVAs comparing means of whinchat behavioural variables in different crop types.

Dependent Variable	Crop Type	Mean	SD	Degrees of Freedom	F	<i>p</i> -value
Proportion of time on ground (arcsin transformed)	Acha	0.36	0.27	2	0.84	0.44
	Maize	0.26	0.18			
	Millet	0.29	0.23			
Number of Sallies to ground per minute	Acha	0.54	0.32	2	0.16	0.85
	Maize	0.47	0.30			
	Millet	0.52	0.44			
Number of pecks per minute observed on ground (log transformed)	Acha	0.83	0.50	2	0.35	0.71
	Maize	0.89	0.55			
	Millet	0.72	0.58			
Mean furthest distance moved per min (log transformed)	Acha	3.00	2.11	2	0.41	0.67
	Maize	6.14	7.35			
	Millet	6.31	13.55			

Figure 7.16 shows that the mean height of the last perch each whinchat was viewed on was higher than the mean height of a random potential perch. A paired t-test for the log-transformed values of perch height and random perch height showed this relationship to be highly significant ( $t=-10.5$ ,  $df=112$ ,  $p<0.01^{**}$ ), therefore, whinchats selected perches significantly higher than the average potential perch.

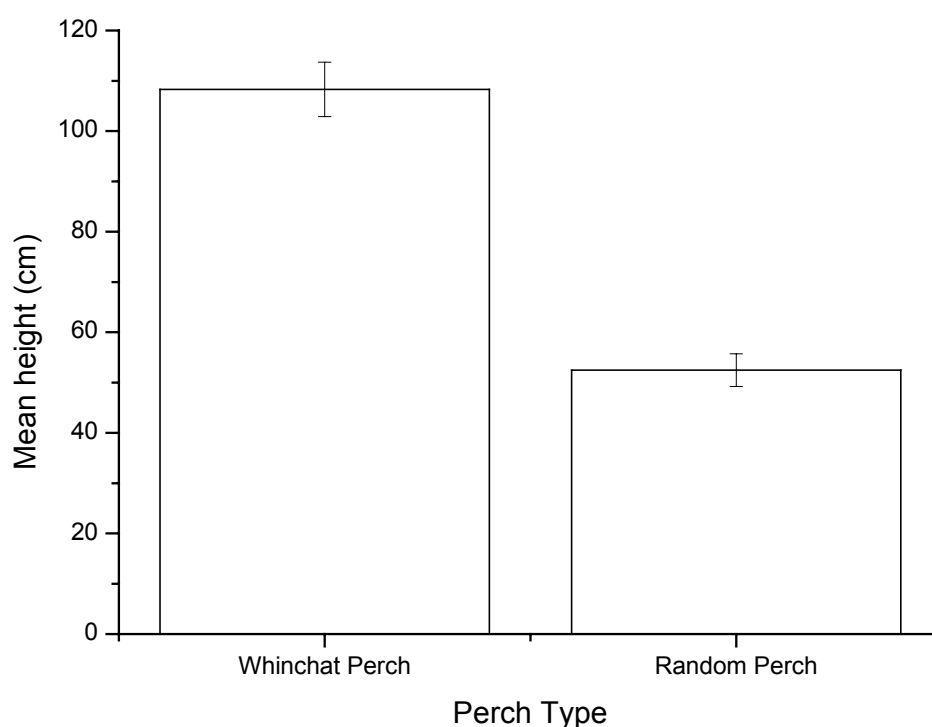


Figure 7.16 Mean height of last perch in an observation period of whinchat and a random potential perch 10m away, in cm. The error bars represent +/- one standard error.

Of 854 active perches viewed during whinchat observations, Table 7.7 shows that the most common was shrub, used 262 times followed by grass or weeds used 167 times. In total crops were used 184 times, 21.6% of the observed perches, with maize and millet being the most commonly used. Acha was never observed as a perch.

Table 7.7 Frequency of use by whinchats of different perch types during observations.

Perch	Frequency used by Whinchat
Shrub	262
Grass/Weed	167
Millet	98
Maize	76
Tree	55
Mound	22
Rock	14
Sorghum	7
Okra	3

On 18 occasions invertebrate prey was seen in the bill of a whinchat of which 6 were identified more precisely, or to family. These were one grasshopper, one fly, one

caterpillar, one cricket, one large ant and one insect larva. On four occasions, when an area where a whinchat had gone to ground was examined after the observation, large numbers of ants were seen, once a large number of termites were seen where small, unidentified prey had been seen in the bird's bill, and once termite holes were seen but no termites. On eight occasions birds appeared to pursue prey in the air without going to the ground, of these two were successful and it was not determined whether the other six were successful.

## **7.4 Discussion**

Results from the Generalised Linear Models show that whinchats are particularly associating with areas with low tree density, low bare ground cover and low leaf litter, based on high Akaike weights for these variables. Whinchats were also associated with a higher percentage cover of short and medium vegetation but low Akaike weights for these variables indicated that this was not a strong relationship. Rock cover and old farmland had intermediate Akaike weights and polynomial fits to the density data indicated a more complex relationship with these variables, with whinchat densities highest at the lower and upper end of the values recorded for both variables. These results show that whinchats occur most commonly in more open areas of farmland, and are present in high densities on acha, maize and millet fields, as displayed in Figure 7.7, although the crop preference does not figure in the model once the effect on density of other variables are taken into account. These results are validated by the positive correlation between the predicted and observed values for the validation dataset.

Previous studies in European breeding grounds have found a preference in whinchats for set-aside fields rather than cereal fields (Berg & Part 1994) which, as whinchats are ground-nesters, has been attributed to the reduced risk of nest predation in more dense vegetation and reduced damage to nests from active cultivation. On wintering grounds in Africa, where nesting is not occurring, the limitations on the whinchats will be those of adult predation risk, foraging efficiency and competition. The results for the sample of perch sites show that whinchats prefer perches, at a mean of 108cm, that are significantly taller than the randomly-selected perches, with a mean of 52cm.



It has been found, in Germany, that, along with food abundance and mowing time, the density of available hunting perches is an important factor in habitat use by whinchats in grassland (Oppermann 1990). This may be the case on agricultural land on the Jos Plateau and may be indicated by the association with greater cover of medium height herbaceous vegetation. The presence of shrubs, grass, weeds and other potential perches on old farmland and scrub along with cereal stems in stubble fields, all well used as perches during observations, may mean that this is not a limiting factor for whinchats on the study-sites.

There is no estimate of adult predation risk on the study sites but, of potential avian predators of passerines observed on transects, the number of registrations either flying or perched were 13 shikra (*Accipiter badius*), 11 gabar goshawks (*Melierax gabar*), 7 dark chanting goshawks (*Melierax metabates*), 83 Montague's harriers (*Circus pygargus*) and 23 pallid harriers (*Circus macrourus*) during the whole survey period. These appear to be relatively low numbers, considering over 2000 transects were conducted, so it is possible that this will not detrimentally affect whinchats using open areas, but even low densities of predators could have non-lethal effects on whinchat behaviour (Lima 1998). The perception of greater predation risk can alter foraging behaviour in birds so that they may select for non-ideal habitat, only foraging in areas with higher perceived predation risk, but higher potential foraging rates, when under starvation pressure. This has been observed in redshanks, *Scolopax totanus*, in the UK, which choose to forage far from cover in mussel beds until starvation pressure forces them to forage in more risky areas of salt marsh, where they are 4.8 times more likely to come under attack from sparrowhawks (Cresswell 1994). Habitat choice of whinchats on the Jos Plateau could be affected by this phenomenon, particularly in Vom, where the highest number of raptors in a single site were observed, but sample sizes are low and responses to predation risk, interacting with foraging pressure and competition can be very complicated and would involve more detailed study (Lind & Cresswell 2005; Minderman et al. 2006).

Whinchats are insectivorous, central place foragers (Andersson 1981) and will select for habitats which have a sufficient density of prey where they are able catch them, mainly on the ground during sallies from a hunting perch. Migrant passerines have been shown to select for areas of higher food availability (Johnson & Sherry 2001).

There is no estimate available of arthropod abundance in the different habitats observed but the presence of herbaceous vegetation is likely to positively affect the density of invertebrates available for hunting whilst an increased amount of bare ground is likely to host decreased densities of prey. The absolute abundance of prey is, however, complicated by variations in the relative abundance, or how easy the prey is to catch, which is likely to be higher in more open areas with less obstructing vegetation. The negative association of leaf litter with whinchat density is possibly due to the foraging strategy of whinchats being based on visual cues from a raised perch and increased leaf litter provides increased cover on the ground for prey thus a decreased chance of being detected by the bird, whereas higher cover of herbaceous vegetation, which is weakly implicated in increased whinchat densities, could provide habitat for invertebrates without providing concealment from the raised view of a hunting whinchat.

The complete absence of whinchats from Maijuju, which is a site on the edge of the Jos Plateau at 950m in altitude compared to 1250m in Vom and Laminga, despite seemingly suitable farmland habitat being present, suggests also that the high plateau provides better habitat. This may be due to habitat selection, with greater mean tree density in Maijuju leading whinchats to select the more open habitat present at higher altitudes, but whinchats are widely distributed in Nigeria, apart from the far north, in guinea savanna and savanna/forest mosaics (Keith et al. 1992), so it appears odd that no birds were found. Passerine migrants can, however, have a patchy distribution, depending on the numbers of birds migrating over a wide area and whether the birds are generalists or specialists, with specialists having more limited ranges (Newton 1995). The wide range in densities of whinchats observed between sites on the Jos Plateau indicate that, in their wintering grounds, the birds are more specialists than generalists so may be more prone to patchy distributions. A similar study, including a survey of arthropod abundance in a lowland area of Nigeria where whinchats occur would be interesting.

The focal observations indicate that there is no difference in foraging effort, when measured by the proportion of time spent on the ground, the number of sallies to the ground, the number of pecks whilst viewed on the ground and the mean furthest distance moved per minute observed, between the different farmland habitats the

whinchats were observed in. Breeding whinchats demonstrate rapid adaptation to variations in food density, with foraging effort closer to the nest with high densities of food (Andersson 1981), so they would be expected to expend more effort foraging in habitats with lower food density. The results suggests that there is no difference in prey availability, although the difficulty in observing the birds on the ground and the difficulty in identifying the size and taxa of prey items means that there might be differences in the quality and quantity of food ingested that were missed in the data presented here. The models discussed above indicate that whinchats have higher densities in different farmland habitats and it is possible that prey availability is much lower in areas where whinchats are at lower density, such as more wooded areas with higher tree density, nevertheless, within the habitats they do select for there appears to be little difference in behaviour to suggest a difference in prey availability and habitat quality.

Whinchats are declining in Europe and the current theory is that this is due to a change in the management of pastures in which they breed from late to early mowing which disrupts nests and prey (Britschgi et al. 2006). The timescale of the data provided here is not sufficient to determine the population trend of whinchats in West Africa but more detailed surveys on the habitat preferences, diet and foraging efficiency, perhaps also tied in with the effect of competition from larger birds inhabiting similar niches, such as Heuglin's wheatear and northern wheatear, both of which were viewed successfully chasing whinchats, would indicate whether there are any potential mechanisms to further explain the gradual decline of whinchat populations on their breeding grounds. Competition between migrants and resident birds on wintering grounds have been suggested as a population-limiting factor for sedge warblers and whitethroats (Baillie & Peach 1992) although recent behavioural studies in the Sahel have indicated that this competition may be less significant than previously thought (Wilson & Cresswell 2007). In the Democratic Republic of Congo it has been suggested that whinchats fill an empty niche left vacant by resident birds (Dejaife 1994), although this is not thought to be the case on the Jos Plateau, where many open country species were observed alongside whinchats.

The evidence from the data presented here suggests that farming at the intensity observed on the Jos Plateau should not have a detrimental effect as whinchats were

most common in Vom, where the most intense farming activity was concentrated, whereas the area with the greatest similarity to natural savanna and the lowest farming intensity, Fobur, had the lowest densities of whinchats on the high plateau. In light of this, potential management options for whinchat populations could include the removal of trees and the encouragement of activities which increase herbaceous vegetation growth, such as leaving land fallow or greater conversion of thick scrub land to cereal crops. The conversion of scrub and savanna to open, intensive farming, whilst potentially beneficial for whinchats, has been demonstrated in previous chapters to be potentially harmful for avian diversity generally and for the greater number of species which select for more wooded habitats. Until more evidence exists, management specifically for whinchat populations should not be encouraged.

In summary, whinchats are associated with areas with lower tree density, bare ground cover and leaf litter, and appear associated with higher cover of herbaceous vegetation. They exist in scrub, old farmland and on the major cereal crop types but are rare or absent from areas at lower altitude immediately adjacent to the high plateau. In the habitats in which they occur there is no difference in foraging effort but the quality and quantity of the food ingested is not known. Whinchats require perch sites higher than the surrounding vegetation, which are abundant in the open habitats they use. Whinchat numbers may be limited by survival on wintering grounds, or may be limited on breeding grounds or migration, and until these facts are determined no management options for whinchats, which may be detrimental to other species, should be encouraged.

## Chapter 8 Discussion

### ***8.1 How does Farmland on the Jos Plateau Compare as a Habitat for African Birds?***

Farmland on the Jos Plateau hosts a large number of, and a wide variety of, bird species, indicating the need to ensure that it and other, similar, habitats in Africa continue to do so. Observations were made of 237 species of birds whilst conducting transects on farmland and, as the Canonical Correspondence Analysis in Figure 3.16 shows, many of these species were selecting for crop fields and fallow land as well as for scrub and rocky habitat. These figures suggest that farmland on the Jos Plateau supports a high diversity of bird species which are using the human-disturbed habitat as well as the more natural habitats available to them. Number of species is a rough determinate of the quality of a habitat but it is interesting, none-the-less, to compare the number of species viewed during this study to those observed during other studies in Africa. The number of species for this limited area compares well with counts of species in more pristine savanna habitats, with 117 non-raptor species observed during three two-month surveys of a savanna-forest mosaic in the Ivory Coast over 28 years (Thiollay 1998), 92 bird species on a 6 week survey in four different savanna habitats in Hluhluwe-Umfolozi national park in South Africa (Skowno & Bond 2003) and 128 species during a 10 month survey of acacia savanna in Swaziland (Monadjem 2001) being three examples. When compared to forest habitats the number of species observed on farmland in the study area is also high, with 197 species recorded in forest fragments in South Western Nigeria over three years (Manu et al. 2007) and 237 species also recorded from surveys of four forest reserves in Ghana (Ntiamoa-Baidu et al. 2000). Of other studies on African farmland, 85 species were recorded over 68 500m long transects in Burkina Faso (Soderstrom et al. 2003) and 224 species were observed over 70 60 minute Timed species counts in Ethiopia (Wilson et al. 1997), which compares well with 237 species overall during this study.

## ***8.2 What determines the Avian Diversity Observed on Farmland?***

### ***8.2.1 Farming Intensity***

The study site incorporates gradients of farming intensities, which create distinct habitat mosaics and vegetation structures, as described in Chapter 3. More intensively farmed land, such as that at the Vom study site, is more open, with larger fields, fewer field borders and fewer trees and shrubs. There is a larger area given over to crops and fallow land than scrub, whereas in Fobur a larger area is given over to scrub than farmed land (see Figure 3.5), and individual farmers tend to farm larger areas of land. More intensively farmed land also involves the application of more fertilisers, pesticides and herbicides but no significant differences between sites were evident from the questionnaires, with almost all farmers applying chemicals to their crops and quantities were difficult to confirm. There was a drop off in avian diversity on the more intensively farmed Vom site compared to less intensively-farmed sites such as Fobur, as described in Chapters 3 and 5. Different, and fewer, species of birds were associated with more crop land and fallow land compared with those associated with rock and scrub (Figure 3.16), and tree density was the most important variable determining bird species richness and diversity, with tree density being lowest in Vom. The difficulty in directly measuring farming intensity, the variation between farms and fields within and between sites and the multivariate nature of the data makes a comparison of avian biodiversity that directly relates to farming intensity difficult, but the data clearly indicates a correlation between differences in bird communities and areas where farming intensity appears to be different.

The evidence displayed here parallels observations in Europe that increased intensity of farming has led to a decline in biodiversity (Bignal & McCracken 1996; Chamberlain et al. 2000; Tilman et al. 2001). The evidence also seems to be in line with observations in South Africa, West Africa and East Africa that indicate that less-intensive farming methods such as mixed cropping regimes (Mangnall & Crowe 2003) and small scale, heterogeneous farming (Wilson et al. 1997; Soderstrom et al. 2003) can be beneficial to bird species richness.

To ensure high avian diversity on farmland in Africa it appears that incorporating management practices that reduce intensity and increase habitat heterogeneity would be effective. This could include cultivating a wide variety of crops, as occurs on the Jos Plateau, keeping field sizes small and encouraging small-holdings rather than large farms and limiting the amount of and frequency of applications of fertiliser, pesticide and herbicide. These policies would be a challenge to implement due to the need and desire of African states to increase crop yields to feed a growing human population, but funds for subsidies could enable farmers to be given incentives, as occurs in regions such as the European Union (Green et al. 2005).

### **8.2.2 Retention of Natural Habitat**

One consequence of the intensification of agriculture on the Jos Plateau appears to be a reduction in the area of more natural habitat such as woodland and scrub, as the proportions of habitats from the study sites in Figure 3.5 shows. There is a gradation in the proportion of scrub habitat on transects which correlates with the gradation of farming intensity from Fobur to Vom. Figure 3.16 shows a large number of savanna species clustered in transects with higher lengths of scrub habitat and Chapters 5 and 6 show that the most consistently important variable in the models of transect data, whether species richness, diversity or individual species densities, is tree density. The only model where increased tree density consistently resulted in lower bird density was for whinchats, Chapter 7, so, generally, tree density to medium levels resulted in higher values for the dependent variables. Figure 4.1 shows that many species of birds also prefer to keep close to retained more natural habitat that forms the edge of field even when they are foraging on actively farmed land. Rocky habitat and rock cover also resulted in high species richness, diversity and densities of red-cheeked cordon-bleu, partly because of retention of natural habitat where cultivation was more difficult because of the terrain.

The retention of specific types of natural habitat has been implicated in retaining levels of biodiversity in European farmland, including hedgerows (Gillings & Fuller 1998; Hinsley & Bellamy 2000), woodland borders (Fuller et al. 2001; Peach et al. 2004), grasslands (Moreira et al. 2005; Batary et al. 2007) and wetlands (Bradbury & Kirby 2006). The general approach of ensuring a heterogenous landscape, both in

terms of the land in use and retained natural habitats has also been suggested as effective (Benton et al. 2003). In Burkina Faso the retention of old-growth trees on farmland has been shown to particularly benefit hole-nesting species (Soderstrom et al. 2003) and a mixture of farmland and native Coastal Fynbos vegetation recorded the highest numbers of species in a South African survey (Mangnall & Crowe 2003) which may even indicate that the potential for biodiversity could be even higher on human-disturbed land than in less disturbed natural habitats, consistent with the succession and disturbance theory (Connell 1978).

The obvious importance of retained habitat on farmland on the Jos Plateau and other areas of Africa suggests that perhaps the most important management prescriptions for farmland will be those that do retain scrub, woodland and other types of habitat, or even simply retain a proportion of field-edge habitat. These could include education as to the potential benefits of forest and savanna woodland to local communities, such as sustainable firewood, avoidance of water run-off, retention of exploitable materials and species, and potential tourism value. Subsidies could also be used to encourage the retention of scrub as field borders and the retention of larger tracts of scrub and woodland between agricultural land. The provision of alternative sources of wood, such as plantations, could also be a possibility as long as they, themselves, do not reduce biodiversity.

### **8.2.3 The Creation of New Habitats**

Farming activity on the Jos Plateau has led to the creation and expansion of habitats that were not present, or present at much lower levels when agricultural activity was at much lower levels. These include open grassland habitats, which vary depending on the crop being cultivated, and some irrigated areas during the dry season. Crops can provide seed and fruit food, and habitats for invertebrate food, which may not have been present before. Without data from the Jos Plateau from when farmland was less extensive in area, it is difficult to describe how bird communities may have changed, but Figure 3.16 shows how birds such as rufous-naped lark, whinchat, African quail finch, plain-backed pipit, crested lark and sun lark are associated with the open grassland-type habitats formed by the cultivation of crops, as the literature states is the case (Keith et al. 1992; Borrow & Demey 2001). These species are both granivores



and insectivores, which can use the food provided by the crop fields and that have adapted to an open environment. These species would not be found in numbers in more closed savanna woodland, although it is likely that savanna on the Jos Plateau, due to the altitude, may not have been as dense and high as that at lower altitudes before extensive human disturbance. How irrigation has improved the habitat is hard to assess because the data on irrigated land is limited due to the low area irrigation takes up on the transects, but human disturbance has provided mining pools in the agricultural landscape that provide habitats for many species of water birds (*Pers. obs.*).

The presence of farmland usually attracts a different community of birds to that which would have been observed in the original habitat. In the case of the central Nigerian Guinea savanna belt the open, disturbed habitats formed by farming activity enables bird species which are more common further north, towards the Sudan savanna and Sahelian belts, to increase their numbers and extend their ranges further South as the habitat becomes more suitable for them. Birds such as the African silverbill, cut-throat finch and the red-billed hornbill have their main distributions further North but are increasing in numbers in Guinea savanna (Borrow & Demey 2001) and the rufous scrub robin is a species of the semi-arid belt in West Africa and has been observed on transects and has recently been observed breeding on the Jos Plateau for the first time (Ulf Ottosson, *Pers. comm.*). These observations indicate the movement south of the Sahelian zone, which is being hastened by the increase in farming activity creating dryer, open habitats south of the Sahara. This could also result in an increase in the habitat used by many Palearctic migrants, which winter in the Sahel, but do not appear to have moved South yet (Salewski et al. 2002).

The reaction to the change in the general habitat of the Guinea savanna zone in West Africa will be important, not just to the diversity of wildlife, but also to the economic well-being of the areas affected (Wezel & Rath 2002). As the arid zone moves South, hastened by human disturbance (Thomas 1997), land will decrease in fertility and water shortages will occur. Coupled with the effect of global warming this could lead to great human suffering (Watson et al. 1997). The management of farmland to reduce the effects of desertification may also, indirectly, benefit bird diversity, so the work

conducted on farmland birds in Africa may have wider interest than simply those interested in the effect of human disturbance on wildlife diversity.

### **8.3 Wildlife-Friendly Farming or Land Sparing?**

The management prescriptions discussed up to this point have all been focused on how to make agricultural land more attractive to wildlife, whilst still using the land for active cultivation. This policy of extensive rather than intensive farming has been studied and encouraged in Europe, with the European Union offering large subsidies to farmers who carry out specific agri-environment schemes (Chamberlain et al. 2000; Critchley et al. 2004). Some of these schemes have been shown to have a positive effect on the target species of declining bird, for example, the introduction of non-cultivated skylark plots in the UK (Clarke et al. 2007). Other schemes are more general in scope and the benefits are less easily quantified, for example, subsidies for leaving set-aside fields fallow, which has been shown to increase bird diversity in Ireland, but that different forms of set-aside may be more appropriate for different areas (Bracken & Bolger 2006).

There is, however, an argument over whether these types of measures are the most efficient and effective ways of maintaining biodiversity whilst, at the same time, ensuring that a growing global human population is sufficiently well fed. The biodiversity value of farmland seems to decline with increasing yield (Donald et al. 2001b) and the payments made to farmers are perceived to partly offset this reduction in yields (Green et al. 2005). Wildlife friendly farming must, if yields are reduced, be carried out over a larger area of land to reach the same yield as high intensity farming on a smaller area, and may result in a doubling of the world's cropland area by the year 2050 (Green et al. 2005). High intensity farming may, therefore, free up land to be retained in a natural state, "land sparing", perhaps in the form of reserves or parks, which could host a higher diversity of species than extensive farmland, and a model has suggested that this may be the best method of attaining the two goals of food production and biodiversity retention (Green et al. 2005). The retention of natural habitats is essential, particularly in areas of high biodiversity around the tropics, as is the necessity to feed the human population, but the increase in cropland area in developing countries is unavoidable (Tilman et al. 2001). Also, if natural habitats

become completely fragmented with intensively farmed areas, that are “wildlife deserts” as far as many specialist species are concerned, then many of these species may decline anyway due to the limitations of the small fragments (Sekercioglu et al. 2002) and, of course, protected areas may not guarantee the survival of species due to human encroachment and illegal exploitation (Caro & Scholte 2007). Extensive farmland has been shown to be used by forest and savanna species (Wilson et al. 1997; Luck & Daily 2003) and many species could potentially use less intensive farmland habitat as corridors between fragments of natural habitat (Ricketts et al. 2001; Sekercioglu et al. 2002; Tubelis et al. 2004).

Perhaps the best option, if sufficient land is found to be available, is to have areas of intensive farmland with extensive corridors of wildlife friendly farmland between natural fragments, which are, themselves, surrounded by a buffer-zone of wildlife friendly farmland. The combined yield of the intensive and extensive farmland can then be calculated so as to be sufficient to feed the human population. Putting these sorts of policies into place would require a great deal of research and cooperation between social scientists and ecologists (Mattison & Norris 2005).

#### ***8.4 Areas for Future Research***

The data presented here are largely base-line data describing the bird community of a little-studied habitat, African farmland. There are many possibilities to expand on this research, both in terms of the science of habitat selection of the birds and the underlying mechanisms and the policy implications of the management prescriptions discussed. The validation process has shown that the models are valid, if not to predict absolute densities and diversities of birds on farmland on the Jos Plateau then to predict the trends that should be observed when in particular habitats or at differing levels of farming intensity. These models could be tested elsewhere on the Plateau, or, even better, in adjacent lowlands to see if similar patterns are observed in the altitudinal range at which most farmland in West Africa is sited. If this is so, then the models may then have uses beyond the Plateau and even beyond Nigeria to other, similar agricultural areas in Africa where the same, or similar, bird species occur. The survey methods described here could then be used as the basis for studies elsewhere, although other methods would have to be developed for projects with more restricted

time spans considering the small number of species with registration numbers on the transects sufficient for the models run to converge. If these models can be replicated elsewhere, and with other species, more specific management prescriptions may emerge for the areas in question.

The European example has taught us that much detailed work must be undertaken in order to determine the mechanisms behind patterns observed in farmland birds. This research will require significant funds so the priority is likely to be on bird species which are known or suspected to be at risk from changing farming practices, such as the Hinde's babbler and Sharpe's Longclaw in Kenya (Muchai et al. 2002b; Shaw & Masina 2003). The European example has also taught us, however, that previously common birds are those that often suffer the greatest population declines when farming practices change (Fuller et al. 1996) so I recommend that studies continue on currently common farmland birds, such as the red-cheeked cordon-bleu, which may glean information which will be useful to conserve that species and similar ones with similar foraging patterns on the Jos Plateau and elsewhere. These should involve determining the food availability, particularly seeds and invertebrates, on different farmland sites and further behavioural studies, such as that carried out on whinchats described in Chapters 2 and 7. Food availability over the whole year may fluctuate and different farming practices, such as crop rotation, set-aside and pesticide and herbicide application may affect the density and availability of seed and invertebrate resources, both around Jos and across Africa.

Ecological research should go hand-in-hand with social, economic and policy research (Mattison & Norris 2005) and this should be a priority with the impending increase in cropland and likely increase in farming intensity in Africa (Tilman et al. 2001). The possibility of subsidies, particularly for the retention of trees and shrubs in and around fields, should be considered, and should work in parallel with activities to reduce the pressure on farmland savannas due to demand for firewood (Martins 2005; Lehmkuhl et al. 2007). Subsidies may also help where crop type is seen to be an important issue for a species under study. Due to the lack of funds available to the governments of developing nations, research should be conducted on the possibility of sourcing these funds from developed nation governments, businesses or organisations.

## **8.5 Conclusions**

African farmland is a habitat hosting a high diversity of bird life, which is threatened by impending agricultural intensification. Studies relating to the conservation of wildlife on farmland need to receive higher priority and more resources as farmland area increases in developing countries. Ecologists, social sciences and economists need to cooperate in order to limit the potential effects of farmland expansion and intensification, which include a loss of natural habitat for exploitation, a loss of biodiversity, desertification and the resultant social and ecological upheaval. These challenges will increase in importance as the effects of global warming start to take effect. Studies such as this one will hopefully prove useful in the attempts to develop Africa more sustainably in the future.

## Chapter 9 References

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# Appendix

Table 1 Bird species observed on transects.

English	Scientific	Abbreviation	Number of Distance Records
Long-tailed Cormorant	<i>Phalacrocorax africanus</i>		0
Grey Heron	<i>Ardea cinerea</i>		0
Black-headed Heron	<i>Ardea melanocephala</i>		1
Purple Heron	<i>Ardea purpurea</i>		0
Green-backed Heron	<i>Butorides striatus</i>		0
Cattle Egret	<i>Bubulcus ibis</i>	CAEG	360
Little Egret	<i>Egretta garzetta</i>		0
Intermediate Egret	<i>Egretta intermedia</i>		0
Hamerkop	<i>Scopus umbretta</i>		1
Abdim's Stork	<i>Ciconia abdimii</i>		0
White-faced Whistling Duck	<i>Dendrocygna viduata</i>		0
Black-shouldered Kite	<i>Elanus caeruleus</i>		6
African Cuckoo Hawk	<i>Aviceda cuculoides</i>		0
Black Kite	<i>Milvus migrans</i>		0
Hooded Vulture	<i>Necrosyrtes monachus</i>		4
Short-toed Eagle	<i>Circaetus gallicus</i>		1
Gymnogene	<i>Polyboroides typus</i>		0
Eurasian Marsh Harrier	<i>Circus aeruginosus</i>		1
Pallid Harrier	<i>Circus macrourus</i>		2
Montagu's Harrier	<i>Circus pygargus</i>		1
Dark Chanting Goshawk	<i>Melierax metabates</i>		1
Shikra	<i>Accipiter badius</i>		2
Gabar Goshawk	<i>Melierax gabar</i>		2
Lizard Buzzard	<i>Kaupifalco monogrammicus</i>		5
Red-necked Buzzard	<i>Buteo auguralis</i>		0
Wahlberg's Eagle	<i>Aquila wahlbergi</i>		0
Common Kestrel	<i>Falco tinnunculus</i>		14
Lesser Kestrel	<i>Falco naumanni</i>		0
Fox Kestrel	<i>Falco alopex</i>		4
Grey Kestrel	<i>Falco ardosiaceus</i>		3
Red-necked Falcon	<i>Falco chicquera</i>		0
Lanner Falcon	<i>Falco biarmicus</i>		1
Double-spurred Francolin	<i>Francolinus bicalcaratus</i>	DSFR	73
Common Quail	<i>Coturnix coturnix</i>	COQU	21
Stone Partridge	<i>Ptilopachus petrosus</i>	STPA	70
Little buttonquail	<i>Turnix sylvatica</i>		1
African crane	<i>Crecopsis egregia</i>		1
White-bellied Bustard	<i>Eupodotis senegalensis</i>		1
Spotted Thick-knee	<i>Burhinus capensis</i>		8
Senegal Thick-knee	<i>Burhinus senegalensis</i>		8
Temminck's Courser	<i>Cursorius temminckii</i>		10
African Wattled Lapwing	<i>Vanellus senegallus</i>	AWLP	46
Common Sandpiper	<i>Actitis hypoleucos</i>		0
Common Greenshank	<i>Tringa nebularia</i>		0

Table 2 Bird species observed on transects.

English	Scientific	Abbreviation	Number of Distance Records
Four-banded Sandgrouse	<i>Pterocles quadricinctus</i>		15
Speckled Pigeon	<i>Columba guinea</i>	SPPI	71
Feral pigeon	<i>Columba livia</i>		0
Adamawa Turtle Dove	<i>Streptopelia hypopyrrha</i>	ADAM	383
Laughing Dove	<i>Streptopelia senegalensis</i>	LAFF	714
Vinaceous Dove	<i>Streptopelia vinacea</i>	VIDO	103
Red-eyed Dove	<i>Streptopelia semitorquata</i>		15
Black-billed Wood Dove	<i>Turtur abyssinicus</i>		85
Namaqua Dove	<i>Oena capensis</i>		15
Bruce's Green Pigeon	<i>Treron waalia</i>		29
Senegal Parrot	<i>Poicephalus senegalus</i>		35
Red-headed Lovebird	<i>Agapornis pullarius</i>		1
Rose-ringed Parakeet	<i>Psittacula krameri</i>		4
Violet Turaco	<i>Musophaga violacea</i>		6
Western Grey Plantain-eater	<i>Crinifer piscator</i>	WGPE	160
Great Spotted Cuckoo	<i>Clamator glandarius</i>		1
Jacobin Cuckoo	<i>Clamator jacobinus</i>		2
Levaillant's Cuckoo	<i>Clamator levaillantii</i>		2
African Grey Cuckoo	<i>Cuculus gularis</i>		1
Klaas's Cuckoo	<i>Chrysococcyx klaas</i>		1
Didric Cuckoo	<i>Chrysococcyx caprius</i>		0
Senegal Coucal	<i>Centropus senegalensis</i>	SECO	91
Marsh Owl	<i>Asio capensis</i>		1
Greyish Eagle Owl	<i>Bubo cinerascens</i>		2
Pearl-spotted Owlet	<i>Glaucidium perlatum</i>		0
Freckled Rock Nightjar	<i>Caprimulgus tristigma</i>		5
Long-tailed Nightjar	<i>Caprimulgus climacurus</i>		7
African Palm Swift	<i>Cypsiurus parvus</i>		0
Little Swift	<i>Apus affinis</i>		0
Speckled Mousebird	<i>Colius striatus</i>	MOUS	217
Pygmy Kingfisher	<i>Ceyx pictus</i>		1
Malachite Kingfisher	<i>Alcedo cristata</i>		1
Pied Kingfisher	<i>Ceryle rudis</i>		0
Grey-headed Kingfisher	<i>Halcyon leucocephala</i>		10
Striped Kingfisher	<i>Halcyon chelicuti</i>		0
Little Bee-eater	<i>Merops pusillus</i>		4
Swallow-tailed Bee-eater	<i>Merops hirundineus</i>		4
Red-throated Bee-eater	<i>Merops bullocki</i>	RBBE	54
European Bee-eater	<i>Merops apiaster</i>		0
Abyssinian Roller	<i>Coracias abyssinica</i>		26
Rufous-crowned Roller	<i>Coracias naevia</i>		4
Blue-bellied Roller	<i>Coracias cyanogaster</i>		1
Broad-billed roller	<i>Eurystomus glaucurus</i>		5
Red-billed Wood Hoopoe	<i>Phoeniculus purpureus</i>	RBWH	39
Black Wood Hoopoe	<i>Rhinopomastus aterrimus</i>		2
Hoopoe	<i>Upupa epops</i>		2
Red-billed Hornbill	<i>Tockus erythrorhynchus</i>		26
African Grey Hornbill	<i>Tockus nasutus</i>		52

Table 3 Bird species observed on transects.

English	Scientific	Abbreviation	Number of Distance Records
Yellow-fronted Tinkerbird	<i>Pogoniulus chrysoconus</i>	YFTI	34
Vieillot's Barbet	<i>Lybius vielloti</i>		14
White-headed Barbet	<i>Lybius leucocephalus</i>		10
Bearded Barbet	<i>Lybius dubius</i>	BEBA	22
Greater Honeyguide	<i>Indicator indicator</i>	GRHN	5
Lesser Honeyguide	<i>Indicator minor</i>		2
Eurasian Wryneck	<i>Jynx torquilla</i>		3
Fine-spotted Woodpecker	<i>Campethera punctuligera</i>		3
Cardinal Woodpecker	<i>Dendropicos fuscescens</i>		1
Grey Woodpecker	<i>Mesopicos goertae</i>		18
Rufous-naped Lark	<i>Mirafra africana</i>	RNLA	30
Flappet Lark	<i>Mirafra rufocinnamomea</i>		1
Sun Lark	<i>Galerida modesta</i>	SUNL	207
Crested Lark	<i>Galerida cristata</i>	CRES	248
Red-capped Lark	<i>Calandrella cinerea</i>		3
Chestnut-backed Sparrow-Lark	<i>Eremopterix leucotis</i>		91
Fanti Saw-wing	<i>Psolidoprocne obscura</i>		0
Banded Martin	<i>Riparia cincta</i>		0
Lesser Striped Swallow	<i>Hirundo abyssinica</i>		0
Red-rumped Swallow	<i>Hirundo daurica</i>		0
African Rock Martin	<i>Hirundo fuligula</i>		0
Ethiopian Swallow	<i>Hirundo aethiopica</i>		91
Barn Swallow	<i>Hirundo rustica</i>		6
House Martin	<i>Delichon urbica</i>		0
Rufous-chested Swallow	<i>Hirundo semirufa</i>		0
Yellow Wagtail	<i>Motacilla flava</i>		6
Long-billed Pipit	<i>Anthus similis</i>		0
Plain-backed Pipit	<i>Anthus leucophrys</i>	PBPI	62
Tree Pipit	<i>Anthus trivialis</i>		35
Red-throated Pipit	<i>Anthus cervinus</i>		54
Yellow-throated Longclaw	<i>Macronyx croceus</i>	YTLC	38
Red-shouldered Cuckoo-shrike	<i>Campephaga phoenicea</i>		3
Yellow-throated Leaflove	<i>Chlorocichla flavicollis</i>		7
Common Bulbul	<i>Pycnonotus barbatus</i>	BUL	793
African Thrush	<i>Turdus pelios</i>	AFTH	83
Common Rockthrush	<i>Monticola saxatilis</i>		2
Snowy-headed Robin-Chat	<i>Cossypha niveicapilla</i>		8
White-crowned Robin-Chat	<i>Cossypha albicapilla</i>		1
Common Redstart	<i>Phoenicurus phoenicurus</i>		0
Rufous Scrub Robin	<i>Cercotrichas galactotes</i>		2
Whinchat	<i>Saxicola rubetra</i>	WHIN	337
Northern Wheatear	<i>Oenanthe oenanthe</i>		8
Heuglin's Wheatear	<i>Oenanthe bottae</i>	HEWH	106
Familiar Chat	<i>Cercomela familiaris</i>	FACH	35
Northern Ant-eating Chat	<i>Myrmecocichla aethiops</i>	NAEC	78
White-fronted Black Chat	<i>Myrmecocichla albifrons</i>		13
Mocking Cliff Chat	<i>Myrmecocichla cinnamomeiventris</i>	MOCC	10

Table 4 Bird species observed on transects.

English	Scientific	Abbreviation	Number of Distance Records
African Moustached Warbler	<i>Melocichla mentalis</i>		9
Icterine Warbler	<i>Hippolais icterina</i>		1
Melodious Warbler	<i>Hippolais polyglotta</i>		2
Senegal Eremomela	<i>Eremomela pusilla</i>	SEER	46
Northern Crombec	<i>Sylvietta brachyura</i>		11
Willow Warbler	<i>Phylloscopus trochilus</i>		12
Wood Warbler	<i>Phylloscopus sibilatrix</i>		1
Garden Warbler	<i>Sylvia borin</i>		13
Common Whitethroat	<i>Sylvia communis</i>	COWH	100
Black-Backed Cisticola	<i>Cisticola eximius</i>		38
Zitting Cisticola	<i>Cisticola juncidis</i>	ZICI	32
Dorst's Cisticola	<i>Cisticola dorsti</i>		14
Rufous Cisticola	<i>Cisticola rufus</i>		2
Rock-loving Cisticola	<i>Cisticola aberrans</i>	RLCS	22
Singing Cisticola	<i>Cisticola cantans</i>	SICI	23
Winding Cisticola	<i>Cisticola galactotes</i>		6
Tawny-flanked Prinia	<i>Prinia subflava</i>	TFPR	210
Red-winged Warbler	<i>Heliolais erythroptera</i>		16
Grey-backed Cameroptera	<i>Cameroptera brachyura</i>	GBCA	54
Oriole-Warbler	<i>Hypergerus atriceps</i>		0
Northern Black Flycatcher	<i>Melaenornis edolioides</i>	NBFL	57
Pale Flycatcher	<i>Bradornis pallidus</i>	PAFL	66
Pied Flycatcher	<i>Ficedula hypoleuca</i>		16
Spotted Flycatcher	<i>Muscicapa striata</i>		6
Senegal Batis	<i>Batis senegalensis</i>		23
Common Wattle-eye	<i>Platysteira cyanea</i>		1
African Blue Flycatcher	<i>Elminia longicauda</i>		4
African Paradise Flycatcher	<i>Terpsiphone viridis</i>		2
Brown Babbler	<i>Turdoides plebejus</i>	BRBA	88
Blackcap Babbler	<i>Turdoides reinwardii</i>		8
White-shouldered Black Tit	<i>Parus guineensis</i>		1
Yellow Penduline Tit	<i>Anthoscopus parvulus</i>		12
Pygmy Sunbird	<i>Anthreptes platurus</i>	PYSU	31
Green-headed Sunbird	<i>Nectarinia verticalis</i>		12
Scarlet-chested Sunbird	<i>Nectarinia senegalensis</i>	SCCH	310
Variable Sunbird	<i>Nectarinia venusta</i>	VASN	319
Copper Sunbird	<i>Nectarinia cuprea</i>		12
Yellow White-eye	<i>Zosterops senegalensis</i>	YWEY	38
Emin's Shrike	<i>Lanius gubernator</i>		5
Woodchat Shrike	<i>Lanius senator</i>		2
Yellow-billed Shrike	<i>Corvinella corvina</i>	YBSH	130
Brubru	<i>Nilaus afer</i>		4
Northern Puffback	<i>Dryoscopus gambensis</i>		1
Black-crowned Tchagra	<i>Tchagra senegala</i>	BCTC	130
Tropical Boubou	<i>Laniarius aethiopicus</i>		1
Yellow-crowned Gonolek	<i>Laniarius barbarus</i>	YCGO	112
Sulphur-breasted Bush Shrike	<i>Malaconotus sulfureopectus</i>		1
Grey-headed Bush Shrike	<i>Malaconotus blanchoti</i>		7

Table 5 Bird species observed on transects.

English	Scientific	Abbreviation	Number of Distance Records
Fork-tailed Drongo	<i>Dicrurus adsimilis</i>		59
Piapiac	<i>Ptilostomus afer</i>	PIAP	45
Pied Crow	<i>Corvus albus</i>		0
Neuman's Starling	<i>Onychognathus morio</i>		0
Purple Glossy Starling	<i>Lamprotornis purpureus</i>	PGST	53
Lesser Blue-eared Starling	<i>Lamprotornis chloropterus</i>		40
Bronze-tailed Glossy Starling	<i>Lamprotornis chalcurus</i>		7
Splendid Glossy Starling	<i>Lamprotornis splendidus</i>		5
Long-tailed Glossy Starling	<i>Lamprotornis caudatus</i>		44
Violet-backed Starling	<i>Cinnyricinclus leucogaster</i>		14
Yellow-billed Oxpecker	<i>Buphagus africanus</i>		11
Grey-headed Sparrow	<i>Passer griseus</i>	GHSP	139
Bush Petronia	<i>Petronia dentata</i>	BUPE	69
Speckle-fronted Weaver	<i>Sporopipes frontalis</i>	SPWV	533
Chestnut-crowned Sparrow-weaver	<i>Plocepasser superciliosus</i>		42
Little Weaver	<i>Ploceus luteolus</i>	LIWV	39
Black-necked Weaver	<i>Ploceus nigricollis</i>		9
African Masked Weaver	<i>Ploceus velatus</i>		16
Heuglin's Masked Weaver	<i>Ploceus heuglini</i>		2
Village Weaver	<i>Ploceus cucullatus</i>	VIWV	505
Red-billed Quail	<i>Quelea erythropus</i>		0
Black-winged Red Bishop	<i>Euplectes hordeaceus</i>	BWRB	128
Northern Red Bishop	<i>Euplectes franciscanus</i>	BISH	3197
Yellow-crowned Bishop	<i>Euplectes afer</i>		3
Yellow-mantled Widowbird	<i>Euplectes macrourus</i>		33
Red-winged Pytilia	<i>Pytilia phoenicoptera</i>		1
Bar-breasted Firefinch	<i>Lagonosticta rufopicta</i>	BAFF	48
Red-billed Firefinch	<i>Lagonosticta senegala</i>	RBFF	218
Black-bellied Firefinch	<i>Lagonosticta rara</i>		51
Rock Firefinch	<i>Lagonosticta sanguinodorsalis</i>	ROFF	68
Black-faced Firefinch	<i>Lagonosticta larvata</i>		7
Lavender Waxbill	<i>Estrilda caerulescens</i>	LAWX	50
Orange-cheeked Waxbill	<i>Estrilda melpoda</i>	OCWX	79
Black-rumped Waxbill	<i>Estrilda troglodytes</i>	BRWX	261
Red-cheeked Cordon-bleu	<i>Uraeginthus bengalus</i>	BLEU	1262
Zebra Waxbill	<i>Amandava subflava</i>		15
African Quail Finch	<i>Ortygospiza atricollis</i>	QUFI	311
African Silverbill	<i>Lonchura cantans</i>	SILV	85
Bronze Mannikin	<i>Lonchura cucullata</i>	MANN	968
Cut-throat	<i>Amadina fasciata</i>		17
Village Indigobird	<i>Vidua chalybeata</i>		10
Quail Finch Indigobird	<i>Vidua nigeriae</i>		0
Pin-tailed Wydah	<i>Vidua macroura</i>	PTWY	156
White-rumped Seedeater	<i>Serinus leucopygius</i>	WRSE	32
Yellow-fronted Canary	<i>Serinus mozambicus</i>		10
Cinnamon-breasted Rock Bunting	<i>Emberiza tahapisi</i>	BUNT	437



Figure 1 Millet field before harvesting. Photo by Mark Hulme.



Figure 2 Maize field after harvesting. Photo by Mark Hulme.





Figure 3 Acha field before harvesting. Photo by Mark Hulme.



Figure 4 Yam ridges. Photo by Mark Hulme.





Figure 5 Low intensity farmland, Fobur. Photo by Mark Hulme.



Figure 6 Medium intensity farmland, Laminga. Photo by Mark Hulme.





Figure 7 High intensity farmland, acha in the dry season, Vom. Photo by Mark Hulme.



Figure 8 Mark Hulme, Chris Nyam and farmer being interviewed, Laminga Village. Photo by Juliet Vickery.



Figure 9 Common bulbul, Laminga. Photo by Ross McGregor



Figure 10 Red-cheeked cordon-bleu, Laminga. Photo by Martin Stervander.



Figure 11 Whinchat, *Lamprolaima*. Photo by Mark Hulme.